Minnesota

Water Works
Operations Manual

Quality On Tap!

Our Commitment Our Profession

Acknowledgements

The original vision of the people who created this manual was to have it be a “need to know” study guide for people taking the water operator certification exam. The final product has turned out to be much more than just a study guide for taking the exam. All of the information contained in the manual is very useful in understanding the operation of a water supply system, both large and small.

Publication of the first edition of this manual was made possible through a grant from the US Environmental Protection Agency, Office of Drinking Water, to the Minnesota Department of Health and Minnesota Training Coalition.

The Minnesota Department of Health then contracted with the Minnesota Rural Water Association for the layout, design and dissemination of this manual. The Minnesota Department of Health continues to support the updating of this manual.

The expertise of many individuals has been utilized to bring together an overview of key elements of the operation and maintenance of a water system. Some of those individuals include, but are not limited to, John Thom, Gunilla Montgomery, Virginia Reiner, Dick Clark, Doug Mandy, Stew Thornley, Bob Smude, Roger Larson, Gerald Smith, Phil Moroukian, Glen Moreland, and Minnesota Rural Water Association staff members Jim Plahn, Mike Roers, Tim Hagemeier, Larry Bailey, Sharon Larsen and Ruth Hubbard.

This manual will hopefully give you a basic understanding of a water system. Operators should use this manual as a catalyst for further research of your individual system. We encourage your continued educational growth through attendance at the many training efforts sponsored by Minnesota Training Coalition members.

A special thank you to water industry personnel and professional associations for the use of photographs, graphics, and illustrations for the manual.

Disclaimer

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Fourth Publication Date: Summer 2009
Third Publication Date: Summer 2001
Second Publication Date: Summer 1997
First Publication Date: Spring 1994

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Water Resources

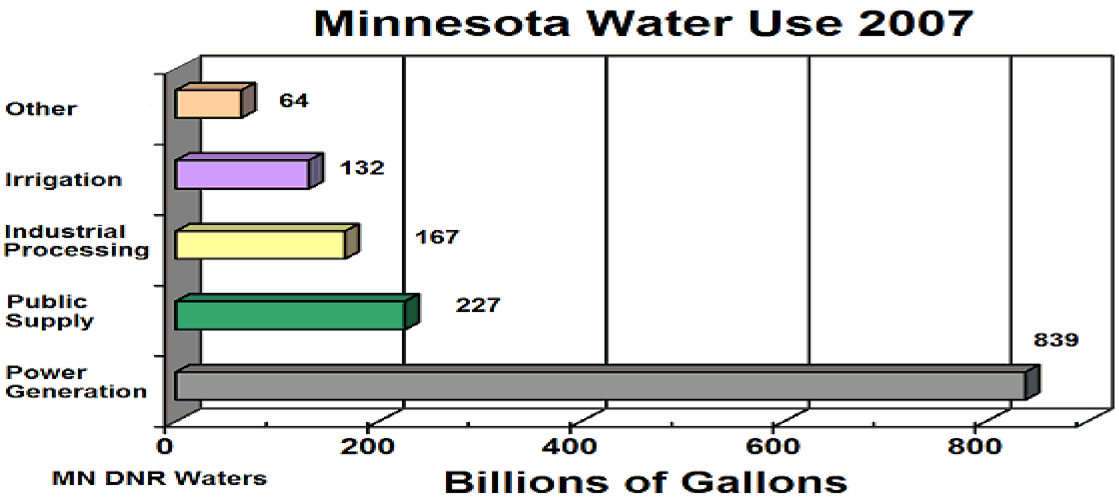
Our planet has a vast supply of water beneath its surface, on its surface, and above its surface in the atmosphere. The Earth holds about 320 million cubic miles of water with more than 97 percent of it contained in its oceans. Because of its high salt content, ocean water cannot be used by humans for drinking or farming. Salt can be removed from the water, but the treatment involved is expensive. Only about 3 percent of the world's water is fresh or unsalted. In addition, only about 25 percent of this amount is readily available. The rest is locked in glaciers and ice-caps.

The distribution or freshwater throughout the world is not uniform. The ratio of groundwater to surface water also varies from location to location. Minnesota is typical of the rest of the United States in that most of its water (approximately 85 percent) is contained in aquifers or underground formations (such as rock, sand, and gravel) that contain water in its pores or crevices. The remainder can be found in surface sources such as lakes, streams, wetlands, and reservoirs.

WATER USE AND CONSUMPTION

Vast amounts of water are used for many purposes in Minnesota. The national average for water consumption is approximately 100 gallons per day per person. This figure includes all water used and can vary greatly, especially as a result of variations in industrial usage. More than 1.429 trillion gallons of water were withdrawn from available Minnesota supplies in 2007.

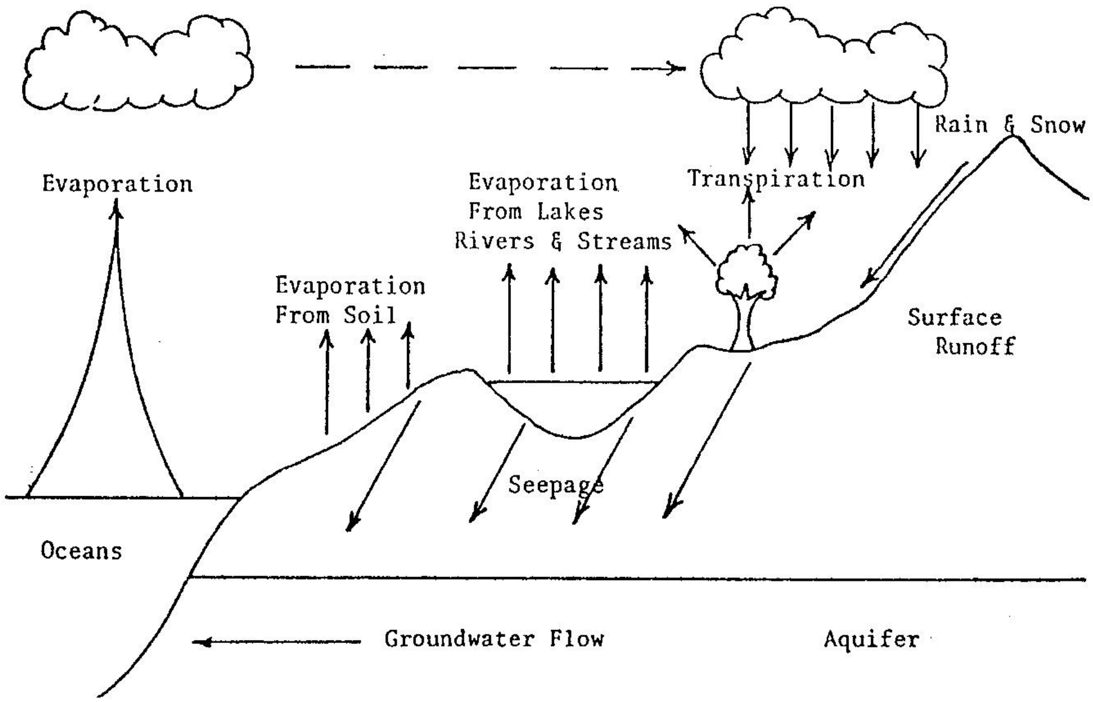
The water supply found in Minnesota is used for domestic consumption, municipal needs, industrial production, food processing, irrigation, livestock, navigation, recreation, fish and wildlife habitat, power generation, waste assimilation, and other miscellaneous categories. This water comes from both groundwater and surface sources and is supplied both from public utilities and through privately owned wells.



The importance of water is reflected in its use for consumption. Public water supplies account for approximately 38 percent of the consumptive water use in Minnesota. Domestic use, livestock watering, irrigation, and industrial processing account for the remaining consumptive use, with power generation using water mostly on a pass-through basis.

HYDROLOGIC CYCLE

The water cycle is a continuous process of water evaporating from the earth, moving to the clouds, and then returning to the ground as precipitation.



The water cycle consists of several components:

Evaporation/Transpiration

The first stage of the process involves evaporation, water changing from a liquid state to a vapor or gas phase. Approximately one-third of the water in the atmosphere comes from the surface of the ocean. Evaporation from inland streams and lakes accounts for the remaining two-thirds of the water vapor entering the atmosphere.

When water evaporates, impurities are left behind in the source. This means that saltwater, which is unfit for human consumption, is converted into freshwater through evaporation as the salt is left behind in the sea. Another source of water in the atmosphere is water from vegetation. The process of a plant releasing water vapor directly into the air is called transpiration.

Condensation

After the water has entered the atmosphere, it rises until it begins to cool, condenses to water droplets or ice, and forms clouds.

Precipitation

After the clouds have taken on as much moisture as they can hold, the process of releasing this moisture starts. This takes place in the form of precipitation: rain, sleet, snow, etc. (Virtually all of the world's freshwater supply has been delivered in this manner.)

Infiltration

Some of the precipitation infiltrates into the soil through percolation to become groundwater while the rest remains on the surface as surface water. Most of the groundwater remains near the surface to be used by plant life, after which it returns to the atmosphere through transpiration. A small percentage of the groundwater evaporates from the soil directly to the atmosphere without being used by the plants.

The remaining groundwater continues to percolate through the soil until it reaches the groundwater aquifer. At this point the water may be extracted through wells for human consumption.

GROUNDWATER SOURCES

Groundwater is the most common source of water for small-to-medium sized communities in the United States. Approximately 75 percent of the nation's water supplies use groundwater for their source, but they supply only 25 percent of the water used in the country. In Minnesota, all but 24 water supplies use groundwater as their source.

Groundwater is water that has percolated through the ground into the soil or rock below. Groundwater is water stored in aquifers: consolidated or nonconsolidated geologic materials saturated with water. Groundwater reaches the aquifers through recharge areas, where the aquifer is directly exposed to precipitation, through infiltration from overlying sediment or rock, or where lakes, swamps, wetlands, and other sources of standing water connect to the aquifer. This connection can be through a sand layer or some other porous layer of soil.

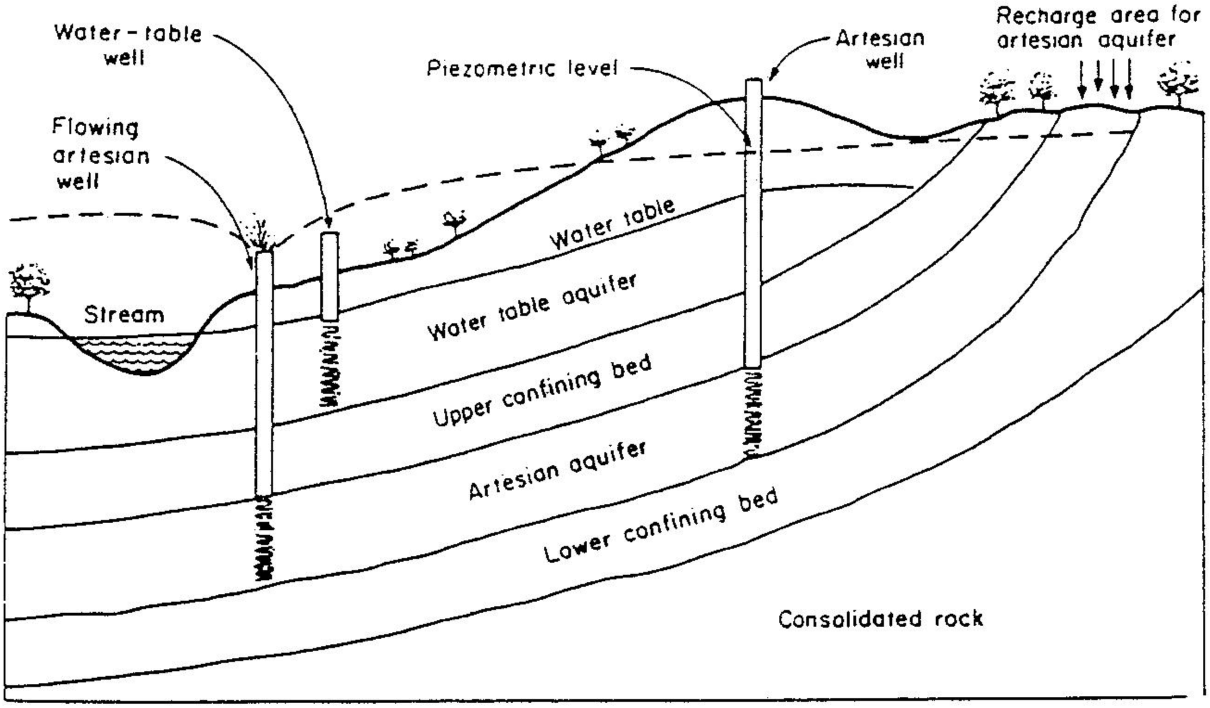
An aquifer is an underground layer of gravel, sand, sandstone, shattered rock, limestone, or other formation that holds water. An aquifer will not only hold water, but will allow the water to move to an area of lower pressure within the aquifer.

A water table aquifer consists of soil or rock, usually near the land surface, containing water that is held above a confining soil layer. An example of this would be beach sand surrounding a lake where the water surface in the sand is generally the same elevation as the lake.

An artesian aquifer is a geologic formation between two confining layers, such as sand between two clay layers. The top of the water in the aquifer is under pressure, causing the water to rise above the aquifer when a well is constructed into the aquifer. The distance that the water will rise in the well is determined by the geology, the hydrologic characteristics of the aquifer, and the elevation of the aquifer recharge area.

A flowing well is one constructed into the artesian aquifer where the water reaches the surface by its own pressure. Another type of flowing condition is a spring in a hillside in which groundwater reaches the surface and becomes a brook or stream. Groundwater will flow to an area of lower head or pressure. You could think of the movement of groundwater as an underground river or stream. This area of lower pressure may be a pumping well, spring, lake, or stream.

Hydrologic Conditions Found in Aquifers



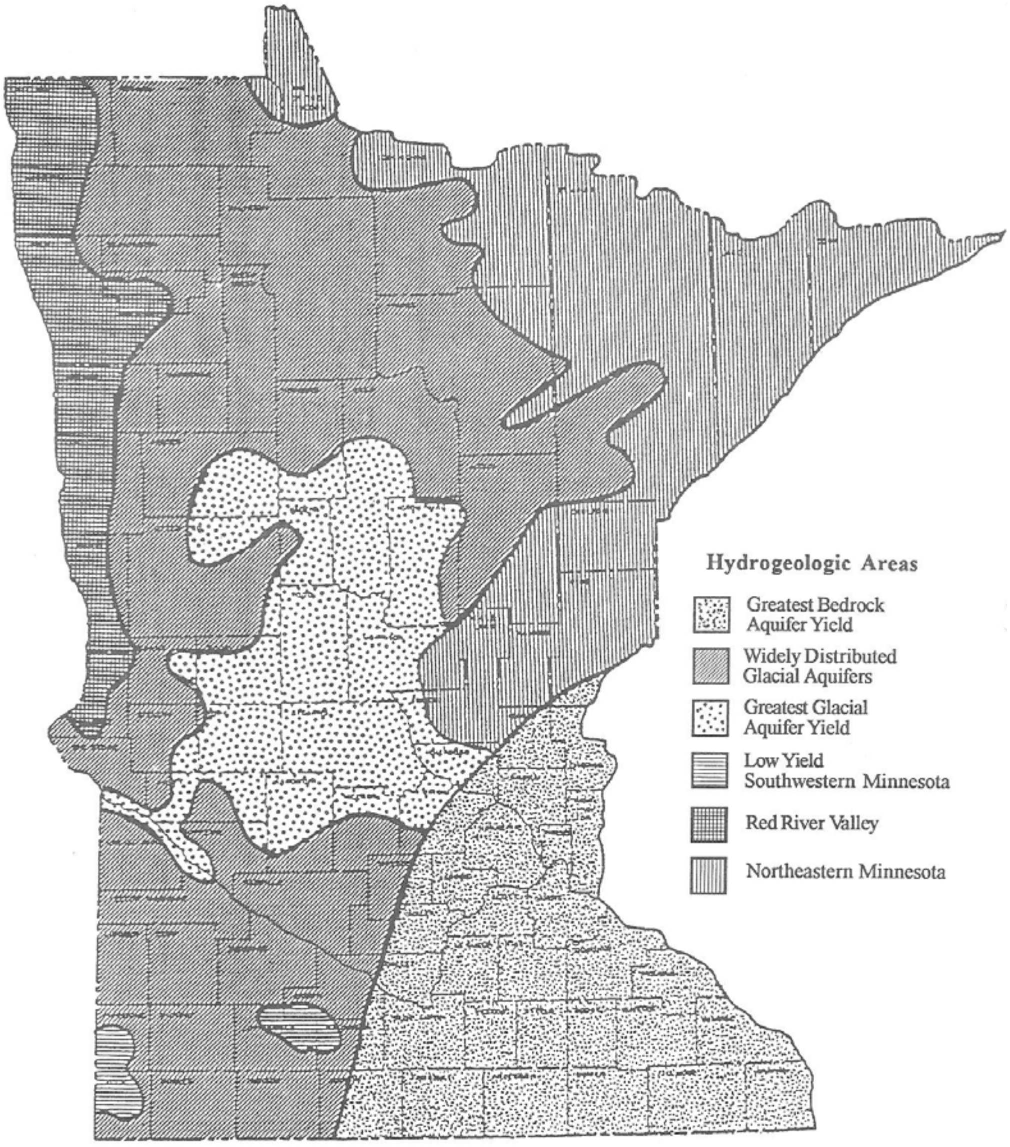
The major groundwater aquifers in Minnesota occur in either unconsolidated glacial drift or consolidated rocks.

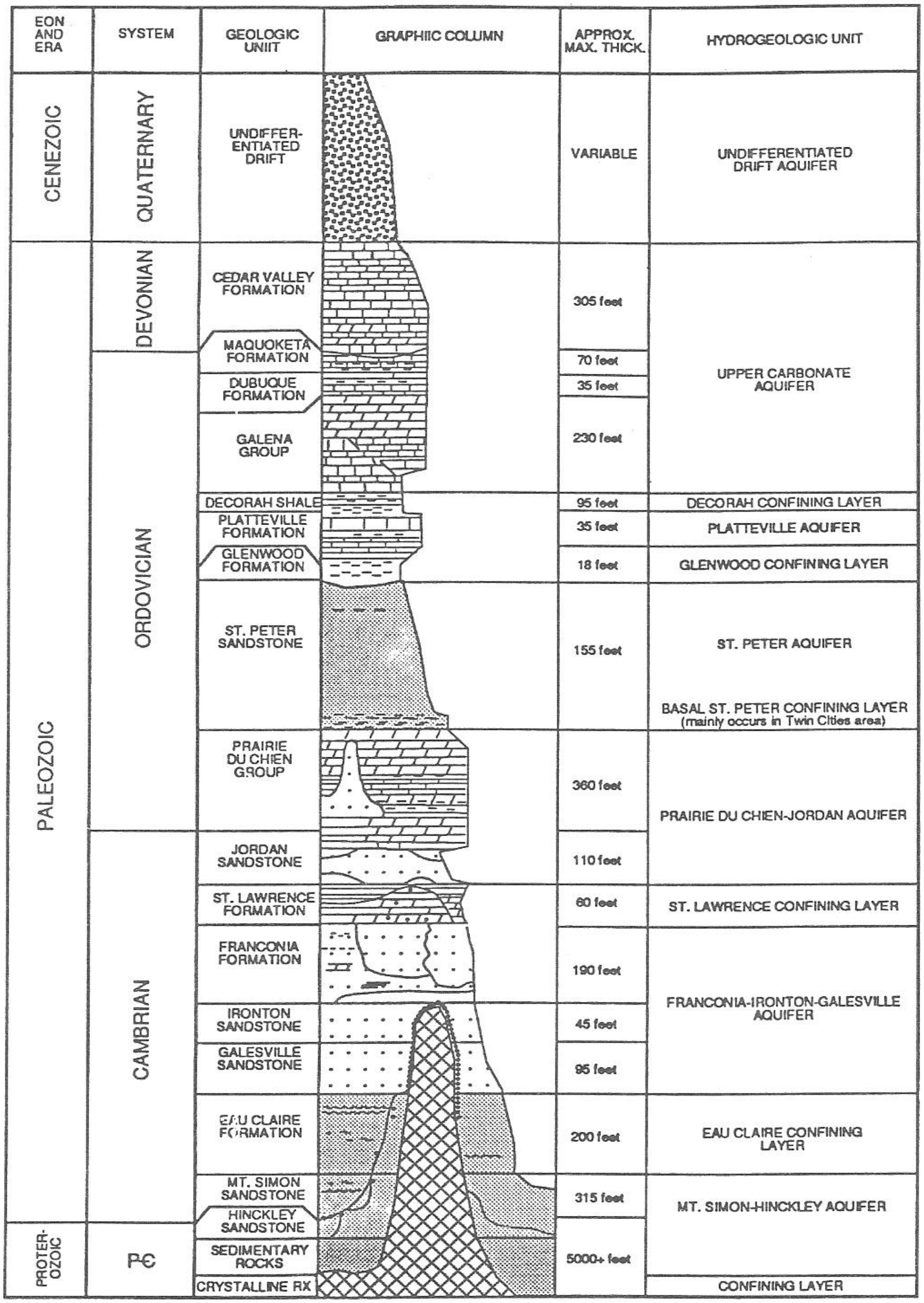
Unconsolidated glacial drift aquifers

Glacial drift is a general term for clay, sand or gravel deposited by a glacier. Glacial drift can be more than 800 feet thick in Minnesota. It was deposited during the Ice Age. When composed of sand and gravel, glacial drift can be a source of large supplies of water. High clay content, however, makes these deposits less useful for water production. Unconsolidated glacial drift is used for wells in most areas of the state except the southeast, a strip along the Minnesota River, and parts of northeastern Minnesota.

Consolidated rock aquifers

These are aquifers composed of sandstone, limestone, and dolomite. They underlie varying thicknesses of glacial deposits. These aquifers are used mainly in southeastern Minnesota.





EON AND ERA	SYSTEM	GEOLOGIC UNIT	APPROX. MAX. THICK.	HYDROGEOLOGIC UNIT
CENEZOIC	QUATERNARY	UNDIFFERENTIATED DRIFT	VARIABLE	UNDIFFERENTIATED DRIFT AQUIFER
PALEOZOIC	DEVONIAN	CEDAR VALLEY FORMATION	305 feet	UPPER CARBONATE AQUIFER
	ORDOVICIAN	MAQUOKETA FORMATION	70 feet	
		DUBUQUE FORMATION	35 feet	
		GALENA GROUP	230 feet	
		DECORAH SHALE	95 feet	DECORAH CONFINING LAYER
		PLATTEVILLE FORMATION	35 feet	PLATTEVILLE AQUIFER
		GLENWOOD FORMATION	18 feet	GLENWOOD CONFINING LAYER
		ST. PETER SANDSTONE	155 feet	ST. PETER AQUIFER BASAL ST. PETER CONFINING LAYER (mainly occurs in Twin Cities area)
		PRAIRIE DU CHIEN GROUP	360 feet	PRAIRIE DU CHIEN-JORDAN AQUIFER
	CAMBRIAN	JORDAN SANDSTONE	110 feet	
		ST. LAWRENCE FORMATION	60 feet	ST. LAWRENCE CONFINING LAYER
		FRANCONIA FORMATION	190 feet	FRANCONIA-IRONTON-GALESVILLE AQUIFER
		IRONTON SANDSTONE	45 feet	
		GALESVILLE SANDSTONE	95 feet	
		EAU CLAIRE FORMATION	200 feet	EAU CLAIRE CONFINING LAYER
		MT. SIMON SANDSTONE	315 feet	MT. SIMON-HINCKLEY AQUIFER
PROTEROZOIC	P-Є	HINCKLEY SANDSTONE		
		SEDIMENTARY ROCKS	5000+ feet	
		CRYSTALLINE RX		CONFINING LAYER

Sequence of Bedrock Aquifer Systems and Confining Beds for Southeastern Minnesota

SURFACE WATER SOURCES

Surface waters supply about 75 percent of the water consumed by people in the United States. Even though a larger number of water systems in the United States use a groundwater source, on the average, they are smaller and serve fewer people. Surface water is more likely to supply large cities, such as Los Angeles, New York, and Chicago. These cities can withdraw billions of gallons of surface water each day, and Minneapolis taps directly into the Mississippi River, while St. Paul uses water from the Mississippi after passing it through a chain of lakes.

With so many people relying on surface sources for their supply of safe, palatable drinking water, it is important that operators understand the factors that influence the flow of surface water. Surface water comes from precipitation and groundwater that enters the surface supplies through springs or aquifers that connect with a lake or stream.

Precipitation

Precipitation can end up either as ground or surface water. The intensity of a rainfall can be a factor in determining its destination. A slow, steady rain will soften the ground, allowing the precipitation to percolate into the soils and enter the groundwater flow. This will result in less flow to surface waters. On the other hand, a heavy rain will increase the surface water flow as the ground is packed and hardened by the rain, causing it to run off, instead of penetrating, the soil.

The type of soil also makes a difference in determining how much water will percolate into the ground and enter the groundwater flow. A soil heavy in clay may absorb water from a rainfall for a short period of time before it begins to swell and block water percolation. The Red River Valley in northwestern Minnesota, an area that was once the bottom of a prehistoric lake, has very tight clayish soil.

Soils of gravel or sand allow water to percolate very readily, thus reducing the chances of localized flooding. The area around the Mississippi River in central Minnesota, from St. Cloud to Becker and Elk River, is an example of this type of soil.

The activities of human beings can greatly affect the ability of the soil to absorb water. Paving large areas of land for highways, parking lots, and driveways or draining wetlands, for agricultural use or community expansion results in far less water entering the ground and more of it running off to surface waterways. On the other hand, when rain falls on areas with mainly vegetative cover, more than 75 percent of it eventually finds its way to underground aquifers.

Water that doesn't penetrate the ground will reenter the cycle as surface water runoff. Once the soil becomes saturated by the precipitation, additional precipitation will cause runoff, forming creeks, streams, rivers, and lakes. This water will contain large amounts of suspended material (such as silts and organic material) that may contaminate the water, making it unfit for human consumption unless treated.

Regional water resources depend on climate, topography, and the nature of the soils. Minnesota's location in the northern part of the United States produces a cool climate, and when combined with the moderate rainfall the area receives, has contributed to the large number of lakes in the state.

Topography

The state's topography, which is greatly affected by the glaciers that passed over the land thousands of years ago, also played a role in the development of the lakes. These huge bodies of moving ice produced glacial sand, gravel, and clay deposits and carved depressions in the earth that later served as basins for lakes. Minnesota has more than 15,000 lake basins, mostly in the northeastern and central sections of the state. Numerous lakes have placed the state at the head of three major drainage basins: The Great Lakes, the Mississippi River, and the Red River of the North.

Minnesota's 25,000 miles of streams also exhibit considerable diversity. North Shore streams plunge toward Lake Superior, forming rapids and falls. Streams to the west and south of the Arrowhead region become unpredictable, changing quickly from placid flows to heavy rapids. In northwestern and southwestern parts of the state, lakes are scarcer and are typically shallow. In the southeast portion of Minnesota, spring-fed streams tumble through wooded bluffs.

Water and Impurities

Water is the universal solvent and in nature, it is never totally pure. No matter how isolated it is from sources of contamination, it will always have some chemicals. Gases or minerals in the air, soil, or rock are dissolved by the water. Some dissolved materials give water its characteristic taste, and “pure water” is generally considered to be flat and tasteless.

Minerals can cause hardness (calcium or magnesium), color (iron), contamination (arsenic), and radioactivity (radium, radon) in the water. Humans can cause contamination through the improper use of pesticides or fertilizers and through the disposal of waste. These impurities can dissolve in the water, causing it to be contaminated.

Minerals and impurities are normally present in very small concentrations, and are measured in parts per million (ppm) (how many parts of impurities in a million parts of water) or milligrams per liter (mg/l). The terms are equivalent and are used interchangeably in water and wastewater. Some contaminants can also be measured in parts per billion (ppb) or micrograms per liter (µg/l), which are also essentially equivalent.

Groundwater dissolves much of the material that it percolates through. It is generally harder than surface water, and it usually contains more iron and manganese. As stated earlier, water in nature is not pure. The table below shows typical concentration ranges for chemicals dissolved in ground or surface water.

	CONCENTRATIONS FOUND IN GROUND WATER	**CONCENTRATIONS FOUND IN SURFACE WATER**
Total Hardness	300 - 400 ppm	75 - 200 ppm
Alkalinity	250 - 350 ppm	45 - 250 ppm
Dissolved Oxygen	near 0	2 - 14 ppm
Carbon Dioxide	1 - 10 ppm	low
Calcium Hardness	high	sometimes high, usually low
Magnesium Hardness	tends to be high	sometimes high, usually low

Water that exists in nature, like any other material, undergoes changes. These changes are driven by both physical and chemical means. The quality of groundwater is generally slower to change, especially when it comes from deeper aquifers. Groundwater is not directly exposed to air pollution, contamination from run-off (if the well is properly constructed), or wastewater discharge. The quality of groundwater is also protected by natural filtration, which can remove some contaminants, as water percolates through the soils and rock.

Chemicals (either organic or inorganic) that dissolve in water can change its characteristics and may cause it to become contaminated. Among other things, these chemicals could change its pH, cause hardness, or add dissolved oxygen.

When contamination is found in groundwater, the use of a specific aquifer may have to be discontinued. Some organic chemicals that have contaminated some aquifers are very difficult and expensive to remove. It may be cheaper to drill a new well into a different aquifer. However, in many circumstances other aquifers do not exist, and contaminant cleanup or treatment is necessary.

WATER CHARACTERISTICS

Temperature

The most basic physical change is caused by temperature changes of the water. The warmer the temperature of the water, the more rapid the settling characteristics of the water. This occurs because the molecules of water become more active with a rise in temperature. Any chemicals added will dissolve and react more readily with the solids in the water.

Temperature will affect the time required for mixing and sedimentation when a chemical is added for coagulation. The reaction is accelerated considerably when the water is warmer. The colder the water, the longer it will take for the floc to form. Fortunately, in winter when the temperature generally is colder, less water is needed in the community and the water treatment plant flow is lower. This lower flow lengthens the detention time and allows the floc to form. Warmer temperatures also make disinfection of the water much easier.

Turbidity

Turbidity refers to the cloudiness of the water. It can be a problem in surface water sources. The materials causing the cloudiness can be inorganic (such as clays, silts, or sand) or organic, such as algae and leaf particles.

Turbidity of drinking water is important for a number of reasons. The turbidity in the water may shield bacteria, preventing disinfection chemicals from attacking and destroying the cells. Another health concern relates to organic materials that cause turbidity in the water. These materials, in conjunction with chlorine, can form trihalomethanes and other potentially harmful chemicals.

From an aesthetic standpoint, turbidity in the water makes it less appealing to many people. Most operators have had to field complaints about bubbles and cloudiness in the water, which may be caused, not by turbidity, but by the aerator on faucets in the home.

Turbidity is normally tested using instruments that pass a light through the water and measure the light refraction at a 90-degree angle from the light source. This may be done by process meters that continuously measure the water in line, or by using meters in the lab for grab samples. Most meters used today are of the nephelometric type. They are calibrated by using formazin standards supplied with the meters. The turbidity is expressed in NTU units. For turbidity limits, see Chapter 3 on Regulations and Sanitary Surveys.

Surface water sources usually have higher turbidity than groundwater sources. Groundwater is filtered naturally as it passes through an aquifer. The turbidity of a surface water source can vary greatly from a low of less than one to a high of over 200 NTU.

Color

Color, a physical characteristic of water that is not noticed unless it is very high, is measured by comparing a water sample to a color standard. One color unit has no effect on the water and is usually not detectable while 100 color units could be compared to the color of light tea. There could be many reasons for excessive color in water. For example, in surface water, tannin (which makes the water look brown) is caused by a chemical formed from organic material.

pH

pH is a measure of the hydrogen ion concentration in water. pH is measured on a scale ranging from 0 to 14 with seven considered neutral. At a pH below 7, the water is acidic; at a pH above 7, the water is alkaline. The lower the pH, the greater the acidity; the higher the pH, the greater the alkalinity. A change of one (1) pH means a ten-fold increase or decrease in the hydrogen ion concentration.

When mixed with water, an acid releases excess hydrogen ions (H+), and an alkaline material produces excess hydroxyl ions (OH-). Carbon dioxide (CO_2), which creates a “weak” acid (H_2C0_3), lowers the pH of the water, while lime, calcium hydroxide ($CA[OH]_2$), raise the pH.

The normal range of pH for drinking water is 6.5 to 8.5. Water with a lower pH tends to be more corrosive; at a higher pH it tends to produce scale. However, it is not always true that water with a pH below 7 will cause corrosion or that water above pH 7 will scale. The corrosion index must be calculated separately for each condition. The stability point of water is the point at which it is neither corrosive nor scale forming. Softened water, for example, usually has a stability point at slightly over 8 on the pH scale. For more information on corrosion, see Chapter 25 on Corrosion in this manual.

Hardness

Hardness in water is caused by significant amounts of calcium or magnesium components. The hardness is classified into carbonate or non-carbonate hardness depending on what molecules are combined with the calcium or magnesium. If they are combined with carbonate ions (CO_3), the hardness is carbonate hardness; if combined with other ions, it is non-carbonate hardness.

The operator needs some basic information about the water to be able to determine if the hardness is carbonate or non-carbonate. Either type can be calculated if the total hardness and total alkalinity is known. If the total hardness equals the total alkalinity, the hardness is of the carbonate type. Non-carbonate hardness is equal to the total hardness minus the total alkalinity.

Example:

Total Hardness	265 ppm as $CaCO_3$,
Total Alkalinity	200 ppm as $CaCO_3$,
Carbonate Hardness	200 ppm $CaCO_3$
Non-carbonate Hardness	265 ppm - 200 ppm = 65 ppm $CaCO_3$

This information is useful for an operator of a softening plant when selecting the type of chemical to use in removing hardness from the water. If the carbonate hardness is high, the chemical of choice for removal of the hardness would most likely be lime; if the non-carbonate hardness is high, some soda ash or caustic soda may need to be added to attack that hardness. See Chapter 15 on Hardness in this manual for a further, more detailed discussion of hardness.

Dissolved Solids

The total dissolved solids can have a significant impact on the quality of water. The amount of dissolved solids affects the water for almost all of its uses, whether for drinking, agricultural, or industrial use. The recommended maximum limit of dissolved solids in drinking water is 500 ppm. The problems caused by dissolved material relate to taste and odor, hardness, and corrosion and scaling in the distribution system, among others.

Several different types of dissolved solids could be toxic if the levels become too high. These include barium, arsenic, cadmium, chromium, lead, mercury, selenium, and silver. Each of these is regulated by the EPA and has maximum contaminant levels assigned to them. See Chapter 3 on Regulations and Sanitary Surveys in this manual for further information about the rules.

Organics

Organic material can cause problems in terms of health effects, treatment and taste, odor, and color of water. Some organics are potential carcinogens; that is they may cause cancer. Cancer-causing substances may be formed when naturally occurring organic material formed by plant and animal decomposition combines with chlorine, forming trihalomethanes. Others may already be present in the raw surface or groundwater as a result of contamination of the water source.

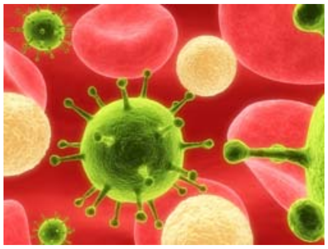
Some major sources of organic contamination are pesticides, herbicides, domestic waste, and industrial waste.

Algae

Algae (one-celled, microscopic, and larger) aquatic plants, some microscopic, can be quite abundant in a surface water source, especially during the summer months and especially if the water contains nutrients that encourage their growth, such as phosphorus from domestic run-off or industrial pollution. Algae may cause taste and odor problems, clog filters, and produce nuisance slime growths on intake pipes and equipment.

Bacteria

Bacteria are microscopic one-celled organisms that multiple by simple division. Bacteria are universally distributed. Many of them are essential. For example, they aid in the decomposition of dead organic material. However, there are numerous disease-producing bacteria that the water industry needs to guard against. These may cause typhoid fever, dysentery, cholera, and gastroenteritis. Some bacteria, although not harmful, may cause taste and odor problems. Examples of such bacteria are sulfur bacteria, which may produce hydrogen sulfide, or crenothrix iron bacteria which can produce disagreeable taste, odors, and stains.



Disease-causing bacteria are called pathogenic bacteria. It is often hard to test for and identify them. Therefore, their presence is determined by testing for the presence of an indicator organism, usually coliform bacteria. This group of bacteria is found in the intestines of warm-blooded animals; it is also common in soil. A more specific group of bacteria are the fecal coliforms, which are directly associated with contamination from human or animal wastes. Presence of coliform bacteria indicates general bacterial contamination. The presence of fecal coliform indicates contamination from a human or animal source.

Protozoans

Protozoans are single celled, usually microscopic, organisms. Some protozoans, such as Giardia and Cryptosporidium, are commonly found in rivers, lakes, and streams contaminated with animal feces or which receive wastewater from sewage treatment plants. When a water system uses surface water as its source, Giardia and Cryptosporidium must be removed in the clarification process because they are very difficult to kill with the usual forms of disinfection. If a person is infected, the symptoms may last seven or more days and include diarrhea, stomach cramps, nausea, fatigue, dehydration, and headaches. Protozoans are very difficult to test for; 100 or more gallons of water must be piped through a filter with openings less than one micron in size at 1 gpm or less. The particles trapped by the filter are then analyzed using very sophisticated methods to determine if any protozoa are present.

Viruses

Viruses are the smallest living organisms capable of producing infection and causing disease. Viruses that may be carried by water include the hepatitis and polio virus. They are very difficult to test for; usually large amounts of water have to be tested by using very sophisticated methods.

Radionuclides

Radiological contaminants emit radioactivity as they decompose. Sources of radioactive material are likely the aquifer minerals the water moves through. Radium 226, radium 228, uranium, and radon are the most common radioactive elements found in Minnesota. Radiological elements tend to be a greater problem in groundwater than in surface water, and radon may be elevated in groundwater that has been in contact with granite.

3

Regulations and Sanitary Surveys

The drinking water industry, like any other, operates under a set of guidelines. Based on the most current and best available knowledge, rules and recommended standards have been established to ensure safe and reliable drinking water to the public. The operation of public drinking water supply systems is regulated by the Section of Drinking Water Protection of the Minnesota Department of Health (MDH).

The Federal Safe Drinking Water Act (SDWA) was passed into law in 1974 as an attempt to ensure the quality of drinking water throughout the United States. Major amendments, which greatly expanded the scope and impact of the Act on water systems, were made in 1986 and 1996.

The federal government, through the U.S. Environmental Protection Agency (EPA), sets standards for drinking water quality and establishes the frequency at which water samples must be collected and analyzed. Primary standards are health based and are enforceable. Secondary standards are based on how the water looks and tastes and are guidelines only, not rules that can be enforced.

PRIMARY STANDARDS

Primary Standards may be either Maximum Contaminant Levels (MCLs) or Treatment Technique Requirements (TTR). In addition, there is a Maximum Contaminant Level Goal (MCLG) at which there should be no adverse health effects.

Maximum Contaminant Level Goal

A person drinking water containing a particular contaminant at this level over his or her lifetime should experience no ill effects. As implied by the title, this number is a goal not an enforceable standard. For chemicals which are believed to cause cancer, the MCLG is set at zero since there is no known safe level for this type of chemical.

Maximum Contaminant Level

This is the enforceable standard. EPA sets the MCL as close to the MCLG as is feasible. In this case, “feasible” refers to use of the Best Available Technology (BAT), which takes costs and technology into consideration. The MCL is the number against which the water samples from your system are judged for compliance with the regulations.

Treatment Technique Requirements

Treatment Technique Requirements are set for contaminants which are difficult or costly to measure. For these contaminants, EPA may choose to require specific water treatment practices (such as filtration or corrosion control) to prevent health problems. This is done instead of setting an MCL for these contaminants.

SECONDARY STANDARDS

The Secondary Maximum Contaminant Level (SMCL) is a number associated with the aesthetic quality of the water, such as taste, odor, or color. Water with contaminants above the SMCL may not be pleasant to drink but will not cause health problems. According to EPA, these numbers are guidelines, not enforceable standards.

STATE PRIMACY

In return for federal grant money, the states administer and enforce safe drinking water regulations in their jurisdictions. The term “primacy” is used to identify states that have taken over responsibility for administering and enforcing safe drinking water regulations. The MDH obtained primacy in 1977 and since then has administered and enforced the State drinking water regulations.

Primary responsibilities of the MDH regarding the SDWA are to:

- Enforce SDWA regulations;
- Conduct sanitary surveys of PWSs;
- Certify laboratories analyzing drinking water contaminants according to the SDWA; and
- Review plans for new or modified PWS facilities.

Minnesota safe drinking water regulations are established under the Federal SDWA and define a PWS as ‘a system providing piped water for human consumption and either containing a minimum of 15 service connections or 15 living units, or serving at least 25 persons daily for (at least) 60 days a year.’

The regulations also differentiate between a Community Public Water Supply (CPWS) system, a Noncommunity Public Water Supply (NCPWS) system, and a Nontransient-Noncommunity Public Water Supply (NTNCPWS) system. Each is described below:

COMMUNITY PUBLIC WATER SYSTEM

A CPWS system is ‘a system which serves at least 15 service connections or living units used by year-round residents, or regularly serves at least 25 year-round residents.’ Municipalities, mobile home parks, apartments, housing subdivisions, nursing homes, state hospitals, and correctional institutions are all examples of community systems.

NONCOMMUNITY PUBLIC WATER SYSTEM

A NCPWS system is ‘any public water supply that is not a community water supply and that serves a transient population.’ The following are examples of noncommunity systems: seasonal facilities such as children’s camps; recreational camping areas; resorts or year-round facilities which serve at least 25 persons who are not residents thereof, such as churches, entertainment facilities, gasoline service stations; marinas; migrant labor camps; parks; and restaurants.

NONTRANSIENT NONCOMMUNITY PUBLIC WATER SYSTEM

A NTNC-PWS system is ‘a public water supply that is not a community water supply and that regularly serves at least 25 of the same persons over six months per year.’ Factories, office buildings, day-care centers, and schools are among the different types of nontransient-noncommunity systems.

Since CPWSs are, in general, providing water to people where they permanently reside, most of the MCLs for organic and inorganic chemicals in water are based on the potential health effects from long-term exposure.

Conversely, NCPWSs (excluding the NTNCPWSs, of which there are large numbers) mostly serve travelers or people who have other primary sources of drinking water. Therefore, the EPA has ruled that these systems must only monitor for coliform bacteria and nitrates, contaminants that may have an acute or immediate health effect on the consumer. One of the reasons for the limited monitoring of these supplies is the large cost of more detailed monitoring.

Under the SDWA, CPWSs and NTNCPWSs are required to be monitored for contaminants in four general categories: microbiological, radiochemical, organic, and inorganic chemicals. NCPWSs are primarily tested for microbiological contaminants and nitrates and nitrites.

SDWA RULES

SDWA regulations are continually being revised and expanded (see following pages in this chapter for rule summaries). These rules are subject to change and should be used only as a guide to the Minnesota safe drinking water program, rather than a strict legal interpretation of the SDWA.

- Consumer Confidence Report (CCR) Rule
- Ground Water Rule
- Lead and Copper Rule
- Microbial and Disinfection By-Products (MDBP) Rules
- Phase II/V Rules include Inorganic Chemicals (IOCs), Synthetic Organic Chemicals (SOCs), and Volatile Organic Chemicals (VOCs)
- Public Notification Rule
- Surface Water Treatment Rules
- Total Coliform Rule
- Unregulated Contaminant Monitoring Rule (UCMR)
- Filter Backwash Recycling Rule
- Radionuclides Rules
- Arsenic and Clarifications to Compliance and New Source Monitoring Rule

SANITARY SURVEYS

The SDWA also requires sanitary surveys are conducted at all community PWSs, and MDH district engineers conduct a sanitary survey at each PWS at least once every 18 months. A sanitary survey reviews critical components of a public water system, and states have the authority to define both outstanding performance and significant deficiencies.

Eight specific components that must be reviewed during a survey (to the extent they apply to the water system being surveyed) include:

- Source
- Treatment
- Distribution system
- Finished water storage
- Pumps, pump facilities, and controls
- Monitoring, reporting, and data verification
- System management and operation
- Operator compliance with state requirements

An example of typical findings made during a sanitary survey can be found as standards in Chapter 26 on Plan Review.

RECORD MAINTENANCE

Water systems must maintain the following records:

- Results of bacteriological analysis for at least the last five years and results of chemical analysis for at least the last 10 years.
- Records of action taken to correct violations must be kept for at least three years after the last action was taken with respect to a particular violation.
- Copies of written reports, summaries, or communications relating to sanitary surveys conducted by the purveyor, private consultants, or local, state or federal agencies must be kept for at least ten years after completion of the survey.
- Records concerning scheduling of improvements must be kept not less than five years following expiration of the period scheduled for the improvement.

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Consumer Confidence Report Rule: A Quick Reference Guide

Overview of the Rule

Title	Consumer Confidence Report (CCR) Rule, 40 CFR, Part 141, Subpart O.
Purpose	Improve public health protection by providing educational material to allow consumers to make educated decisions regarding any potential health risks pertaining to the quality, treatment, and management of their drinking water supply.
General Description	The CCR Rule requires all community water systems to prepare and distribute a brief annual water quality report summarizing information regarding source, any detected contaminants, compliance, and educational information.
Utilities Covered	Community water systems (CWSs), all size categories.

Public Health Related Benefits

Implementation of the CCR Rule will result in . . .	‣ Increased consumer knowledge of drinking water quality, sources, susceptibility, treatment, and drinking water supply management. ‣ Increased awareness of consumers to potential health risks, so they may make informed decisions to reduce those risks, including taking steps toward protecting their water supply. ‣ Increased dialogue with drinking water utilities and increased understanding of consumers to take steps toward active participation in decisions that affect public health.

Annual Requirements

CWSs with 15 or more connections or serving at least 25 year round residents must prepare and distribute a CCR to all billing units or service connections.	‣ *April 1* - Deadline for CWS that sells water to another CWS to deliver the information necessary for the buyer CWS to prepare their CCR (req. outlined in 40 CFR 141.152). ‣ *July 1* - Deadline for annual distribution of CCR to customers and State or local primacy agency for report covering January 1 - December 31 of previous calendar year. ‣ *October 1* - (or 90 days after distribution of CCR to customers, whichever is first) - Deadline for annual submission of proof of distribution to State or local primacy agency. ‣ A system serving 100,000 or more persons must also post its current year's report on a publicly accessible site on the Internet. Many systems choose to post their reports at the following EPA website http://yosemite.epa.gov/ogwdw/ccr.nsf/america. ‣ All systems must make copies of the report available on request.

Small Water System Flexibility

- With the permission of the Governor of a State (or designee), or where the tribe has primacy, in lieu of mailing, systems serving fewer than 10,000 persons may publish their CCR in a local newspaper.*
- With the permission of the Governor of a State (or designee), or where the tribe has primacy, in lieu of mailing and/or publication, systems serving 500 or fewer persons may provide a notice stating the report is available on request.*

*Questions regarding whether the necessary permission has been granted should be addressed to the local State or primacy agency.

Major Provisions to be Included in the CCR

Water System Information

	Name/phone number of contact person.
	Information on public participation opportunities (time and place for meetings or hearings).
	Information for non-English speaking populations (if applicable).

Source of Water

	Type (ex. groundwater or surface water), commonly used name, and location of water sources (ex. Potomac River, Snake River Plain Aquifer, etc.) (Exact locations/coordinates of wells and intakes should not be included for security reasons.)
	Availability of source water assessment.
	Brief summary on potential sources of contamination (if available).

Definitions

	Maximum Contaminant Level (MCL).
	Maximum Contaminant Level Goal (MCLG).
	Treatment Technique (TT) (if applicable).
	Maximum Residual Disinfectant Level (MRDL) (if applicable).
	Maximum Residual Disinfectant Level Goal (MRDLG) (if applicable).
	Action Level (AL) (if applicable).
	Variances and Exemptions (if applicable).

Detected Contaminants

	Table summarizing data on detected regulated and unregulated contaminants that were detected during the last round of sampling.
	Known or likely source of each detected contaminant.
	Health effects language for any violations, exceedances or when Arsenic levels are > 0.01 mg/L or $\leq$ 0.05 mg/L.
	Information on *Cryptosporidium*, Radon, and other contaminants (if applicable).

Compliance with Drinking Water Regulations

	Explanation of violations, length of violations, potential health effects, and steps taken to correct the violations.
	Explanation of variance/exemption (if applicable).

Required Educational Information

	Explanation of contaminants and their presence in drinking water including bottled water.
	Warning for vulnerable or immunocompromised populations about *Cryptosporidium*.
	Informational statements on arsenic, nitrate, lead, and TTHM (if applicable).
	EPA's Safe Drinking Water Hotline Number of (1-800-426-4791).

For additional information on the CCR Rule

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA website at www.epa.gov/safewater/ccr1.html; log onto the CCRiWriter website to use EPA's template at www.CCRiWriter.com; view 40 CFR 141 subpart O; or contact your State or local primacy agency's drinking water representative.

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Final Ground Water Rule

Summary

The Environmental Protection Agency (EPA) promulgated the final Ground Water Rule (GWR) in October 2006 to reduce the risk of exposure to fecal contamination that may be present in public water systems that use ground water sources. EPA proposed the GWR on May 10, 2000 (65 *Federal Register* 30194). The rule establishes a risk-targeted strategy to identify ground water systems that are at high risk for fecal contamination. The GWR also specifies when corrective action (which may include disinfection) is required to protect consumers who receive water from ground water systems from bacteria and viruses.

Background

The 1996 Amendments to the Safe Drinking Water Act required EPA to develop regulations that require disinfection of ground water systems “as necessary” to protect the public health (section 1412(b)(8)).

Ground water occurrence studies and recent outbreak data show that pathogenic viruses and bacteria can occur in public water systems that use ground water and that people may become ill due to exposure to contaminated ground water.

Most cases of waterborne disease are characterized by gastrointestinal symptoms (e.g., diarrhea, vomiting, etc.) that are frequently self-limiting in healthy individuals and rarely require medical treatment. However, these same symptoms are much more serious and can be fatal for persons in sensitive subpopulations (such as young children, the elderly, and persons with compromised immune systems).

Viral and bacterial pathogens are present in human and animal feces, which can, in turn, contaminate drinking water. Fecal contamination can reach ground water sources, including drinking water wells, from failed septic systems, leaking sewer lines, and by passing through the soil and large cracks in the ground. Fecal contamination from the surface may also get into a drinking water well along its casing or through cracks if the well is not properly constructed, protected, or maintained.

EPA does not believe all ground water systems are fecally contaminated; data indicate that only a small percentage of ground water systems are fecally contaminated. However, the severity of health impacts and the number of people potentially exposed to microbial pathogens in ground water indicate that a regulatory response is warranted.

About this Regulation

The GWR applies to more than 147, 000 public water systems that use ground water (as of 2003). The rule also applies to any system that mixes surface and ground water if the ground water is added directly to the distribution system and provided to consumers without treatment equivalent to surface water treatment. In total, these systems provide drinking water to more than 100 million consumers.

***Final Requirements**:* The rule addresses risks through a risk-targeting approach that relies on four major components:

1. Periodic sanitary surveys of ground water systems that require the evaluation of eight critical elements and the identification of significant deficiencies (e.g., a well located near a leaking septic system). States must complete the initial survey by December 31, 2012 for most community water systems (CWSs) and by December 31, 2014 for CWSs with outstanding performance and for all non-community water systems.

2. Source water monitoring to test for the presence of *E. coli*, enterococci, or coliphage in the sample. There are two monitoring provisions:
   -*Triggered monitoring* for systems that do not already provide treatment that achieves at least 99.99 percent (4-log) inactivation or removal of viruses and that have a total coliform-positive routine sample under Total Coliform Rule sampling in the distribution system.
   -*Assessment monitoring*- As a complement to triggered monitoring, a State has the option to require systems, at any time, to conduct source water assessment monitoring to help identify high risk systems.

3. Corrective actions required for any system with a significant deficiency or source water fecal contamination. The system must implement one or more of the following correction action options:
   -correct all significant deficiencies,
   -eliminate the source of contamination,
   -provide an alternate source of water, or
   -provide treatment which reliably achieves 99.99 percent (4-log) inactivation or removal of viruses.

4. Compliance monitoring to ensure that treatment technology installed to treat drinking water reliably achieves at least 99.99 percent (4-log) inactivation or removal of viruses.

Environmental and Public Health Benefits

The GWR will reduce public health risk from contaminated ground water drinking water sources, especially in high-risk or high-priority systems. The GWR is estimated to reduce the average number of waterborne viral (rotovirus and echovirus) illnesses by nearly 42,000 illnesses each year from the current baseline estimate of approximately 185,000 (a 23 percent reduction in total illnesses). In addition, nonquantified benefits from the rule resulting in illness reduction from other viruses and bacteria are expected to be significant.

Cost of the Regulation

The GWR will result in increased costs to public water systems and States. The mean annualized present value national compliance costs of the final GWR are estimated to be approximately $62 million (using three percent discount rate). Public water systems will bear the majority of costs. The annual household costs for community water systems (including those that do not add treatment) range from $0.21 to $16.54. Annual household costs for the subset of systems that undertake corrective actions range from $0.45 to $52.38, with 90 percent having household cost increases of no more than $3.20.

How to Get Additional Information

For general information on the GWR, please contact the Safe Drinking Water Hotline, at (800) 426-4791. The Safe Drinking Water Hotline is open Monday through Friday, excluding Federal holidays, from 10 a.m. to 4 p.m., Eastern time. For copies of the Federal Register notice of the final regulation, visit the EPA Safewater Web site, http://www.epa.gov/safewater/disinfection/gwr.

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Lead and Copper Rule: A Quick Reference Guide

Overview of the Rule

Title	**Lead and Copper Rule (LCR)[1], 56 FR 26460 - 26564, June 7, 1991**
Purpose	**Protect public health by minimizing lead (Pb) and copper (Cu) levels in drinking water, primarily by reducing water corrosivity. Pb and Cu enter drinking water mainly from corrosion of Pb and Cu containing plumbing materials.**
General Description	**Establishes action level (AL) of 0.015 mg/L for Pb and 1.3 mg/L for Cu based on 90th percentile level of tap water samples. An AL exceedance is not a violation but can trigger other requirements that include water quality parameter (WQP) monitoring, corrosion control treatment (CCT), source water monitoring/treatment, public education, and lead service line replacement (LSLR).**
Utilities Covered	**All community water systems (CWSs) and non-transient, non-community water systems (NTNCWSs) are subject to the LCR requirements.**

Public Health Benefits

Implementation of the LCR has resulted in . . .

- **Reduction in risk of exposure to Pb that can cause damage to brain, red blood cells, and kidneys, especially for young children and pregnant women.**
- **Reduction in risk of exposure to Cu that can cause stomach and intestinal distress, liver or kidney damage, and complications of Wilson's disease in genetically predisposed people.**

Lead and Copper Tap Sampling Requirements

- **First draw samples must be collected by all CWSs & NTNCWSs at cold water taps in homes/buildings that are at high risk of Pb/Cu contamination as identified in 40 CFR 141.86(a).**
- **Number of sample sites is based on system size (see Table 1).**
- **Systems must conduct monitoring every 6 months unless they qualify for reduced monitoring (see Table 2).**

Table 1: Pb and Cu Tap and WQP Tap Monitoring

Size Category	System Size	Number of Pb/Cu Tap Sample Sites		Number of WQP Tap Sampling Sites	
		Standard	Reduced	Standard	Reduced
Large	**> 100K**	100	50	25	10
	50,001-100K	60	30	10	7
Medium	**10,001 - 50K**	60	30	10	7
	3,301 - 10K	40	20	3	3
Small	**501 - 3,300**	20	10	2	2
	101 - 500	10	5	1	1
	≤ 100	5	5	1	1

Table 2: Criteria for Reduced Pb/Cu Tap Monitoring[a]

Can Monitor . . .	***If the System . . .***
Annually	1. Serves ≤ 50,000 and is ≤ both ALs for 2 consecutive 6-month monitoring periods; ***or***
	2. Meets Optimal Water Quality Parameter (OWQP) specifications for 2 consecutive 6-month monitoring periods.
Triennially	1. Serves ≤ 50,000 and is ≤ both ALs for 3 consecutive years of monitoring; ***or***
	2. Meets OWQP specifications for 3 consecutive years of monitoring; ***or***
	3. Has 90th percentile Pb levels ≤ 0.005 mg/L & 90th percentile Cu level ≤ 0.65 mg/L for 2 consecutive 6-month periods (*i.e*, accelerated reduced Pb/Cu tap monitoring), ***or***
	4. Meets the 40 CFR 141.81(b)(3) criteria.
Once every 9 years	Serves ≤ 3,300 and meets monitoring waiver criteria found at 40 CFR 141.86(g).

[a] Samples are collected at reduced number of sites (see Table 1 above).

Treatment Technique and Sampling Requirements

CORROSION CONTROL TREATMENT INSTALLATION: All large systems (except systems that meet the requirements of 40 CFR 141.81(b)(2) or (3)) must install CCT. Medium and small systems that exceed either AL must install CCT.

WATER QUALITY PARAMETER MONITORING: All large systems are required to do WQP monitoring. Medium and small systems that exceed either AL are required to do WQP monitoring.

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[1] The June 1991 LCR was revised with the following Technical Amendments:
56 FR 32112, July 15, 1991;
57 FR 28785, June 29, 1992;
59 FR 33860, June 30, 1994;
and the LCR Minor Revisions
65 FR 1950, January 12, 2000.

Treatment Technique and Sampling Requirements if the AL is Exceeded

❶ Water Quality Parameter (WQP) Monitoring

- All systems serving > 50,000 people, and those systems serving ≤ 50,000 people if 90th percentile tap level > either AL, must take WQP samples during the same monitoring periods as Pb/Cu tap sample.
- Used to determine water corrosivity, and if needed, to help identify type of CCT to be installed and how CCT should be operated (*i.e.*, establishes OWQP levels).
- WQPs include: pH, alkalinity, calcium, conductivity (initial WQP monitoring only), orthophosphate (if phosphate-based inhibitor is used); silica (if silicate-based inhibitor is used), and temperature (initial WQP monitoring only).
- Samples are collected within distribution system (*i.e.*, WQP tap samples), with number of sites based on system size (see Table 1), and at each entry point to distribution system (EPTDS).
- Systems installing CCT, must conduct follow-up monitoring for 2 consecutive 6-month periods – WQP tap monitoring is conducted semi-annually; EPTDS monitoring increases to every two weeks.
- After follow-up monitoring, State sets ranges of values for the OWQPs.
- Reduced WQP tap monitoring is available for systems in compliance with OWQPs; *Reduced monitoring does not apply to EPTDS monitoring.*
- For systems ≤ 50,000, WQP monitoring is not required whenever 90th percentile tap levels are ≤ both ALs.

❷ Public Education (PE)

- Only required if Pb AL is exceeded *(no public education is required if only Cu AL exceeded).*
- Informs Public Water System's (PWS) customers about health effects, sources, and what can be done to reduce exposure.
- Includes billing inserts sent directly to customers, pamphlets or brochures distributed to hospitals & other locations that provide services to pregnant woman & children, and for some CWSs, newspaper notices and public service announcements (PSAs) submitted to TV/radio stations.
- System must begin delivering materials within 60 days of Pb AL exceedance and continue every 6 months for PSAs and annually for all other forms of delivery for as long as it exceeds Pb AL.
- Different delivery methods and mandatory language for CWSs & NTNCWSs.
- Can discontinue delivery whenever ≤ Pb AL; but must recommence if Pb AL subsequently exceeded.
- PE requirements are in addition to the Public Notification required in 40 CFR Subpart Q.

❸ Source Water Monitoring and Treatment

- All systems that exceed Pb or Cu AL must collect source water samples to determine contribution from source water to total tap water Pb/Cu levels and make a source water treatment (SOWT) recommendation within 6 months of the exceedance.
- One set of samples at each EPTDS is due within 6 months of first AL exceedance.
- If State requires SOWT; system has 24 months to install SOWT.
- After follow-up Pb/Cu tap and EPTDS monitoring, State sets maximum permissible levels for Pb & Cu in source.

❹ Corrosion Control Treatment

- Required for all large systems (except systems that meet the requirements of 40 CFR 141.81(b)(2) or (b)(3)) and medium/small systems that exceed either AL. The system shall recommend optimal CCT within 6 months.
- Corrosion control study required for large systems.
- If State requires study for medium or small systems, it must be completed within 18 months.
- Once State determines type of CCT to be installed, PWS has 24 months to install CCT.
- Systems installing CCT must conduct 2 consecutive 6-months of follow-up monitoring.
- After follow-up Pb/Cu tap & WQP monitoring, State sets OWQPs.
- Small & medium systems can stop CCT steps if ≤ both ALs for 2 consecutive 6-month monitoring periods.

If the system continues to exceed the AL after installing CCT and/or SOWT...

❺ Lead Service Line (LSL) Monitoring

- Two types of sampling associated with LSL replacement (LSLR):
  - *Optional* - Monitoring from LSL to determine need to replace line. If all Pb samples from line ≤ 0.015 mg/L then LSL does not need to be replaced and counts as replaced line.
  - *Required* - Monitoring if entire LSL is ***not*** replaced to determine impact from "partial" LSLR. Sample is collected that is representative of water in service line that is partially replaced.
- Monitoring only applies to system subject to LSLR.

❻ Lead Service Line Replacement

- System must replace LSLs that contribute more than 0.015 mg/L to tap water levels.
- Must replace 7% of LSL per year; State can require accelerated schedule.
- If only a portion of a LSL is replaced, PWS must:
  - Notify customers at least 45 days prior to replacement about the potential for increased Pb levels;
  - Collect sample within 72 hours of replacement and mail/post results within 3 days of receipt of results.
- Systems can discontinue LSLR whenever ≤ Pb AL in tap water for 2 consecutive monitoring periods.

For additional information on the LCR, call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA web site at www.epa.gov/safewater/lcrmr/implement.html; or contact your State drinking water representative.

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Office of Water
(4606)

EPA 816-F-01-010
May 2001
www.epa.gov/safewater

Stage 1 Disinfectants and Disinfection Byproducts Rule: A Quick Reference Guide

Overview of the Rule

Title	**Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR)** **63 FR 69390 - 69476, December 16, 1998, Vol. 63, No. 241** **Revisions to the Interim Enhanced Surface Water Treatment Rule (IESWTR), the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR), and Revisions to State Primacy Requirements to Implement the Safe Drinking Water Act (SDWA) Amendments** **66 FR 3770, January 16, 2001, Vol 66, No. 29**
Purpose	**Improve public health protection by reducing exposure to disinfection byproducts. Some disinfectants and disinfection byproducts (DBPs) have been shown to cause cancer and reproductive effects in lab animals and suggested bladder cancer and reproductive effects in humans.**
General Description	**The Stage 1 DBPR is the first of a staged set of rules that will reduce the allowable levels of DBPs in drinking water. The new rule establishes seven new standards and a treatment technique of enhanced coagulation or enhanced softening to further reduce DBP exposure. The rule is designed to limit capital investments and avoid major shifts in disinfection technologies until additional information is available on the occurrence and health effects of DBPs.**
Utilities Covered	**The Stage 1 DBPR applies to all sizes of community water systems and nontransient noncommunity water systems that add a disinfectant to the drinking water during any part of the treatment process and transient noncommunity water systems that use chlorine dioxide.**

Public Health Benefits

Implementation of the Stage 1 DBPR will result in . . .	‣ **As many as 140 million people receiving increased protection from DBPs.** ‣ **24 percent average reduction nationally in trihalomethane levels.** ‣ **Reduction in exposure to the major DBPs from use of ozone (DBP = bromate) and chlorine dioxide (DBP = chlorite).**
Estimated impacts of the Stage 1 DBPR include . . .	‣ **National capital costs: $2.3 billion** ‣ **National total annualized costs to utilities: $684 million** ‣ **95 percent of households will incur an increase of less than $1 per month.** ‣ **4 percent of households will incur an increase of $1-10 per month.** ‣ **<1 percent of households will incur an increase of $10-33 per month.**

Critical Deadlines and Requirements

For Drinking Water Systems

January 1, 2002	**Surface water systems and ground water systems under the direct influence of surface water serving ^{3} 10,000 people must comply with the Stage 1 DBPR requirements.**
January 1, 2004	**Surface water systems and ground water systems under the direct influence of surface water serving < 10,000, and all ground water systems must comply with the Stage 1 DBPR requirements.**

For States

December 16, 2000	**States submit Stage 1 DBPR primacy revision applications to EPA (triggers interim primacy).**
December 16, 2002	**Primacy extension deadline - all states with an extension must submit primacy revision applications to EPA.**

For additional information on the Stage 1 DBPR

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA web site at www.epa.gov/safewater; or contact your State drinking water representative.

Additional material is available at www.epa.gov/safewater/mdbp/implement.html.

Regulated Contaminants/Disinfectants

Regulated Contaminants	MCL (mg/L)	MCLG (mg/L)	Regulated Disinfectants	MRDL* (mg/L)	MRDLG* (mg/L)
Total Trihalomethanes (TTHM)	**0.080**		**Chlorine**	**4.0 as Cl_2**	**4**
Chloroform Bromodichloromethane Dibromochloromethane Bromoform		- zero 0.06 zero			
Five Haloacetic Acids (HAA5)	**0.060**		**Chloramines**	**4.0 as Cl_2**	**4**
Monochloroacetic acid Dichloroacetic acid Trichloroacetic acid Bromoacetic acid Dibromoacetic acid		- zero 0.3 - -	**Chlorine dioxide**	**0.8**	**0.8**
Bromate (plants that use ozone)	**0.010**	**zero**	***Stage 1 DBPR includes maximum residual disinfectant levels (MRDLs) and maximum residual disinfectant level goals (MRDLGs) which are similar to MCLs and MCLGs, but for disinfectants.**		
Chlorite (plants that use chlorine dioxide)	**1.0**	**0.8**			

Treatment Technique

Enhanced coagulation/enhanced softening to improve removal of DBP precursors (See Step 1 TOC Table) for systems using conventional filtration treatment.

Step 1 TOC Table - Required % Removal of TOC

Source Water TOC (mg/L)	Source Water Alkalinity, mg/L as $CaCO_3$		
	0-60	> 60-120	> 120
> 2.0 to 4.0	35.0%	25.0%	15.0%
> 4.0 to 8.0	45.0%	35.0%	25.0%
> 8.0	50.0%	40.0%	30.0%

[1] Systems meeting at least one of the alternative compliance criteria in the rule are not required to meet the removals in this table.

[2] Systems practicing softening must meet the TOC removal requirements in the last column to the right

Routine Monitoring Requirements

	Coverage	Monitoring Frequency	Compliance
TTHM/HAA5	Surface and ground water under the direct influence of surface water serving ≥ 10,000	4/plant/quarter	Running annual average
	Surface and ground water under the direct influence of surface water serving 500 - 9,999	1/plant/quarter	Running annual average
	Surface and ground water under the direct influence of surface water serving < 500	1/plant/year in month of warmest water temperature**	Running annual average of increased monitoring
	Ground water serving ≥ 10,000	1/plant/quarter	Running annual average
	Ground water serving < 10,000	1/plant/year in month of warmest water temperature**	Running annual average of increased monitoring
Bromate	Ozone plants	Monthly	Running annual average
Chlorite	Chlorine dioxide plants	Daily at entrance to distribution system; monthly in distribution system	Daily/follow-up monitoring
Chlorine dioxide	Chlorine dioxide plants	Daily at entrance to distribution system	Daily/follow-up monitoring
Chlorine/Chloramines	All systems	Same location and frequency as TCR sampling	Running annual average
DBP precursors	Conventional filtration	Monthly for total organic carbon and alkalinity	Running annual average

** System must increase monitoring to 1 sample per plant per quarter if an MCL is exceeded.

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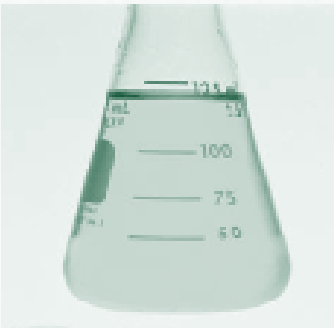
Stage 1 Disinfectants and Disinfection Byproducts Rule: Laboratory Quick Reference Guide



Overview of the Rule

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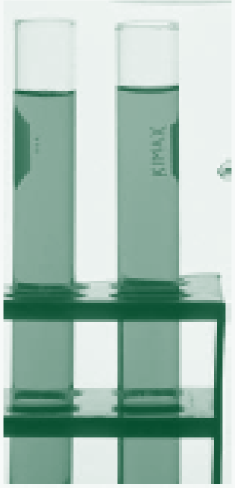


Critical Deadlines and Requirements

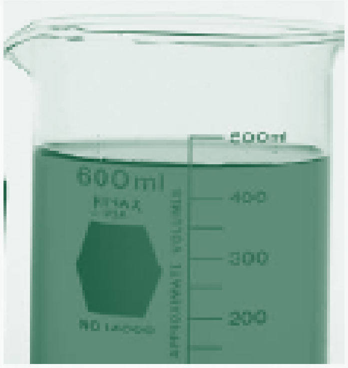
January 1, 2002	**Surface water systems and ground water systems under the direct influence of surface water (GWUDI) serving ³ 10,000 people must comply with the Stage 1 DBPR requirements.**
January 1, 2004	**Surface water systems and GWUDI serving < 10,000, and all ground water systems must comply with the Stage 1 DBPR requirements.**

Routine Monitoring Requirements

Regulated Contaminants/ Disinfectants	Coverage	Monitoring Frequency
TTHM/HAA5	**Surface and GWUDI serving ³ 10,000**	**4/plant/quarter**
	Surface and GWUDI serving 500 - 9,999	**1/plant/quarter**
	Surface and GWUDI serving < 500	**1/plant/year in month of warmest water temperature***
	Ground water serving ³ 10,000	**1/plant/quarter**
	Ground water serving < 10,000	**1/plant/year in month of warmest water temperature***
Bromate[†]	**Ozone plants**	**Monthly at entrance to distribution system**
Chlorite	**Chlorine dioxide plants**	**Daily at entrance to distribution system; monthly in distribution system**
Chlorine/Chloramines	**All systems**	**Same location and frequency as Total Coliform Rule sampling**
Chlorine dioxide	**Chlorine dioxide plants**	**Daily at entrance to distribution system**
DBP precursors (TOC/Alkalinty/SUVA)	**Conventional filtration systems**	**Monthly for total organic carbon and alkalinity or the SUVA alternative**

* System must increase monitoring to 1 sample per plant per quarter if an MCL is exceeded.

[†] Reduced Bromate monitoring may be available based on results of optional Bromide monitoring - See Stage 1 DBPR.



Laboratory Considerations

- **Obtain certification (or state approval) to perform new analyses.**
- **Become familiar with new monitoring requirements.**
- **Prepare for increased number of samples (e.g., storage, supplies, staff).**
- **Schedule to accommodate large number of samples, holding times, and demands on instrumentation.**

For additional information on the Stage 1 DBPR

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA web site at www.epa.gov/safewater; or contact your State drinking water representative.

Additional material is available at www.epa.gov/safewater/mdbp/implement.html.

Routine Monitoring Requirements

Regulated Contaminants/ Disinfectants	MCL (mg/L)	MRDL (mg/L)	Analytical Method	Preservative/Quenching Agent	Holding Time Sample/Extract	Sample Container Size & Type[1]
TTHM * (Sum of: chloroform bromodichloromethane dibromochloromethane bromoform)	0.080		EPA 502.2	Sodium thiosulfate (immediately acidify to pH<2 with HCl, if VOCs are included in analysis), OR ascorbic acid and immediate acidification to pH<2 with HCl. Samples must be dechlorinated prior to acidification.	14 days at 4ºC	40 - 120 mL glass w/Teflon-lined septum
			EPA 524.2			
			EPA 551.1	Sodium sulfite or ammonium chloride with a phosphate buffer (pH = 4.5 - 5.5).	14 days at 4ºC/14 days at <-10ºC	60 mL glass vial w/Teflon-lined septum
HAA5 * (Sum of: monochloroacetic acid dichloroacetic acid trichloroacetic acid monobromoacetic acid dibromoacetic acid)	0.060		EPA 552.1	Ammonium chloride	28 days at 4ºC away from light/48 hours	>100 mL amber glass w/Teflon-lined septum
			EPA 552.2	Ammonium chloride	14 days at 4ºC away from light/7 days at 4ºC or 14 days at £ -10ºC	>50 mL amber glass w/Teflon-lined septum
			SM 6251B	Ammonium chloride	9 days at 4ºC/21 days at -11ºC	40 - 60 mL glass vial w/Teflon-lined septum
Bromate *	0.010		EPA 300.1	Ethylenediamine	28 days	> 30 mL plastic or glass
Bromide +			EPA 300.0 EPA 300.1	Ethylenediamine	28 days	> 30 mL plastic or glass
Chlorite + (Daily at entrance to distribution system)	1.0		SM 4500-ClO_2 E	None	Immediately	>500 mL plastic or glass
			EPA 300.0 EPA 300.1	Ethylenediamine	14 days at 4ºC protected from light	> 30 mL opaque plastic or glass
Chlorite * (Monthly in distribution system)	1.0		EPA 300.0 EPA 300.1	Ethylenediamine	14 days at 4ºC protected from light	> 30 mL opaque plastic or glass
Chlorine +		4.0 as Cl_2	Free - 4500-Cl D, F, G, H	None	Immediately	> 500 mL plastic or glass
			Combined - 4500-Cl D, F, G			
			Total - 4500-Cl D, E, F, G, I			
Chloramines +		4.0 as Cl_2	4500-Cl D, E, F, G, I	None	Immediately	> 500 mL plastic or glass
Chlorine Dioxide +		0.8 as ClO_2	4500-ClO_2 D, E	None	Immediately	> 500 mL plastic or glass
pH +			EPA 150.1, 150.2, 4500 H+ B, or ASTM D1293-95	None	Immediately	> 500 mL plastic or glass
DBP Precursors + (TOC/Alkalinity/SUVA)	Treatment Technique: Enhanced coagulation/ enhanced softening to improve removal of DBP precursors for suface water systems using conventional filtration treatment or lime softening.		SM 5310 B, C and D for TOC or DOC portion of SUVA	Acidify TOC samples to pH < 2. Filter DOC sample through 0.45 µm pore diameter filter as soon as possible after collection (£ 48 hours) and then acidify same as TOC.	28 days stored at 4ºC and protected from light	>100 mL amber glass w/Teflon-lined septum
			SM 5910 B for UV_{254} portion of SUVA	Filter through 0.45 µm pore diameter filter as soon as possible after collection (£ 48 hours).	£ 48 hours stored at 4ºC and protected from light	> 100 mL amber glass w/Teflon-lined septum
			ASTM D1067-92B or SM 2320 B or I-1030-85 for alkalinity	None	14 days stored at 4ºC and protected from light	> 200 mL plastic or glass

1 - Note the sample volumes specified in this table are estimates. The actual sample container volumes should be specified by the laboratory(s) performing the analyses.
+ - Indicates the analysis must be performed by a party approved by the state.
* - Indicates the laboratory must be certified to analyze the sample.

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Stage 2 Disinfectants and Disinfection Byproducts Rule: A Quick Reference Guide For Schedule 1 Systems

Overview of the Rule

Title	**Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) 71 FR 388, January 4, 2006, Vol. 71, No. 2**
Purpose	**To increase public health protection by reducing the potential risk of adverse health effects associated with disinfection byproducts (DBPs) throughout the distribution system. Builds on the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR) by focusing on monitoring for and reducing concentrations of two classes of DBPs - TTHM and HAA5 - in drinking water.**
General Description	**Stage 2 DBPR requires some systems to complete an Initial Distribution System Evaluation (IDSE) to characterize DBP levels in their distribution systems and identify locations to monitor DBPs for Stage 2 DBPR compliance. The Stage 2 DBPR bases TTHM and HAA5 compliance on a locational running annual average (LRAA) calculated at each monitoring location.**
Utilities Covered *	▸ **All community water systems (CWSs) and nontransient noncommunity water systems (NTNCWSs) that either add a primary or residual disinfectant other than ultraviolet light, or deliver water that has been treated with a primary or residual disinfectant other than ultraviolet light.** ▸ **Schedule 1 includes CWSs and NTNCWSs serving 100,000 or more people OR CWSs and NTNCWSs that are part of a combined distribution system in which the largest system serves 100,000 or more people.**

*** NTNCWSs serving < 10,000 people do not need to complete any of the IDSE options, but must conduct Stage 2 DBPR compliance monitoring.**

Stage 2 DBPR Regulated Contaminants

Regulated Contaminants		MCLG (mg/L)	MCL (mg/L)
Total Trihalomethanes (TTHM)			**0.080 LRAA**
	Chloroform Bromodichloromethane Dibromochloromethane Bromoform	0.07 zero 0.06 zero	
Five Haloacetic Acids (HAA5)			**0.060 LRAA**
	Monochloroacetic acid Dichloroacetic acid Trichloroacetic acid Bromoacetic acid Dibromoacetic acid	0.07 zero 0.02 - -	

IDSE Requirements**

IDSE Option	Description
Standard Monitoring	**Standard monitoring is one year of increased monitoring for TTHM and HAA5 in addition to the data being collected under Stage 1 DBPR. These data will be used with Stage 1 DBPR data to select Stage 2 DBPR TTHM and HAA5 compliance monitoring locations. Any system may conduct standard monitoring to meet the IDSE requirements of the Stage 2 DBPR.**
System Specific Study (SSS)	**Systems that have extensive TTHM and HAA5 data (including Stage 1 DBPR compliance data) or technical expertise to prepare a hydraulic model may choose to conduct a system specific study to select Stage 2 DBPR compliance monitoring locations.**
40/30 Certification †	**The term "40/30" refers to a system that during a specific time period has all individual Stage 1 DBPR compliance samples less than or equal to 0.040 mg/L for TTHM and 0.030 mg/L for HAA5 and has no monitoring violations during the same time period. These systems have no IDSE monitoring requirements, but will still need to conduct Stage 2 DBPR compliance monitoring.**
Very Small System (VSS) Waiver †	**Systems that serve fewer than 500 people and have eligible TTHM and HAA5 data can qualify for a VSS Waiver and would not be required to conduct IDSE monitoring. These systems have no IDSE monitoring requirements, but will still need to conduct Stage 2 DBPR compliance monitoring.**
EPA has developed several tools to assist systems with complying with the Stage 2 DBPR IDSE requirements. These materials can be downloaded at www.epa.gov/safewater/disinfection/stage2.	

**** NTNCWSs serving < 10,000 people do not need to complete any of the IDSE options.**
† Systems that are notified by EPA or the state their VSS waiver or 40/30 certification has not been approved will need to complete Standard Monitoring or System Specific Study.

For additional information on the Stage 2 DBPR

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA web site at www.epa.gov/safewater/disinfection/stage2; or contact your state drinking water representative.

Compliance with Stage 2 DBPR MCLs (Routine Monitoring)

Source Water Type	Population Size Category	Monitoring Frequency[1]	Total Distribution System Monitoring Locations Per Monitoring Period[2]
Subpart H	**<500**	**per year**	**2**
	500-3,300	**per quarter**	**2**
	3,301-9,999	**per quarter**	**2**
	10,000-49,999		**4**
	50,000-249,999		**8**
	250,000-999,999		**12**
	1,000,000-4,999,999		**16**
	≥5,000,000		**20**
Ground Water	**<500**	**per year**	**2**
	500-9,999		**2**
	10,000-99,999	**per quarter**	**4**
	100,000-499,999		**6**
	≥500,000		**8**

Operational Evaluation

Systems must begin complying with the operational evaluation provision of the Stage 2 DBPR.

[1] All systems must monitor during month of highest DBP concentrations.

[2] Systems on quarterly monitoring must take dual sample sets every 90 days at each monitoring location, except for subpart H systems serving 500-3,300. Systems on annual monitoring and subpart H systems serving 500-3,300 are required to take individual TTHM and HAA5 samples (instead of a dual sample set) at the locations with the highest TTHM and HAA5 concentrations, respectively. If monitoring annually, only one location with a dual sample set per monitoring period is needed if highest TTHM and HAA5 concentrations occur at the same location, and month.

Critical Deadlines and Requirements

For Drinking Water Systems (Schedule 1)

January 4, 2006	**Systems serving fewer than 500 people that have TTHM and HAA5 compliance data qualify for a VSS Waiver from conducting an IDSE, unless informed otherwise by U.S. EPA or state primacy agency.**
October 1, 2006	**Systems that do not receive a VSS Waiver must submit to the U.S EPA or state primacy agency either a:** ▸ **Standard monitoring plan,** ▸ **System specific study plan, or** ▸ **40/30 certification.**
October 1, 2007	**Systems conducting standard monitoring or SSS begin collecting samples in accordance with their approved plan.**
September 30, 2008	**No later than this date, systems conducting standard monitoring or a SSS complete their monitoring or study.**
January 1, 2009	**No later than this date, systems conducting standard monitoring or a SSS must submit their IDSE report.**
April 1, 2009	**Consecutive systems must begin monitoring for chlorine or chloramines as specified under the Stage 1 DBPR.**
April 1, 2012	**No later than this date, systems must:** ▸ **Complete their Stage 2 DBPR Compliance Monitoring Plan (Systems serving more than 3,300 people must submit their Monitoring Plan to the state.)*** ▸ **Begin complying with monitoring requirements of the Stage 2 DBPR.**†
January 2013	**Systems must begin complying with rule requirements to determine compliance with the operational evaluation levels for TTHMs and HAA5s.**

For States

January - June 2006	**States are encouraged to inform systems serving fewer than 500 people and do not qualify for a VSS Waiver from the IDSE requirements should begin complying with standard monitoring requirements.**
September 30, 2007	**States must approve the system's standard monitoring plan, 40/30 certification, or system specific study plan or notify the system that the state has not completed its review.**
October 4, 2007	**States are encouraged to submit final primacy applications or extension requests to EPA.**
January 4, 2008	**Final primacy applications must be submitted to EPA, unless granted an extension.**
March 31, 2009	**States must approve the system's IDSE report or notify the system that the state has not completed its review of the IDSE report.**
January 4, 2010	**Final primacy revision applications from states with approved 2-year extensions agreements must be submitted to EPA.**

* A monitoring plan is not required if the IDSE report includes all information required in the monitoring plan.

† States may allow up to an additional 24 months for compliance with MCLs for systems requiring capital improvements.

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The Standardized Monitoring Framework: A Quick Reference Guide

Overview of the Framework

Title	**The Standardized Monitoring Framework (SMF), promulgated in the Phase II Rule on January 30, 1991 (56 FR 3526).**
Purpose	**To standardize, simplify, and consolidate monitoring requirements across contaminant groups. The SMF increases public health protection by simplifying monitoring plans and synchronizing monitoring schedules leading to increased compliance with monitoring requirements.**
General Description	**The SMF reduces the variability within monitoring requirements for chemical and radiological contaminants across system sizes and types.**

Additional Requirements

The SMF outlined on these pages summarizes existing systems' ongoing federal monitoring requirements only. Primacy agencies have the flexibility to issue waivers, with EPA approval, which take into account regional and state specific characteristics and concerns. To determine exact monitoring requirements, the SMF must be used in conjunction with any EPA approved waiver and additional requirements as determined by the primacy agency.

New water systems may have different and additional requirements as determined by the primacy agency.

SMF Benefits

Implementation of the SMF results in . . .

- **Increased public health protection through monitoring consistency.**
- **A reduction in the complexity of water quality monitoring from a technical and managerial perspective for both primacy agencies and water systems.**
- **Equalizing of resource expenditures for monitoring and vulnerability assessments.**
- **Increased water system compliance with monitoring requirements.**

Regulated Contaminants

Inorganic Contaminants (IOCs)	**Fifteen (15)** (Nitrate, Nitrite, total Nitrate/Nitrite, and Asbestos are exceptions to SMF)
Synthetic Organic Contaminants (SOCs) & Volatile Organic Contaminants (VOCs)	**Fifty-One (51)**
Radionuclides	**Four (4)**

Utilities Covered

All PWSs	**Nitrate** **Nitrite**
CWSs	**IOCs** **SOCs** **VOCs** **Radionuclides**
NTNCWSs	**IOCs** **SOCs** **VOCs**

For additional information:

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA web site at www.epa.gov/safewater/ or contact your primacy agency's drinking water representatives.

See 40 CFR 141.23 regarding IOCs; 40 CFR 141.24 regarding VOCs and SOCs; and 40 CFR 141.26 regarding Radionuclides.

Office of Water (4606) EPA 816-F-04-010 www.epa.gov/safewater March 2004

STANDARDIZED MONITORING FRAMEWORK

IOCs, SOCs, VOCs		Second Cycle									Third Cycle								
		1st Period			2nd Period			3rd Period			1st Period			2nd Period			3rd Period		
Inorganic Contaminants (IOCs)[1]		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Groundwater (Below MCL)																		
	Waiver[2]	*									*								
	No Waiver	*			*			*			*			*			*		
	Surface Water (Below MCL)																		
	Waiver[2]	*									*								
	No Waiver	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Groundwater and Surface Water (Above MCL)[3]																		
	Reliably and Consistently ≤ MCL for Groundwater Systems	*			*			*			*			*			*		
	Reliably and Consistently ≤ MCL for Surface Water Systems	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	> MCL or Not Reliably and Consistently ≤ MCL	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Synthetic Organic Contaminants (SOCs)		02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
	Population >3,300 (Below Detection Limit)																		
	Waiver	X			X			X			X			X			X		
	< Detect and No Waiver	**			**			**			**			**			**		
	Population ≤3,300 (Below Detection Limit)																		
	Waiver	X			X			X			X			X			X		
	< Detect and No Waiver	*			*			*			*			*			*		
	Above Detection Limit																		
	Reliably and Consistently ≤ MCL[4]	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	≥ Detect or Not Reliably and Consistently ≤ MCL	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Volatile Organic Contaminants (VOCs)		02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
	Groundwater (Below Detection Limit)																		
	< Detect, Vulnerability Assessment, and Waiver[5]	*						*						*					
	No Waiver[6]	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Surface Water (Below Detection Limit)																		
	< Detect, Vulnerability Assessment, and Waiver[7]	X			X			X			X			X			X		
	No Waiver[8]	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Above Detection Limit																		
	Reliably and Consistently < MCL[4]	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	≥ Detect or Not Reliably and Consistently ≤ MCL	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****

STANDARDIZED MONITORING FRAMEWORK

EXCEPTIONS		Second Cycle									Third Cycle								
		1st Period			2nd Period			3rd Period			1st Period			2nd Period			3rd Period		
Nitrate		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	CWSs & NTNCWSs																		
	Surface Water with 4 Quarters of Results < 1/2 MCL[9]	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Groundwater Reliably and Consistently < MCL[9]	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	≥ 1/2 MCL	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****
	TNCWSs																		
	Standard Monitoring	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Nitrite		02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
	< 1/2 MCL	#									#								
	Reliably and Consistently < MCL[9]	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	≥ 1/2 MCL or not Reliably and Consistently < MCL	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Radio-nuclides		02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
	< Detection Limit	!		****				*									*		
	≥ Detection Limit but ≤ 1/2 MCL			****				*						*					
	> 1/2 MCL but ≤ MCL			****				*			*			*			*		
	> MCL			****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Asbestos		02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
	Waiver	X			X			X			X			X			X		
	No Waiver, Reliably and Consistently ≤ MCL, or vulnerable to asbestos contamination[10]	*									*								
	> MCL	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****

Legend

* = 1 sample at each entry point to distribution system (EPTDS).

** = 2 quarterly samples at each EPTDS. Samples must be taken during 1 calendar year during each 3-year compliance period.

**** = 4 quarterly samples at each EPTDS within time frame designated by the primacy agency.

X = No sampling required unless required by the primacy agency.

= Systems must monitor at a frequency specified by the primacy agency.

! = When allowed by the primacy agency, data collected between June 2000 and December 8, 2003 may be grandfathered to satisfy the initial monitoring requirements due in 2004 for gross alpha, radium 226/228, and uranium.

[1] Until January 22, 2006 the maximum contaminant level (MCL) for arsenic is 50 µg/L; on January 23, 2006 the MCL for arsenic becomes 10 µg/L.

[2] Based on 3 rounds of monitoring at each EPTDS with all analytical results below the MCL. Waivers are not permitted under the current arsenic requirements, however systems are eligible for arsenic waivers after January 23, 2006.

[3] A system with a sampling point result above the MCL must collect quarterly samples, at that sampling point, until the system is determined by the primacy agency to be reliably and consistently below the MCL.

[4] Samples must be taken during the quarter which previously resulted in the highest analytical result. Systems can apply for a waiver after 3 consecutive annual sampling results are below the detection limit.

[5] Groundwater systems must update their vulnerability assessments during the time the waiver is effective. Primacy agencies must re-confirm that the system is non-vulnerable within 3 years of the initial determination or the system must return to annual sampling.

[6] If all monitoring results during initial quarterly monitoring are less than the detection limit, the system can take annual samples. If after a minimum of 3 years of annual sampling with all analytical results less than the detection limit, the primacy agency can allow a system to take 1 sample during each compliance period. Systems are also eligible for a waiver.

[7] Primacy agencies must determine that a surface water system is non-vulnerable based on a vulnerability assessment during each compliance period or the system must return to annual sampling.

[8] If all monitoring results during initial quarterly monitoring are less than the detection limit, the system can take annual samples. Systems are also eligible for a waiver.

[9] Samples must be taken during the quarter which previously resulted in the highest analytical result.

[10] Systems are required to monitor for asbestos during the first 3-year compliance period of each 9-year compliance cycle. A system vulnerable to asbestos contamination due solely to corrosion of asbestos-cement pipe must take 1 sample at a tap served by that pipe. A system vulnerable to asbestos contamination at the source must sample at each EPTDS.

NOTES:

United States
Environmental Protection
Agency

Office of Water
(4606)

EPA 816-F-00-023
May 2000

The Public Notification Rule

A Quick Reference Guide

Highlights

- Revises timing and distribution requirements — notice must be provided within 24 hours (Tier 1, instead of 72 hours), 30 days (Tier 2, instead of 14 days), or one year (Tier 3, instead of 90 days), based on the potential severity of the situation
- Expands list of violations and situations requiring immediate notification and broadens applicability of the public notice to other situations
- Simplifies mandatory health effects language and adds standard language for monitoring violations and for encouraging notice distribution
- Consolidates public notification requirements previously found in other parts of drinking water regulations
- Increases primacy agency flexibility
- Amends Consumer Confidence Report (CCR) regulations to conform to changes made in public notification regulations

Title

Revisions to the Public Notification Regulations for Public Water Systems (40 CFR Part 141, subpart Q), published May 4, 2000 (65 *FR* 25981)

Purpose

To notify the public any time a water system violates national primary drinking water regulations or has other situations posing a risk to public health

Effective Date

Rule is effective **June 5, 2000**
PWSs in jurisdictions directly implemented by EPA must meet these revised requirements **October 31, 2000**
PWSs in primacy states must meet these revised requirements **May 6, 2002** or when the state adopts the revised regulations, whichever is sooner

Applicability

All PWSs violating national primary drinking water regulations, operating under a variance or exemption, or having other situations posing a risk to public health

Timing and Distribution

Notices must be sent within 24 hours, 30 days, or one year depending on the tier to which the violation is assigned (see page 2). The clock for notification starts when the PWS learns of the violation. Notices must be provided to persons served (not just billing customers).

Multilingual Requirements

Where the PWS serves a large proportion of non-English speakers, the PWS must provide information in the appropriate language(s) on the importance of the notice or on how to get assistance or a translated copy

Printed on Recycled Paper

Tier 1 (Immediate Notice, Within 24 Hours)

Notice as soon as practical or within 24 hours via radio, TV, hand delivery, posting, or other method specified by primacy agency, along with other methods if needed to reach persons served. PWSs must also initiate consultation with primacy agency within 24 hours. Primacy agency may establish additional requirements during consultation.

- Fecal coliform violations; failure to test for fecal coliform after initial total coliform sample tests positive
- Nitrate, nitrite, or total nitrate and nitrite MCL violation; failure to take confirmation sample
- Chlorine dioxide MRDL violation in distribution system; failure to take samples in distribution system when required
- Exceedance of maximum allowable turbidity level, if elevated to Tier 1 by primacy agency
- Special notice for non-community water systems (NCWSs) with nitrate exceedances between 10 mg/L and 20 mg/L, where system is allowed to exceed 10 mg/L by primacy agency
- Waterborne disease outbreak or other waterborne emergency
- Other violations or situations determined by the primacy agency

Tier 2 (Notice as Soon as Possible, Within 30 Days)

Notice as soon as practical or within 30 days. Repeat notice every three months until violation is resolved. CWSs: Notice via mail or direct delivery. NCWSs: Notice via posting, direct delivery, or mail. Primacy agencies may permit alternate methods. All PWSs must use additional delivery methods reasonably calculated to reach other consumers not notified by the first method.

- All MCL, MRDL, and treatment technique violations, except where Tier 1 notice is required
- Monitoring violations, if elevated to Tier 2 by primacy agency
- Failure to comply with variance and exemption conditions

*** Turbidity consultation:** Where PWSs have a treatment technique violation resulting from a single exceedance of the maximum allowable turbidity limit or an MCL violation resulting from an exceedance of the two-day turbidity limit, they must consult their primacy agency within 24 hours. Primacy agencies will then determine whether a Tier 1 notice is necessary. If consultation does not occur within 24 hours, violations are automatically elevated to Tier 1.

Tier 3 (Annual Notice)

Notice within 12 months; repeated annually for unresolved violations. Notices for individual violations can be combined into an annual notice (including the CCR, if public notification requirements can still be met). CWSs: Notice via mail or direct delivery. NCWSs: Notice via posting, direct delivery, or mail. Primacy agencies may permit alternate methods. All PWSs must use additional delivery methods reasonably calculated to reach other consumers not notified by the first method.

- Monitoring or testing procedure violations, unless primacy agency elevates to Tier 2
- Operation under a variance and exemption
- Special public notices (fluoride secondary maximum contaminant level (SMCL) exceedance, availability of unregulated contaminant monitoring results)

Requirements for Ongoing Violations

All new billing units and customers must be notified of ongoing violations or situations requiring notice

Relationship to the CCR

Where appropriate, the public notification and CCR requirements are consistent:

- Health effects language for MCL, MRDL, and treatment technique violations are the same
- Multilingual and certification requirements are similar
- CCR may be used for Tier 3 notification, provided public notification timing, content, and delivery requirements are met

Reporting and Record Keeping

- PWSs have ten days to send a certification of compliance and a copy of the completed notice to the primacy agency
- PWS and primacy agency must keep notices on file for three years
- Primacy agencies must report public notification violations to EPA on a quarterly basis

Primacy Requirements

- Primacy agencies must submit complete and final requests for approval of program revisions in order to maintain primacy for public notification
- Primacy agencies have up to 2 years to adopt the new regulations
- Primacy agencies must establish enforceable requirements and procedures if they choose to use any of the flexibilities allowed them in the public notification regulation (e.g., if they allow a PWS to use a different notification method or if they elevate a Tier 2 violation to Tier 1)

Materials Available to Support This Rule

EPA/ASDWA *Public Notification Handbook* provides sample notice templates for water systems and other aids for water systems preparing notices

Primacy Guidance for the Public Notification Rule provides guidance and formats for states preparing primacy program revisions to adopt public notification rule

For More Information

Safe Drinking Water Hotline
1-800-426-4791

Office of Ground Water and Drinking Water Web Site
http://www.epa.gov/safewater/pn.html

Contents of Notice (see sample notice on last page)

Unless otherwise specified in the regulations,* each notice must contain:

1) A description of the violation or situation, including contaminant levels, if applicable
2) When the violation or situation occurred
3) Any potential adverse health effects (using standard health effects language from Appendix B of the public notification rule or the standard monitoring language, see below)
4) The population at risk
5) Whether alternative water supplies should be used
6) What actions consumers should take
7) What the system is doing to correct the violation or situation
8) When the water system expects to return to compliance or resolve the situation
9) The name, business address, and phone number of the water system owner or operator
10) A statement (see below) encouraging distribution of the notice to others, where applicable

** These elements do not apply to notices for fluoride SMCL exceedances, availability of unregulated contaminant monitoring data, and operation under a variance or exemption. Content requirements for these notices are specified in the rule.*

Standard Language:

Standard Monitoring Language: We are required to monitor your drinking water for specific contaminants on a regular basis. Results of regular monitoring are an indicator of whether or not our drinking water meets health standards. During [period] we [did not monitor or test/did not complete all monitoring or testing] for [contaminant(s)] and therefore cannot be sure of the quality of the drinking water during that time.

Standard Distribution Language: Please share this information with all the people who drink this water, especially those who may not have received this notice directly (for example, people in apartments, nursing homes, schools, and businesses). You can do this by posting this notice in a public place or distributing copies by hand or mail.

Sample Public Notice

DRINKING WATER WARNING

Springfield water has high levels of nitrate

DO NOT GIVE THE WATER TO INFANTS UNDER SIX MONTHS OLD OR USE IT TO MAKE INFANT FORMULA

4 - The population at risk

AVISO
NO USE EL AGUA PARA PREPARAR ALIMENTOS PARA BEBES

Este informe contiene información muy importante sobre su agua potable. Hable con alguien que lo entienda bien o llame al teléfono 555-1200 para hablar en español sobre este aviso.

Information for Spanish speakers

Water sample results received June 22, 1999 showed nitrate levels of 12 milligrams per liter (mg/l). This is above the nitrate standard, or maximum contaminant level (MCL), of 10 mg/l. Nitrate in drinking water is a serious health concern for infants less than six months old.

2 - When the violation or situation occurred

1 - A description of the violation or situation

What should I do?
DO NOT GIVE THE WATER TO INFANTS. *Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome.* Blue baby syndrome is indicated by blueness of the skin. Symptoms in infants can develop rapidly, with health deteriorating over a period of days. If symptoms occur, seek medical attention immediately.

3 - Potential health effects

Water, juice, and formula for children <u>under six months of age</u> should not be prepared with tap water. Bottled water or other water low in nitrates should be used for infants until further notice. Springfield Water Company and the Springfield Health Department are providing free bottled water to families with infants. Water is available between 9 a.m. and 5 p.m. Monday through Friday at the Health Department office at the Town Hall. Water will be provided until the nitrate problem is resolved.

5 - Whether alternate water supplies should be used

6 - Actions consumers should take

Do not boil the water. Boiling, freezing, filtering, or letting water stand does not reduce the nitrate level. Excessive boiling can make the nitrates more concentrated, because nitrates remain behind when the water evaporates.

Adults and children older than six months can drink the tap water (nitrate is a concern for infants because they can't process nitrates in the same way adults can). However, if you are pregnant or have specific health concerns, you may wish to consult your doctor.

What happened? What is being done?
Nitrate in drinking water can come from natural, industrial, or agricultural sources (including septic systems and run-off). Levels of nitrate in drinking water can vary throughout the year. We'll let you know when the amount of nitrate is again below the limit.

We are investigating water treatment and other options. These may include drilling a new well or mixing the water with low-nitrate water from another source. We anticipate resolving the problem by July 15.

7 - What is being done to correct the violation or situation

8 - When the system expects to return to compliance

For more information, please contact John Smith of the Springfield Water Company at (602) 555-1212. This notice was prepared and distributed by the Springfield Water Company, 500 Main Street, Springfield.

9 - Name, phone number, and business address for more information

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments, nursing homes, schools, and businesses). You can do this by posting this notice in a public place or distributing copies by hand or mail.

10 - Standard distribution language

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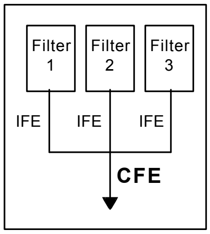
Long Term 1 Enhanced Surface Water Treatment Rule: A Quick Reference Guide

Overview of the Rule

Title	**Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) 67 FR 1812, January 14, 2002, Vol. 67, No. 9**
Purpose	**Improve public health protection through the control of microbial contaminants, particularly *Cryptosporidium*. Prevent significant increases in microbial risk that might otherwise occur when systems implement the Stage 1 Disinfectants and Disinfection Byproducts Rule.**
General Description	**Builds upon the requirements of the 1989 Surface Water Treatment Rule (SWTR). Smaller system counterpart of the Interim Enhanced Surface Water Treatment Rule (IESWTR).**
Utilities Covered	**Public water systems that use surface water or ground water under the direct influence of surface water (GWUDI) and serve fewer than 10,000 people.**

Major Provisions

Control of *Cryptosporidium*	‣ **The maximum contaminant level goal (MCLG) is set at zero.** ‣ **Filtered systems must physically remove 99% (2-log) of *Cryptosporidium*.** ‣ **Unfiltered systems must update their watershed control programs to minimize the potential for contamination by *Cryptosporidium* oocysts.** ‣ ***Cryptosporidium* is included as an indicator of GWUDI.**
Combined Filter Effluent (CFE) Turbidity Performance Standards  	***Specific CFE turbidity requirements depend on the type of filtration used by the system.*** **Conventional and direct filtration:** ‣ **£ 0.3 nephelometric turbidity units (NTU) in at least 95% of measurements taken each month.** ‣ **Maximum level of turbidity: 1 NTU.** **Slow sand and diatomaceous earth (DE) filtration:** ‣ **Continue to meet CFE turbidity limits specified in the SWTR:** • **1 NTU in at least 95% of measurements taken each month.** • **Maximum level of turbidity: 5 NTU.** **Alternative technologies (other than conventional, direct, slow sand, or DE):** ‣ **Turbidity levels are established by the State based on filter demonstration data submitted by the system.** • **State-set limits must not exceed 1 NTU (in at least 95% of measurements) or 5 NTU (maximum).**

Turbidity Monitoring Requirements

Combined Filter Effluent	‣ **Performed at least every 4 hours to ensure compliance with CFE turbidity performance standards.**[1]
Individual Filter Effluent (IFE) (for systems using conventional and direct filtration only)	***Since the CFE may meet regulatory requirements even though one filter is producing high turbidity water, the IFE is measured to assist conventional and direct filtration treatment plant operators in understanding and assessing individual filter performance.*** ‣ **Performed continuously (recorded at least every 15 minutes).** ‣ **Systems with two or fewer filters may conduct continuous monitoring of CFE turbidity in place of individual filter effluent turbidity monitoring.** ‣ **Certain follow-up actions are required if the IFE turbidity (or CFE for systems with two filters) exceeds 1.0 NTU in 2 consecutive readings or more (i.e., additional reporting, filter self-assessments, and/or comprehensive performance evaluations (CPEs)).**

For additional information on the LT1ESWTR

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA web site at www.epa.gov/safewater/mdbp/lt1eswtr.html; or contact your State drinking water representative.

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[1] This frequency may be reduced by the State to once per day for systems using slow sand/alternative filtration or for systems serving 500 persons or fewer regardless of the type of filtration used.

Disinfection Profiling and Benchmarking Requirements

Community and non-transient non-community public water systems must evaluate impacts on microbial risk before changing disinfection practices to ensure adequate microbial protection is maintained. This is accomplished through a process called disinfection profiling and benchmarking.

What are the disinfection profiling and benchmarking requirements?

- **Systems must develop a disinfection profile, which is a graphical compilation of weekly inactivation of *Giardia lamblia*, taken on the same calendar day each week over 12 consecutive months. (Systems using chloramines, ozone, or chlorine dioxide for primary disinfection must also calculate inactivation of viruses). Results must be available for review by the State during sanitary surveys.**
- **A State may deem a profile unnecessary if the system has sample data collected after January 1, 1998–during the month of warmest water temperature and at maximum residence time in the distribution system–indicating TTHM levels are below 0.064 mg/L and HAA5 levels are below 0.048 mg/L.**
- **Prior to making a significant change to disinfection practices, systems required to develop a profile must calculate a disinfection benchmark and consult with the State. The benchmark is the calculation of the lowest monthly average of inactivation based on the disinfection profile.**

Additional Requirements

- **Construction of new uncovered finished water reservoirs is prohibited.**

Critical Deadlines and Requirements

For Drinking Water Systems

March 15, 2002	Construction of uncovered finished reservoirs is prohibited.
July 1, 2003	No later than this date, systems serving between 500-9,999 persons must report to the State: - Results of optional monitoring which show levels of TTHM < 0.064 mg/L and HAA5 < 0.048 mg/L, OR - System has started profiling.
January 1, 2004	No later than this date, systems serving fewer than 500 persons must report to the State: - Results of optional monitoring which show levels of TTHM < 0.064 mg/L and HAA5 < 0.048 mg/L, OR - System has started profiling.
June 30, 2004	Systems serving between 500 and 9,999 persons must complete their disinfection profile unless the State has determined it is unnecessary.
December 31, 2004	Systems serving fewer than 500 persons must complete their disinfection profile unless the State has determined it is unnecessary.
January 14, 2005	Surface water systems or GWUDI systems serving fewer than 10,000 people must comply with the applicable LT1ESWTR provisions (e.g., turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).

For States

January 2002	As per the IESWTR, States begin first round of sanitary surveys (at least every 3 years for community water systems and every 5 years for non-community water systems).
October 14, 2003	States are encouraged to submit final primacy applications to EPA.
January 14, 2004	Final primacy applications must be submitted to EPA unless granted an extension.
December 2004	States must complete first round of sanitary surveys for community water systems (as per the IESWTR).
January 14, 2006	Final primacy revision applications from States with approved 2-year extension agreements must be submitted to EPA.
December 2006	States must complete first round of sanitary surveys for non-community water systems (as per the IESWTR).

Public Health Benefits

Implementation of the LT1ESWTR will result in . . .	- Increased protection against gastrointestinal illnesses from *Cryptosporidium* and other pathogens through improvements in filtration. - Reduced likelihood of endemic illness from *Cryptosporidium* by an estimated 12,000 to 41,000 cases annually. - Reduced likelihood of outbreaks of cryptosporidiosis.
Estimated impacts of the LT1ESWTR include . . .	- National total annualized cost: $39.5 million. - 90% of affected households will incur an increase of less than $1.25 per month. - One percent of affected households are likely to incur an increase of more than $10 per month.

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Comprehensive Surface Water Treatment Rules Quick Reference Guide: Systems Using Conventional or Direct Filtration

Overview of the Rules

Title	**Surface Water Treatment Rule** (SWTR) - 40 CFR 141.70-141.75 **Interim Enhanced Surface Water Treatment Rule** (IESWTR) - 40 CFR 141.170-141.175 **Filter Backwash Recycling Rule** (FBRR) - 40 CFR 141.76 **Long Term 1 Enhanced Surface Water Treatment Rule** (LT1ESWTR) - 40 CFR 141.500-141.571
Purpose	Improve public health protection through the control of microbial contaminants, particularly viruses, *Giardia*, and *Cryptosporidium*.
General Description	The **Surface Water Treatment Rules**: ▸ Applies to all public water systems (PWSs) using surface water or ground water under the direct influence of surface water (GWUDI), otherwise known as **"Subpart H systems."** ▸ Requires all Subpart H systems to disinfect. ▸ Requires Subpart H systems to filter unless specific filter avoidance criteria are met. ▸ Requires individual filter monitoring and establishes combined filter effluent (CFE) limits. ▸ Applies a treatment technique requirement for control of microbials.

Overview of Requirements

The purpose of this table is show how the requirements for the IESWTR and LT1ESWTR build on the existing requirements established in the original SWTR.

APPLICABILITY: PWSs that use surface water or ground water under the direct influence of surface water (Subpart H) that practice conventional or direct filtration.		**Final Rule Dates**			
		SWTR 1989	**IESWTR 1998**	**LT1ESWTR 2002**	**FBRR 2001**
Population Served	≥10,000	✓	✓	▨	✓
	< 10,000	✓	N/A (except for sanitary survey provisions)	✓	✓
Regulated Pathogens	99.99% (4-log) removal/inactivation of viruses	✓	Regulated under SWTR	Regulated under SWTR	Regulated under SWTR
	99.9% (3-log) removal/inactivation of *Giardia lamblia*	✓	Regulated under SWTR	Regulated under SWTR	Regulated under SWTR
	99% (2-log) removal of Cryptosporidium	▨	✓	✓	Regulated under IESWTR & LT1ESWTR
Residual Disinfectant Requirements	Entrance to distribution system (≥0.2 mg/L)	✓	Regulated under SWTR	Regulated under SWTR	▨
	Detectable in the distribution system	✓	Regulated under SWTR	Regulated under SWTR	▨
Turbidity Performance Standards	Combined Filter Effluent	✓	✓	✓	▨
	Individual Filter Effluent	▨	✓	✓	▨
Disinfection Profiling & Benchmarking	Systems must profile inactivation levels and generate benchmark, if required	▨	✓	✓	▨
Sanitary Surveys (state requirement)	CWS: Every 3 years NCWS: Every 5 years	▨	✓	Regulated under IESWTR	▨
Covered Finished Reservoirs/Water Storage Facilities (new construction only)		▨	✓	✓	▨
Operated by Qualified Personnel as Specified by State		✓	Regulated under SWTR	Regulated under SWTR	Regulated under SWTR

(CWS) Community Water System (NCWS) Non-community Water System

Turbidity

There are two ways turbidity is measured: **Combined Filter Effluent (CFE)** and **Individual Filter Effluent (IFE)**.

Turbidity: Monitoring and Reporting Requirements

Turbidity Reporting Requirements *(Reports due by the 10th day of the following month the system serves water to the public.)*	**Monitoring/ Recording Frequency**	**SWTR As of June 29, 1993**	**IESWTR ≥ 10,000 people As of January 1, 2002**	**LT1ESWTR < 10,000 people As of January 1, 2005**
CFE 95% Value Report total number of CFE measurements and number and percentage of CFE measurements ≤ 95th % limit.	At least every 4 hours*	≤ 0.5 NTU	≤ 0.3 NTU	≤ 0.3 NTU
CFE Maximum Value Report date and value of any CFE measurement that exceeded CFE maximum limit.	At least every 4 hours*	5 NTU Contact state within 24 hours	1 NTU Contact state within 24 hours	1 NTU Contact state within 24 hours
IFE Monitoring Report IFE monitoring conducted and any follow-up actions.	Monitor continuously every 15 minutes	None	Monitor–exceedances require follow-up action	Monitor–exceedances require follow-up action. Systems with 2 or fewer filters may monitor CFE continuously in lieu of IFE.

*Monitoring frequency may be reduced by the state to once per day for systems serving 500 or fewer people.

IFE Follow-Up and Reporting Requirements

	IESWTR (≥ 10,000)			**LT1ESWTR (< 10,000) ****		
Condition	**Action**	**Report**	**By**	**Action**	**Report**	**By**
2 consecutive recordings >0.5 NTU taken 15 minutes apart at the end of the first 4 hours of continuous filter operation after backwash/offline:	Produce filter profile within 7 days (if cause not known)	‣ Filter # ‣ Turbidity value ‣ Date ‣ Cause (if known) or report profile was produced	10th of the following month			
2 consecutive recordings > 1.0 NTU taken 15 minutes apart:	Produce filter profile within 7 days (if cause not known)	‣ Filter # ‣ Turbidity value ‣ Date ‣ Cause (if known) or report profile was produced	10th of the following month		‣ Filter # ‣ Turbidity value ‣ Date ‣ Cause (if known)	10th of the following month
2 consecutive recordings > 1.0 NTU taken 15 minutes apart at the same filter for **3 months in a row**:	Conduct filter self-assessment within 14 days	‣ Filter # ‣ Turbidity value ‣ Date ‣ Report filter self-assessment produced	10th of the following month	Conduct a filter self-assessment within 14 days. Systems with 2 filters that monitor CFE in lieu of IFE must do both filters.	‣ Date filter self-assessment triggered & completed	10th of the following month (or within 14 days of filter self-assessment being triggered if triggered in last 4 days of the month)
2 consecutive recordings > 2.0 NTU taken 15 minutes apart at the same filter for 2 months in a row:	Arrange for CPE within 30 days & submit report within 90 days	‣ Filter # ‣ Turbidity value ‣ Date	10th of the following month	Arrange for CPE within 60 days & submit CPE report within 120 days	‣ Date CPE triggered	10th of the following month
		Submit CPE report	90 days after exceedance		Submit CPE report	120 days after exceedance

** Systems serving fewer than 10,000 people must begin complying with these requirements beginning January 1, 2005.

IFE performance is measured in systems using conventional or direct filtration. The performance of each individual filter is critical to controlling pathogen breakthrough. The **CFE** turbidity results may mask the performance of an individual filter since the individual filter may have a turbidity spike of a short duration not detected by 4 hour CFE readings.

The IESWTR and LT1ESWTR created more stringent CFE turbidity standards and established a new IFE turbidity monitoring requirement to address *Cryptosporidium*. These new turbidity standards assure conventional and direct filtration systems will be able to provide 2-log *Cryptosporidium* removal.

Disinfection

Disinfection must be sufficient to ensure that the total treatment process (disinfection plus filtration) of the system achieves at least:

- 99.9% (3-log) inactivation and/or removal of *Giardia lamblia*.
- 99.99% (4-log) inactivation and/or removal of viruses.

Cryptosporidium must be removed by filtration and no inactivation credits are currently given for disinfection. Systems must also comply with the maximum residual disinfectant level (MRDL) requirements specified in the Stage 1 Disinfectants/ Disinfection Byproducts Rule (Stage 1 DBPR).

Residual Disinfectant Monitoring and Reporting Requirements

Location	Concentration	Monitoring Frequency	Reporting (Reports due 10th of the following month)
Entry to distribution system.	Residual disinfectant concentration cannot be < 0.2 mg/L for more than 4 hours.	Continuous, but states may allow systems serving 3,300 or fewer persons to take grab samples from 1 to 4 times per day, depending on system size.	Lowest daily value for each day, the date and duration when residual disinfectant was < 0.2 mg/L, and when state was notified of events where residual disinfectant was < 0.2 mg/L.
Distribution system - same location as total coliform sample location(s).	Residual disinfectant concentration cannot be undetectable in greater than 5% of samples in a month, for any 2 consecutive months. Heterotrophic plate count (HPC) ≤ 500/mL is deemed to have detectable residual disinfectant.	Same time as total coliform samples.	Number of residual disinfectant or HPC measurements taken in the month resulting in no more than 5% of the measurements as being undetectable in any 2 consecutive months.

Disinfection Profiling and Benchmarking Requirements

A **disinfection profile** is the graphical representation of a system's microbial inactivation over 12 consecutive months.

A **disinfection benchmark** is the lowest monthly average microbial inactivation value. The disinfection benchmark is used as a baseline of inactivation when considering changes in the disinfection process.

Disinfection Profiling and Benchmarking Requirements Under IESWTR & LT1ESWTR

The purpose of disinfection profiling and benchmarking is to allow systems and states to assess whether a change in disinfection practices creates a microbial risk. Systems should develop a disinfection profile that reflects *Giardia lamblia* inactivation (systems using ozone or chloramines must also calculate inactivation of viruses), calculate a benchmark (lowest monthly inactivation) based on the profile, and consult with the state prior to making a significant change to disinfection practices.

REQUIREMENT	IESWTR	LT1ESWTR
AFFECTED SYSTEMS:	Community, non-transient non-community, and transient systems.	Community and non-transient non-community systems only.
BEGIN PROFILING BY:	April 1, 2000	➤ July 1, 2003 for systems serving 500-9,999 people. ➤ January 1, 2004 for systems serving fewer than 500 people.
FREQUENCY & DURATION:	**Daily** monitoring for 12 consecutive calendar months to determine the total logs of *Giardia lamblia* inactivation (and viruses, if necessary) for each day in operation.	**Weekly** inactivation of *Giardia lamblia* (and viruses, if necessary), on the same calendar day each week over 12 consecutive months.
STATES MAY WAIVE DISINFECTION PROFILING REQUIREMENTS IF:	TTHM annual average <0.064 mg/L and HAA5 annual average <0.048 mg/L: ➤ Collected during the same period. ➤ Annual average is arithmetic average of the quarterly averages of four consecutive quarters of monitoring. ➤ At least 25% of samples at the maximum residence time in the distribution system. ➤ Remaining 75% of samples at representative locations in the distribution system.	One TTHM sample <0.064 mg/L and one HAA5 sample <0.048 mg/L: ➤ Collected during the month of warmest water temperature; **AND** ➤ At the maximum residence time in the distribution system. Samples must have been collected after January 1, 1998.
DISINFECTION BENCHMARK MUST BE CALCULATED IF:	Systems required to develop a disinfection profile and are considering any of the following: ➤ Changes to the point of disinfection. ➤ Changes to the disinfectant(s) used. ➤ Changes to the disinfection process. ➤ Any other modification identified by the state. Systems must consult the state prior to making any modifications to disinfection practices.	Same as IESWTR, and systems must obtain state approval prior to making any modifications to disinfection practices.

Filter Backwash Recycling Rule

The FBRR applies to PWSs that use surface water or ground water under the direct influence of surface water, practice conventional or direct filtration, and recycle spent filter backwash, thickener supernatant, or liquids from dewatering processes. The FBRR requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state. The FBRR was developed to improve public health protection by assessing and changing, where needed, recycle practices for improved contaminant control, particularly microbial contaminants. Systems were required to submit recycle notification to the state by December 8, 2003.

Filter Backwash Critical Deadlines and Requirements

June 8, 2004	➤ Return recycle flows through the processes of a system's existing conventional or direct filtration system or an alternate recycle location approved by the state (a 2-year extension is available for systems making capital improvements to modify the recycle return location). ➤ Collect recycle flow information and retain on file.
June 8, 2006	Complete all capital improvements associated with relocating recycle return location (if necessary).

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Comprehensive Surface Water Treatment Rules Quick Reference Guide: Systems Using Slow Sand, Diatomaceous Earth, or Alternative Filtration

Overview of the Rules

Title	**Surface Water Treatment Rule** (SWTR) - 40 CFR 141.70-141.75 **Interim Enhanced Surface Water Treatment Rule** (IESWTR) - 40 CFR 141.170-141.175 **Long Term 1 Enhanced Surface Water Treatment Rule** (LT1ESWTR) - 40 CFR 141.500-141.571
Purpose	Improve public health protection through the control of microbial contaminants, particularly viruses, *Giardia*, and *Cryptosporidium*.
General Description	The **Surface Water Treatment Rules**: ▸ Applies to all public water systems (PWSs) using surface water or ground water under the direct influence of surface water (GWUDI), otherwise known as "**Subpart H systems.**" ▸ Requires all Subpart H systems to disinfect. ▸ Requires Subpart H systems to filter unless specific filter avoidance criteria are met. ▸ Applies a treatment technique requirement for control of microbials.

Overview of Requirements

The purpose of this table is show how the requirements for the IESWTR and LT1ESWTR build on the existing requirements established in the original SWTR.

APPLICABILITY: PWSs that use surface water or ground water under the direct influence of surface water (Subpart H) that practice slow sand, diatomaceous earth or alternative filtration.		**Final Rule Dates**		
		SWTR 1989	**IESWTR 1998**	**LT1ESWTR 2002**
Population Served	≥10,000	✓	✓	■
	< 10,000	✓	N/A (except for sanitary survey provisions)	✓
Regulated Pathogens	99.99% (4-log) removal/inactivation of viruses	✓	Regulated under SWTR	Regulated under SWTR
	99.9% (3-log) removal/inactivation of *Giardia lamblia*	✓	Regulated under SWTR	Regulated under SWTR
	99% (2-log) removal of *Cryptosporidium*	■	✓	✓
Residual Disinfectant Requirements	Entrance to distribution system (≥ 0.2 mg/L)	✓	Regulated under SWTR	Regulated under SWTR
	Detectable in the distribution system	✓	Regulated under SWTR	Regulated under SWTR
Turbidity Performance Standards	Combined Filter Effluent - Slow Sand and Diatomaceous Earth	✓	Regulated under SWTR	Regulated under SWTR
	Combined Filter Effluent - Alternative	✓	✓	✓
Disinfection Profiling & Benchmarking	Systems must profile inactivation levels and generate benchmark, if required	■	✓	✓
Sanitary Surveys (state requirement)	CWS: Every 3 years NCWS: Every 5 years	■	✓	Regulated under IESWTR
Covered Finished Reservoirs/Water Storage Facilities (new construction only)		■	✓	✓
Operated by Qualified Personnel as Specified by State		✓	Regulated under SWTR	Regulated under SWTR

(CWS) Community Water System (NCWS) Non-community Water System

Turbidity

Turbidity is measured as Combined Filter Effluent (CFE) for slow sand, diatomaceous earth, and alternative filtration. The CFE 95th % value and CFE maximum value for slow sand and diatomaceous earth were not lowered in the IESWTR and LT1ESWTR since these filtration technologies are assumed to provide 2-log *Cryptosporidium* removal with the turbidity limits established by SWTR. Alternative filtration technologies (defined as filtration technologies other than conventional, direct, slow sand, or diatomaceous earth) must demonstrate to the state that filtration and/or disinfection achieve 3-log Giardia and 4-log virus removal and/or inactivation. The IESWTR and LT1ESWTR also require alternative filtration technologies to demonstrate 2-log Cryptosporidium removal.

Turbidity: Monitoring and Reporting Requirements

Turbidity Type and Reporting Requirements *(Reports due by the 10th day of the following month the system serves water to the public.)*		**Monitoring/ Recording Frequency**	**SWTR As of June 29, 1993**	**IESWTR ≥10,000 people As of January 1, 2002**	**LT1ESWTR < 10,000 people As of January 1, 2005**
Slow Sand & Diatomaceous Earth	CFE 95%	At least every 4 hours*	≤1 NTU	Regulated under SWTR	Regulated under SWTR
	CFE Max	At least every 4 hours*	5 NTU	Regulated under SWTR	Regulated under SWTR
Alternative ➤ **Membranes** ➤ **Cartridges** ➤ **Other**	CFE 95%	At least every 4 hours*	≤1 NTU	Established by state	Established by state (not to exceed 1 NTU)
	CFE Max	At least every 4 hours*	5 NTU	Established by state	Established by state (not to exceed 5 NTU)

*Monitoring frequency may be reduced by the state to once per day for systems using slow sand or alternative filtration. Monitoring frequency may be reduced by the state to once per day for systems serving 500 or fewer people regardless of type of filtration used.

CFE Turbidity: Reporting Requirements

Report to State:	**SWTR Measurements**	**IESWTR Measurements**	**LT1ESWTR Measurements****
Within 10 days after the end of the month:	Total number of monthly measurements	Total number of monthly measurements	Total number of monthly measurements
	Number and percent less than or equal to designated 95th percentile turbidity limits	Number and percent less than or equal to designated 95th percentile turbidity limits	Number and percent less than or equal to designated 95th percentile turbidity limits
	Date and value exceeding 5 NTU	Date and value exceeding 5 NTU for slow sand and diatomaceous earth or maximum level set by state for alternative filtration	Date and value exceeding 5 NTU for slow sand and diatomaceous earth or maximum level set by state for alternative filtration
Within 24 hours:	Exceedances of 5 NTU for CFE	Exceedances of 5 NTU for slow sand and diatomaceous earth or maximum CFE level set by state for alternative filtration	Exceedances of 5 NTU for slow sand and diatomaceous earth or maximum CFE level set by state for alternative filtration

** Systems serving fewer than 10,000 people must begin complying with these requirements beginning January 1, 2005.

Disinfection

Disinfection must be sufficient to ensure that the total treatment process (disinfection plus filtration) of the system achieves at least:

- 99.9% (3-log) inactivation and/or removal of *Giardia lamblia*.
- 99.99% (4-log) inactivation and/or removal of viruses.

Cryptosporidium must be removed by filtration and no inactivation credits are currently given for disinfection. Systems must also comply with the maximum residual disinfectant level (MRDL) requirements specified in the Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 DBPR).

Residual Disinfectant Monitoring and Reporting Requirements

Location	**Concentration**	**Monitoring Frequency**	**Reporting (Reports due 10th of the following month)**
Entry to distribution system.	Residual disinfectant concentration cannot be < 0.2 mg/L for more than 4 hours.	Continuous, but states may allow systems serving 3,300 or fewer persons to take grab samples from 1 to 4 times per day, depending on system size.	Lowest daily value for each day, the date and duration when residual disinfectant was < 0.2 mg/L, and when state was notified of events where residual disinfectant was < 0.2 mg/L.
Distribution system - same location as total coliform sample location(s).	Residual disinfectant concentration cannot be undetectable in greater than 5% of samples in a month, for any 2 consecutive months. Heterotrophic plate count (HPC) ≤ 500/mL is deemed to have detectable residual disinfectant.	Same time as total coliform samples.	Number of residual disinfectant or HPC measurements taken in the month resulting in no more than 5% of the measurements as being undetectable in any 2 consecutive months.

Disinfection Profiling and Benchmarking Requirements

A **disinfection profile** is the graphical representation of a system's microbial inactivation over 12 consecutive months.

A **disinfection benchmark** is the lowest monthly average microbial inactivation value. The disinfection benchmark is used as a baseline of inactivation when considering changes in the disinfection process.

Disinfection Profiling and Benchmarking Requirements Under IESWTR & LT1ESWTR

The purpose of disinfection profiling and benchmarking is to allow systems and states to assess whether a change in disinfection practices creates a microbial risk. Systems should develop a disinfection profile that reflects *Giardia lamblia* inactivation (systems using ozone or chloramines must also calculate inactivation of viruses), calculate a benchmark (lowest monthly inactivation) based on the profile, and consult with the state prior to making a significant change to disinfection practices.

REQUIREMENT	IESWTR	LT1ESWTR
AFFECTED SYSTEMS:	Community, non-transient non-community, and transient systems.	Community and non-transient non-community systems only.
BEGIN PROFILING BY:	April 1, 2000	➤ July 1, 2003 for systems serving 500-9,999 people. ➤ January 1, 2004 for systems serving fewer than 500 people.
FREQUENCY & DURATION:	**Daily** monitoring for 12 consecutive calendar months to determine the total logs of *Giardia lamblia* inactivation (and viruses, if necessary) for each day in operation.	**Weekly** inactivation of *Giardia lamblia* (and viruses, if necessary), on the same calendar day each week over 12 consecutive months.
STATES MAY WAIVE DISINFECTION PROFILING REQUIREMENTS IF:	TTHM annual average <0.064 mg/L and HAA5 annual average <0.048 mg/L: ➤ Collected during the same period. ➤ Annual average is arithmetic average of the quarterly averages of four consecutive quarters of monitoring. ➤ At least 25% of samples at the maximum residence time in the distribution system. ➤ Remaining 75% of samples at representative locations in the distribution system.	One TTHM sample <0.064 mg/L and one HAA5 sample <0.048 mg/L: ➤ Collected during the month of warmest water temperature; **AND** ➤ At the maximum residence time in the distribution system. Samples must have been collected after January 1, 1998.
DISINFECTION BENCHMARK MUST BE CALCULATED IF:	Systems required to develop a disinfection profile and are considering any of the following: ➤ Changes to the point of disinfection. ➤ Changes to the disinfectant(s) used. ➤ Changes to the disinfection process. ➤ Any other modification identified by the state. Systems must consult the state prior to making any modifications to disinfection practices.	Same as IESWTR, and systems must obtain state approval prior to making any modifications to disinfection practices.

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Comprehensive Surface Water Treatment Rules Quick Reference Guide: Unfiltered Systems

Overview of the Rules

Title	**Surface Water Treatment Rule** (SWTR) - 40 CFR 141.70-141.75 **Interim Enhanced Surface Water Treatment Rule** (IESWTR) - 40 CFR 141.170-141.175 **Long Term 1 Enhanced Surface Water Treatment Rule** (LT1ESWTR) - 40 CFR 141.500-141.571
Purpose	Improve public health protection through the control of microbial contaminants, particularly viruses, *Giardia*, and *Cryptosporidium*.
General Description	The **Surface Water Treatment Rules**: ➤ Applies to all public water systems (PWSs) using surface water or ground water under the direct influence of surface water (GWUDI), otherwise known as "**Subpart H systems.**" ➤ Requires all Subpart H systems to disinfect. ➤ Requires Subpart H systems to filter unless specific filter avoidance criteria are met. ➤ Requires unfiltered systems to perform source water monitoring and meet site specific conditions for control of microbials.

Overview of Requirements

The purpose of this table is show how the requirements for the IESWTR and LT1ESWTR build on the existing requirements established in the original SWTR.

APPLICABILITY: PWSs that use surface water or ground water under the direct influence of surface water (Subpart H) that do not provide filtration.		**Final Rule Dates**		
		SWTR 1989	**IESWTR 1998**	**LT1ESWTR 2002**
Population Served	≥ 10,000	✓	✓	■
	< 10,000	✓	N/A (except for sanitary survey provisions)	✓
Regulated Pathogens	99.99% (4-log) inactivation of viruses	✓	Regulated under SWTR	Regulated under SWTR
	99.9% (3-log) inactivation of *Giardia lamblia*	✓	Regulated under SWTR	Regulated under SWTR
	99% (2-log) removal of *Cryptosporidium* (through watershed control)	■	✓	✓
Residual Disinfectant Requirements	Entrance to distribution system (≥ 0.2 mg/L)	✓	Regulated under SWTR	Regulated under SWTR
	Detectable in the distribution system	✓	Regulated under SWTR	Regulated under SWTR
Unfiltered System Requirements	Avoidance Criteria	✓	✓	✓
Disinfection Profiling & Benchmarking	Systems must profile inactivation levels and generate benchmark, if required	■	✓	✓
Sanitary Surveys (state requirement)	CWS: Every 3 years NCWS: Every 5 years	■	✓	Regulated under IESWTR
Covered Finished Reservoirs/Water Storage Facilities (new construction only)		■	✓	✓
Operated by Qualified Personnel as Specified by State		✓	Regulated under SWTR	Regulated under SWTR

(CWS) Community Water System (NCWS) Non-community Water System

Filtration Avoidance Criteria

Since December 30, 1991, systems must meet source water quality and site specific conditions to remain unfiltered. If any of the following criteria to avoid filtration are not met, systems must install filtration treatment within 18 months of the failure. The following table outlines the avoidance criteria established by the SWTR and later enhanced by the IESWTR and LT1ESWTR.

Filtration Avoidance Criteria

		Requirement	Frequency
SOURCE WATER QUALITY CONDITIONS	**Microbial Quality**	Monitor fecal coliform or total coliform density in representative samples of source water immediately prior to the first point of disinfectant application: ➤ **Fecal coliform density** concentrations must be ≤ 20/100 mL; **OR** ➤ **Total coliform density** concentrations must be ≤ 100/100 mL. Sample results must satisfy the criteria listed above in at least 90% of the measurements from previous 6 months.	1 to 5 samples per week depending on system size and every day the turbidity of the source water exceeds 1 NTU.
	Turbidity	Prior to the first point of disinfectant application, turbidity levels cannot exceed 5 NTU.	Performed on representative grab samples of source water every four hours (or more frequently).
SITE SPECIFIC CONDITIONS	**Systems must:**	Calculate total inactivation ratio daily and provide 3-log *Giardia lamblia* and 4-log virus inactivation daily (except any one day each month) in 11 of 12 previous months (on an ongoing basis).	Take daily measurements before or at the first customer at each residual disinfectant concentration sampling point: ➤ Temperature ➤ pH (if chlorine used) ➤ Disinfectant contact time (at peak hourly flow) ➤ Residual disinfectant concentration measurements (at peak hourly flow)
	System must comply with:	➤ MCL for total coliforms in 11 of 12 previous months (as per Total Coliform Rule). ➤ Stage 1 Disinfection Byproducts Rule requirements (as of January 1, 2002, for systems serving ≥ 10,000 or January 1, 2004, for systems serving < 10,000).	
	Systems must have:	➤ Adequate entry point residual disinfectant concentration (see disinfection requirements). ➤ Detectable residual disinfectant concentration in the distribution system (see disinfection requirements). ➤ Redundant disinfection components or automatic shut-off whenever residual disinfectant concentration < 0.2 mg/L. ➤ A watershed control program minimizing potential for contamination by *Giardia lamblia* cysts and viruses in source water; IESWTR and LT1ESWTR update this requirement by adding *Cryptosporidium* control measures. ➤ An annual on-site inspection by state or approved third party with reported findings. ➤ Not been identified as a source of a waterborne disease outbreak.	

Disinfection

Disinfection must be sufficient to ensure that the total treatment process of the system achieves at least:

- 99.9% (3-log) inactivation of *Giardia lamblia*.
- 99.99% (4-log) inactivation of viruses.

Currently, *Cryptosporidium* must be controlled through the watershed control program and no inactivation credits are currently given for disinfection. Systems must also comply with the maximum residual disinfectant level (MRDL) requirements specified in the Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 DBPR).

Residual Disinfectant Monitoring and Reporting Requirements

Location	**Concentration**	**Monitoring Frequency**	**Reporting (Reports due 10th of the following month)**
Entry to distribution system.	Residual disinfectant concentration cannot be < 0.2 mg/L for more than 4 hours.	Continuous, but states may allow systems serving 3,300 or fewer persons to take grab samples from 1 to 4 times per day, depending on system size.	Lowest daily value for each day, the date and duration when residual disinfectant was < 0.2 mg/L, and when state was notified of events where residual disinfectant was < 0.2 mg/L.
Distribution system - same location as total coliform sample location(s).	Residual disinfectant concentration cannot be undetectable in greater than 5% of samples in a month, for any 2 consecutive months. Heterotrophic plate count (HPC) # 500/mL is deemed to have detectable residual disinfectant.	Same time as total coliform samples.	Number of residual disinfectant or HPC measurements taken in the month resulting in no more than 5% of the measurements as being undetectable in any 2 consecutive months.

System Reporting Requirements

Report to State:	**What to report:**
Within 10 days after the end of the month:	➤ Source water quality information (microbial quality and turbidity measurements). ➤ In addition to the disinfection information above, systems must report the daily residual disinfectant concentration(s) and disinfectant contact time(s) used for calculating the CT value(s).
By October 10 each year:	➤ Report compliance with all watershed control program requirements. ➤ Report on the on-site inspection unless conducted by state in which the state must provide the system a copy of the report.
Within 24 hours:	➤ Turbidity exceedances of 5 NTU and waterborne disease outbreaks.
As soon as possible but no later than the end of the next business day:	➤ Instance where the residual disinfectant level entering the distribution system was less than 0.2 mg/L.

Disinfection Profiling and Benchmarking Requirements

A **disinfection profile** is the graphical representation of a system's microbial inactivation over 12 consecutive months.

A **disinfection benchmark** is the lowest monthly average microbial inactivation value. The disinfection benchmark is used as a baseline of inactivation when considering changes in the disinfection process.

Disinfection Profiling and Benchmarking Requirements Under IESWTR & LT1ESWTR

The purpose of disinfection profiling and benchmarking is to allow systems and states to assess whether a change in disinfection practices creates a microbial risk. Systems should develop a disinfection profile that reflects *Giardia lamblia* inactivation (systems using ozone or chloramines must also calculate inactivation of viruses), calculate a benchmark (lowest monthly inactivation) based on the profile, and consult with the state prior to making a significant change to disinfection practices.

REQUIREMENT	IESWTR	LT1ESWTR
AFFECTED SYSTEMS:	Community, non-transient non-community, and transient systems.	Community and non-transient non-community systems only.
BEGIN PROFILING BY:	April 1, 2000	➤ July 1, 2003 for systems serving 500-9,999 people. ➤ January 1, 2004 for systems serving fewer than 500 people.
FREQUENCY & DURATION:	**Daily** monitoring for 12 consecutive calendar months to determine the total logs of *Giardia lamblia* inactivation (and viruses, if necessary) for each day in operation.	**Weekly** inactivation of *Giardia lamblia* (and viruses, if necessary), on the same calendar day each week over 12 consecutive months.
STATES MAY WAIVE DISINFECTION PROFILING REQUIREMENTS IF:	TTHM annual average <0.064 mg/L and HAA5 annual average <0.048 mg/L: ➤ Collected during the same period. ➤ Annual average is arithmetic average of the quarterly averages of four consecutive quarters of monitoring. ➤ At least 25% of samples at the maximum residence time in the distribution system. ➤ Remaining 75% of samples at representative locations in the distribution system.	One TTHM sample <0.064 mg/L and one HAA5 sample <0.048 mg/L: ➤ Collected during the month of warmest water temperature; **AND** ➤ At the maximum residence time in the distribution system. Samples must have been collected after January 1, 1998.
DISINFECTION BENCHMARK MUST BE CALCULATED IF:	Systems required to develop a disinfection profile and are considering any of the following: ➤ Changes to the point of disinfection. ➤ Changes to the disinfectant(s) used. ➤ Changes to the disinfection process. ➤ Any other modification identified by the state. Systems must consult the state prior to making any modifications to disinfection practices.	Same as IESWTR, and systems must obtain state approval prior to making any modifications to disinfection practices.

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Office of Water
(4606)

EPA 816-F-01-035
November 2001
www.epa.gov/safewater

Total Coliform Rule:
A Quick Reference Guide

Overview of the Rule

Title	**Total Coliform Rule (TCR)** **54 FR 27544-27568, June 29, 1989, Vol. 54, No. 124**[1]
Purpose	**Improve public health protection by reducing fecal pathogens to minimal levels through control of total coliform bacteria, including fecal coliforms and *Escherichia coli (E. coli)*.**
General Description	**Establishes a maximum contaminant level (MCL) based on the presence or absence of total coliforms, modifies monitoring requirements including testing for fecal coliforms or *E. coli,* requires use of a sample siting plan, and also requires sanitary surveys for systems collecting fewer than five samples per month.**
Utilities Covered	**The TCR applies to all public water systems.**

Public Health Benefits

Implementation of the TCR has resulted in . . .	- **Reduction in risk of illness from disease causing organisms associated with sewage or animal wastes. Disease symptoms may include diarrhea, cramps, nausea, and possibly jaundice, and associated headaches and fatigue.**

What are the Major Provisions?

ROUTINE Sampling Requirements

- **Total coliform samples must be collected at sites which are representative of water quality throughout the distribution system according to a written sample siting plan subject to state review and revision.**
- **Samples must be collected at regular time intervals throughout the month except groundwater systems serving 4,900 persons or fewer may collect them on the same day.**
- **Monthly sampling requirements are based on population served (see table on next page for the minimum sampling frequency).**
- **A reduced monitoring frequency may be available for systems serving 1,000 persons or fewer and using only ground water if a sanitary survey within the past 5 years shows the system is free of sanitary defects (the frequency may be no less than 1 sample/quarter for community and 1 sample/year for non-community systems).**
- **Each total coliform-positive routine sample must be tested for the presence of fecal coliforms or *E. coli*.**
- **If any routine sample is total coliform-positive, repeat samples are required.**

REPEAT Sampling Requirements

- **Within 24 hours of learning of a total coliform-positive ROUTINE sample result, at least 3 REPEAT samples must be collected and analyzed for total coliforms:**
  - **One REPEAT sample must be collected from the same tap as the original sample.**
  - **One REPEAT sample must be collected within five service connections upstream.**
  - **One REPEAT sample must be collected within five service connections downstream.**
  - **Systems that collect 1 ROUTINE sample per month or fewer must collect a 4th REPEAT sample.**
- **If any REPEAT sample is total coliform-positive:**
  - **The system must analyze that total coliform-positive culture for fecal coliforms or *E.coli*.**
  - **The system must collect another set of REPEAT samples, as before, unless the MCL has been violated and the system has notified the state.**

Additional ROUTINE Sample Requirements

- **A positive ROUTINE or REPEAT total coliform result requires a minimum of five ROUTINE samples be collected the following month the system provides water to the public unless waived by the state.**

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[1] The June 1989 Rule was revised as follows: Corrections and Technical Amendments, 6/19/90 and Partial Stay of Certain Provisions (Variance Criteria) 56 FR 1556-1557, Vol 56, No 10.

Note: The TCR is currently undergoing the 6 year review process and may be subject to change.

Public Water System ROUTINE Monitoring Frequencies

Population	Minimum Samples/ Month	Population	Minimum Samples/ Month	Population	Minimum Samples/ Month
25-1,000*	1	21,501-25,000	25	450,001-600,000	210
1,001-2,500	2	25,001-33,000	30	600,001-780,000	240
2,501-3,300	3	33,001-41,000	40	780,001-970,000	270
3,301-4,100	4	41,001-50,000	50	970,001-1,230,000	300
4,101-4,900	5	50,001-59,000	60	1,230,001-1,520,000	330
4,901-5,800	6	59,001-70,000	70	1,520,001-1,850,000	360
5,801-6,700	7	70,001-83,000	80	1,850,001-2,270,000	390
6,701-7,600	8	83,001-96,000	90	2,270,001-3,020,000	420
7,601-8,500	9	96,001-130,000	100	3,020,001-3,960,000	450
8,501-12,900	10	130,001-220,000	120	³ 3,960,001	480
12,901-17,200	15	220,001-320,000	150		
17,201-21,500	20	320,001-450,000	180		

*Includes PWSs which have at least 15 service connections, but serve <25 people.

What are the Other Provisions?

Systems collecting fewer than 5 ROUTINE samples per month . . .	Must have a sanitary survey every 5 years (or every 10 years if it is a non-community water system using protected and disinfected ground water).**
Systems using surface water or ground water under the direct influence of surface water (GWUDI) and meeting filtration avoidance criteria . . .	Must collect and have analyzed one coliform sample each day the turbidity of the source water exceeds 1 NTU. This sample must be collected from a tap near the first service connection.

** As per the IESWTR, states must conduct sanitary surveys for community surface water and GWUDI systems in this category every 3 years (unless reduced by the state based on outstanding performance).

How is Compliance Determined?

- Compliance is based on the presence or absence of total coliforms.
- Compliance is determined each calendar month the system serves water to the public (or each calendar month that sampling occurs for systems on reduced monitoring).
- The results of ROUTINE and REPEAT samples are used to calculate compliance.

A Monthly MCL Violation is Triggered if:

A system collecting fewer than 40 samples per month . . .	Has greater than 1 ROUTINE/REPEAT sample per month which is total coliform-positive.
A system collecting at least 40 samples per month . . .	Has greater than 5.0 percent of the ROUTINE/REPEAT samples in a month total coliform-positive.

An Acute MCL Violation is Triggered if:

Any public water system . . .	Has any fecal coliform- or *E. coli*-positive REPEAT sample *or* has a fecal coliform- or *E. coli*-positive ROUTINE sample followed by a total coliform-positive REPEAT sample.

What are the Public Notification and Reporting Requirements?

For a Monthly MCL Violation	▸ The violation must be reported to the state no later than the end of the next business day after the system learns of the violation. ▸ The public must be notified within 14 days.[2]
For an Acute MCL Violation	▸ The violation must be reported to the state no later than the end of the next business day after the system learns of the violation. ▸ The public must be notified within 72 hours.[2]
Systems with ROUTINE or REPEAT samples that are fecal coliform- or *E. coli*-positive . . .	Must notify the state by the end of the day they are notified of the result or by the end of the next business day if the state office is already closed.

For additional information on the TCR

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA web site at www.epa.gov/safewater/mdbp/mdbp.html; or contact your state drinking water representative.

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[2] The revised Public Notification Rule will extend the period allowed for public notice of monthly violations to 30 days and shorten the period for acute violations to 24 hours. These revisions are effective for all systems by May 6, 2002 and are detailed in 40 CFR Subpart Q.

United States
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4606

EPA 815-F-01-004
January 2001

Unregulated Contaminant Monitoring Regulation:
Monitoring for List 1 Contaminants by Selected Small Public Water Systems

Introduction
Section 1445(a)(2) of the Safe Drinking Water Act (SDWA), as amended in 1996, requires the U.S. Environmental Protection Agency (EPA) to establish criteria for a program to monitor unregulated contaminants in drinking water and to publish a list of the contaminants to be monitored. A randomly selected sample of 800 community water systems (CWSs) and non-transient, non-community water systems (NTNCWSs) that serve 10,000 or fewer persons (small systems) will monitor their water for these contaminants. EPA will pay the costs of shipping the samples and analyzing them in a laboratory. The purpose of this monitoring is to collect data to support the U.S. EPA Administrator's decisions regarding whether or not to regulate contaminants such as those on the Drinking Water Contaminant Candidate List to protect public health.

To implement this requirement, EPA promulgated the revisions to the Unregulated Contaminant Monitoring Regulations (UCMR) for Public Water Systems (PWSs). Published on September 17, 1999, and supplemented on March 2, 2000 and January 11, 2001, the regulation substantially revised the previous Unregulated Contaminant Monitoring program and specified:

- Which PWSs must monitor
- How a randomly selected sample set of small PWSs will be chosen to monitor
- Which contaminants systems must monitor
- When, where, and how often samples must be taken
- Which laboratory methods are to be used for analyzing the samples
- What quality control procedures, in addition to those in the laboratory methods, must be followed
- What the requirements are for reporting the results of the monitoring
- What roles the States and Indian Tribes will play in implementing the monitoring program.

EPA has organized the contaminants on the UCMR (1999) List into three lists based on the availability of analytical methods to detect their presence in drinking water and the type of monitoring to be conducted: List 1, Assessment Monitoring, consists of 12 chemical contaminants for which standard analytical methods are available; List 2, Screening Survey, consists of 16 contaminants for which there are new analytical methods that will be used; and List 3, Pre-Screen Testing, consists of 9 contaminants for which analytical methods are being researched. This fact sheet is concerned with List 1, Assessment Monitoring. Table 1 identifies the List 1 contaminants and their uses or environmental sources.

What Systems Must Monitor for List 1 Contaminants? (See §141.40(a)(1))
A randomly selected sample of 800 small water systems will conduct Assessment Monitoring, to establish a statistically valid data set. These systems are part of their State's Monitoring Plan. If your system is among those selected, you should have been notified by your State drinking water agency or EPA. EPA will also select 30 of the 800 systems to be "Index Systems." These systems must monitor every year during the 5-year UCMR listing cycle. They also must report on their operating conditions, such as water source and pumping rates. Small system monitoring will be paid for by EPA, including provisions for sampling equipment, and sample shipping, testing, and analysis.

Table 1: UCMR (1999) List 1 Contaminants and Their Uses or Sources		
Contaminant	**CASRN**	**Use or Environmental Source**
2,4-dinitrotoluene	121-14-2	Used in the production of isocyanate, dyes, and explosives
2,6-dinitrotoluene	606-20-2	Used as a mixture with 2,4-dinitrotoluene (similar uses)
Acetochlor	34256-82-1	Herbicide used with cabbage, citrus, coffee, and corn crops
DCPA mono acid; DCPA di acid	887-54-7; 2136-79-0	Degradation products of DCPA; an herbicide used on grasses and weeds with fruit and vegetable crops; the two DCPA degradates are measured and reported as a single analyte
4,4'-DDE	72-55-9	Degradation product of DDT; a general insecticide
EPTC	759-94-4	Herbicide used on annual grasses and weeds, with potatoes and corn
Molinate	2212-67-1	Selective herbicide used with rice; controls watergrass
MTBE	1634-04-4	Octane enhancer in unleaded gasoline
Nitrobenzene	98-95-3	Used in the production of aniline, which is used to make dyes, herbicides, and drugs
Perchlorate	14797-73-0	Oxygen additive in solid fuel propellant for rockets, missiles, and fireworks
Terbacil	5902-51-2	Herbicide used with sugarcane, alfalfa, and some fruit, etc.

When and How Often Must Monitoring Occur? (See §141.40(a)(5))
The effective implementation date of the Assessment Monitoring requirement is January 1, 2001. Small system Assessment Monitoring must occur during 1 year of the 3-year period from January 1, 2001 to December 31, 2003, as specified in the State's Monitoring Plan. Monitoring will be conducted at about one-third of the selected small systems each year.

The State or EPA will specify the year and months in which each selected small system must conduct Assessment Monitoring. At least one sample must be taken between May 1 and July 31, when the water system is vulnerable to contamination, or during another period of greatest vulnerability, as specified by the State or EPA. Small systems that use surface water or ground water under the influence of surface water as sources must sample four times per year (once every 3 months). Samples will be taken from ground water systems twice during the one year of Assessment Monitoring: once during the period of greatest vulnerability, and 5 to 7 months before or after the vulnerable period sampling.

From Where Must Samples be Taken? (See §141.40(a)(5))
Assessment Monitoring samples must be taken at the entry points to the distribution system, such as the representative Phase II/V sampling points specified by the State, unless otherwise specified by the State or EPA. If your State requires source water monitoring, inquire with your State or EPA drinking water program contact for further guidance. Small systems must collect the samples with EPA-supplied equipment and send them to EPA-specified laboratories. (In some cases, the State may elect to collect the samples, especially if the State already collects samples from a system for regulated contaminant monitoring. The State will inform systems of their responsibilities if the State elects to collect the samples.) EPA will pay for shipping the unregulated contaminant monitoring samples, testing by the EPA-specified laboratory, and reporting of the analytical results for these small systems.

How Are the Samples to be Analyzed? (See §141.40(a)(5) and Appendix A)
Samples are to be analyzed by an EPA-specified laboratory, which will be required on contract to adhere to the UCMR's quality control (QC) specifications. (For details, see the *Unregulated Contaminant Monitoring Regulation Analytical Methods and Quality Control Manual* [EPA 815-R-00-006] and its supplements.) EPA currently has contracts in place to analyze samples taken at small systems.

What Data Must be Reported to EPA? (See §141.35(d))
Analytical results that are reported must include the UCMR Data Elements listed in Table 2. Many of these are QC measures and will be provided by the laboratory.

How Will the Monitoring Data be Reported to EPA? (See §141.35(e))
Small systems will not have to report monitoring results directly to EPA. Instead, EPA will arrange to receive the results from the designated contract laboratory; copies will be sent to the system and to the State. The system will have 30 days to review and comment on the data. EPA will wait for an additional 60 days before placing the data in the National

Drinking Water Contaminant Occurrence Database to allow for review by the system and the State. Each small system, however, is still responsible for ensuring compliance with State reporting requirements.

Table 2: UCMR Data Elements for Reporting Sample Results

Public Water System (PWS) Identification Number	Analytical Method Number
PWS Facility Identification Number – Identification Number and Sampling Point Type Identification	Sample Analysis Type
Sample Collection Date	Sample Batch Identification Number
Sample Identification Number	Minimum Reporting Level
Contaminant/Parameter	Minimum Reporting Level Unit of Measure
Analytical Results – Sign	Analytical Precision
Analytical Results – Value	Analytical Accuracy
Analytical Results – Unit of Measure	Spiking Concentration
Note: Small systems must provide information in **bold,** or ensure that it is correct.	

Are There Requirements for Notifying the Public?

Yes. Under the Consumer Confidence Report (CCR) Rule, as specified in 40 CFR §141.153(d), CWSs must report the monitoring results whenever unregulated contaminants are detected. CCRs are to be sent to all billing customers each year by July 1. (The CCR Rule does not apply to non-community water systems.) In addition, the Public Notification Rule (40 CFR §141.207), published on May 4, 2000 (65 FR 25981), requires PWSs to notify the public annually that the results of monitoring for unregulated contaminants are available. Therefore, CWSs and NTNCWSs must provide public notice if they are required to monitor for unregulated contaminants. Details on these reporting requirements can be found in the documents *Preparing Your Drinking Water Consumer Confidence Report* (EPA 816-R-99-002) and *Public Notification Handbook* (EPA 816-R-00-010). Both are available on the Web at www.epa.gov/safewater.

Where Can I Get More Information?

More information on the UCMR is available from the following sources:

- *Federal Register* notices of September 17, 1999 (64 FR 50556), March 2, 2000 (65 FR 11372), and January 11, 2001 (66 FR 2273).
- The EPA Office of Ground Water and Drinking Water Web Site (www.epa.gov/safewater/ucmr.html).
- *Unregulated Contaminant Monitoring Regulation Analytical Methods and Quality Control Manual* (EPA 815-R-00-006).
- *Supplement A to the Unregulated Contaminant Monitoring Regulation Analytical Methods and Quality Control Manual* (EPA 815-R-00-002).
- *Unregulated Contaminant Monitoring Regulation Guidance for Operators of Public Water Systems Serving 10,000 or Fewer People* (EPA 815-R-01-002).
- The Safe Drinking Water Hotline (800 426-4791).

EPA is developing additional guidance materials, so check the Office of Ground Water and Drinking Water Web Site often for the latest information about them.

Table 3, at right, lists UCMR contacts in the EPA regional offices and the Agency's Technical Support Center in Cincinnati, OH.

Table 3: EPA UCMR Contacts

EPA	Contact	Telephone
Region 1	Chris Ryan	617 918-1567
Region 2	Robert Poon	212 637-3821
Region 3	Michelle Hoover	215 814-5258
Region 4	Janine Morris	404 562-9480
Region 5	Janet Kuefler	312 886-0123
Region 6	Andrew J. Waite	214 665-7332
Region 7	Stan Calow	913 551-7410
Region 8	Rod Glebe	303 312-6627
Region 9	Jill Korte	415 744-1853
Region 10	Gene Taylor	206 553-1389
Technical Support Center	Dan Hautman	513 569-7948

NOTES:

United States Environmental Protection Agency
Office of Water 4606
EPA 815-F-01-003
January 2001

Unregulated Contaminant Monitoring Regulation:

Monitoring for List 1 Contaminants by Large Public Water Systems

Introduction
The Safe Drinking Water Act (SDWA) requires community water systems (CWSs) and non-transient, non-community water systems (NTNCWSs) that serve more than 10,000 persons (large systems) to monitor their water for the presence of unregulated contaminants. The purpose of this monitoring is to collect data to support the U.S. Environmental Protection Agency (EPA) Administrator's decisions regarding whether or not to regulate contaminants such as those on the Drinking Water Contaminant Candidate List to protect public health.

To implement this requirement, the U.S. EPA promulgated revisions to the Unregulated Contaminant Monitoring Regulations (UCMR). Published on September 17, 1999, and supplemented on March 2, 2000 and January 11, 2001, the UCMR specifies:

- Which public water systems (PWSs) must monitor
- How a randomly selected sample set of small PWSs will be chosen to monitor
- Which contaminants systems must monitor
- When, where, and how often samples must be taken
- Which laboratory methods are to be used for analyzing the samples
- What quality control procedures, in addition to those in the laboratory methods, must be followed
- What the requirements are for reporting the results of the monitoring
- What roles the States and Indian Tribes will play in implementing the monitoring program.

EPA has organized the contaminants on the UCMR (1999) List into three lists based on the availability of analytical methods to detect their presence in drinking water and the type of monitoring to be conducted: List 1, Assessment Monitoring, consists of 12 chemical contaminants for which standard analytical methods are available; List 2, Screening Survey, consists of 16 contaminants for which new analytical methods will be used; and List 3, Pre-Screen Testing, consists of 9 contaminants for which analytical methods are being researched. This fact sheet is concerned with List 1, Assessment Monitoring. Table 1 on the next page identifies the List 1 contaminants and their uses or environmental sources.

What Systems Must Monitor for List 1 Contaminants? (See §141.40(a)(1))
All large community and non-transient, non-community water systems that do not purchase all of their water from another system must conduct monitoring. Large systems serve more than 10,000 persons. If you are unsure of your status as a PWS, contact your State drinking water administrator or your EPA regional contact.

When and How Often Must Monitoring Occur? (See §141.40(a)(5))
The effective implementation date of the Assessment Monitoring requirement is January 1, 2001. Large systems must conduct Assessment Monitoring during any continuous 12-month period from January 1, 2001 to December 31, 2003. (See Table 2, below, for details.) At least one sample must be taken during a time when the water system is vulnerable to contamination.

Table 1: UCMR (1999) List 1 Contaminants and Their Uses or Sources		
Contaminant	**CASRN**	**Use or Environmental Source**
2,4-dinitrotoluene	121-14-2	Used in the production of isocyanate and explosives
2,6-dinitrotoluene	606-20-2	Used as a mixture with 2,4-dinitrotoluene (similar uses)
Acetochlor	34256-82-1	Herbicide used with cabbage, citrus, coffee, and corn crops
DCPA mono acid; DCPA di acid	887-54-7; 2136-79-0	Degradation products of DCPA, an herbicide used on grasses and weeds with fruit and vegetable crops. Both the DCPA degradates are measured and reported as a single analyte
4,4'-DDE	72-55-9	Degradation product of DDT, a general insecticide
EPTC	759-94-4	Herbicide used on annual grasses, weeds, in potatoes and corn
Molinate	2212-67-1	Selective herbicide used with rice, controls watergrass
MTBE	1634-04-4	Octane enhancer in unleaded gasoline
Nitrobenzene	98-95-3	Used in the production of aniline, which is used to make dyes, herbicides, and drugs
Perchlorate	14797-73-0	Oxygen additive in solid fuel propellant for rockets, missiles, and fireworks
Terbacil	5902-51-2	Herbicide used with sugarcane, alfalfa, and some fruit, etc.

From Where Must Samples be Taken? (See §141.40(a)(5))
Samples to be analyzed for the presence of unregulated chemical contaminants must be taken at the entry points to the distribution system, such as the representative Phase II/V sampling points specified by the State, unless otherwise directed by the State or EPA. If your State requires source water monitoring, inquire with your State or EPA drinking water program contact for further guidance.

Table 2: Assessment Monitoring by Type of Water Source	
Source Water Type	**Assessment Monitoring Frequency**
Surface Water	Four quarterly samples, taken as follows: Select either the first, second, or third month of a quarter and sample in that same month of each of four consecutive quarters[1] to ensure that one of these sampling events occurs during the vulnerable time[2]
Ground Water	Two times in a year, taken as follows: Sample during one month of the most vulnerable time[2] and during one month five-to-seven months earlier or later[3]

[1] "Select either the first, second, or third month of a quarter and sample in that same month of each of four consecutive quarters" means that you must monitor during each of the four months of either: January, April, July, October; February, May, August, November; or March, June, September, December.

[2] "Vulnerable time" means May 1 through July 31, unless the State or EPA informs you that it has selected a different period for sampling as your system's vulnerable time.

[3] "Sample during one month of the vulnerable time and during one month five-to-seven months earlier or later" means, for example that if you select May as your "vulnerable time" month to sample, then one month five to seven months earlier would be October, November or December of the preceding year, and one month five to seven months later would be either October, November or December of the same year.

How Are the Samples to be Analyzed? (See §141.40(a)(5) and Appendix A)
Samples are to be analyzed by State- or primacy agency- certified drinking water compliance monitoring laboratories, using methods according to the UCMR's quality control (QC) specifications. (For details, see the *Unregulated Contaminant Monitoring Regulation Analytical Methods and Quality Control Manual* [EPA 815-R-00-006] and its supplements.) Note that it is the water systems' responsibility to use State- or primacy agency- certified laboratories that employ the correct methods. If analyzing samples for perchlorate under the UCMR, labs are required to successfully participate in a special performance testing program (§141.40(a)(5)).

What Data Must be Reported to EPA? (See §141.35(d))
Analytical results that are reported must include the UCMR Data Elements listed in Table 3, at right. Many of these are QC measures and should be provided by the laboratory.

Table 3: UCMR Data Elements for Reporting Sample Results

Public Water System (PWS) Identification Number	Analytical Method Number
PWS Facility Identification Number – Identification Number and Sampling Point Type Identification	Sample Analysis Type
Sample Collection Date	Sample Batch Identification Number
Sample Identification Number	Minimum Reporting Level
Contaminant/Parameter	Minimum Reporting Level Unit of Measure
Analytical Results – Sign	Analytical Precision
Analytical Results – Value	Analytical Accuracy
Analytical Results – Unit of Measure	Spiking Concentration

How Are the Monitoring Data to be Reported to EPA? (See §141.35(e))
The PWS has several options for reporting monitoring data to EPA. It can instruct the laboratory that analyzed its samples to enter the results directly into the electronic template that the Agency will make available on the Office of Ground Water and Drinking Water Homepage on the World Wide Web. (EPA is developing several options for the electronic reporting by laboratories, including a web interface where data can be keyed in and the capability to upload data in batches using standard flat-file or XML formats. Further guidance and tutorials will be available soon.) The PWS can then review the results on-line and electronically indicate its approval to submit the data to EPA. As an alternative, a PWS can require that the laboratory receive its approval before posting analytical data on the EPA electronic reporting system. If the PWS determines that the laboratory lacks either the capability to report electronically to EPA or to provide data to the system prior to their submission to EPA without rekeying, the PWS may ask EPA whether an alternate reporting format may be used. The PWS also must submit the results to the State.

Are There Requirements for Notifying the Public?
Yes. Under the Consumer Confidence Report (CCR) Rule, as specified in 40 CFR §141.153(d), CWSs must report the monitoring results whenever unregulated contaminants are detected. CCRs are to be sent to all billing customers each year by July 1. (The CCR Rule does not apply to non-community water systems.) In addition, the Public Notification Rule (40 CFR §141.207), published on May 4, 2000 (65 FR 25981), requires PWSs to notify the public annually that the results of monitoring for unregulated contaminants are available. Therefore, CWSs and NTNCWSs must provide public notice if they are required to monitor for unregulated contaminants. Details on these reporting requirements can be found in the documents *Preparing Your Drinking Water Consumer Confidence Report* (EPA 816-R-99-002) and *Public Notification Handbook* (EPA 816-R-00-010). Both are available on the Web at www.epa.gov/safewater.

Where Can I Get More Information?
More information on the UCMR is available from the following sources:

- *Federal Register* notices of September 17, 1999 (64 FR 50556), March 2, 2000 (65 FR 11372), and January 11, 2001 (66 FR 2273).
- The EPA Office of Ground Water and Drinking Water Web Site (www.epa.gov/safewater/ucmr.html).
- *Unregulated Contaminant Monitoring Regulation Analytical Methods and Quality Control Manual* (EPA 815-R-00-006).
- *Supplement A to the Unregulated Contaminant Monitoring Regulation Analytical Methods and Quality Control Manual* (EPA 815-R-00-002).
- The Safe Drinking Water Hotline (800 426-4791).

EPA is developing additional guidance materials, so check the Office of Ground Water and Drinking Water Web Site often for the latest information about them.

Table 4, at right, lists UCMR contacts in the EPA regional offices and the Agency’s Technical Support Center in Cincinnati, OH.

Table 4: EPA UCMR Contacts

Region	Contact	Telephone
Region 1	Chris Ryan	617 918-1567
Region 2	Robert Poon	212 637-3821
Region 3	Michelle Hoover	215 814-5258
Region 4	Janine Morris	404 562-9480
Region 5	Janet Kuefler	312 886-0123
Region 6	Andrew J. Waite	214 665-7332
Region 7	Stan Calow	913 551-7410
Region 8	Rod Glebe	303 312-6627
Region 9	Jill Korte	415 744-1853
Region 10	Gene Taylor	206 553-1389
Technical Support Center	Dan Hautman	513 569-7948

NOTES:

United States
Environmental Protection
Agency

Office of Water
(4606)

EPA 816-F-01-019
June 2001
www.epa.gov/safewater

Filter Backwash Recycling Rule: A Quick Reference Guide

Overview of the Rule

Title	Filter Backwash Recycling Rule (FBRR) 66 FR 31086, June 8, 2001, Vol. 66, No. 111
Purpose	Improve public health protection by assessing and changing, where needed, recycle practices for improved contaminant control, particularly microbial contaminants.
General Description	The FBRR requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.
Utilities Covered	Applies to public water systems that use surface water or ground water under the direct influence of surface water, practice conventional or direct filtration, and recycle spent filter backwash, thickener supernatant, or liquids from dewatering processes.

Public Health Benefits

Implementation of FBRR will result in . . .	▸ Reduction in risk of illness from microbial pathogens in drinking water, particularly *Cryptosporidium*.
Estimated impacts of the FBRR include . . .	▸ FBRR will apply to an estimated 4,650 systems serving 35 million Americans. ▸ Fewer than 400 systems are expected to require capital improvements. ▸ Annualized capital costs incurred by public water systems associated with recycle modifications are estimated to be $5.8 million. ▸ Mean annual cost per household is estimated to be less than $1.70 for 99 percent of the affected households and between $1.70 and $100 for the remaining one percent of affected households.

Conventional and Direct Filtration

- Conventional filtration, as defined in 40 CFR 141.2, is a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal. Conventional filtration is the most common type of filtration.
- Direct filtration, as defined in 40 CFR 141.2, is a series of processes including coagulation and filtration, but excluding sedimentation, and resulting in substantial particulate removal. Typically, direct filtration can be used only with high-quality raw water that has low levels of turbidity and suspended solids.

Recycle Flows

- <u>Spent Filter Backwash Water</u> - A stream containing particles that are dislodged from filter media when water is forced back through a filter (backwashed) to clean the filter.
- <u>Thickener Supernatant</u> - A stream containing the decant from a sedimentation basin, clarifier or other unit that is used to treat water, solids, or semi-solids from the primary treatment processes.
- <u>Liquids From Dewatering Processes</u> - A stream containing liquids generated from a unit used to concentrate solids for disposal.

Critical Deadlines and Requirements

For Drinking Water Systems

December 8, 2003	Submit recycle notification to the state.
June 8, 2004	Return recycle flows through the processes of a system's existing conventional or direct filtration system or an alternate recycle location approved by the state (a 2-year extension is available for systems making capital improvements to modify recycle location). Collect recycle flow information and retain on file.
June 8, 2006	Complete all capital improvements associated with relocating recycle return location (if necessary).

For States

June 8, 2003	States submit FBRR primacy revision application to EPA (triggers interim primacy).
June 8, 2005	Primacy extension deadline - all states with an extension must submit primacy revision applications to EPA.

What does a recycle notification include?

- Plant schematic showing origin of recycle flows, how recycle flows are conveyed, and return location of recycle flows.
- Typical recycle flows (gpm), highest observed plant flow experienced in the previous year (gpm), and design flow for the treatment plant (gpm).
- State-approved plant operating capacity (if applicable).

What recycle flow information does a system need to collect and retain on file?

- Copy of recycle notification and information submitted to the state.
- List of all recycle flows and frequency with which they are returned.
- Average and maximum backwash flow rates through filters, and average and maximum duration of filter backwash process (in minutes).
- Typical filter run length and written summary of how filter run length is determined.
- Type of treatment provided for recycle flows.
- Data on the physical dimension of the equalization and/or treatment units, typical and maximum hydraulic loading rates, types of treatment chemicals used, average dose, frequency of use, and frequency at which solids are removed, if applicable.

For additional information on the FBRR

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA web site at www.epa.gov/safewater; or contact your state drinking water representative.

Additional material is available at www.epa.gov/safewater/filterbackwash.html.

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(4606)

EPA 816-F-01-003
June 2001

Radionuclides Rule: A Quick Reference Guide

Overview of the Rule

Title	Radionuclides Rule 66 FR 76708 December 7, 2000 Vol. 65, No. 236
Purpose	Reducing the exposure to radionuclides in drinking water will reduce the risk of cancer. This rule will also improve public health protection by reducing exposure to all radionuclides.
General Description	The rule retains the existing MCLs for combined radium-226 and radium-228, gross alpha particle radioactivity, and beta particle and photon activity. The rule regulates uranium for the first time.
Utilities Covered	Community water systems, all size categories.

Public Health Benefits

Implementation of the Radionuclides Rule will result in . . .	Reduced uranium exposure for 620,000 persons, protection from toxic kidney effects of uranium, and a reduced risk of cancer.
Estimated impacts of the Radionuclides Rule include . . .	Annual compliance costs of $81 million. Only 795 systems will have to install treatment.

Regulated Contaminants

Regulated Radionuclide	MCL	MCLG
Beta/photon emitters*	4 mrem/yr	0
Gross alpha particle	15 pCi/L	0
Combined radium-226/228	5 pCi/L	0
Uranium	30 µg/L	0

*A total of 168 individual beta particle and photon emitters may be used to calculate compliance with the MCL.

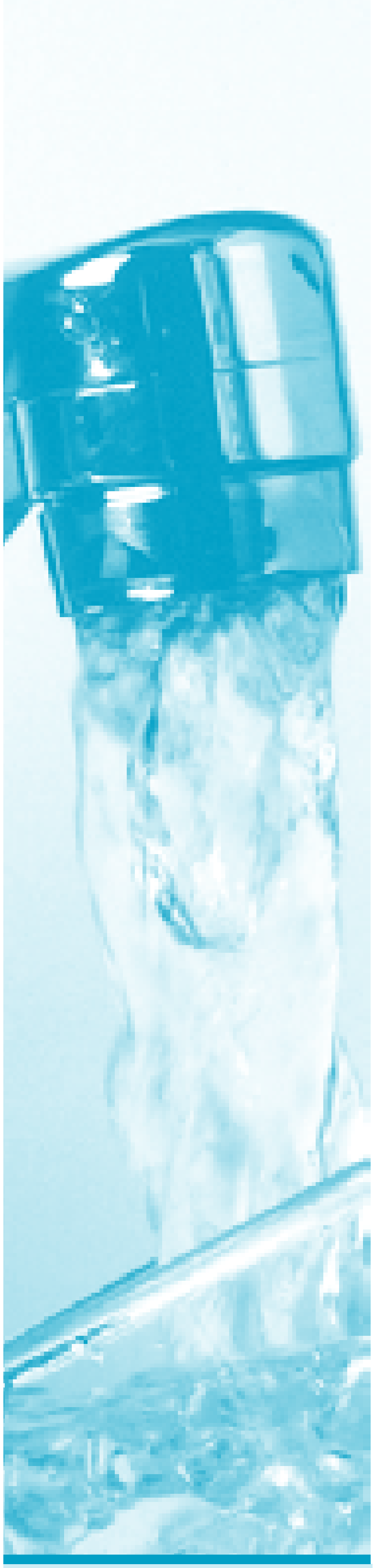
Critical Deadlines & Requirements

For Drinking Water Systems

June 2000 - December 8, 2003	When allowed by the State, data collected between these dates may be eligible for use as grandfathered data (excluding beta particle and photon emitters).
December 8, 2003	Systems begin initial monitoring under State-specified monitoring plan unless the State permits use of grandfathered data.
December 31, 2007	All systems must complete initial monitoring.

For States

December 2000 - December 2003	States work with systems to establish monitoring schedules.
December 8, 2000	States should begin to update vulnerability assessments for beta photon and particle emitters and notify systems of monitoring requirements.
Spring 2001	EPA meets and works with States to explain new rules and requirements and to initiate adoption and implementation activities.
December 8, 2002	State submits primacy revision application to EPA. (EPA approves within 90 days.)



Monitoring Requirements

Gross Alpha, Combined Radium-226/228, and Uranium (1)	Beta Particle and Photon Radioactivity (1)
Initial Monitoring	
Four consecutive quarters of monitoring.	No monitoring required for most CWSs. Vulnerable CWSs (2) must sample for: • Gross beta: quarterly samples. • Tritium and Strontium-90: annual samples.
Reduced Monitoring	
If the average of the initial monitoring results for each contaminant is below the detection limit: One sample every 9 years. If the average of the initial monitoring results for each contaminant is greater than or equal to the detection limit, but less than or equal to one-half the MCL: One sample every 6 years. If the average of the initial monitoring results for each contaminant is greater than one-half the MCL, but less than or equal to the MCL: One sample every 3 years.	If the running annual average of the gross beta particle activity minus the naturally occurring potassium-40 activity is less than or equal to 50 pCi/L: One sample every 3 years.
Increased Monitoring	
A system with an entry point result above the MCL must return to quarterly sampling until 4 consecutive quarterly samples are below the MCL.	If gross beta particle activity minus the naturally occurring potassium-40 activity exceeds 50 pCi/L, the system must: • Speciate as required by the State. • Sample at the initial monitoring frequency.

(1) All samples must be collected at each entry point to the distribution system.
(2) The rule also contains requirements for CWSs using waters contaminated by effluents from nuclear facilities.

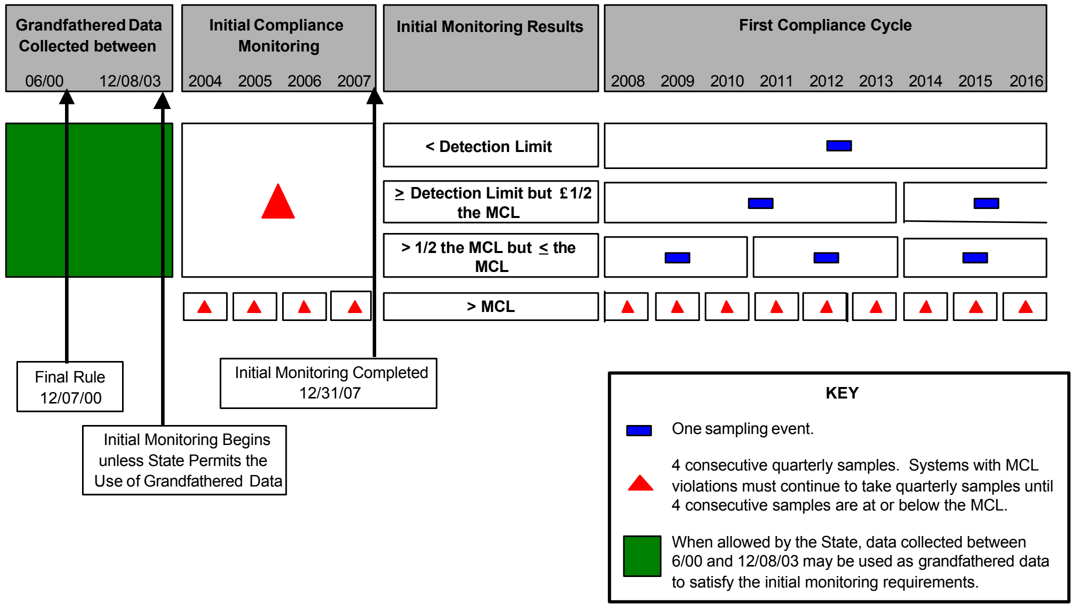
Grandfathering of Data

When allowed by the State, data collected between June, 2000 and December 8, 2003 may be used to satisfy the initial monitoring requirements if samples have been collected from:

- Each entry point to the distribution system (EPTDS).
- The distribution system, provided the system has a single EPTDS.
- The distribution system, provided the State makes a written justification explaining why the sample is representative of all EPTDS.

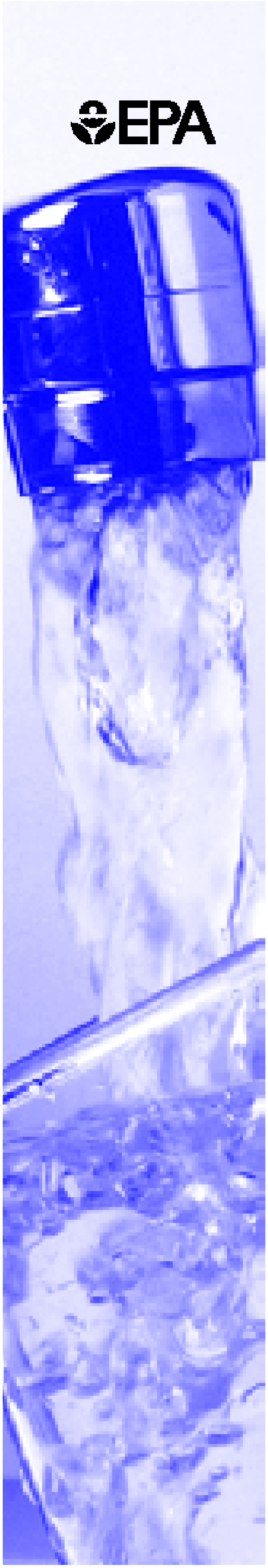
Applicability of the Standardized Monitoring Framework to Radionuclides

(Excluding the Beta Particle and Photon Emitters)



For additional information on the Radionuclides Rule

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA Web site at www.epa.gov/safewater; or contact your State drinking water representative. EPA will provide radionuclide training over the next year.



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(4606)

EPA 816-F-01-004
January 2001

Arsenic and Clarifications to Compliance and New Source Monitoring Rule: A Quick Reference Guide

Overview of the Rule

Title	Arsenic and Clarifications to Compliance and New Source Monitoring Rule 66 FR 6976 (January 22, 2001)
Purpose	To improve public health by reducing exposure to arsenic in drinking water.
General Description	Changes the arsenic MCL from 50 µg/L to 10 µg/L; Sets arsenic MCLG at 0; Requires monitoring for new systems and new drinking water sources; Clarifies the procedures for determining compliance with the MCLs for IOCs, SOCs, and VOCs.
Utilities Covered	All community water systems (CWSs) and nontransient, noncommunity water systems (NTNCWSs) must comply with the arsenic requirements. EPA estimates that 3,024 CWSs and 1,080 NTNCWSs will have to install treatment to comply with the revised MCL.

Public Health Benefits

Implementation of the Arsenic Rule will result in . . .	• Avoidance of 16 to 26 non-fatal bladder and lung cancers per year. • Avoidance of 21 to 30 fatal bladder and lung cancers per year. • Reduction in the frequency of non-carcinogenic diseases.

Critical Deadlines & Requirements

Consumer Confidence Report Requirements *

Report Due	*Report Requirements*
July 1, 2001	For the report covering calendar year 2000, systems that detect arsenic between 25 µg/L and 50 µg/L must include an educational statement in the consumer confidence reports (CCRs).
July 1, 2002 and beyond	For reports covering calendar years 2001 and beyond, systems that detect arsenic between 5 µg/L and 10 µg/L must include an educational statement in the CCRs.
July 1, 2002 - July 1, 2006	For reports covering calendar years 2001 to 2005, systems that detect arsenic between 10 µg/L and 50 µg/L must include a health effects statement in their CCRs.
July 1, 2007 and beyond	For reports covering calendar year 2006 and beyond, systems that are in violation of the arsenic MLC (10 µg/L) must include a health effects statement in their CCRs.

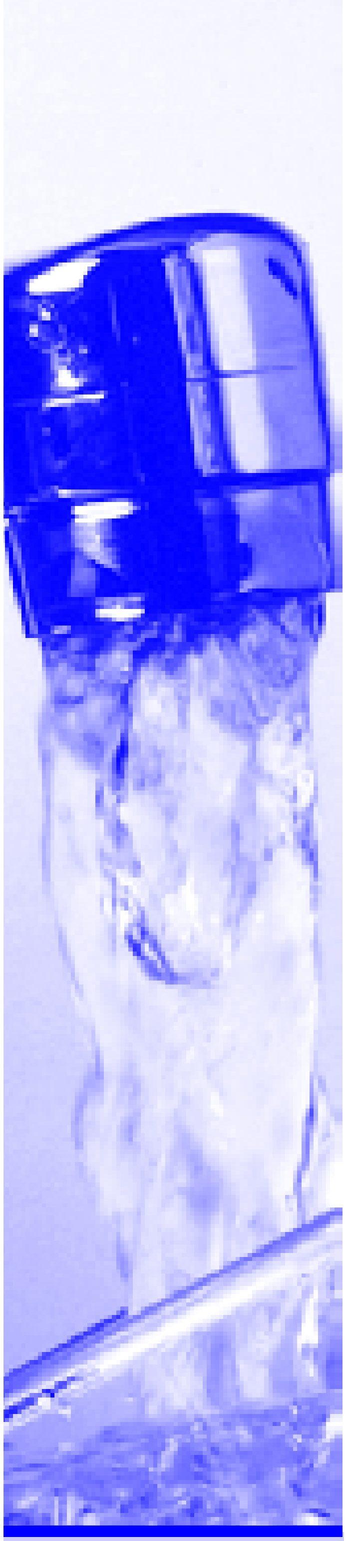
For Drinking Water Systems

Jan. 22, 2004	All *NEW* systems/sources must collect initial monitoring samples for all IOCs, SOCs, and VOCs within a period and frequency determined by the State.
Jan. 1, 2005	When allowed by the State, systems may grandfather data collected after this date.
Jan. 23, 2006	The new arsenic MCL of 10 µg/L becomes effective. All systems must begin monitoring or when allowed by the State, submit data that meets grandfathering requirements.
Dec. 31, 2006	Surface water systems must complete initial monitoring or have a State approved waiver.
Dec. 31, 2007	Ground water systems must complete initial monitoring or have a State approved waiver.

For States

Spring 2001	EPA meets and works with States to explain new rules and requirements and to initiate adoption and implementation activities.
Jan. 22, 2003	State primacy revision applications due.
Jan. 22, 2005	State primacy revision applications due from States that received 2-year extensions.

* For required educational and health effects statements, please see 40 CFR 141.154.



For additional information on the Arsenic Rule

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA Web site at www.epa.gov/safewater; or contact your State drinking water representative. EPA will provide arsenic training over the next year.

Compliance Determination (IOCs, VOCs, and SOCs)

1. Calculate compliance based on a running annual average at each sampling point.
2. Systems will not be in violation until 1 year of quarterly samples have been collected (unless fewer samples would cause the running annual average to be exceeded.)
3. If a system does not collect all required samples, compliance will be based on the running annual average of the samples collected.

Monitoring Requirements for Total Arsenic (1)

Initial Monitoring

One sample after the effective date of the MCL (January 23, 2006). Surface water systems must take annual samples. Ground water systems must take one sample between 2005 and 2007.

Reduced Monitoring

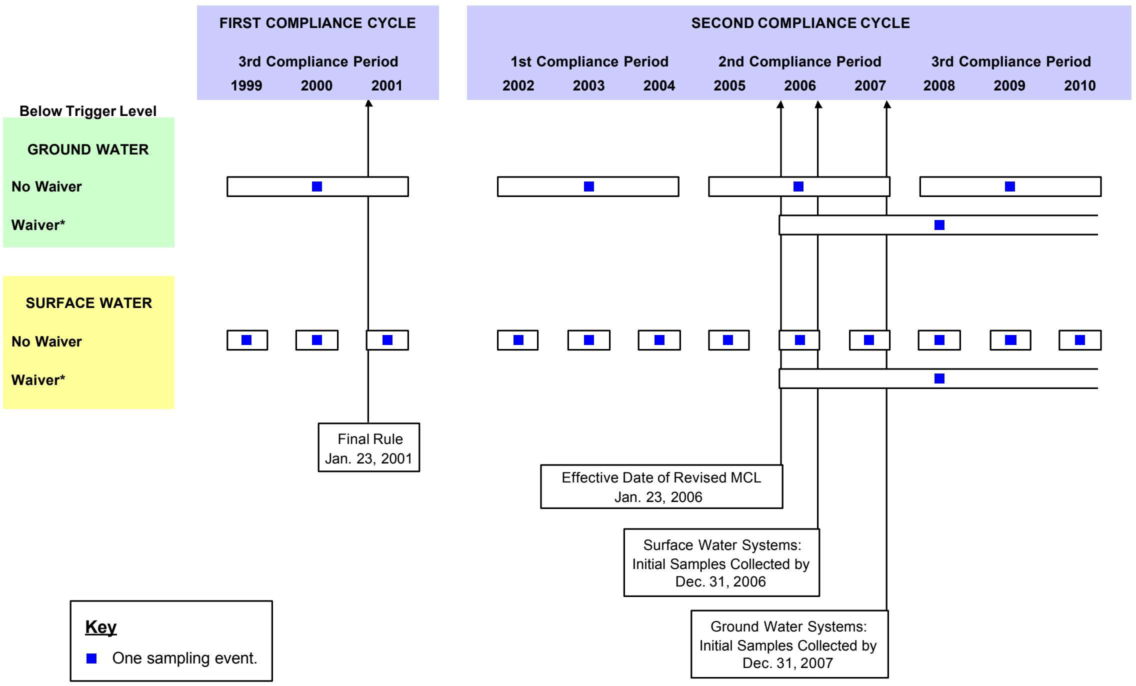
If the initial monitoring result for arsenic is less than the MCL . . .	Ground water systems must collect one sample every 3 years. Surface water systems must collect annual samples.

Increased Monitoring

A system with a sampling point result above the MCL must collect quarterly samples at that sampling point, until the system is reliably and consistently below the MCL.

(1) All samples must be collected at each entry point to the distribution system, unless otherwise specified by the State.

Applicability of the Standardized Monitoring Framework to Arsenic



*Waivers are not permitted under the current arsenic requirements. States may issue 9 year monitoring waivers under the revised final arsenic rule. To be eligible for a waiver, surface water systems must have monitored annually for at least 3 years. Ground water systems must conduct a minimum of 3 rounds of monitoring with detection limits below 10 µg/L.

Emerging Contaminants

Improved analytical methods have made it possible to analyze for contaminants that occur within our environment, and possibly our drinking water. Additional research is needed to understand potential health effects, along with the occurrence and cost of treatment to remove these contaminants from our drinking water.

UNREGULATED CONTAMINANT MONITORING RULE

The Unregulated Contaminant Monitoring Rule (UCMR) collects data for potential contaminants. The program monitors selected large and small water systems for as many as 30 contaminants in a five year cycle. UCMR 1 (2001-2005) monitored 35 contaminants, which included:

- Acetochlor
- MTBE
- Nitrobenzene
- Perchlorate
- Aeromonas
- AlachlorESA
- Lead-210
- Polonium-210
- Cyanobacteria
- Echoviruses
- Helicobacterpylori
- Microsporidia
- Adenoviruses

UCMR 2 (2008-2010) is monitoring contaminants in these categories:

- Insecticide and Insecticide Degradates
- Flame Retardants
- Explosives
- Acetanilide Herbicides and Herbicide Degradates
- Nitrosamines (often resulting from nitrate-reducing bacteria)

UCMR monitoring is based on availability of analytical methods and contaminant prioritization, with known and/or suspected health effects as top priority. Results from each cycle of the UCMR are used to develop the Candidate Contaminant Lists (CCLs) and future regulated contaminants.

PHARMACEUTICALS AND PERSONAL CARE PRODUCTS

Pharmaceuticals and Personal Care Products (PPCPs), including Endocrine Disruptors (EDs), typically refer to any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock. PPCPs represent a diverse collection of thousands of chemical substances, including, but not limited to:

- Prescription drugs
- Estrogenic steroids
- Insect repellant
- Detergent metabolites
- Plasticizers
- Fire retardants
- Antibiotics
- Genotoxic drugs
- Insecticides
- Hormones
- Antibiotics
- Antimicrobials
- Fragrances
- Solvents
- Veterinary drugs
- Sunscreen products
- Antidepressants
- Caffeine
- Antiepileptic drugs
- Nonprescription drugs

MDH has been active in identifying the occurrence of some of these PPCPs and partnered with the U.S. Geological Survey as part of a study, *Presence and Distribution of Organic Wastewater Compounds in Wastewater, Surface, Ground, and Drinking Waters, 2000-2002, Minnesota, Report 2004-5138.*

While research is being done to more fully determine potential health effects related to PPCPs, the best and most cost-effective way to ensure safe drinking water is to protect our drinking water at the source. The federal Office of National Drug Control Policy recommends not flushing prescription drugs down the toilet, unless the accompanying patient information specifically instructs it is safe to do so.

The Minnesota Pollution Control Agency (MPCA) also encourages citizens to dispose of unused pharmaceuticals by keeping the medication in its original container, modifying the contents to discourage consumption, sealing and concealing the package contents, and discarding the container in your garbage can**.** Communities are also implementing pharmaceutical take-back programs to limit the amount of pharmaceuticals disposed of through our wastewater systems.

PERFLUOROCHEMICALS

Perfluorochemicals (PFCs) are a family of man-made chemicals that have been used for decades to make products that resist heat, oil, stains, grease, and water. Common uses include nonstick cookware, stain-resistant carpets and fabrics, as components of fire-fighting foam, and other industrial applications.

Some of the chemicals in the PFC group are perfluorooctane sulfonate (PFOS; $C_8F_{17}SO_3$), perfluorooctanoic acid (PFOA; $C_8F_{15}O_2H$), and perfluorobutanoic acid (PFBA; $C_4F_7O_2H$). The chemical structures of PFCs make them extremely resistant to breakdown in the environment.
PFCs are manmade chemicals and do not occur naturally. Minnesota is one of the few states in the United States where these chemicals were made and used. The 3M Company made PFCs at its Cottage Grove facility beginning in the late 1950's. Wastes from the production process were placed in several local disposal sites. PFCs are used both as an ingredient in the manufacturing process as well as being part of some finished products. It is unclear if PFCs are released from commercial products during normal use.

PFCs are very stable chemicals that do not change or break down in the environment. As a result, they may be found in soil, sediments, water, or in other places. There are a few studies indicating that PFCs easily enter groundwater and move long distances. Some experts suggest that PFCs can also travel long distances in air, deposit on soil, and leach into groundwater.

Studies show that nearly all people have some PFCs in their blood, regardless of age. The way PFCs get into human blood is not known at this time. People could be exposed through food, water, use of commercial products, or from the environment. Some PFCs stay in the human body for many years.

The PFC family of chemicals is relatively new and is the focus of active scientific research. In laboratory animal studies, high concentrations of PFCs cause harmful changes in the liver and other organs. Developmental problems (e.g., delays in growth and maturation) have been seen in the offspring of rats and mice exposed to PFCs while pregnant. Both PFOA and PFOS in high concentrations over a long period of time also cause cancer in laboratory animals. PFBA is not suspected of causing cancer in animals.

MDH has developed drinking water criteria, known as Health Risk Limits (HRLs), for PFOA and PFOS. HRLs are criteria that MDH considers safe for human consumption over a lifetime. In August 2007, MDH enacted a rule with HRLs for PFOA and PFOS of 0.5 micrograms per liter (ug/L) and 0.3 ug/L, respectively. In February 2008, MDH issued a Health Based Value (HBV) for PFBA of 7 ug/L based on studies conducted over the previous year. An HBV is similar to an HRL, but has not been formally enacted through rulemaking.

Due to limited toxicological research on the four remaining PFCs for which MDH's Public Health Laboratory currently tests, there isn't enough scientific information to develop HBVs. However, based on their chemical characteristics, we anticipate that research will show that these four PFCs are less toxic for people than PFOA and PFOS. Levels of these other PFCs, perfluoropentanoic acid (PFPeA), and perfluorohexanoic acid (PFHxA), perfluorobutane sulfonate (PFBS), and perfluorohexane sulfonate (PFHxS), have been very low in area groundwater samples.

Filters containing activated carbon or reverse osmosis units have been shown to be effective at removing PFCs from water supplies where they have been used and tested. Other types of common water treatment systems, such as water softeners, are not likely to remove PFCs. Boiling the water will not remove the PFCs.

USEPA is engaged in a major effort with companies that have made or used PFCs to investigate the ways that PFCs enter the environment, and ultimately how people and animals are exposed to them. In addition, the EPA has announced an initiative to phase out 95% of the uses of PFOA by 2010 and entirely by 2015. PFOA and PFOS production were eliminated by 3M in 2002.

Excerpts taken from MDH Website, dated March 2008.

Math

This chapter is intended to be an aid to the operator in solving everyday operating problems in the operation of a water system. It deals with basic math that would be required for an operator to accomplish his or her everyday work.

Solving math problems requires practice in manipulation and knowledge of what manipulation to make. Listed below is an approach to solving math problems:

1. Decide what the problem asks.
2. List the information given.
3. Decide what units the answer should have.
4. Perform the calculations necessary to solve the problem.
5. Label the answer.

Manipulation of numbers involves many operations, not all of which are covered here. We will review the different operations, so you remember basic operations.

FRACTIONS

Fractions are used when you want to express a portion of the whole. If you have a pie that is cut into eight pieces and you eat one, you have eaten 1/8th of the pie (1 divided by 8).

The top number (numerator) represents how many parts you have and the bottom number (denominator) represents the number in the whole.

The bar or slash in the fraction separates the two numbers and can be read as “divided by.” This means that the top number (numerator) is divided by the bottom number (denominator). Another way to say 1/8 is to say 1 divided by 8.

Fractions can also be used to represent units of measurement such as miles per hour or gallons per day where the ‘per’ represents “divided by”.

DECIMALS

Another method of representing a fraction is by using decimals of tenths, hundredths, etc. This is a much better method to use with a calculator. If you have a fraction and need to express the fraction as a decimal, you can convert the number by dividing the numerator by the denominator.

RATIOS

This is a comparison of two numbers or units, such as 2: 1,000,000 or 2 parts to one million parts.

EXPONENTS

Indicates how many times a number is to be multiplied by itself.

Example:

$2^3 = 2 \times 2 \times 2$, where 3 is the exponent
$4^2 = 4 \times 4$, where 2 is the exponent

UNIT CONVERSIONS

This represents a method of converting from one unit to another, such as cubic feet to gallons. This is one of the most difficult tasks for the operator. You must always write the units down with each number. All units must be checked prior to your calculations to make sure your answer will be in correct units. If the units are incorrect, the number that you calculate is incorrect as well.

The following is a method to use when converting one unit to another:

1. Write down the number and units you wish to convert from on the left.
2. Write down the unit you wish to convert to on the right.
3. Draw a line under both of these. This line means “divided by” and allows you to use a conversion factor.
4. Below this line (on the right) write down the same unit as you wrote down on the left.
5. Write the appropriate conversion number associated with the two units you wrote down on the right.
6. Cancel out the same units. This should leave you with the units that you wish to convert to. Perform the appropriate multiplication and division.

Example:

100 cubic feet is ? gallons

$$\frac{100 \text{ cubic feet} \times 7.5 \text{ gallons}}{1 \text{ cubic}} = 750 \text{ gallons}$$

750 gallons is ? cubic feet

$$\frac{750 \text{ gallons} \times 1 \text{ cubic foot}}{7.5 \text{ gallons}} = 100 \text{ cubic feet}$$

1. How many gallons are contained in 1,200 cubic feet? (9,000 gal)

2. If the treatment plant you work at has a tank that contains 200 gallons of chemical, how many cubic inches are contained in the tank? (46,200 in^3)

ROUNDING OF NUMBER

Rounding is the process of taking a number and reducing the number to one with fewer digits. If you have a number from your calculation such as 2.346567 and you wanted to round to two significant digits you would look at the third digit to the right of the decimal. If this number is greater than 5 raise the second digit up one, if the number is less than 5 leave the number as is. The answer to the above number would be 2.35.

REARRANGEMENT OF A FORMULA

This procedure allows a formula to be converted to solve for an unknown:

$$\text{Detention time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Flow} = \frac{\text{Volume}}{\text{Detention Time}}$$

The rules for the rearrangement of a formula:

If the unit you do not know is being divided by something you know, then multiply both sides of the equation (on each side of the equal sign) by the units that you know.

Example (you know everything but the volume):

$$\text{Detention time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Flow x Detention time} = \frac{\text{Volume x Flow}}{\text{Flow}}$$

$$\text{Volume} = \text{Detention Time x Flow}$$

If the unit you do not know is divided into something you know, then multiply both sides of the equation by the unit you do not know. After that, divide both the sides of the equation by the unit that you do know.

Example (you know everything but the flow):

$$\text{Detention time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Flow x Detention Time} = \frac{\text{Volume x Flow}}{\text{Flow}}$$

$$\frac{\text{Flow x Detention Time}}{\text{Detention Time}} = \frac{\text{Volume}}{\text{Detention Time}}$$

$$\text{Flow} = \frac{\text{Volume}}{\text{Detention Time}}$$

SOLVING WORD PROBLEMS

1. Read the problem.
    a. Underline the given information.
    b. Circle what is being asked for.
    c. Draw a picture and label with the given information.

2. Stop and think about what is being asked for.
    a. Look at the units, many times the units of the item being asked for will tell you how to do the problem.
    b. Do not go on until you understand what is being asked and you know how to proceed.

3. Select the proper formula.
    a. Write down the formula and then start writing down the various information that has been given to you. If you do not have enough information to fill in all but one unit in the formula, you have the wrong formula for the problem.

4. Solve the formula.

5. Ask if the answer is reasonable.
    a. If it is not, you should go back and check your work or possibly you are not using the correct formula.

AREA

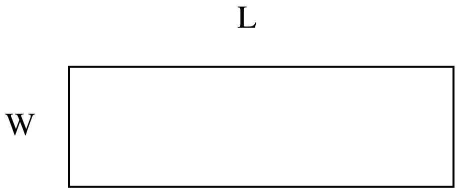
Area of any figure is measured in the second dimension or in square units. In the English system that we normally use in the United States, this would be square inches, square feet, etc. The most common mistake made by operators in working with math is that they do not convert the units so that they are the same. An example of this would be trying to use inches and feet in the same problem. One or the other would have to be converted.

Area conversion factors that are normally used in the water industry are as follows:

1 square foot = 144 square inches
1 square yard = 9 square feet
1 acre = 43,560 square feet
1 square mile = 640 acres or 1 section

RECTANGLE

The area of any rectangle is equal to the product of the length multiplied by the width of the figure.



Example:

Find the area of a rectangle that has a length of 5 feet and width of 3.6 feet?

$$\begin{aligned} A &= L \times W \\ &= 5 \text{ ft} \times 3.6 \text{ ft} \\ &= 18 \text{ ft}^2 \end{aligned}$$

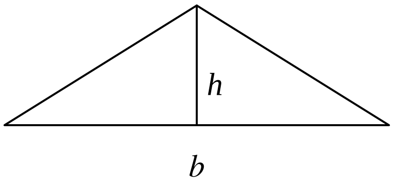
1. How many square feet of tile would it take to finish the lab floor if the room measures 10 feet wide and 15 feet long? (150 ft^2)

2. How many yards of sod would you have to buy to repair a water break hole if the measurements are 10 feet wide and 15 feet long? (16 2/3 YDS^2)

TRIANGLE

The area of a triangle is equal to one half of the base multiplied by the height of the figure. The height of the triangle is found by drawing a line from the angle opposite the base to the base. The area of the triangle is equal one half the area of a rectangle with the same dimensions.

$A = ½ B \times H$



Example:

1. How many square feet are contained in a triangular room that has a base of 25 feet and height of 10 feet? (125 ft^2)

2. How many acres are there in a triangular shaped piece of land that measures 200 feet deep and has a base of 250 feet? (0.57 acres)

CIRCLE

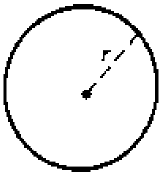
The area of a circle is found in a different manner in that a circle does not have base and height measurements. A circle is defined as a figure that has an arc that is equidistant in all areas from a center point. A line drawn from the center point to any point on the arc is called the radius. A straight line drawn through the center from arc to arc is called the diameter of the circle.

The area of a circle is found by squaring either the radius or the diameter. By doing this operation the units will become squared and at that point the units are right for finding area. If you use the radius of the figure after the units are squared you would multiply the square of the radius times pi or 3.14. Pi is a ratio of the circumference of a circle divided by the diameter, or put another way:

$$\text{Pi} = \frac{\text{Circumference}}{\text{D}}$$

This number is always equal to 3.14. If you find it easier to use the diameter when you work the problem, you multiply the square of the diameter times 0.785. No matter which formula you use, the answer will be the same depending on where you round the answers.

$\text{Area} = 3.14\ r^2$
$\text{Area} = 0.785d^2$



Example:

What is the area in square feet of a circular tank that has a diameter of 35 feet?

$$\begin{aligned}\text{Area} &= 0.785 \text{ x } (35\text{ft x } 35\text{ft}) \\ &= 0.785 \text{ x } 1225 \text{ sq. ft.} \\ &= 961.63 \text{ sq. ft.}\end{aligned}$$

1. How many square feet are there in a circle with a diameter of 45 feet? (1589.63 ft^2)

2. How many gallons of paint would it take to paint a floor in circular pump room that is 25 feet in diameter? A gallon of paint covers 200 square feet. (2.45 gallons)

SURFACE AREA

With the formulas that we have used to this point, it would be a simple matter to find the number of square feet in a room that was to be painted. The area of all of the walls would be calculated and then added together. This would include the ceiling as well as all of the walls in the room.

The area of the top and bottom ends are equal to:

$A = 0.785d^2$
$A = 0.785 \text{ x } (60\text{ft x } 60\text{ft}) \text{ x } 2$
$A = 0.785 \text{ x } 3{,}600 \text{ sq ft x } 2$
$A = 2826 \text{ sq ft x } 2$
$A = 5{,}652 \text{ sq ft}$

The area of the side wall is equal to the circumference of the tank times the depth. When you find the circumference it is as though you cut the tank depth and unroll the side to make it a rectangular figure.

$A = \text{Pi } DH$
$A = 3.14 \text{ x } 60 \text{ ft x } 20 \text{ ft}$
$A = 188.4 \text{ ft x } 20 \text{ ft}$
$A = 3{,}768 \text{ sq ft}$

The total surface area of the cylinder is equal to the sum of the two areas or

$\text{Surface Area} = 5{,}652 \text{ sq ft} + 3{,}768 \text{ sq ft}$
$= 9{,}420 \text{ sq ft}$

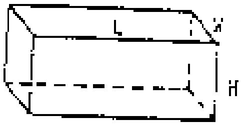
VOLUME

Water operators are usually more interested in what a tank will hold or how many gallons will a truck hold, etc. Volume is measured in the third dimension where a depth or height of the figure is known. The units used are generally cubic feet, cubic inches, acre feet, and gallons. In the water field the volume of most tanks are measured in gallons.

Volume is found by taking the area of the base of the figure and multiplying times the height of the figure. All figures that have been discussed to this point can have a volume calculated for them if you know the depth or height of the figure.

VOLUME OF A RECTANGLE

The volume of a tank that has a rectangular shape is found by multiplying the length times the width times the depth of the tank. This will give you the answer in cubic feet.



$\text{Volume} = L \text{ x } W \text{ x } H$

Example:

What is the volume in cubic feet of a tank that is 50 feet long, 30 feet wide, and 12 feet deep?

Volume = L x W x H
= 50 ft x 30 ft x 12 ft
= 1,500 ft^2 x 12 ft
= 18,000 ft^3

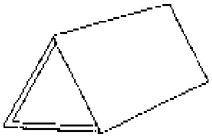
1. What would the volume of a tank be that measures 50 feet long, 24 feet wide and 10 feet deep in gallons? (90,000 gallons)

2. A tank holds 120,000 gallons and is 120 feet long and is 25 feet wide. What is the depth of the tank in feet? (5.3 feet)

VOLUME OF A PRISM

The volume of a prism is equal to the area of the base triangle times the depth or height of the figure.

Volume of Prism = Area of base x height of prism



Example:

Find the volume of a sludge hopper that has a triangle for a base that is 10 square feet and a depth of 6 feet:

Volume = area of base x height
= 10 ft^2 x 6 ft
= 60 ft^3

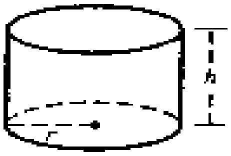
1. Find the volume in cubic feet of a sludge hopper that is triangular in shape that is 3 feet in height and has a base of 2 feet wide and length of 3.5 feet? (10.5 ft^3)

VOLUME OF A CYLINDER

The volume of a cylinder is equal to the area of the base times the height of the figure. The difference in this figure is that when you are working with the area, you must select one of two formulas for finding the area of the base figure. They are as follows:

$$\text{Volume} = 3.14\ R^2 \times H$$

$$\text{Volume} = 0.785\ D^2 \times H$$



Example:

Find the volume of a cylinder with a diameter of 10 feet and a depth of 10 feet?

$$\begin{aligned}\text{Volume} &= 0.785\ D^2 \times H\\ &= 0.785 \times 10\text{ft}^2 \times H\\ &= 0.785 \times 100\text{ft}^2 \times 10\text{ft}\\ &= 78.5\text{ft}^2 \times 10\text{ft}\\ &= 785\text{ft}^3\end{aligned}$$

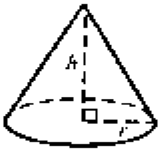
1. How many gallons does a tank that measures 50 feet in diameter and is 23 feet deep hold? (338,531 gallons)

2. If a cylinder holds 25,000 gallons of liquid what is the depth of the container if the radius is 8 feet? (16.59 feet)

VOLUME OF A CONE

The volume of a cone is equal to one-third the area of the base times the height of the figure. The base figure is a circle.

$$\text{Volume} = \frac{0.785 \times D^2 \times H}{3}$$



Example:

Find the volume of a cone with a diameter of 10 feet with a depth of 5 feet?

$$\text{Volume} = \frac{0.785\ (10\text{ft})^2 \times 5\text{ft}}{3}$$

$$= \frac{0.785 \times 100\text{ft}^2 \times 5\text{ft}}{3}$$

$$= \frac{78.5\text{ft}^2 \times 5\text{ft}}{3}$$

$$= \frac{392.5\text{ft}^3}{3}$$

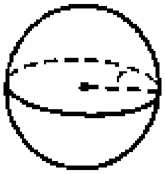
$$= 130.83\ \text{ft}^3$$

1. A sludge hopper is 5 feet in diameter and has a depth of 3 feet. What is the volume in cubic feet? (19.62 ft³)

VOLUME OF A SPHERE

The sphere is a figure in the shape of a ball. The water industry would use this figure in a water tower or a gas holder.

$$\text{Volume} = \frac{3.14 \text{ x } D^3}{6}$$



Example:

Find the volume in cubic feet of a water tower that is in the shape of a sphere that has a diameter of 30 feet.

$$\text{Volume} = \frac{3.14 \text{ x } (30\text{ft x } 30\text{ft x } 30\text{ft})}{6}$$

$$=3.14 \text{ x } 4500 \text{ ft}^3$$

$$=14{,}130 \text{ ft}^3$$

1. What is the volume in gallons of a spheroid water tank that is 24 feet in diameter? (54,289 gallons)

Conversion factors that are used in converting volume to another form are as follows:

1 cubic foot =1,728 cubic inches
1 cubic foot = 7.5 gallons
1 cubic yard = 27 cubic feet
1 acre foot = 43,560 cubic feet
1 quart = .946 liters
1 gallon = 4 quarts
1 gallon = 231 cubic inches
1 liter = 1.06 quarts

The material to this point has been arranged so that you could have a review of the basic skills required to perform your job as a water system operator. There are several other conversions that you must be able to make and they follow the same basic rules as we have used to this point. We will discuss these as they relate to the use that you as an operator will need to know.

TEMPERATURE

The water operator in the United States is used to using the English unit of measurement for temperature, namely Fahrenheit. The water industry in recent years has been converting to the metric system for the measurement of temperature or Celsius.

The formulas for the conversion of temperature are as follows:

Fahrenheit to Celsius

$$°C = \frac{5\ (°F - 32)}{9}$$

$$°F = \frac{(°C \times 9)}{5} + 32$$

1. If the temperature measured in Fahrenheit is 68 degrees, what is the temperature in Celsius? (20 degrees)

2. If you must hold an incubator in the lab at 37 degrees Celsius, what is the temperature in Fahrenheit? (98.6 degrees)

FLOW

The measurement of flow in the water industry is one of the most important calculations that an operator can make in his or her workday. The management of the flow in the water system dictates the operation of the total system from the feeding of chemicals to the collection of bills.

Flow in the treatment plant is a function of the velocity of the water at a given point in the treatment multiplied by the cross sectional area of the pipe or channel. Velocity is the time that it takes an object to travel a given distance. The cross sectional area is equal to the area of the end of the pipe or channel. If the pipe or channel is not flowing full, the area would be calculated using the depth of the water flowing in the pipe.

Flow is generally measured in gallons per minute, gallons per day, or million gallons per day. If you are working with a flow channel or pipe, the cross sectional area multiplied by the velocity will give you the flow in the form of cubic measure per basis of time, such as cubic feet per second.

Velocity is important to the water operator because if the velocity becomes too fast the friction loss in the pipe becomes very high and costs additional money for energy. If you want to calculate the velocity you need to know the distance traveled and length of time that it took to cover the given distance. The following formulas are used to calculate the velocity of a liquid**.**

$$\text{Velocity} = \frac{\text{distance traveled}}{\text{time}}$$

$$\text{Velocity} = \frac{\text{flowrate}}{\text{cross-sectional area}}$$

Example:

Find the velocity if an object travels 22 feet in 15 seconds.

$$\text{Velocity} = \frac{22 \text{ feet}}{15 \text{ seconds}}$$

$$= 1.467 \text{ ft/sec}$$

Example:

Find the velocity in a channel with a flow of 20 cubic feet per second. The channel measures 1 foot wide and the depth of water flowing is 0.5 feet.

$$\text{Velocity} = \frac{20 \text{ ft}^3\text{/sec}}{1 \text{ ft} \times 0.5\text{ft}}$$

$$= \frac{20 \text{ ft}^3\text{/sec}}{0.5\text{ft}^2}$$

$$= 40 \text{ ft/sec}$$

The water operator may calculate the flow based on the cross sectional area of the pipe or channel where the velocity is known. This is represented by the formula:

Quantity or Flow = Cross sectional Area x Velocity
$Q = AV$

Example:

Find the flow in a 1 foot diameter pipe if the velocity equals 5 feet per second. Express the flow in cubic feet per second.

$$Q = 0.785\ D^2 \text{ x } 5\text{ft/sec}$$

$$Q = 0.785\ (1\text{ ft})^2 \text{ x } 5\text{ ft/sec}$$

$$Q = 0.785\text{ ft}^2 \text{ x } 5\text{ft/sec}$$

$$Q = 3.92\text{ ft}^3\text{/sec}$$

If the flow in a water system is in cubic feet, the operator can convert the units into any of the other normal units, such as gallons per minute, gallons per hour, or gallons per day. The units of gallons are commonly used by the operators rather than cubic feet. When the flow from a pump or plant is measured in gallons per minute, as an example, the units can be converted to gallons per hour by multiplying by 60 minutes per hour. The units of flow in gallons per hour can be converted to gallons per day by multiplying the gallons per hour times 24 hours per day. A more common method of expressing flow in larger treatment plants is million gallons per day. Million gallons per day is computed by dividing gallons per day by 1,000,000.

If the flow has been expressed as cubic feet per second and you want to convert the flow to gallons per minute, you would use the following method.

$$\text{GPM} = \text{ft}^3\text{/sec x } 7.5\text{ gal/ft}^3 \text{ x } 60\text{ sec/min}$$

Example:

Find the flow in GPM if the flow in cubic feet per second is equal to 10.

$$\text{GPM} = 10\text{ft}^3\text{/sec x } 7.5\text{ gal/ft}^3 \text{ x } 60\text{ sec/min}$$

$$= 75\text{ gal/sec x } 60\text{ sec/min}$$

$$= 4{,}500\text{ GPM}$$

1. What is the flow to the treatment plant in gpm when the cfs equals 3.5 cfs? (1,575 gpm)

If the flow is expressed in GPM and you would like it in GPH. You would follow this procedure: GPH = GPM x 60 min/hr.

Example:

Find the flow in GPH when the flow equals 250 GPM?

GPH = 250 GPM x 60 min/hr

= 15,000 GPH

1. When the well pumps 400 gpm, what is the flow per hour from the well? (24,000 gph)

If the flow is expressed in GPH and you would like it in GPD you would follow the following procedure: GPD = GPH x 24 hr/day.

Example:

What is the flow in GPD if the GPH equals 15,000?

GPD =15,000 GPH x 24 hr/day

= 360,000 GPD

1. What is the flow per day in a plant if the well pumps 20,000 gph? (480,000 gpd)

If the flow is in GPM and you need GPD, you would multiply the GPM times 1,440 min/day.

GPD = GPM x 1,440 min/day

$$\frac{60 \text{ min}}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} = 1{,}440 \text{ min/day}$$

Example:

What is the flow in GPD if it equals 1,000 GPM?

GPD = 1,000 GPM x 1440 min/day

=1,440,000 GPD

1. A well pumps 150 gpm and runs the total 24 hours of the day. What is the flow from the well in gpd? (216,000 gpd)

When finding the flow in million gallons per day, divide the GPD by 1,000,000

$$\text{MGD} = \frac{\text{GPD}}{1{,}000{,}000}$$

Example:

What is the MGD if the flow is 500 GPM?

$$\text{MGD} = \frac{500\text{ GPM x}1{,}440\text{ min/day}}{1{,}000{,}000}$$

$$\text{MGD} = \frac{720{,}000\text{ GPD}}{1{,}000{,}000}$$

MGD = 0.72 MGD

FLOW CONVERSION FACTORS

1 cubic foot per second = 450 GPM
1 gallon per second = 0.133 CFS
1 gallon per second = 7.98 cubic feet/min
1 GPM = 0.0022 cubic ft/sec
1 GPM =1,440 GPD

LOADING CALCULATIONS FOR THE OPERATOR

The water operator needs to understand the importance of calculating the amount of chemical that he or she adds to the water of the community. This unit may be expressed as either parts per million (ppm) or milligrams per liter (mg/l). They are for all practical purposes considered to be equal.

The calculation tells the operator the number of pounds of chemical being added to the water per million pounds of water. The loadings are calculated by multiplying the following; the flow expressed in MGD, the weight of one gallon of water (8.34 #/gal), and the amount of chemical being added in parts per million.

Pounds per day = MGD x 8.34 lbs/gal x ppm

Example:

If you are adding 15.01 pounds of chlorine to a flow of 1.5 MGD, what is the ppm feed rate?

Chlorine lbs/per day =1.5 MGD x 8.34 lbs/gal x ppm

15.01 lbs/day = 1.5 MGD x 8.34 lbs/gal x ppm

15.01 lbs/day = 12.51 Million lbs/day x ppm

$$\frac{15.01 \text{ lbs/day}}{12.51\text{Million lbs/day x ppm}} = \frac{12.51 \text{ Million lbs/day x ppm}}{12.51 \text{ Million lbs/day x ppm}}$$

$$= 1.2 \text{ ppm}$$

By dividing each side of the equals sign, the right side is cancelled out. Always insert the number on top of the dividing line first into the calculator. 15.01 lbs/day divided by 12.51 lbs/day x ppm will also cancel out the lbs/day leaving you with an answer in ppm.

1. If you are adding 20 pounds of chlorine to a flow rate of 350 gallons per minute, what is the ppm feed rate? (4.8 ppm) Remember to convert to MGD.

A positive displacement chemical feed pump has a maximum daily pumping capacity of 24 gallons per day. The pump is set at 50% stroke and 50% speed, how many gallons of chemical is this pump capable of feeding in a 24 hour period?

Formula for chemical feed pump:

% stroke x % speed x pump capacity (gpd)
Convert % to decimal by dividing by 100.
.50 stroke x .50 speed x 24 hours = 6 gallons per day

1. A positive displacement chemical feed pump has a maximum daily capacity of 6 gallons per day. The pump is set at a 35% stroke and 75% speed, how many gallons of chemical is this pump capable of feeding in a 24 hour period. (1.6 gallons per day)

Many chemicals that are used in the operation of a water system are not pure elemental chemical, but contain some other chemical in combination with the one that you are interested in. An example of this would be calcium hypochlorite (HTH), which is 70 percent available chlorine.

$$\text{Pounds per day} = \frac{\text{pounds pure chemical}}{\text{percent purity}}$$

Example:

How many pounds of HTH would be required to raise the chlorine residual to 50 ppm if a tank contains 0.5 MGD? HTH is 70 percent pure.

$$\text{Pounds HTH} = \frac{\text{MG x 8.34 \#/gal x PPM}}{\text{percent purity}}$$

$$= \frac{0.5 \text{ MGD x } 8.34 \text{ \#/gal x } 50 \text{ PPM}}{.70}$$

$$= \frac{208.5 \text{ \# HTH}}{.70}$$

= 297.85 pounds HTH

WEIGHT CONVERSION FACTORS OF WATER

1 gallon = 8.34 pounds per gallon
1 cubic foot = 62.4 pounds per cubic foot
1 foot of water = 0.434 pounds per square inch
1 pound = 0.454 kilograms
1 kilogram = 2.2 pounds
1 kilogram = 1,000 grams
1 psi = 2.31 feet of water
1 liter = 1,000 grams
1 percent by volume = 10,000 ppm

PRESSURE

Pressure in the water system is what makes the system work. Pressure is caused by the weight of water above a given point in the system. Pressure is generally expressed as pounds per square inch (psi), but it can be expressed as feet of head. To convert from feet of head multiply the head times 0.434 psi/foot of head. When you know the pressure on a given point you can calculate the head in feet by multiplying the pressure times 2.31 feet per psi.

Examples:

Find the pressure on a gauge when the water level above a point is 76 feet.

PSI = 76 feet x 0.434 psi/foot
= 32.98 psi

Find the feet of head when a pressure gauge reads 24 psi.

Head = 24 psi x 2.31 feet/psi
= 55.4 feet

1. A pressure gauge at the base of a water tower reads 67 psi. What is the elevation of the water above the gauge? (154.77 feet)

2. The tower in your community is 245 feet high. If the tower is filled to the 222 foot level, what is the pressure at the base? (96.12 psi)

SPECIFIC YIELD

Feet of head to the water operator likely means more than the pressure that it causes. Head is used in the design of all the pumping equipment that makes the water system work. The operator, in order to understand what head is, must understand some of the terms that are used to explain head. The operation of a well involves many types of head. They are as follows:

Static Water Level

Static means that the water is at rest without movement. The static water level of a well is the distance to the water level in a well from the surface with the pump off.

Pumping Water Level

The level of the water in a well after the pump has operated until the well has stabilized. The measurement is taken from the ground level to the water surface with the pump operating.

Drawdown

The distance between the static water level and the pumping water level.

Static Discharge Head

The static discharge head is the difference in elevation the water is being lifted in feet.

Total Static Head

The distance the water has been lifted above the static water level. It is the sum of the static discharge head and the static water level. This is also the total static head that the pump will have to work against when it is turned on.

Total Dynamic Head

The sum of all the heads including static water level, static discharge head, drawdown, and the friction head in the pipeline. It is also the total pressure that the pump will have to work against after the pump has run for a period of time.

Example:

The water line to the elevated tank is 100 feet above the ground. The static water level is 36 feet below the ground elevation. The pump is turned on and after a period of time the pumping level drops to 52 feet.

What is the static discharge head?	100 feet
What is the total static head?	100 feet + 36 feet = 136 feet
What is the drawdown?	52 feet - 36 feet = 16 feet
What is the total dynamic head?	136 feet + 16 feet = 152 feet

When the amount of drawdown is known along with the flow (in GPM) the specific yield of the well can be analyzed. The specific yield of the well is found by dividing the GPM by the drawdown of the well.

Example:

Find the specific yield of a well if the flow is 1,000 GPM and the drawdown is 50 feet?

$$\text{Specific Yield} = \frac{\text{GPM}}{\text{Drawdown}}$$

$$= \frac{1000 \text{ gpm}}{50 \text{ feet}}$$

$$= 20 \text{ gpm/foot}$$

1. The static level in a well is 34 feet. When the pump is pumping 1,500 gpm, the pumping level is 75 feet. What is the specific yield of the well? (36.58 gpm/ft)

2. A well has static level of 100 feet and a pumping level after 4 hours the pumping level is 185 feet. The pump is pumping a rate of 1,500 gpm. What is the specific yield of the well? (17.64 gpm/ft)

When the pump is started a large amount of energy is required to pump the water, this is normally supplied by electrical power. Power is the rate of doing work and is usually expressed in foot pounds per minute. The water operator is familiar with horsepower, the form of work that is done by lifting water. If the flow from the pump is converted to a weight of water and multiplied by the vertical distance that the water is lifted and then divided by 33,000 foot pounds per minute. This is called water horsepower.

$$\text{Water horsepower} = \frac{\text{gpm} \times 8.34 \text{ lbs/gal} \times \text{head}}{33{,}000 \text{ ft lbs/min}}$$

or

$$\text{Water horsepower} = \frac{\text{gpm} \times \text{head}}{3{,}960}$$

Example:

Find the water horsepower if a pump is expected to pump 100 gpm against a head of 100 feet.

$$\text{Water horsepower} = \frac{100 \text{ gpm} \times 100 \text{ ft}}{3{,}960}$$

$$= \frac{10{,}000}{3{,}960}$$

$$= 2.52 \text{ HP}$$

When you are calculating the required horsepower for a given pump you must remember that no pump is 100% efficient. Likewise, no motor is 100 percent efficient. The following formulas allow the operator to calculate brake horsepower where the efficiency of the pump is considered, and motor horsepower, where both pump efficiency and motor efficiency is considered.

$$\text{Brake horsepower} = \frac{\text{gpm} \times \text{head}}{3{,}960 \times \text{pump eff}}$$

$$\text{Motor horsepower} = \frac{\text{gpm} \times \text{head}}{3{,}960 \times \text{p eff} \times \text{m eff}}$$

1. What size motor would be required to lift 1,000 gpm against 200 feet of head? The pump is 82 percent efficient and motor is 94 percent efficient. (65.53 HP)

2. A pump in a well is designed to pump 2,000 gpm against 250 feet of head. The pump is designed to have an efficiency of 80 percent and the motor has an efficiency of 92 percent. How many horsepower must the motor produce to meet the demand? (171.55 HP)

NOTE: The formulas above are developed for water and wastewater applications where water is the medium being pumped. If the application is being applied to another medium, the specific gravity of the liquid must be applied to the calculation.

DETENTION TIME

The detention time of a tank or piping system is the time that it would take to fill the system or empty the system. This is a theoretical time in that it will not tell you if the tank is short circuiting or not. The detention time is found by calculating the volume of the vessel and dividing it by the flow to the vessel.

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

Example:

Find the detention time of a tank that measures 50 feet long, 30 feet wide, and 10 feet deep with a flow to the tank of 1500 gpm.

$$\text{Detention Time} = \frac{50\text{ ft x }30\text{ ft x }10\text{ ft x }7.5\text{ gal/ft}^3}{1{,}500\text{ gpm}}$$

$$= \frac{112{,}500\text{ gallons}}{1{,}500\text{ gpm}}$$

$$= 75\text{ minutes}$$

1. A tank measures 50 feet in diameter and is 14 feet deep, if the tank receives a flow of 2,500 gpm, what is the detention time of the tank in minutes? (82.43 minutes)

2. What is the detention time in hours of a settling basin that measures 50 feet long, 20 feet wide, and 10 feet deep when a flow of 1,000 gpm is applied to it? (1.25 hours)

Another example of finding detention time is where you would want to know the time water will remain in the piping system. Here you would find the total volume of the pipe and divide by the flow out of the system to the residents connected.

How many hours would it take to use the water in 120,000 feet of 8 inch pipe with a flow out of the system of 1,000 gpm and a flow into the system of 250 gpm?

$$\text{Detention Time} = \frac{.785\text{ x }D^2\text{ x Length}}{1{,}000\text{ gpm} - 250\text{ gpm}} \quad (8\text{ inches / }12\text{ inches} = .67\text{ feet})$$

$$= .785\text{ x }.67\text{ft x }.67\text{ft x }120{,}000\text{ft} = 41{,}866\text{ ft}^3$$

$$= \frac{41{,}866\text{ ft}^3\text{ x }7.5\text{ gal/ft}^3}{750\text{ gpm x }60\text{ min/hr}}$$

$$= \frac{314{,}000 \text{ gal}}{45{,}000 \text{ gph}}$$

$$= 6.98 \text{ hours}$$

1. A piping system has a length of 22,000 feet of 20 inch pipe. How long will it take to fill the pipe if you can pump 1,000 gpm into the pipe? (358 minutes)

FLUORIDATION

The operation of a fluoridation system requires the operator calculate several different things. One of the most common calculations is the amount of fluoride to add to the system in gallons. One thing that you must know is the weight of one gallon of hydrofluosilicic acid, which is approximately 10.3 pounds per gallon. This gallon of acid is also approximately 25 percent acid and 75 percent water. Also, the 25 percent acid is only 79 percent fluoride.

The following calculation shows how many pounds of pure fluoride are contained in one gallon of hydrofluosilicic acid.

$$\text{Fluoride per gallon} = 10.3 \text{ lbs/gal} \times .25 \text{ acid} \times .79 \text{ fl/lbs}$$

$$= 2.57 \text{ lbs acid} \times .79 \text{ fl/lbs}$$

$$= 2.03 \text{ lbs fl/gal}$$

When you want to know how many gallons are required to raise the fluoride residual to a given level you must find the amount of pure chemical that is required and divide this by the amount of pure chemical per gallon of acid.

Example:

How many gallons of hydrofluosilicic acid are required to raise the fluoride residual to 1.2 ppm in 1.0 mgd? The weight of the fluoride is 10.3 pounds per gallon with and acid content of 25 percent and 79 percent purity. Natural fluoride level is 0.

$$\text{Gallons fluoride} = \frac{\text{Mgd} \times 8.34 \text{ lbs/gal} \times \text{ppm}}{\text{pounds per gallon}}$$

$$= \frac{1.0 \text{ mgd} \times 8.34 \text{ lbs/gal} \times 1.2\text{ppm}}{10.3 \text{ lbs/gal} \times .25 \times .79}$$

$$= \frac{10.01 \text{ lbs fl/day}}{2.03 \text{ lbs/gal}}$$

$$= 4.92 \text{ gal}$$

1. How many gallons of hydrofluorsilicic acid is required to raise the fluoride residual to 1.3 ppm when the flow to the system is 150 gpm and it runs 24 hours? The hydrofluosilicic acid is 10.3 lbs/g and 25 percent acid and containing 79 percent fluoride. (1.15 gallons)

If you are using sodium silica fluoride, which is a dry powder rather than a liquid the procedure is the same. First you find the amount of pure chemical needed and divide this by the amount of pure chemical per pound of chemical fed. Sodium silica fluoride is approximately 69 percent pure fluoride for each pound of chemical fed.

Example:

Find the amount of sodium silica fluoride that is required to raise the fluoride residual to 1.3 ppm with a flow of .5 mgd. The sodium silica fluoride is 69 per cent pure fluoride.

$$\text{Pounds per day} = \frac{\text{mgd x 8.34 lbs/g x ppm}}{\text{percent pure}}$$

$$= \frac{\text{0.5 mgd x 8.34 lbs/gal x 1.3 ppm}}{\text{.69 pure}}$$

$$= \frac{\text{5.42 lbs/day}}{.69}$$

$$= \text{7.85 lbs/day}$$

The percent of purity is used in all calculations where you are feeding a chemical that is less than 100 percent pure. If you are buying chemicals, in some cases they are bought in so many dollars per dry pound of a certain chemical. An example of this would be ferric chloride. Ferric is approximately 35 percent pure. Again you must know the weight of one gallon plus the specific gravity of the solution.

Another area where you may use this calculation is when you want to buy so many gallons of pure fluoride.

Example:

Find the number of gallons of fluoride you must buy to obtain 100 gallons of pure fluoride if the percent of purity is equal to 24 percent.

$$\text{Gallons} = \frac{\text{Gallons needed}}{\text{percent}}$$

$$= \frac{100 \text{ gallons}}{.24}$$

$$= 416.66 \text{ gallons}$$

1. How many gallons of acid must you buy to obtain 1,200 gallons of pure fluoride when the percent purity is 23 percent? (5,217 gallons)

SPECIFIC GRAVITY

Specific gravity is a relationship of the liquid to water. A liquid that is heavier than water will have a specific gravity greater than one. If you know the weight per gallon of the liquid you can find the specific gravity of the material by dividing the weight per gallon by the weight of one gallon of water.

$$\text{Specific Gravity} = \frac{\text{weight per gallon}}{\text{weight of water/gallon}}$$

Example:

Find the specific gravity of a chemical that has weight per gallon of 10.6 pounds per gallon.

$$\text{Specific gravity} = \frac{10.6 \text{ pounds per gallon}}{8.34 \text{ pounds per gallon}}$$

$$= 1.27$$

1. A liquid that you are buying weighs 11.4 pounds per gallon. What is the specific gravity of the liquid? (1.37)

When you have a material and you know the specific gravity of the material, you can easily calculate the weight per gallon of the material. In order to find the weight per gallon, take the weight of one gallon of water times the specific gravity of the material.

$$\text{Weight per gallon} = 8.34 \text{ lbs/gal} \times \text{specific gravity}$$

Example:

Find the weight per gallon of a liquid that has specific gravity of 1.04.

Weight per gallon = 8.34 lbs/gal x 1.04

= 8.67 lbs/gal

1. A material has a specific gravity of 2.5. What is the weight per gallon of the material? (20.85 pounds per gallon)

FILTRATION

The operation of sand filters requires the operator to apply the water at a given rate of generally 2 to 6 gallons per minute per square foot of filter area. The filter is generally designed at a rate by the engineer, but the operator must know the basics of how the engineer designed the plant in order to operate it. If one filter is removed from service, what is going to happen to the efficiency of the filters if the flow is not reduced? The loading of a filter is found by dividing the flow in gpm by the surface area of the filter.

Example:

Find the filter loading in gpm/ft^2 when the flow to a filter equals 500 gpm and the filter measures 10 feet wide by 15 feet long.

$$\text{Filter loading} = \frac{\text{gpm}}{\text{filter area}}$$

$$= \frac{500 \text{ gpm}}{10 \text{ ft} \times 15 \text{ ft}}$$

$$= \frac{500 \text{ gpm}}{150 \text{ ft}^2}$$

$$= 3.33 \text{ gpm/ft}^2$$

1. A filter in a plant measures 15 feet wide and 27 feet long and has flow of 2,000 gpm applied to it. What is the loading in gpm/ft^2? (4.94 gpm/ft^2)

2. A plant has a flow of 2,500 gpm and you want to have a loading of 3 gpm/ft^2. How many square feet of filter are needed to handle the flow to the plant? (833 ft^2)

Another area that is important to the operation of filters is the backwash rate that is used to clean the filter. Generally the design engineer will supply a backwash pump larger than is needed to wash the filter and the operator must select a rate that will clean the filter. Most filters are designed to be washed at a rate 12 - 15 gpm/ft^2. The same formula that is used to load the filter is used to calculate the filter backwash rate.

Example:

Find the backwash rate in gpm/ft^2 if a filter is washed at 2,500 gpm and measures 12 feet by 16 feet.

$$\text{Backwash rate} = \frac{\text{gpm}}{\text{filter area}}$$

$$= \frac{2{,}500 \text{ gpm}}{12 \text{ ft} \times 16 \text{ ft}}$$

$$= \frac{2{,}500 \text{ gpm}}{192 \text{ ft}^2}$$

$$= 13.02 \text{ gpm/ft}^2$$

1. A filter that measures 14 feet wide and 15 feet long is backwashed at a flow rate of 3,500 gpm. What is the backwash rate of the filter in gpm/ft^2 ? (16.66 gpm/ft^2)

Another method of calculating the wash rate of filters is in inches of rise per minute. This means that you want to know the upward velocity in the filter per minute. You would calculate this by dividing the gpm of wash water by the number of gallons per inch in the filter.

Example:

Find the inches of rise in a filter that measures 10 feet wide and 12 feet long when the flow from the backwash pump equals 3,000 gpm.

$$\text{Inches of rise} = \frac{\text{gpm}}{\text{gal/in}}$$

$$= \frac{3{,}000 \text{ gpm}}{\dfrac{10 \text{ ft} \times 12 \text{ ft} \times 1 \text{ ft} \times 7.5 \text{ gal/ft}^3}{12 \text{ in/ft}}}$$

$$= \frac{3{,}000 \text{ gpm}}{\dfrac{900 \text{ gal/ft}}{12 \text{ in/ft}}}$$

$$= \frac{3{,}000\text{gpm}}{75 \text{ gal/in}}$$

$$= 40 \text{ in per minute}$$

1. A filter in a plant measures 20 feet square and is 4 feet deep. A flow of 6,000 gpm is applied to the filter during the backwash. What are the inches of rise in the filter? (6 inches per minute)

MOLECULAR WEIGHT

In the operation of a water treatment system, the operator must be able to understand the molecular structure that makes up the chemicals that they use in the day to day operation. A chemical is made up of separate elements that are bonded together to form the material that you are using. Very few chemicals, such as liquid chlorine, are fed in their pure form. The molecular weight of a compound is equal to the atomic weights of the elements making up the compound.

Example:

Find the molecular weight of Calcium Oxide (CaO). The atomic weight of calcium is 40.08 and oxygen is 16.0.

$$\begin{aligned}\text{Molecular weight} &= \text{Calcium weight} + \text{Oxygen weight}\\ &= 40.08 + 16.0\\ &= 56.08\end{aligned}$$

1. Find the molecular weight of $Mg(OH)_2$ when Magnesium has an atomic weight of 24.32, oxygen weight is 16, and hydrogen is 1.008. (58.336)

2. Find the molecular weight of $Ca(OH)_2$ when the weight of calcium is 40.08, oxygen is 16, and hydrogen is 1.008. (74.0960)

SOFTENING CALCULATIONS

The operation of a lime softening treatment plant requires the operator to calculate the amount of lime required to remove a certain amount of hardness from the water.

The first step is to find the amount of lime required (in ppm) to remove the hardness from the water. This is found by subtracting the amount of hardness in the water after softening from the total hardness. Step two is to find the equivalent for the lime that you are using. As an example, if you are removing the hardness using calcium Oxide (CaO) and you are removing calcium bicarbonate $Ca(HCO_3)_2$ you would divide the molecular weight of the CaO by the molecular weight of the $Ca(HCO_3)_2$. After this you would use the basic pounds per day formula.

$$\text{Pounds CaO per day} = \text{MGD} \times \frac{\text{CaO}}{\text{Ca CO}_3} \times 8.34 \text{ lbs/g} \times \text{ppm removed}$$

Example:

Find the amount of lime as CaO that would be needed to remove 200 ppm of calcium bicarbonate from 1 mgd.

$$\text{Pounds CaO} = 1 \text{ mgd} \times \frac{56.01}{100.06} \times 8.34 \text{ lbs/g} \times 200 \text{ ppm}$$

$$= 1 \text{ mgd} \times 0.56 \times 8.34 \text{ lbs/g} \times 200 \text{ ppm}$$

$$= 4.67 \text{ lbs/Million lbs} \times 200 \text{ ppm}$$

$$= 934 \text{ pounds CaO}$$

Another method of softening uses caustic soda or soda ash in place of the calcium oxide. When using something in place of the pebble lime you would substitute that chemical in the place of the calcium oxide in the formula.

1. How many ppm of Hydrate lime ($Ca(OH)_2$ is required to lower the $Ca(HCO_3)^2$ from 450 ppm to 85 ppm? (270 ppm)

2. A treatment plant treats a flow of 140 gpm for a period of 24 hours. The raw water contains 120 ppm of hardness as calcium bicarbonate. The finished water is to be 70 ppm. How many pounds of lime as CaO must be added to obtain this? (47 pounds)

ZEOLITE SOFTENING

This is a process that is generally used as a point of use softening appliance in the home or used in the industrial area where the water must be near zero hardness. It operates by exchanging sodium ions from salt for hardness ions in the water. Zeolite has the ability to remove approximately 35,000 grains of hardness per cubic foot of media. One grain per gallon of hardness equals 17.1 ppm per grain of hardness. If you have the hardness of the water in grains per gallon you can convert the hardness to ppm by multiplying by 17.1 ppm/grain/gallon. If you have the reading in ppm, divide the ppm by the 17.1 grains per gallon.

Example:

Find the grains per gallon of water that contains 230 ppm of hardness as calcium bicarbonate.

$$\text{Grains/ gallon} = \frac{230\text{ ppm}}{\frac{17.1\text{ ppm}}{\text{g/g}}}$$

$$= 13.45\text{ g/g}$$

What is the hardness in ppm when water contains 21 grains per gallon of hardness?

$$\text{ppm hardness} = 21\text{ g/g} \text{ x } 17.1\text{ ppm/g/g}$$

$$= 359.1\text{ ppm}$$

1. A customer has bought a new water softener and the instructions state that you must know the grains per gallon in order to set the control. You have the hardness reading for your water of 130 ppm, what is the reading in grains per gallon? (7.6 grains per gallon)

2. If water contains 18 grains per gallon of hardness. What is the hardness expressed as ppm? (308 ppm)

A zeolite water softener has the ability to exchange the hardness ion for a sodium ion, which will soften the water. A cubic foot of zeolite will remove between 35,000 - 50,000 grains of hardness. If a water contains 20 grains per gallon and you want to know how many gallons the softener will treat before requiring regeneration you must know the volume of zeolite available and the amount of grains that each cubic foot will remove.
Example:

How many gallons will be produced if the softener contains 1,000 cubic feet of zeolite that will remove 45,000 grains per cubic foot? The water being treated contains 15 grains per gallon.

$$\text{Gallons} = \frac{45.000\text{ g/ft}^3 \text{ x } 1000}{15\text{ g/g}}\text{ ft}^3$$

$$= \frac{45{,}000{,}000\text{ grains}}{15\text{ grains/gal}}$$

$$= 3{,}000{,}000\text{ gallons}$$

1. Water contains 22 grains per gallon of hardness. The softener will remove 46,000 grains before requiring regeneration. The tank contains 1,500 cubic feet of zeolite. How many gallons will the softener treat before regeneration? (3,136,363 gal)

SAMPLE PROBLEMS

The following problems are designed to use all of the information that you have learned to this point. Problems may require you to combine formulas to arrive at the answers. Answers are given for each problem. If your answer differs, but is close, it may be in the way the calculation was rounded at some point.

1. What is the area of the water surface in a tank that measures 25 feet wide and 32 feet long? (800 ft^2)

2. What is the area in square inches of a 10 inch ductile iron pipe? (78.5 in^2)

3. What is the circumference of a standpipe that has a radius of 22 feet and a height of 200 feet? (138.16 feet)

4. What is the volume in cubic feet of a tank that measures 50 feet long, 35 feet wide, and is 12 feet deep? (21,000 ft^3)

5. What is the volume in gallons of a circular tank that measures 50 feet in diameter and has a sidewall depth of 18 feet? (264,937 gallons)

6. What is the detention time of a tank that measure 45 feet in diameter and has depth of 22 feet? The flow to the tank is 2,300 gpm. (114 min.)

7. How many pounds of chlorine would it take to raise the residual of the above tank to 50 ppm? (109.37 pounds)

8. Calcium hypochlorite is 70 percent available chlorine. How many pounds would be required to raise the residual of 400,000 gallons of water to 50 ppm? (238.28 pounds)

9. Determine the flow in cubic feet per second if the velocity in a 12 inch pipe is 4 feet per second? (3.14 ft^3/sec)

10. Before a pump was started the static level was 48 feet from the surface. After the pump was started the pumping level was lowered to 120 feet. If the pump was pumping 1,200 gpm what is the specific yield in gpm/ft? (16.67 gpm/ft)

11. How many pounds of hydrated lime would be required to treat 5.0 mgd of water to reduce the calcium bicarbonate from 120 ppm to 80 ppm? (1,234 pounds)

12. How many gallons of water will be pumped from a well expressed as mgd if the pump runs for a period of 13 hours at 1,800 gpm? (1.404 mgd)

13. The discharge pressure gauge reads 120 psi at the pump head. How many feet of head will the pump have to produce to overcome the pressure? (277.2 feet)

14. A standpipe measures 25 feet in diameter and stands 80 feet high. How many gallons are contained in the tank when the water level is at the 60 feet? (220,781 gallons)

KMnO4 FEED RATE

1. 24 gallon per day pump output
2. Stroke 40%
3. Speed 40%
4. Flow rate: 320 gpm + 400 gpm = 720 gpm
5. 720 gpm x 60 min. x 24 hrs = 1,036,800 gallons
6. 1,036,800 gallons divided by 1,000,000 = <u>1.04 MGD</u>
7. 3% solution KMnO4
8. .03 x 8.34 lbs/gal = .25 lbs KMnO4 per gallon
9. .40 x .40 x 24 gpd = 3.84 pump output gallons/day
10. 3.84 pump output gallons x .25 = .96 pounds of KMnO4
    Formula: lbs/day = ppm x 8.34 lbs/gal x 1.04 MGD
11. .96 lbs KMnO4 = ppm x 8.34 lbs/gal x 1.04 MGD
12. .96 lbs KMnO4 = ppm x 8.67 million pounds
13. <u>.96 lbs KMnO4</u>
    8.67 million pounds
14. Answer: 0.11 ppm dosage

CALCULATION FOR UN-ACCOUNTED FOR WATER

The Department of Natural Resources allows for a 10% water loss. Formula to Determine Water Loss: take water pumped or purchased, subtract water metered (sold), then divide by water pumped or purchased. (Convert to % by multiplying answer by 100).

Example:

$$\frac{\text{110,000 gallons pumped (purchased)} - \text{100,000 gallons metered (sold)}}{\text{110,000 gallons pumped (purchased)}}$$

Water loss is 10%.

Using a yearly average is the best way to determine your water loss. Remember to track your monthly usage for fire hydrant flushing, fires, water leaks, and ice rinks. Compare the usage from previous days water use to determine the amount of water used for these activities. This is not considered un-accounted for water; you only need to show where the water went when it is not metered. This water will be added to the gallons metered or (sold) in the water loss calculation.

Example:

1. The city pumped 10,000,000 gallons and sold 9,000,000 gallons. What is the % water loss? (10%)

Well Construction

It is important that the water operator have some understanding of well construction and how Minnesota regulates it. Poor construction methods cannot only contaminate aquifers but can also endanger their source. See the chapter on “Rules Relating to Wells and Borings” for a summary of items of interest to the water-supply operator.

WELLHEAD PROTECTION

Under MN Rule 4720 (4720.5100 – 0.5590), any well added to a municipal water supply system will trigger the development of a Wellhead Protection Plan, not only for the new well, but for all wells in the public water supply system.

The purpose for wellhead protection “set-back” is to prevent harmful contaminants from entering public water wells. Since the early 1900s, isolation distances have been used to prevent disease organisms from entering public wells. *However, between wells and contamination sources isolation distances have been set mainly to prevent bacteriological contaminants from entering wells. They are not as effective in preventing chemical contaminants from entering wells.* This is because chemicals either do not degrade or breakdown over time or because their breakdown products are as toxic as the parent compound. The Minnesota Department of Health (MDH) is leading efforts to establish a wellhead protection program that will help prevent chemical contaminants from entering public wells.

The focus of wellhead protection is the wellhead protection area (WHPA). The WHPA includes the surface and subsurface areas that supply water to a public well. Once the WHPA is determined for a public well, the vulnerability of the well and the local geological setting are assessed to determine potential sources of contamination that may affect the well. Next, a contaminant source inventory is conducted to identify potential contaminant sources in the WHPA, and a plan for managing these sources is developed. Implementing a WHPA plan to protect a public well will require the cooperation of public water suppliers, land owners, local governments, state agencies, and the general public.

Wellhead protection has proven to be an effective method to protect public wells from contamination that can result from land use activities. Minnesota is required, under provisions of the federal Safe Drinking Water Act, to develop and implement a Wellhead Protection Program. The Minnesota Department of Health has completed the State’s written groundwater rule changes necessary for implementing a mandatory wellhead protection program. All public water suppliers will eventually be required to develop and implement wellhead protection plans; however, voluntary participation is currently being encouraged.

Potential Contamination Sources

Category	Sources	
Agriculture	Animal burial areas	Irrigation sites
	Animal feedlots	Manure spreading area/pits
	Fertilizer storage/use	Pesticide storage/use
Commercial	Airports	Jewelry/metal plating
	Auto repair shops	Laundromats
	Boatyards	Medical institutions
	Construction areas	Paint shops
	Car washes	Photography establishments
	Cemeteries	Railroad tracks and yards
	Dry cleaners	Research laboratories
	Gas stations	Scrap and junkyards
	Golf courses	Storage tanks
Industrial	Asphalt plants	Petroleum production/storage
	Chemical manufacture/storage	Pipelines
	Electronics manufacture	Septage lagoons and sludge
	Electroplaters	Storage tanks
	Foundries/metal fabricators	Toxic and hazardous spills
	Machine/metalworking shops	Wells (operating/abandoned)
	Mining and mine drainage	Wood preserving facilities
Residential	Fuel Oil	Septic systems, cesspools
	Furniture stripping/refinishing	Sewer lines
	Household hazardous products	Swimming pools (chemicals)
	Household lawns	
Other	Hazardous waste landfills	Recycling/reduction facilities
	Municipal incinerators	Road deicing operations
	Municipal landfills	Road maintenance depots
	Municipal sewer lines	Storm water drains/basins
	Open-burning sites	Transfer stations

WELL SITING

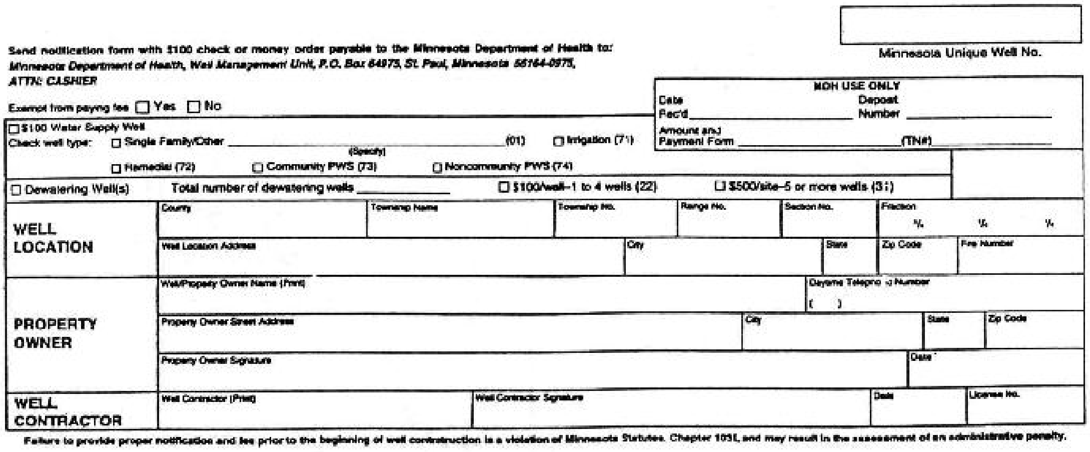
When in need of a first well or a new well, city officials should follow the guidelines below:

1. All municipal water-supply wells should be designed by a competent professional engineer who knows the geology of the area where the well is to be constructed and has experience and expertise in well design and drilling and is familiar with State requirements.

2. Considerations in site selection include the location of existing water towers, storage areas, and treatment plants as well as the availability of the property and whether or not the city owns this property. In addition, the well should be located so that it will not be contaminated by any identifiable source in the area. Variables influencing the movement of contaminants through the groundwater include: contour of the land, slope of the water table (which could be different than that of the surface), geology permeability or transmissivity of the soil.

3. A well construction plan, specifications, and a well construction notification must be submitted to the Minnesota Department of Health (MDH) for approval prior to construction. The well contractor must also notify MDH by phone, fax, or in person at least 24 hours prior to the start of construction. Government owned wells are exempt from the notification fee.

WELL NOTIFICATION



Send notification form with $100 check or money order payable to the Minnesota Department of Health to:
Minnesota Department of Health, Well Management Unit, P.O. Box 64975, St. Paul, Minnesota 55164-0975,
ATTN: CASHIER

Minnesota Unique Well No.

MDH USE ONLY
Date Rec'd ________ Deposit Number ________
Amount and Payment Form ________ (TN#) ________

Exempt from paying fee ☐ Yes ☐ No

☐ $100 Water Supply Well
Check well type: ☐ Single Family/Other ________ (Specify) (01) ☐ Irrigation (71)
☐ Remedial (72) ☐ Community PWS (73) ☐ Noncommunity PWS (74)

☐ Dewatering Well(s) Total number of dewatering wells ________ ☐ $100/well–1 to 4 wells (22) ☐ $500/site–5 or more wells (31)

WELL LOCATION	County	Township Name	Township No.	Range No.	Section No.	Fraction ¼ ¼ ¼	
	Well Location Address	City	State	Zip Code	Fire Number		
PROPERTY OWNER	Well/Property Owner Name (Print)	Daytime Telephone Number ( )					
	Property Owner Street Address	City	State	Zip Code			
	Property Owner Signature	Date					
WELL CONTRACTOR	Well Contractor (Print)	Well Contractor Signature	Date	License No.			

Failure to provide proper notification and fee prior to the beginning of well construction is a violation of Minnesota Statutes, Chapter 103I, and may result in the assessment of an administrative penalty.

4. The well must be constructed by a licensed well contractor in accordance with Minnesota's Rules Regarding Wells and Borings (Well Code - MN Rules Chapter 4725)

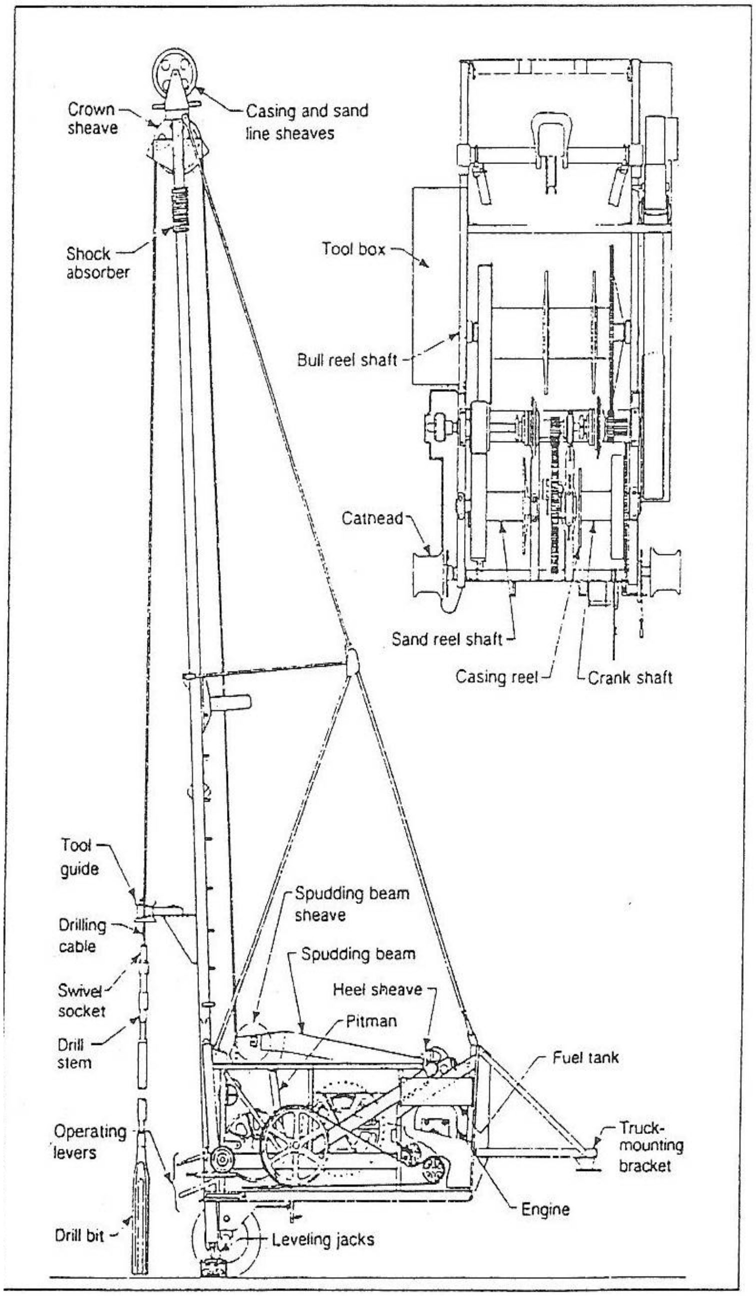
Before a well site will be approved by the Minnesota Department of Health, it must meet minimum distance requirements from various contamination sources. These distances, established by rule, are guided by a concern for the toxicity of the contaminants, the ability of the material to penetrate the soil, and the contaminant's potential concentration. The chapter summarizing the "Rules Related to Wells and Boring" includes a listing of the minimum isolation distances required in Minnesota's Water Well Code for a potable-water well.

DRILLING METHODS

In Minnesota, two basic methods of well construction are used: the cable tool method and the mud rotary method. Other methods--such as air rotary drilling, air percussion drilling, bucket drilling (for very large diameter wells), jetting, and augering--are used occasionally, but the cable tool and rotary methods are the most common. There are a number of different rotary methods that are now used including dual rotary, rotaomic, mud rotary, and air rotary/hammer. Small diameter, shallow “sand-points” are commonly driven by hand and use the water table aquifer.

CABLE TOOLS

Cable tool drilling--also known as percussion drilling, churn drilling, solid tool or spudding--is a widely used method of drilling wells in Minnesota. The cable tool drill operates by raising and lowering a heavy set of tools, called a tool string, suspended from a cable. This tool string has a drilling bit, which is a heavy chisel-shaped tool four to five feet long and flared at the end to the size of the well being drilled, and a swivel socket at the top that enables the string to rotate. The drill stem is a round bar which provides the weight for drilling and guides the rest of the tools. The cable is threaded over a pulley or crown sheave at the top of the mast, down to a walking beam, and on to a cable drum where the excess cable is stored. The up and down drilling motion is transmitted to the tool string by the action of the walking beam. Additional cables or lines are used to raise the casing or lower the bailers or other tools during the process.



The constant raising and lowering of the tool string by the walking beam action results in the breaking up of the rock and sediment into smaller pieces called “cuttings.” The length of the cable (stroke) can be adjusted so that the bit will strike the bottom with the force needed. The socket at the end of the tool string allows the bit to turn on impact and create the drilling action. Typically, four-to-six feet are drilled with each run of the drill bit. Hard rock is drilled at a faster operating speed than clays and soft material. Cuttings, which are mixed with a small amount of water, are removed from the hole by “bailing.” A bailer consists of a hollow pipe, smaller in diameter than the drill hole or casing, usually six-to-twenty feet long with a valve on the bottom to retain the cuttings. The bailer is lowered to the bottom of the hole where it fills with a mixture of water and cuttings, and is then raised to the surface where the cuttings are discharged. It is through the examination of the cuttings that the driller determines the types of formations to record on the well record.

As the drilling proceeds, casing is continually forced into the ground. This is accomplished by attaching “drive clamps” to the tool string. The walking beam raises and lowers the string rapidly, and the weight of the tool string hitting against the top of the casing causes the casing to advance downward into the hole. The bottom of the casing is equipped with a hardened fitting called a “drive shoe” that protects the end of the pipe from damage. The top of the casing is also protected by a drive cap during the driving process.

The complete process involves the drilling of a few inches--or at most a few feet--past the end of the casing, bailing the hole to remove the cuttings, driving the casing, and then resuming the drilling. In a bedrock well, the casing would generally end at the top of the solid rock, with open hole drilled into the water-bearing strata. Some geological conditions require an inner casing and cement grout.

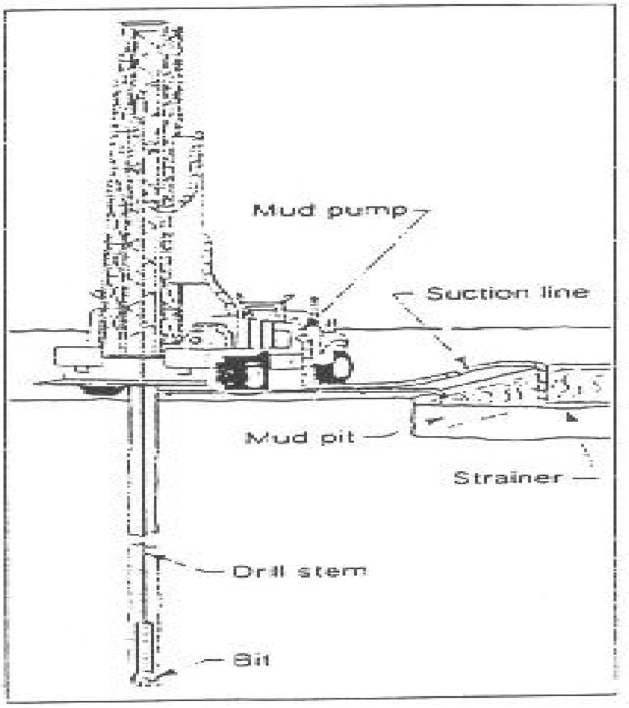
In a well completed in gravel or sand, the casing would be driven to the desired depth and normally a screen would be installed. A well screen is a sieve or strainer-like device that has holes or other openings small enough to allow water to pass into the well, but large enough to keep sediment out of the well. The screen, which is smaller than the casing, is telescoped or lowered to the bottom of the hole along with a packer to seal the screen to the casing. The casing is then pulled back to expose the screen to the producing formation.

Accurate samples can be obtained with a cable tool rig. It is possible to test for water quantity and quality of each formation as drilling progresses. While the reduced speed in overall drilling conditions is a disadvantage, a cable tool rig may be the best equipment for drilling a fractured rock well, or for large diameter wells. A cable tool rig may have to cease drilling if it encounters a large rock or boulder. In some cases explosives may be used to either shatter the boulder or move it out of the way of the drilling operation.

The cable tool method is often used for drilling large-diameter municipal wells in Minnesota.

ROTARY WELL DRILLING

Rotary well drilling is widely used in Minnesota. This is a method of drilling in which the bore hole is made with a constantly rotating bit. The bit is connected to a series of hollow-threaded drill pipes. A circulating fluid or “mud” is pumped down the drill pipe to the bit, where it then exits and flows upward. The fluid carries the drill cuttings to the surface and stabilizes the bore hole until a casing is installed. This process continues until the bit encounters a suitable water-bearing formation. Unlike the cable tool method, rotary wells are usually not cased until the final depth of the hole is reached.



The speed that can be achieved with rotary well drilling makes it a popular method. It was originally developed for the oil-drilling industry. The rotary rock bit with its roller cutters allow the drills to penetrate sands, gravel, clays, and, more importantly, boulders and bedrock formations more easily than other methods.

DRIVEN WELLS

In places where water is available near the surface, hand driven wells can be practical. The usual depth limit of hand-driven wells, “sand points” or “points”, is around 35 feet. Depths to 50 feet or more may be reached with weight or power assistance. However, since most drive points are pumped with shallow well jet pumps, the water level must be within 20’ of the surface for the pump to work.

Sediment must be easy to drive through; rock, hard clays, silts, and very fine sands often present difficulties in completing a well. Many attempts at driving wells result in the point either being damaged or deviated off the vertical direction, by boulders or bedrock.

Many driven wells are started by auguring or digging a hole as deep as possible into the ground. The drive point, consisting of heavy-duty reinforced well screen with a steel drive cone on the bottom, is coupled with the first length of drive pipe, or casing. This assembly is lowered into the pre-dug starting hole. Then a drive cap is screwed on the top of the casing and a heavy weight is used to strike the drive cap, forcing the point into the ground. When the length of casing reaches ground level, the drive cap is removed, another length of pipe threaded on, the drive cap added, and the process continued.

A driven well is used in many remote locations for limited supplies of water. It can be installed by one or two people in a matter of hours or days, depending on driving conditions. Because driven wells are usually very shallow, they are susceptible to surface or near-surface contamination. Also, well points tend to encrust of plug up very quickly due to the galvanized casing used for most sandpoints on the market and due to fouling of the screen openings at a faster rate because of carbonates entering their small diameter. Yield is usually limited because of pumping systems available, the small diameter of the casing, and their usual application in aquifers with limited yield. Driven wells are commonly installed by homeowners at lake cabins. However, the well construction and siting still must comply with the well code.

WELL SCREENS AND GRAVEL PACKS

SCREENS

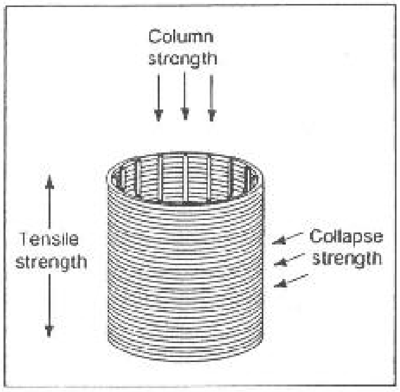
Wells completed in unconsolidated formations such as sand or gravel, and, under some circumstances, wells completed in loosely consolidated formations or consolidated formations with thin, loosely cemented beds are typically equipped with a well screen attached to the bottom of the casing. The purpose of the well screen is to prevent sediment from entering the well while allowing water to enter the well.

Metal, wire-wound, continuous-slot well screens are the most popular ones used. They provide the largest percentage of open area for a given slot size, consistent with adequate strength. Stainless steel is the most popular of the available metals because of its resistance to corrosion and its ability to withstand acid treatment (which may be used to remove encrustations when rehabilitating a well). Similarly constructed PVC plastic screens are manufactured, but have somewhat less open area, than metal screens of the same slot size. Where extra strength is required, a combination of continuous-slot screen over perforated pipe is available.

Many other screen variations save on initial cost but offer considerably less open area, poorer performance, and, often, shorter useful life. Casing can be perforated or slots can be cut with a welding torch; such irregular openings are effective in gravel aquifers or gravel-packed wells but may result in sediment problems in the well because of the irregular and coarse opening. Metal mesh screen wrapped around or inside perforated pipe (the pipe provides necessary strength) or metal mesh inserts pressed into drilled holes in the pipe are typical of drive points available to homeowners at their local hardware store. These screens are easily plugged by sand grains, and their copper-based metal construction invites galvanic corrosion problems.

The size of the opening in a screen is designated by “slot” size or “gauze”. Slot size is the width of the opening in thousands of an inch. (10 to 40 slot is common) Gauze is the number of openings in a mesh per inch, and is more commonly used on smaller diameter screens for domestic wells. Gauze sizes of 80-90 are typical.

Screen length is influenced by the characteristics of the aquifer as well as by the anticipated yield. Screen length, in a homogeneous thick aquifer, has a greater effect on well yield than screen diameter. Doubling the screen diameter will typically result in only a 10 to 15 percent increase in well yield. Ideally, screens are placed at the base of an aquifer to maximize yield. Grain size of aquifer materials can be determined, such as through sieve analysis, to properly design a screen.



GRAVEL PACKS

In an artificially gravel-packed well, the formation material (sediment) around the well screen is removed and replaced by a coarser material of high uniformity, usually about five times the diameter of the native material. It is designed to (1) increase the permeability of the formation and screen, (2) exclude virtually all of the formation material beyond the gravel pack, and (3) stabilize the formation.

Gravel-pack construction is more expensive for numerous reasons: the borehole diameter must be larger to accommodate gravel, which may be up to 5 inches thick; accurately graded gravel must be purchased and hauled to the site. Increased labor is required to construct the well and install the gravel, and in some cases, a temporary water casing may have to be installed and removed. The gravel must be smooth and rounded for maximum permeability; sharp, irregular shapes tend to pack more tightly during development and leave smaller spaces than rounded grains. It must be low in calcareous material, such as limestone, that could be dissolved by acid treatment used during rehabilitation of a well, leaving gaps in the pack and causing slumping. Since it could be possible that encrustation will eventually develop, the requirement for acid treatment must be anticipated.

The additional cost of using gravel pack may be justified in these situations:

1. A well in fine, uniform sand where development will not significantly improve permeability.
2. A thick artesian aquifer. This may permit use of a smaller diameter, longer screen. (Production increases only about ten percent if the diameter of the well is doubled, but it doubles if the screen length is doubled.)
3. Laminated formations (or formations with alternating finer and coarser layers). The finest sand layers in the aquifer determine the maximum screen slot size and the particle size in the gravel pack; however, gravel-packing permits use a larger slot screen.
4. Loosely cemented sandstones. Large consolidated formations may cause sand pumping.

The gravel is best placed by washing the gravel down a conductor or tremie pipe. So that it is placed from the bottom of the hole upward. This prevents bridging (voids left in the pack) and sorting of the gravel (larger particles falling faster than smaller ones through the water or drilling mud), which would result from simply dumping the gravel into the annular space. Use of a temporary outer casing prevents sloughing of the borehole wall, which could eventually produce voids.

GROUTING

An open annular space between a drill hole and a casing, or between an inner and an outer casing, presents a direct pathway from the surface for contaminants to enter a well and the groundwater or to migrate from one aquifer to another. Besides preventing surface or near-surface contamination from entering a well, grouting provides support for the casing (particularly important for plastic casing), prevents inter-aquifer flow, seals a casing to prevent “washouts” due to flowing wells, and protects steel casing from corrosion.

Grouting is a good idea for all wells, but is specifically required in some situations. Grouting refers to the filling or sealing of a space with a low permeability material or grout such as cement or a bentonite clay slurry. A variety of grouts are acceptable (cement, cement sand, bentonite) depending on geology. All public wells must be grouted full-depth.

GROUT MATERIALS

Water wells have been grouted with a variety of materials, mixtures, and additives but most contain either Portland cement or sodium bentonite. The Minnesota Water Well Construction Code requires that any open annular space be grouted and prescribes specific grout types for specific geologic or construction circumstances.

Cement Grout

Neat cement grout is a mixture of 94 pounds of Portland cement and not more than six gallons of water.

Bentonite

Sodium bentonite is a clay principally comprised of the mineral montmorillonite. Bentonites have the ability to swell upon contact with water, theoretically up to 15 times the dry volume, but typically eight to ten times. Bentonite may be used as a grout in unconsolidated materials such as glacial drift or alluvium (deposits from rivers and wells). Minnesota Rules allow two types of bentonite grout - bentonite grout which contains a minimum of 10% bentonite and 10% sand, cuttings or granular bentonite, and high solids bentonite grout which contains a minimum of 15% bentonite. The product must be designed as a grout or sealant and must be mixed according to manufacturer’s specifications.

GROUTING METHODS

To ensure a complete and effective seal, free of voids, and to comply with state regulations, grouts must be pumped into the annular space from the bottom upward, through a grout tremie pipe or by grouting through the bottom of the casing.

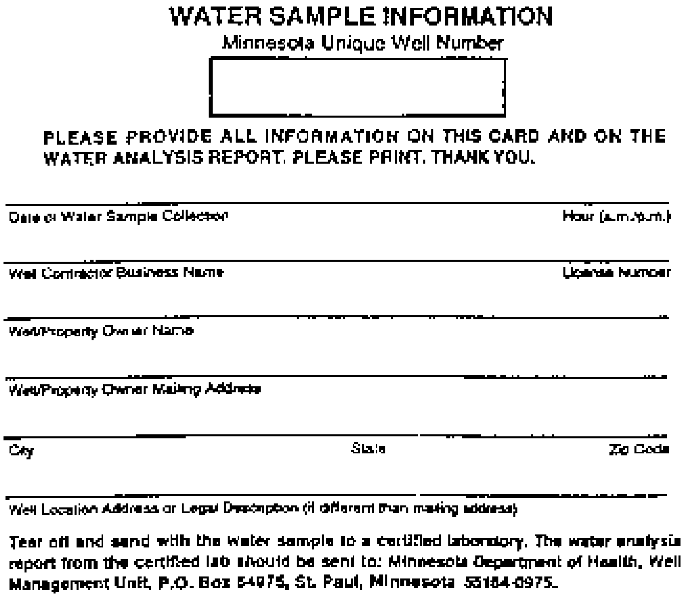
WELL RECORDS

There are many ways to obtain a well record of the depth and type of each formation encountered during the drilling. Most commonly, samples are taken as the hole is drilled from the surface to the bottom of the hole. This method is generally used to determine what types of soils or rock are being drilled into and to find the water-bearing formations. The Minnesota Geological Survey (MGS) at the University of Minnesota maintains records of most of the wells in the state, including historical well records of wells drilled before 1974. It is an excellent source of information about the geology of Minnesota.

Since 1974, the Minnesota Water Well Code has required licensed well contractors to submit a well and boring record within 30 days of construction of a new well. The record should include information about the geology, depth, diameter, drawdown, distance from sources of contamination, construction details of the well, and remarks about the drilling of the well. A copy is given to the Minnesota Geological Survey, Minnesota Department of Natural Resources, the property owner, and the local government (if required).

WATER SAMPLE INFORMATION

The well construction rules requires that a water sample be taken and tested for total coliform bacteria and nitrate nitrogen prior to placing the well in service. The results and the water sample information form must be sent to the well management unit at the Minnesota Department of Health.



WATER SAMPLE INFORMATION

Minnesota Unique Well Number

☐

PLEASE PROVIDE ALL INFORMATION ON THIS CARD AND ON THE WATER ANALYSIS REPORT. PLEASE PRINT. THANK YOU.

Date of Water Sample Collection _______ Hour (a.m./p.m.)

Well Contractor Business Name _______ License Number

Well/Property Owner Name

Well/Property Owner Mailing Address

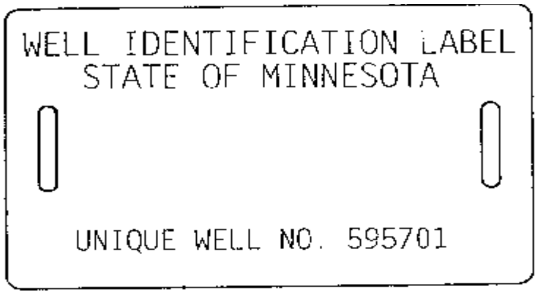
City _______ State _______ Zip Code

Well Location Address or Legal Description (if different than mailing address)

Tear off and send with the water sample to a certified laboratory. The water analysis report from the certified lab should be sent to: Minnesota Department of Health, Well Management Unit, P.O. Box 64975, St. Paul, Minnesota 55164-0975.

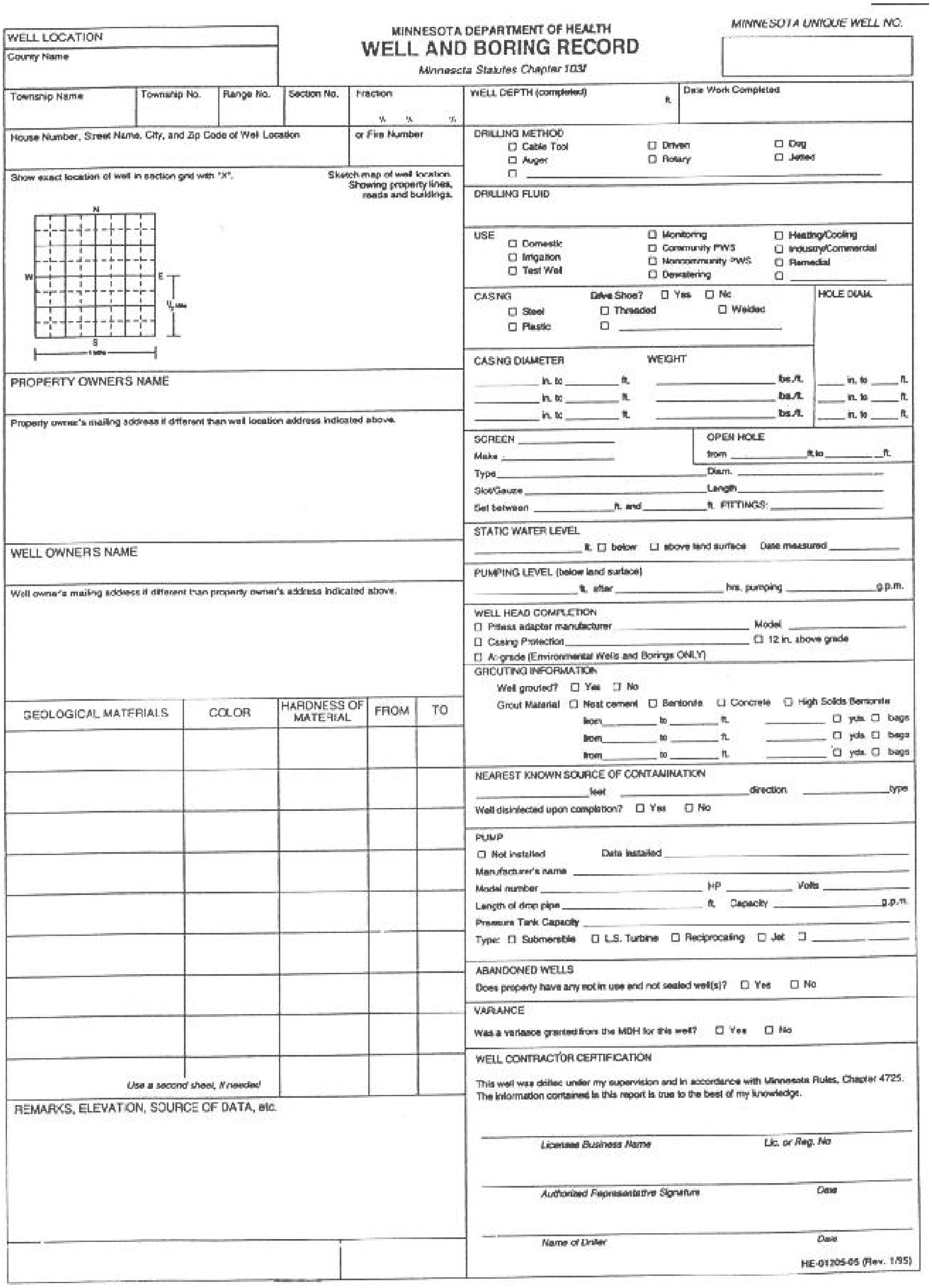
WELL LABEL

The Minnesota Department of Health provides well contractors with a metal identification label. The label is stamped with the Minnesota Unique Well Number and must be attached to the well casing or pump pedestal.



WELL IDENTIFICATION LABEL
STATE OF MINNESOTA

UNIQUE WELL NO. 595701



MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

MINNESOTA UNIQUE WELL NO.

WELL LOCATION

County Name

Township Name	Township No.	Range No.	Section No.	Fraction ¼ ¼ ¼

House Number, Street Name, City, and Zip Code of Well Location

or Fire Number

Show exact location of well in section grid with "X".

Sketch map of well location.
Showing property lines,
roads and buildings.

PROPERTY OWNERS NAME

Property owner's mailing address if different than well location address indicated above.

WELL OWNERS NAME

Well owner's mailing address if different than property owner's address indicated above.

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
Use a second sheet, if needed				

REMARKS, ELEVATION, SOURCE OF DATA, etc.

WELL DEPTH (completed) ft.

Date Work Completed

DRILLING METHOD
☐ Cable Tool ☐ Driven ☐ Dug
☐ Auger ☐ Rotary ☐ Jetted
☐ ______

DRILLING FLUID

USE
☐ Domestic ☐ Monitoring ☐ Heating/Cooling
☐ Irrigation ☐ Community PWS ☐ Industry/Commercial
☐ Test Well ☐ Noncommunity PWS ☐ Remedial
☐ Dewatering ☐ ______

CASING Drive Shoe? ☐ Yes ☐ No
☐ Steel ☐ Threaded ☐ Welded
☐ Plastic ☐ ______

HOLE DIAM.

CASING DIAMETER WEIGHT
______ in. to ______ ft. ______ lbs./ft. ______ in. to ______ ft.
______ in. to ______ ft. ______ lbs./ft. ______ in. to ______ ft.
______ in. to ______ ft. ______ lbs./ft. ______ in. to ______ ft.

SCREEN ______
Make ______
Type ______
Slot/Gauze ______
Set between ______ ft. and ______ ft.

OPEN HOLE
from ______ ft. to ______ ft.
Diam. ______
Length ______
FITTINGS: ______

STATIC WATER LEVEL
______ ft. ☐ below ☐ above land surface Date measured ______

PUMPING LEVEL (below land surface)
______ ft. after ______ hrs. pumping ______ g.p.m.

WELL HEAD COMPLETION
☐ Pitless adapter manufacturer ______ Model ______
☐ Casing Protection ______ ☐ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

GROUTING INFORMATION
Well grouted? ☐ Yes ☐ No
Grout Material ☐ Neat cement ☐ Bentonite ☐ Concrete ☐ High Solids Bentonite
from ______ to ______ ft. ______ ☐ yds. ☐ bags
from ______ to ______ ft. ______ ☐ yds. ☐ bags
from ______ to ______ ft. ______ ☐ yds. ☐ bags

NEAREST KNOWN SOURCE OF CONTAMINATION
______ feet ______ direction ______ type
Well disinfected upon completion? ☐ Yes ☐ No

PUMP
☐ Not installed Date installed ______
Manufacturer's name ______
Model number ______ HP ______ Volts ______
Length of drop pipe ______ ft. Capacity ______ g.p.m.
Pressure Tank Capacity ______
Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐ ______

ABANDONED WELLS
Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

VARIANCE
Was a variance granted from the MDH for this well? ☐ Yes ☐ No

WELL CONTRACTOR CERTIFICATION

This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Licensee Business Name *Lic. or Reg. No.*

Authorized Representative Signature *Date*

Name of Driller *Date*

HE-01205-05 (Rev. 1/95)

WELL DEVELOPMENT

An important step in well construction is the development of the well to maximize well efficiency and the quantity of sand-free water that the aquifer is capable of producing. Development is the process of removing fine material and drill cuttings or residue from the aquifer adjacent to the screen. This will help prevent the water entering the bore hole from carrying sand into the well and pump. Development can be accomplished in many ways. A screened well can be surged using air or water. Air surging involves pressurizing the casing with air, so that the water level is forced down in the well to a level just above the top of the screen. The pressure is then released quickly, which allows the water to rush back into the well, carrying sand with it into the screen where it can then be removed.

Water jetting is another method of developing a screened well. This involves the installation of an air line down to the screen and air nozzles to jet air into the sands surrounding the screen, thereby removing the fine material from the well hole. Note: air jetting has the potential to actually plug an aquifer.

The development of a rock well without a screen (an open-hole well) may differ in that the driller may use the blast-and-bail method. This involves the use of explosives in the hole and the removal of the rubble from the bottom of the hole by the same bailer that was used in the drilling process. Blast-and-bail is used in sandstone or other rock formations to increase the well's yield. Hydraulic fracturing, the process of injecting water at sufficient pressure to fracture the rock, is used in some hard rocks like granite.

TEST PUMPING

After the well has been developed, it must be pumped to ensure that it does not produce sand and that it will give the required amount of water. Test pumping involves the installation of a pump large enough to withdraw water at a volume above the required flow expected from the well. For example, for a 1,500 gallon per minute (gpm) well, a 2,000-to-2,500 gpm test pump with a control valve would be installed so that the pumping level could be controlled at any level up to the capacity of the pump. The test pump will usually be driven by a variable-speed engine rather than by an electric motor. This allows the operator to vary the speed of the pump. The test pump is initially run at a low flow and increased as needed until either the pumping level is reached or the well has met capacity. The water being pumped from the well should be monitored for sand and turbidity, and pumped until the turbidity is removed from the water. Once the turbidity is removed, the pumping rate should be increased until the desired capacity has been reached, or until the well has failed to meet the desired yield due to either an unacceptable sand concentration, or an unacceptable low pumping level.

With the test pumping completed, the production pump should be selected for the well. At this point, the information that was gained in the test pumping becomes important. The level at which the well pumped at a specific rate dictates where the pump should be set. The test pumping will also provide information about what size head the pump will have to pump against and the horsepower needed to pump the required amount of water. Generally, the production pump will be sized at 75 percent of the test pump level, although this can vary. The pump will usually be sized to the capacity of the well based on the test pump data. Normally an open-hole, sedimentary-rock well yields 50 to 75 percent of capacity. A screened well in glacial drift usually yields 50 percent of capacity.

DISINFECTION

The Well Code requires that a new, repaired, or reconditioned well must be disinfected with at least 50 parts per million (ppm) chlorine solution in all parts of the well for a period of at least two hours. Effectiveness in killing living organisms increases as either the concentration of chlorine or the contact time increases. For a well-repair operation, the Code permits the alternative of applying 200 ppm chlorine when beginning the repair, in effect disinfecting throughout the operation.

It is important to flush the well surfaces above the static water level with the chlorine solution. Contamination on these surfaces would not otherwise be contacted by the disinfectant but could later be washed down by condensation moisture, fluctuations in static levels, or water returned through “bleeder” systems.

Disinfection is necessary after any work on a well, because it is virtually impossible to avoid microbiological contamination during drilling or repair. Pipe and other materials are not sterile when purchased. They are often coated with greases or other compounds which are residuals from manufacturing processes or are deliberately added to retard rust during storage. Tools and pipes pick up bacteria from the ground surface. It is a common, but dangerous, assumption that all the bacteria introduced into the well during drilling are only “harmless, vegetative types.” Bird and animal wastes contain organisms harmful to man and are scattered everywhere on the ground surface.

It is equally dangerous to assume that cleanliness is unimportant since disinfection takes care of everything. Iron bacteria are non-pathogenic organisms that cause severe staining, plugging, taste, and odor problems. They are nearly impossible to eliminate if allowed to become established in a well. They can be carried from well to well on the driller’s tools. Any water used in drilling must be chlorinated clear water, must contain a free chlorine residual at time of use, and should be conveyed in clean sanitary containers or water lines. Drilling fluids should have a free chlorine residual at all times. By eliminating contamination as fast as it is introduced, the driller maintains a clean well and greatly improves the probability that bacteriological tests on the completed well will be satisfactory.

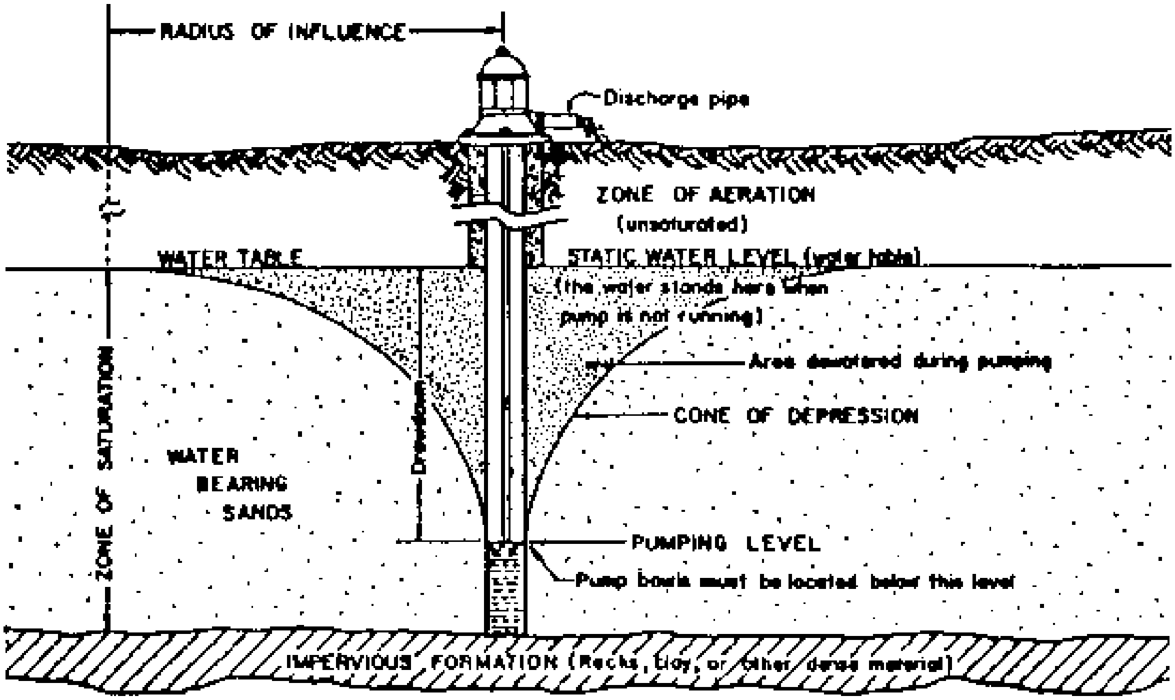
A chlorine solution is the simplest and most effective means of disinfecting all parts of the water system.

Well drillers frequently use calcium hypochlorite, which is 65 percent available chlorine and is available as a dry powder, granules, or tablets. The material is relatively stable and maintains 90 percent of its strength over several months if stored in a cool, dry location. The tablets can be dumped directly into the well prior to pump installation to ensure that the deepest part of the well is disinfected. However, for purposes of well disinfection, that is required by the Well Code, any solid chlorine product must first be mixed with water. A chlorine/water solution is necessary to flush down the casing above the water level and, after the pump is installed, to negotiate small passages through the pitless unit and between a submersible pump and the casing. Because solutions diffuse very slowly, they may not reach all parts of the well in a reasonable time unless mixed by some means, such as alternately starting and stopping the pump.

If the well driller does not install the pump or if there is a delay between well construction and pump installation and/or connection to the distribution piping, the well should be disinfected after each stage. Bacteria should never be given an opportunity to grow and gain a foothold anywhere in the water system.

MEASURING LEVELS IN WELLS

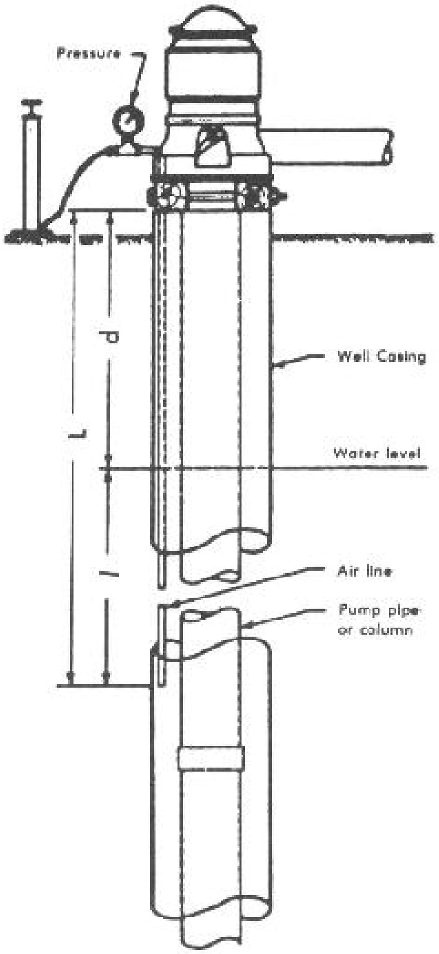
One of the most important pieces of information the water-system operator needs is the water levels in the well before startup (static level) and the water level after the pump has run and the well has reached a stable condition (pumping level). The pumping water level has been reached when the water level in the well has stopped dropping. In most cases, this takes at least one hour and can often take much longer. The level will drop rapidly right after the pump starts and then slow considerably, dropping to an inch per hour or less, until the drop stops. What has happened is that the pump has lowered the head pressure exerted by the aquifer in the vicinity of the well. This area of depression is called the cone of depression. It extends from the well out to a point at which the pressure equalizes and returns to normal. If wells are located too close together, the cones will intersect and cause a drop in pumping capacity.



There are a number of different ways that the operator can find the static and pumping-water levels in the well. They include the use of:

An air line

The air line, which is often installed permanently in the well, consists of 1/8- or 1/4-inch copper tubing, plastic tubing, or iron pipe and is long enough to extend from the surface to below the lowest water expected in the well. The air line may be fastened to the pump column when the pump is installed. Care must be taken in the installation of the line to make sure it is air tight. The vertical length of the air line, from the pressure gauge to the bottom, must be carefully measured at the time of installation.



A pressure gauge is attached to the air line at the surface together with a method for introducing air, such as from a tire pump or air compressor. The depth to the water is calculated by pumping air into the line until the maximum reading on the gauge is obtained. This reading is equal to the pressure exerted by the column of water standing outside the airline. It is customary to use an altitude gauge that is graduated in feet of water. If the gauge reads in pounds per square inch (psi), the reading can be multiplied by 2.31 feet per square inch to convert the reading to feet.

Example:

What is the depth to water if the air line is 125 feet long and the maximum gauge reading is 50 feet?

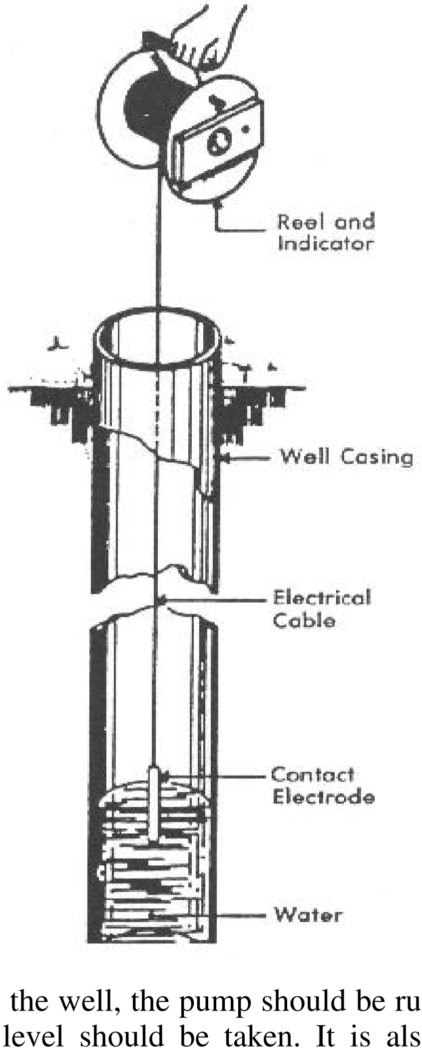
Answer: 75 feet (Depth = 125 feet of air line - 50 feet, gauge reading)

An electric measuring line

A single conductor insulated wire can be used to accurately measure water levels in pumping wells. One end of the wire is bared and enclosed in a slotted or perforated pipe, which prevents it from touching the casing or pump when lowered into the well. The pipe also serves as a weight when lowering the wire. Transducers are now more common. There are a variety of tools used for measuring water levels electronically, and they can measure continuously.

The other end of the wire is attached to the casing or to some other part of the metal pump assembly. A battery is connected in series with a meter or other indicator. The circuit is completed when the end of the wire in the well touches the water. At this point, the meter reading is steady. The depth of the water is determined by measuring the amount of wire in the well. The wire can be marked at ten-foot intervals to help make the measurement. A small, hand-operated reel with a brush takeoff for the battery circuit makes it easier to handle the wire. A double conductor wire can also be used. This will eliminate the return circuit through the pump or casing, but it also increases the diameter of the wire.

One of the disadvantages of the electrical measuring line is that the wire may lodge or hook under a coupling or other obstruction in the well. The wire can then be loosened by tying it off and waiting for the pump to operate.

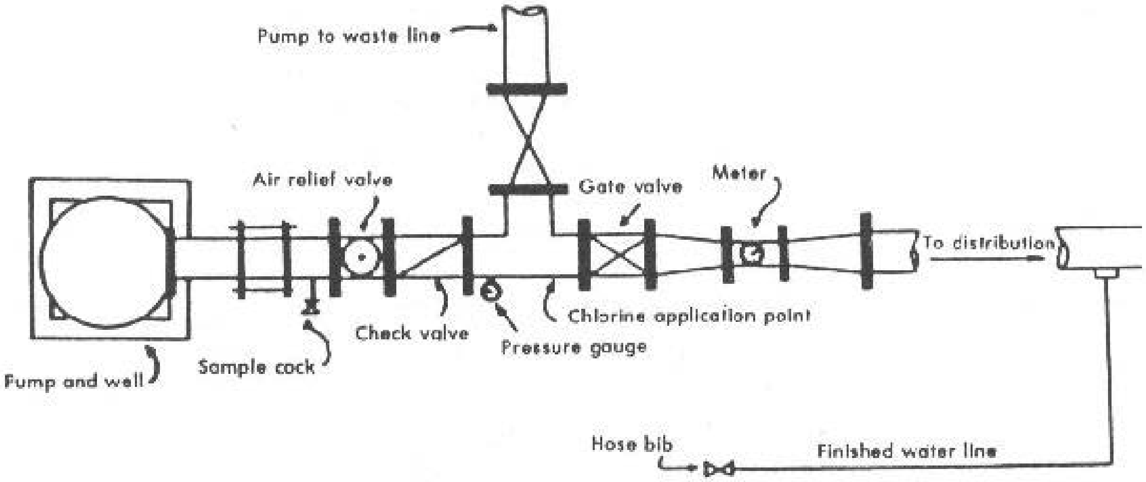


A steel tape

Water levels can be measured accurately with a flat steel measuring tape that has a weight attached to the end. The tape and weight are lowered into the well until the weighted end is below the water level and an even foot mark is opposite some reference point, such as the casing vent or pump base. The tape is removed and the wetted length is subtracted from the foot mark held at the measuring point which gives the depth to water. Carpenter's chalk can be rubbed onto several feet of the tape in advance to make it easier to determine the exact length of the wetted part.

This method should not be used when the pump is operating, when the casing leaks, or when some other problem causes splashing or running water in the well. This can make the water mark on the tape difficult to read.

After the operator has measured the static level of the water in the well, the pump should be run for a time to let the water stabilize and then the pumping level should be taken. It is also important to measure the flow in gallons per minute (gpm) that the pump is producing.



The drawdown is found by subtracting the pumping level from the static level. A historical record of the drawdown can help the operator in deciding on the condition of the well and when maintenance is required. Water yield can change for a variety of reasons, among them the wear of the pump impellers due to sand pumping. Wear on the impellers can cause the pump to move less water. Consequently, the pumping level rises. A decline in the water yield, and a lowering in the pumping level, would indicate that the problem is with the well. A clogged screen or the cave-in of an open-hole well are examples of this type of problem.

The specific yield, or specific capacity, of the well is figured by dividing the flow from the well by the feet of drawdown. An average well will have a yield of 15-40 gpm/foot of drawdown while a poor well will be less than 10 gpm/foot. Rapid change in this yield or a decrease of 75 percent from the original yield indicates that the well needs maintenance. Additional reduction in the yield may leave the well unrepairable.

WELL DISCLOSURE

Before a property is sold or transferred, the seller must disclose the number, location, and status of all wells on the property to the buyer. A Well Disclosure Certificate is filed with the deed at the time of recording. The certificate informs the buyer about wells on the property. A copy of the certificate is sent to the Minnesota Department of Health. If wells are identified that are not in use, the new owner must either have the wells sealed, start using them again, or obtain maintenance permits.

MINNESOTA DEPARTMENT OF HEALTH

Well Management Unit PO Box 64975. St Paul. Minnesota 55164-0975 (612) 215-0819 or -800-383-9808

WELL DISCLOSURE CERTIFICATE

PLEASE TYPE OR PRINT ALL INFORMATION

Person filing deed must attach a $20 fee payable to the county recorder.

A. PROPERTY DESCRIPTION

Attach a legal description of the property if the property does not have a lot number, block number, and addition name.

COUNTY	LOT NUMBER	BLOCK NUMBER	ADDITION NAME
STREET ADDRESS			
CITY	STATE	ZIP CODE	P.IN. NO. **(OPTIONAL)**

B. PROPERTY BUYER MAILING ADDRESS AFTER CLOSING

FIRST NAME	MIDDLE INITIAL	LAST NAME	
COMPANY NAME (IF APPLICABLE)			
ADDRESS			
ADDRESS			
CITY	STATE	ZIP CODE	TELEPHONE NUMBER

C. CERTIFICATION BY SELLER

I certify that the information provided on this certificate is accurate and complete to the best of my knowledge.

Signature of Seller or Designated Representative of Seller __________________ Date __________________

D. CERTIFICATION BY BUYER

The buyer or person authorized to act on behalf of the buyer, must sign a Well Disclosure Certificate for all deeds given in fulfillment of a contract for deed if there is a well on the property.

In the absence of a seller's signature, the buyer, or person authorized to act on behalf of the buyer may sign this well certificate. No signature is required by the buyer if the seller has signed above.

Based on disclosure information provided to me by the seller or other available information, I certify that the information on this certificate is accurate and complete to the best of my knowledge.

Signature of Buyer or Designated Representative of Buyer

Date

INSTRUCTIONS FOR COMPLETING THE WELL DISCLOSURE CERTIFICATE

A $20 FEE MUST BE ATTACHED TO THIS FORM WHEN SUBMITTING THIS FORM TO THE COUNTY RECORDER'S OFFICE. THE FEE IS TO BE PAID BY THE BUYER OR PERSON FILING THE DEED. PLEASE MAKE THE CHECK PAYABLE TO THE COUNTY RECORDER.

BUYER, SELLER, AND PROPERTY INFORMATION

A. **PROPERTY DESCRIPTION** — provide the county, house number, street name, street type, street direction (if applicable), city, and zip code; and, if applicable, the lot number, block number, and addition name (for example, White Pine Addition, block 4, lot 12). If the property is located in a rural area without a lot number, block number, and addition name, attach a complete legal description of the property.

B. **PROPERTY BUYER MAILING ADDRESS AFTER CLOSING** — provide the buyer's full name (or company name, if buyer is a company), full address, and phone number (including area code). Be sure to include a complete mailing address. If the property is jointly owned, provide the name of a contact person.

C. **CERTIFICATION BY SELLER OR BUYER** — The seller should sign this certificate before it is submitted to the county recorder's office. If the seller is unable to sign the document, the buyer may sign the certificate before it is submitted to the county recorder's office.

Where deeds are given in fulfillment of a **CONTRACT FOR DEED** the well disclosure certificate **MUST** be signed by the **BUYER.**

WELL INFORMATION

Provide the following information for **EACH WELL BEING DISCLOSED.**

WELL LOCATION

Provide the county name, quartile (one quarter section is required), section number, township number, and range number.

WELL STATUS INFORMATION

Indicate the status of each well. CHECK ONLY 1 BOX.

In Use — A well is "in use" if the well is operated on a daily, regular, or seasonal basis. A well in use includes a well that operates for the purpose of irrigation, fire protection, or emergency pumping.

Not In Use — A well is "not in use" if the well does not meet the definition of "in use" above and has not been sealed by a licensed well contractor.

Sealed — A well is "sealed" if a licensed contractor has completely filled a well by pumping grout material throughout the entire bore hole after removal of any obstructions from the well. A well is "capped" if it has a metal or plastic cap or cover which is threaded, bolted, or welded into the top of the well to prevent entry into the well. A "capped" well is not a "sealed" well.

If the well described has been sealed by a licensed well contractor, indicate the year when the well was sealed, if known. If the well is not in use and has not been sealed by a licensed well contractor or a licensed well sealing contractor, check the well status as not in use.

SKETCH MAP

Complete the sketch map as instructed.

NOTE: It a well is not in use it must be SEALED by a licensed well contractor or a well owner must obtain a MAINTENANCE PERMIT from the Minnesota Department of Health and pay an annual maintenance fee of $100. Maintenance permits are not transferable. If a well is operable and properly maintained, a maintenance permit is not required.

If you have any questions, please contact the Minnesota Department of Health, Division of Environmental Health, Section of Drinking Water Protection, Well Management Unit at 215-0819 (metropolitan Minneapolis—St. Paul) or 1 -800-383-9808 (greater Minnesota).

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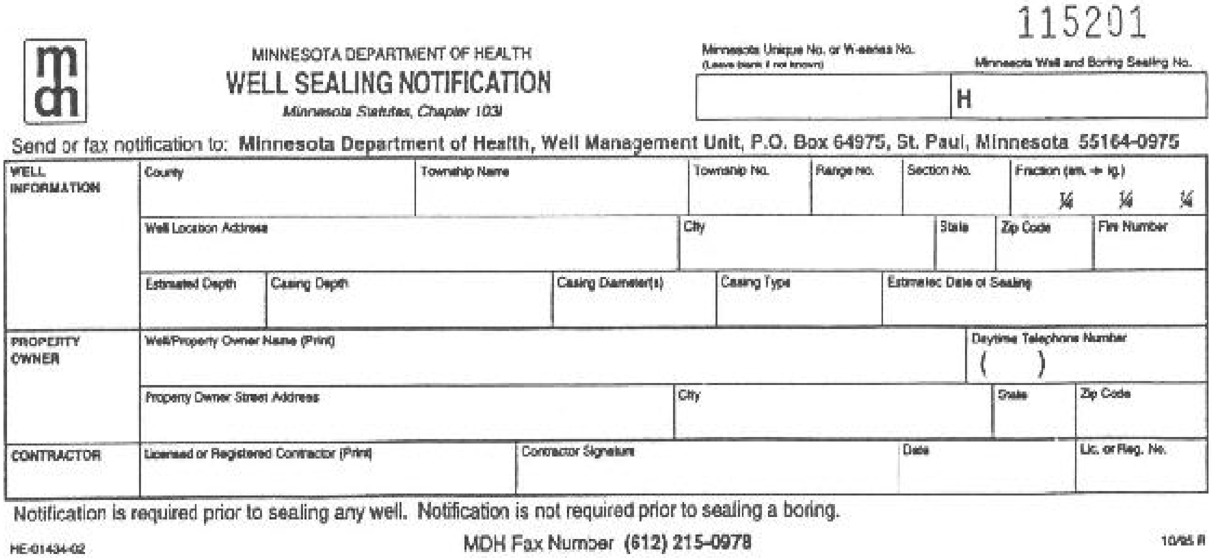
WELL SEALING

Any well no longer in use must be sealed by a licensed well contractor or by a person with a limited well-sealing contractor's license obtained from the Minnesota Department of Health (MDH) unless it is made operable or unless a maintenance permit is obtained from MDH. See Chapter 7 "Rules Related to Wells and Borings" for the specific well sealing requirements. Before sealing a well, the contractor is required to notify the MDH. The contractor has to prepare a Well and Boring Sealing Record and submit it to MDH.



115201

MINNESOTA DEPARTMENT OF HEALTH

WELL SEALING NOTIFICATION

Minnesota Statutes, Chapter 103I

Minnesota Unique No. or W-series No. (Leave blank if not known)

Minnesota Well and Boring Sealing No. H

Send or fax notification to: **Minnesota Department of Health, Well Management Unit, P.O. Box 64975, St. Paul, Minnesota 55164-0975**

WELL INFORMATION	County	Township Name	Township No.	Range no.	Section No.	Fraction (sm. → lg.) ¼ ¼ ¼
	Well Location Address	City	State	Zip Code	Fire Number	
	Estimated Depth	Casing Depth	Casing Diameter(s)	Casing Type	Estimated Date of Sealing	
PROPERTY OWNER	Well/Property Owner Name (Print)	Daytime Telephone Number ( )				
	Property Owner Street Address	City	State	Zip Code		
CONTRACTOR	Licensed or Registered Contractor (Print)	Contractor Signature	Date	Lic. or Reg. No.		

Notification is required prior to sealing any well. Notification is not required prior to sealing a boring.

HE-01434-02

MDH Fax Number (612) 215-0978

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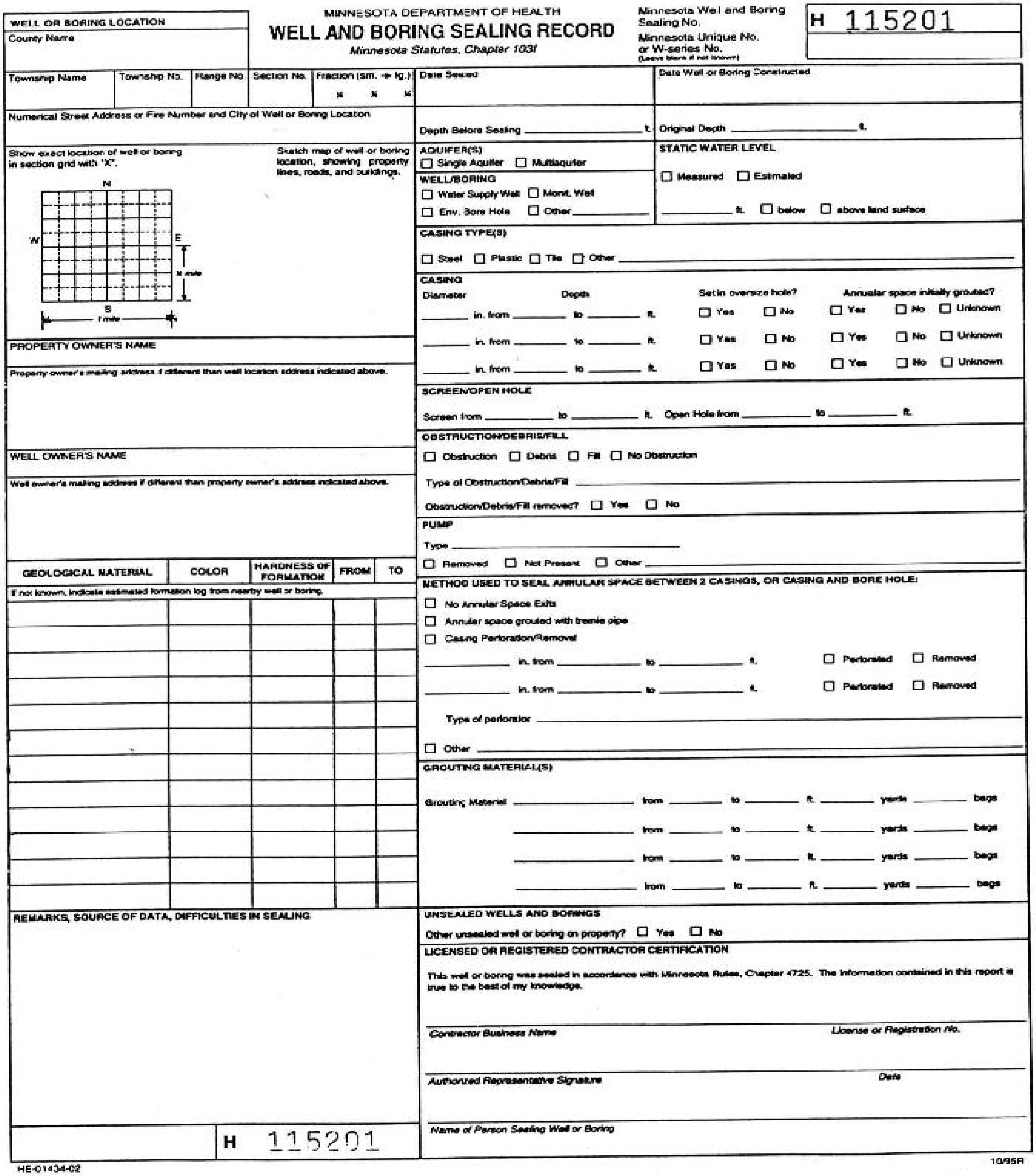

WELL OR BORING LOCATION
County Name

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING SEALING RECORD

Minnesota Statutes, Chapter 103I

Minnesota Well and Boring Sealing No. H 115201

Minnesota Unique No. or W-series No. (Leave blank if not known)

Township Name	Township No.	Range No.	Section No.	Fraction (sm. → lg.) ¼ ¼ ¼

Date Sealed

Date Well or Boring Constructed

Numerical Street Address or Fire Number and City of Well or Boring Location

Depth Before Sealing ____________ ft.

Original Depth ____________ ft.

Show exact location of well or boring in section grid with "X".

N W E S ½ mile 1 mile

Sketch map of well or boring location, showing property lines, roads, and buildings.

AQUIFER(S)
☐ Single Aquifer ☐ Multiaquifer

WELL/BORING
☐ Water Supply Well ☐ Monit. Well
☐ Env. Bore Hole ☐ Other ____________

STATIC WATER LEVEL
☐ Measured ☐ Estimated
____________ ft. ☐ below ☐ above land surface

CASING TYPE(S)
☐ Steel ☐ Plastic ☐ Tile ☐ Other ____________

CASING

Diameter	Depth	Set in oversize hole?	Annular space initially grouted?
______ in.	from ______ to ______ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown
______ in.	from ______ to ______ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown
______ in.	from ______ to ______ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown

PROPERTY OWNER'S NAME

Property owner's mailing address if different than well location address indicated above.

SCREEN/OPEN HOLE
Screen from ______ to ______ ft. Open Hole from ______ to ______ ft.

OBSTRUCTION/DEBRIS/FILL
☐ Obstruction ☐ Debris ☐ Fill ☐ No Obstruction
Type of Obstruction/Debris/Fill ____________
Obstruction/Debris/Fill removed? ☐ Yes ☐ No

WELL OWNER'S NAME

Well owner's mailing address if different than property owner's address indicated above.

PUMP
Type ____________
☐ Removed ☐ Not Present ☐ Other ____________

GEOLOGICAL MATERIAL	COLOR	HARDNESS OF FORMATION	FROM	TO
If not known, indicate estimated formation log from nearby well or boring.				

METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE:
☐ No Annular Space Exits
☐ Annular space grouted with tremie pipe
☐ Casing Perforation/Removal
______ in. from ______ to ______ ft. ☐ Perforated ☐ Removed
______ in. from ______ to ______ ft. ☐ Perforated ☐ Removed
Type of perforator ____________
☐ Other ____________

GROUTING MATERIAL(S)
Grouting Material ______ from ______ to ______ ft. ______ yards ______ bags
______ from ______ to ______ ft. ______ yards ______ bags
______ from ______ to ______ ft. ______ yards ______ bags
______ from ______ to ______ ft. ______ yards ______ bags

REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING

UNSEALED WELLS AND BORINGS
Other unsealed well or boring on property? ☐ Yes ☐ No

LICENSED OR REGISTERED CONTRACTOR CERTIFICATION

This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Contractor Business Name *License or Registration No.*

Authorized Representative Signature *Date*

Name of Person Sealing Well or Boring

H 115201

HE-01434-02 10/95R

NOTES: Well Construction


6

Rules Relating to Wells and Borings

A well provides a reliable, safe supply of drinking water when the well is properly constructed and maintained. The standards for the proper location, construction, repair, and sealing of wells in the state of Minnesota are contained in Minnesota Rules, Chapter 4725, Rules Relating to Wells and Borings. Minnesota Rules, Chapter 4725 regulates wells, including water supply, wells monitoring, wells elevator, dewatering wells, environmental bore holes, and vertical heat exchangers. Drilling done to explore for minerals or petroleum is regulated under a different set of rules, Minnesota Rules, Chapter 4727. Minnesota Statues, Chapter 103I contains the statutory authority for well and boring contractor licensing, administrative procedures for notifications, permits, and record submittal, the duties and responsibilities of the Commission of Health, well disclosure, and additional requirements for wells and borings.

A complete copy of the rules is available by consulting an official copy of Minnesota Rules, or online at: http://www.revisor.leg.state.mn.us/arule/4725.

A complete copy of Minnesota Statue, Chapter 103I can be accessed online at: https://www.revisor.leg.state.mn.us/statutes/?id=103I

A copy of the Isolation Distances From a Water Supply Well

ISOLATION DISTANCES FROM A WATER-SUPPLY WELL

Minnesota Rules, Chapter 4725
Rules Relating to Wells and Borings
August 4, 2008

Minnesota Department of Health
Well Management Section
Environmental Health Division
625 North Robert Street, P.O. Box 64975
St. Paul, Minnesota 55164-0975
651/201-4600 or 800/383-9808

This list of isolation distances is summarized from Minnesota Rules, Chapter 4725. These distances are to be measured horizontally from the water-supply well. Minnesota Statutes, section 103I.205, subdivision 6, prohibits constructing, placing, or installing an actual or potential contaminant source at a location from a well that is less than the minimum distance prescribed by rule. The minimum isolation distances must be maintained between a new well and a source of contamination no longer in use, unless all contaminants have been removed from the source, and visibly contaminated soils have been removed. For complete regulations, consult these rules and Minnesota Statutes, Chapter 103I. Additional information and explanation can be obtained by consulting the Rules Handbook, A Guide to the Rules Relating to Wells and Borings, or by contacting the Well Management Section, Minnesota Department of Health (MDH).

Absorption area of a soil dispersal system	
average flow greater than 10,000 gallons/day	300 feet[1]
serving a facility handling infectious or pathological wastes	150 feet[1]
average flow 10,000 gallons/day or less	50 feet[1]
Agricultural chemical	
tank or container with 25 gallons or more or 100 pounds or more dry weight, or equipment filling or cleaning area without safeguards	150 feet
storage or equipment filling or cleaning area with safeguards	100 feet
storage or equipment filling or cleaning area with safeguards and roofed	50 feet
buried piping	50 feet
multiple tanks or containers for residential retail sale or use, no single tank or container exceeding, but aggregate volume exceeding 56 gallons or 100 pounds dry weight	50 feet
Anhydrous ammonia tank	50 feet
Animal	
feedlot, unroofed, 300 or more animal units	100 feet[1]
feedlot, more than 1.0, but less than 300 animal units	50 feet[1]
building or poultry building, including a horse riding area, more than 1.0 animal unit	50 feet[1]
rendering plant	50 feet
feeding or watering area within a pasture, more than 1.0 animal unit	50 feet[1]
area to bury more than one animal unit	50 feet
building, feedlot, confinement area, or kennel, 0.1 to 1.0 animal unit	20 feet[1,2]
Building, building projection, deck, overhang, permanent structure	3 feet[3]

Cesspool	75 feet[1]
Cistern or reservoir, buried, nonpressurized water supply	20 feet
Commercial compost site	50 feet
Construction or demolition debris disposal area	50 feet[1]
Cooling water pond, industrial	50 feet[1]
Deicing chemicals, bulk road	50 feet[1]
Dry well (sewage)	75 feet[1]
Electric transmission line	10 feet[4]
Electrical transformer storage area, oil-filled	50 feet
Elevator boring, not conforming to rule	50 feet
conforming to rule	20 feet
Fertilizer chemigation tank, safeguarded, from irrigation well only	20 feet[5]
Floor drain, grate, or trough	
connected to a buried sewer	50 feet
if buried sewer is air-tested, approved materials, serving one building, or two or less single-family residences	20 feet[2]
Frost-proof yard hydrant or discharge of a frost-proof hydrant draining into the soil, fire hydrant or flushing hydrant	10 feet
Gas (flammable or volatile) pipe	10 feet[4]
Grave or mausoleum	50 feet
Gravel pocket or French drain for clear water drainage	20 feet
Gray-water dispersal area	50 feet[1]
Hazardous substance	
tank or container, above ground or underground, 56 gallons or more, or 100 pounds or more dry weight, without safeguards	150 feet
tank or container, above ground or underground, 56 gallons or more, or 100 pounds or more dry weight with safeguards	100 feet
buried piping	50 feet
multiple storage tanks or containers for residential retail sale or use, no single tank or container exceeding 56 gallons or 100 pounds, but aggregate volume exceeding	50 feet
Horizontal ground source closed loop heat exchanger buried piping	50 feet
Horizontal ground source closed loop heat exchanger buried piping and horizontal piping, approved materials and heat transfer fluid	10 feet[2]
Household solid waste disposal area, single residence	50 feet[1]
Interceptor, including a flammable waste or sediment	50 feet
Land spreading area for sewage, septage, or sludge	50 feet[1]
Landfill or dump, mixed municipal solid waste from multiple persons	300 feet[1]
Landfill, permitted demolition debris	300 feet[1]
Leaching pit	75 feet[1]
Liquid propane (LP) tank	10 feet[4]

Manure (liquid) storage basin or lagoon	
unpermitted or noncertified	300 feet[1]
approved earthen liner	150 feet[1]
approved concrete or composite liner	100 feet[1]
Manure (solid) storage area, not covered with a roof	100 feet[1]
Ordinary high water level of a stream, river, pond, storm water retention pond, lake, or reservoir	35 feet[2]
Petroleum	
tank or container, 1100 gallons or more, without safeguards	150 feet
tank or container, 1100 gallons or more, with safeguards	100 feet
tank or container, buried, between 56 and 1100 gallons	50 feet
tank or container, not buried, between 56 and 1100 gallons	20 feet[6]
buried piping	50 feet
Petroleum or crude oil pipeline to a refinery or distribution center	100 feet
Pit or unfilled space more than four feet in depth	20 feet
Pollutant or contaminant that may drain into the soil	50 feet[1]
Privy, nonportable	50 feet[1]
portable (privy) or toilet	20 feet[2]
Sand filter, watertight; peat filter; or constructed wetland	50 feet
Scrap yard	50 feet
Seepage pit	75 feet[1]
Septic tank	50 feet
Sewage holding tank, watertight	50 feet
Sewage sump	
capacity 100 gallons or more	50 feet
capacity less than 100 gallons, tested, conforming to rule	20 feet[2]
Sewage treatment device, watertight	50 feet
Sewer, buried	
collector, municipal, serving a facility handling infectious or pathological wastes, open-jointed or unapproved materials	50 feet
approved materials, tested, serving one building, or two or less single-family residences	20 feet[2]
Solid waste transfer station	50 feet
Storm water drain pipe, 8 inches or greater in diameter	20 feet[2]
Swimming pool, in-ground	20 feet
Unused, unsealed well or boring	50 feet
Vertical heat exchanger (vertical) piping, conforming to rule	35 feet[2]
horizontal piping conforming to rule	10 feet[2]

Wastewater rapid infiltration basin, municipal or industrial	300 feet[1]
Wastewater spray irrigation area, municipal or industrial	150 feet[1]
Wastewater stabilization pond	
municipal, 500 or more gallons/acre/day of leakage	300 feet[1]
municipal, less than 500 gallons/acre/day of leakage	150 feet[1]
industrial	150 feet[1]
Wastewater treatment unit tanks, vessels and components (Package plant)	100 feet
Water treatment backwash disposal area	50 feet[1]
Water treatment backwash holding basin, reclaim basin, or surge tank	
with a direct sewer connection	50 feet
with a backflow protected sewer connection	20 feet

Additional Isolation Distances For Community Public Water-Supply Wells

Highest water or flood level	50 feet
Property line, unless legally controlled through an easement	50 feet

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[1] A sensitive water-supply well must be located at least twice the indicated distance.

A sensitive water-supply well is a well with less than 50 feet of watertight casing, and which is not cased below a confining layer or confining materials of at least 10 feet in thickness.

[2] A community public water-supply well must be a minimum of 50 feet from this contamination source.

[3] A well or boring may not be constructed inside a building except as provided for by Minnesota Rules, part 4725.2175.

[4] A well or boring may be located between 5 and 10 feet of an electric transmission line, gas pipe or LP tank if the well or boring is placarded, and work is not performed on the well or boring unless the electric line is deenergized and grounded or shielded, and the LP tank does not contain flammable gas.

[5] The 20-foot distance applies only to an irrigation well and a fertilizer chemigation supply tank meeting the requirements of Minnesota Rules, Chapter 1505.

[6] A community public water-supply well must be a minimum of 50 feet from a petroleum tank or container, unless the tank or container is used for emergency pumping and is located in a room or building separate from the community well; and is of double-wall construction with leak detection between walls; or is protected with secondary containment.

Visit the MDH Well Management Section Web site at: *www.health.state.mn.us/divs/eh/wells*
Visit Minnesota Rules, Chapter 4725 Web site at: *www.revisor.leg.state.mn.us/rules/?id=4725*
Visit Minnesota Statutes, Chapter 103I Web site at: *www.revisor.leg.state.mn.us/statutes/?id=103I*

To request this document in another format call 651/201-4600. Deaf and hard-of-hearing: TTY 651/201-5797

Notes:

Pumps

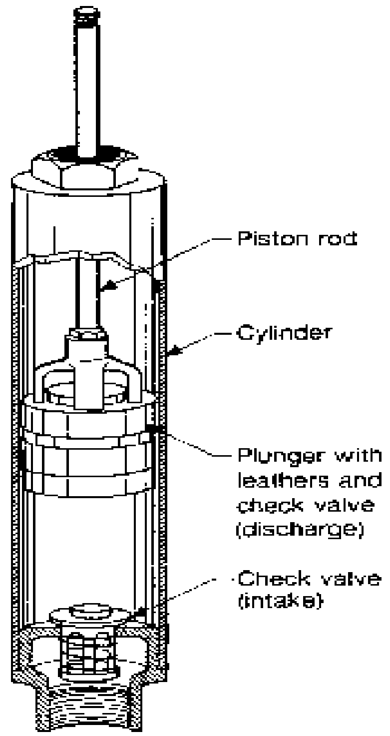
SELECTION OF A PUMP

A water system needs to move the water produced from the source to its customers. In almost all cases in Minnesota, the source is at a lower elevation than the user so the water must be raised to a higher level. Some type of pumping equipment must be used to generate the pressure for raising the water to the higher elevation.

Many different types of pumps can be used with the selection depending on the work that needs to be done. One type would be used for transferring water from a well to a tower; another would be better suited for pumping sludge containing a lime byproduct from a softening plant; still another would be used for feeding a chemical into the water for treatment. Among the considerations in selecting a pump are the maximum flow needed in gallons per minute (gpm), the head it needs to pump against, and the accuracy needed for flow control.

POSITIVE DISPLACEMENT PUMPS

The positive displacement pump is commonly used to feed chemicals into the water or to move heavy suspension, such as sludge. One type of positive displacement pump consists of a piston that moves in a back and forth motion within a cylinder. It is used primarily to move material that has large amounts of suspended material, such as sludges. The cylinder will have check valves that operate opposite to each other, depending on the motion of the piston. One check will be located on the suction side of the piston and will open as the piston moves back, creating a larger cylinder area. After the piston has reached the longest stroke position, the motion of the piston will reverse. This action will open the discharge check valve and close the suction check. The contents of the piston are then discharged to discharge piping. After the discharge, the motion of the piston will reverse and the suction stroke will begin. This action will take place as long as power is applied to the pump.

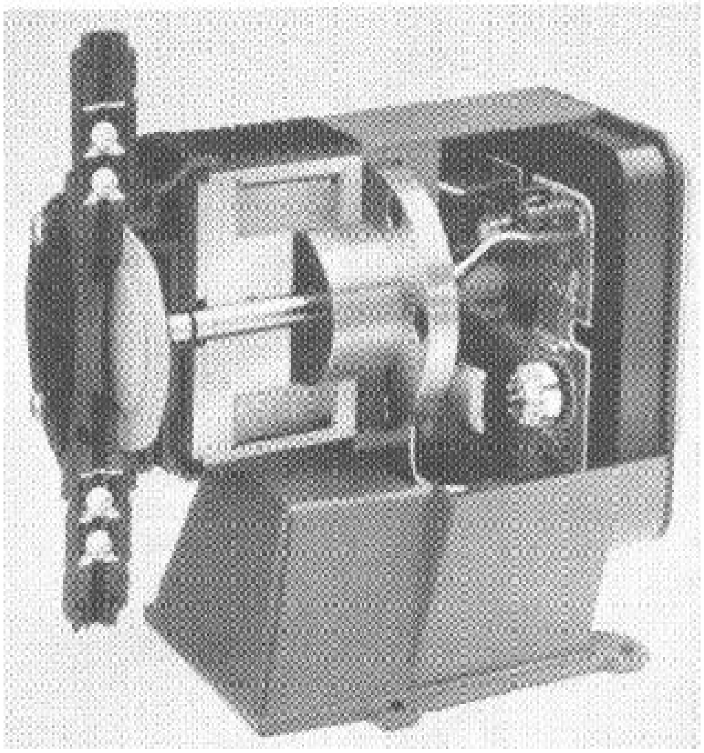


Sticks and stones and other material can become lodged in the check valves of a piston pump, reducing the pump's rate or stopping it completely. When this happens, the check covers must be taken off and the material removed. <u>GREAT CAUTION SHOULD BE EXERCISED WHEN REMOVING THE COVERS SINCE PRESSURE MAY HAVE BUILT UP IN THE CHAMBER.</u>

Because high pressure could damage parts of the pump or cause the piping material to fail, the positive displacement pump should never be throttled on the discharge side of the piston.

The power for a large piston pump is generally an electric motor connected to the piston by way of a gear head and connecting rod.

Another type of positive displacement pump used in the water industry is the diaphragm pump. This pump operates the same way as the piston pump except that, in place of a piston that moves in a cylinder, a flexible diaphragm moves back and forth in a closed area. The check valves operate in the same fashion as they feed or move liquid in the pump. This type of pump is used when high accuracy is required. Most of these pumps are operated by the use of a solenoid that will pulse a set number of times per minute. This pulsing, which is termed frequency, is variable and can be set by the operator or by a control signal. The length of the stroke can also be adjusted in order to vary the size of chamber that fills with liquid.



Larger diaphragm pumps may be operated by mechanical means in a fashion similar to the piston pump. The biggest difference is the replacement of the piston with a flexible diaphragm. The diaphragm is attached to a metal rod that is operated by an eccentric cam driven by an electric motor.

Large diaphragm pumps--used to move sludge or other liquids that contain large amounts of suspended materials--may be driven hydraulically with either oil or air used as the driving force. The material to be pumped will be on one side of the diaphragm with the air or oil on the opposite side. The problem with using this type of pump is that the driving material and the liquid could mix if the diaphragm ruptured.

Another drawback of the diaphragm pump is the pulsing action that the diaphragm imparts to the pumped material. This can often be overcome by the use of air chambers on the discharge side of the pump. One more disadvantage is that, if the pump is running slowly and discharging directly into a flow line, the chemical may not be mixed into the water. The reason being that water is running continuously at the injection point, but the chemical is added in pulses.

WHAT ARE CENTRIFUGAL PUMPS

Because it delivers a constant flow of water at a constant pressure for any given set of conditions, the centrifugal pump is ideal for delivering water to customers. Most well pumps are centrifugal pumps. They are ideal for use in the distribution system since they do not produce pulsating surges of flow and pressure.

This pump operates on the theory of centrifugal force. As the impeller rotates in the pump case, it tends to push water away from the center of the rotation. As the water is pushed away from the center of the impeller, additional water is pulled into the eye, or center, of the impeller. The water that has been pushed to the outside of the impeller is removed from the pump through the discharge piping. This water will have a pressure that is determined by the pitch of the impeller and the speed at which the impeller is turning. There are many types of centrifugal pumps, but they all have major parts in common.

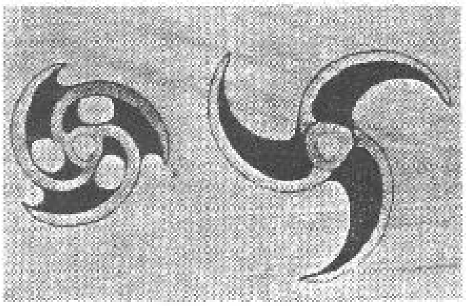
Pump Case - The pump case or volute is designed to allow the liquid being pumped to move to the center of the impeller as well as to allow the water to be removed from the pump through the discharge. The case, which fits closely around the impeller on all but the discharge side, is made of cast iron or brass. If the liquid is abrasive or corrosive, other materials, such as a rubber lining, may be used.

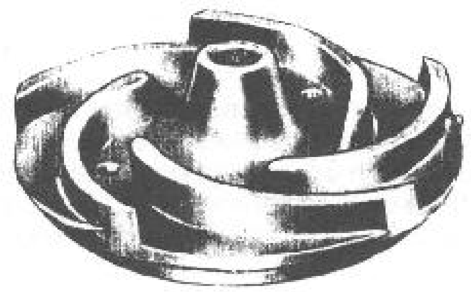
Impellers - The impeller generates the centrifugal force that moves the liquid. Variations in the impeller are based on whether a particular application calls for large quantities of water, high pressure, or both. The design of the impeller is important to the development of pressure and flow.

Impellers in centrifugal pumps can be classified by size, type, and speed. There are three types of impellers for centrifugal pumps:

Open Impeller

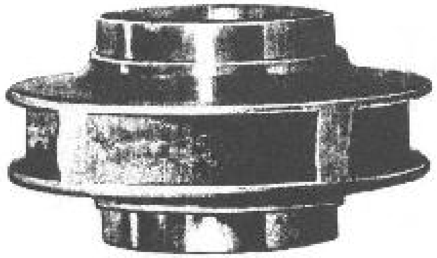
An open impeller has its vanes exposed on the bottom side, a design that allows the pump to move liquids that contain large solids. Open impellers are used in propeller pumps in which the head is low (usually less than 20 feet) and the volume of water pumped is high. The rate of flow can easily be set by adjusting the clearance of the bottom of the impeller to the pump casing. The larger the clearance is, the less will be pumped.





Semi-Open Impeller

This design contains many of the same characteristics of the open impeller. The semi-open impeller has a shroud, or cover, on one side. It is used to pump liquids that contain medium-size solids.



Closed Impeller

This is the impeller of choice in most pump designs and is used in cases where the liquid being pumped has few solids since it will pump the liquid with less wasted energy. With this design, there is a cover on both sides of the impeller with the vanes completely enclosed. The eye of the impeller is surrounded by a skirt, which fits into a recess in the pump casing and ensures that the water from the discharge side of the impeller does not recirculate back to the suction side. The impeller is set in the center of the pump casing.

The skirt of the impeller is surrounded by a wear ring to reduce problems which can seriously affect pump performance and the life of the impeller. The pressure inside the volute of the pump increases when the pump is operating. A zone of high pressure in the volute and low pressure in the suction eye is set up.

As the water jets from the high- to the low-pressure area, the material of the volute and impeller will be worn away. Abrasive material in the water can also contribute to the wear.

The wear ring on the impeller is designed to be a sacrificial element. It absorbs the wear, saving the impeller from damage. A certain amount of water is recirculated, causing energy to be wasted, as water jets from the high- to the low-pressure side of the impeller back to the suction eye. Normally the clearance can be adjusted to keep such recirculation to a minimum.

Centrifugal pumps can have more than one impeller, often called stage. Each additional stage increases the head that the pump can pump against. If one impeller will pump against 60 feet of head, two will pump against approximately 120 feet, three against 180 feet, etc. The rate of the flow in gpm will not be affected by additional impellers since that is dictated by the diameter of the impeller. It will be no greater than what the first impeller can deliver.

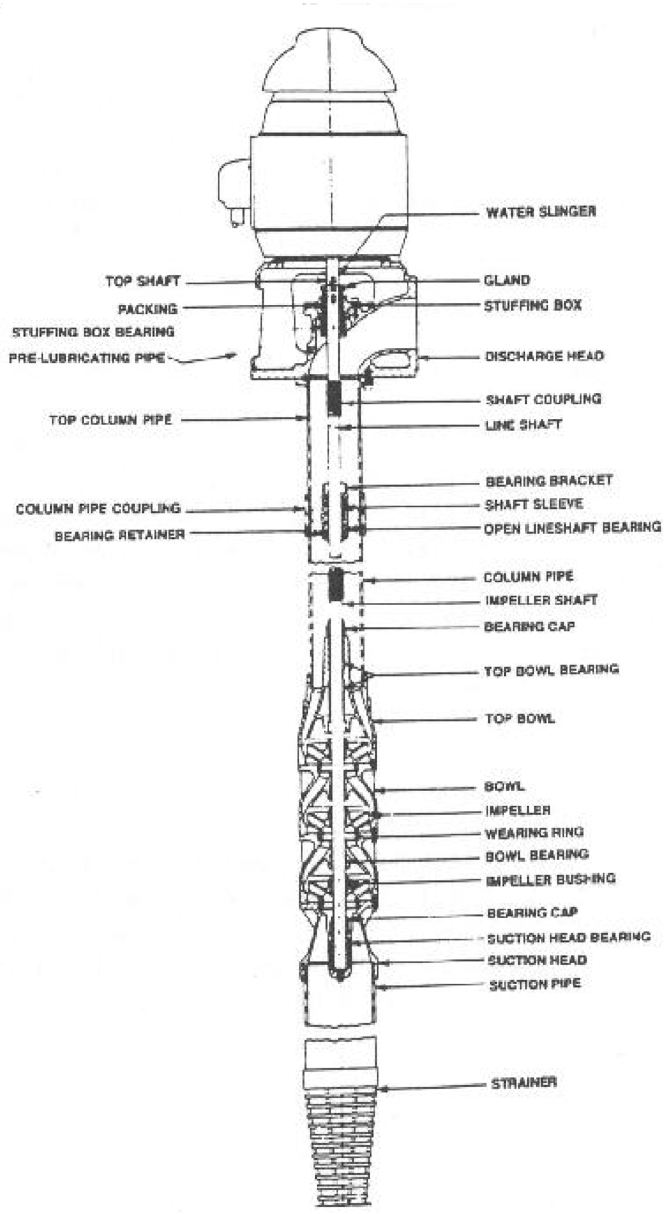
TYPES OF CENTRIFUGAL PUMPS

VERTICAL TURBINE PUMPS

A line shaft turbine pump is one of the most common pumps to be used in the water industry. The pump consists of bowls that contain the impellers, which are connected with each other through the pump shaft bearings.

A turbine pump will usually be staged with more than one impeller to overcome the head conditions that are encountered in the operation. The water from one stage will be discharged into the suction eye of the next stage, a process that will continue until the head is overcome. The size or diameter of the first impeller dictates the volume capacity of the pump in gpm.

The vertical turbine pump contains the following parts: power source, discharge head, pump column, pump shaft, shaft bearings, and the pump itself.



Discharge Head
The discharge head is designed to support the weight of the pump and column pipe along with the shafting. It connects the pump column to the discharge piping and contains the stuffing box that allows the pump shaft to pass into the column pipe. It is designed to contain the pressure the pump is creating.

Pump Column

The pump column, a pipe that connects to the bottom of the discharge head and supports the pump below, is generally ten feet long with a bearing contained in each coupling. The bearing, which is lubricated with the water being pumped, is made of brass and has a rubber insert in the retainer.

Pump Shafting

Pump shafting transfers the energy from the power source to the pump. It is generally made of steel and has stainless-steel shaft sleeves every ten feet. The pump shaft runs in the retainer bearings located between the column couplings. If the water is very corrosive, the entire shaft may be made of stainless steel or another corrosion-resistant material. The size of the shaft will vary with the size of the pump.

SUBMERSIBLE PUMPS

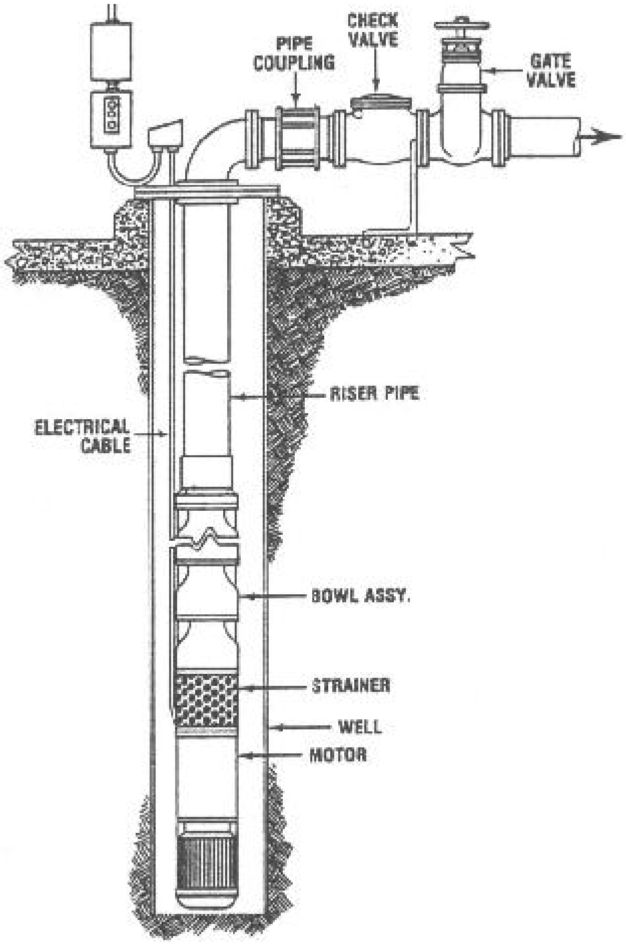
The submersible pump is especially suited to deepwell and booster service for industrial, commercial, and municipal water systems. The pump utilizes a submersible motor coupled directly to the bowl assembly and is designed to operate completely submerged in the fluid being pumped. Power is supplied to the motor by waterproof electrical cable. In deepwell applications the pump motor and cable are suspended in the well by the riser pipe. Booster applications involve installing the unit in a steel suction barrel or horizontally in a pipe line. Since the entire unit is either enclosed or below the surface of the ground, there are several applications where the submersible pump has many advantages.

- Extremely deep wells where problems with shafting are likely to be encountered (such as in crooked wells).
- In installations where flooding would damage standard above ground motors.
- Applications such as boosters pumps which require quiet operation.
- Installations where there is little or no floor space.
- Horizontal pipeline booster pumps placed directly in the pipeline where conditions require a minimum amount of excavation or use of land surface.
- Dewatering applications.

TYPICAL OPERATION

Submersible pumps may be operated and controlled in the same manner as any other type of turbine pump in similar applications. No special consideration peculiar to the submersible is generally necessary, with the exception of the motor starting equipment. The motor, being installed in the pumped fluid, may not be subjected to the same ambient temperature as the overload relays in the starter. It is usually best to use current sensing type overload relays under this condition rather than the thermal type.

CONSTRUCTION DETAILS



Surface Mounting Plate

The surface mounting plate holds the weight of the suspended unit and incorporates an elbow or fitting connected to the discharge piping. The surface plate also provides a junction box for terminating the electrical cable from the pump motor.

Rise Pipe

The riser pipe connects the submersible pump to the surface plate. The pump discharges through this pipe to the surface. It may be several hundred feet long in a deep well application or a short connection piece in a booster pump.

Electrical Cable

The waterproof electrical cable extends from the top of the unit to the surface.

Pump Bowl Assembly

The Pump Bowl Assembly consists of single or multiple stages to meet exact system head requirements. A wide range of bowl sizes is available to meet system capacity requirements. Standard construction includes cast iron bowls with bronze impellers on a stainless steel pump shaft. A suction strainer is used to prevent foreign objects from entering the pump.

Electric Motor

The submersible Electric Motor is attached to the lower end of the bowl assembly becoming an integral part of the submersible unit. The motor thrust bearing carries the thrust load of the pump.

Suction Barrel

For booster service a Suction Barrel may be utilized. Its size will depend on specific installation requirements. For high pressure allocations the suction barrel is extended to accommodate additional bowls.

Low Lift Centrifugal Pumps

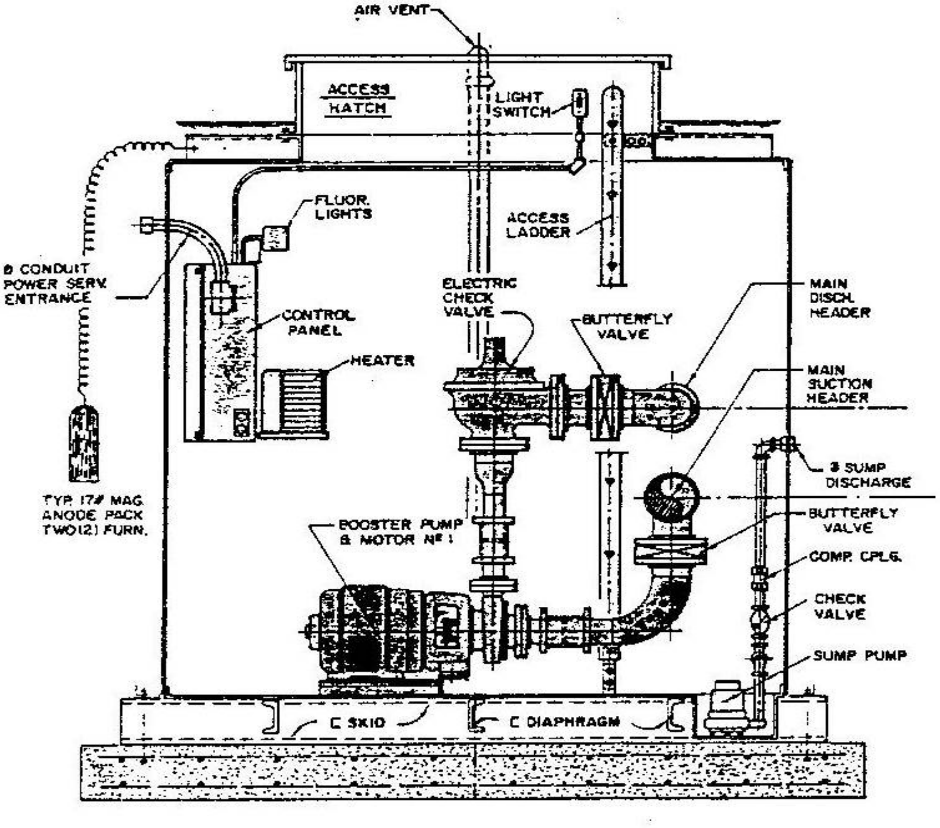
Among other uses, these are used to pump water from at surface source to a treatment plant.

High Lift Centrifugal Pumps

These are used to pump water from a treatment plant to the distribution system.

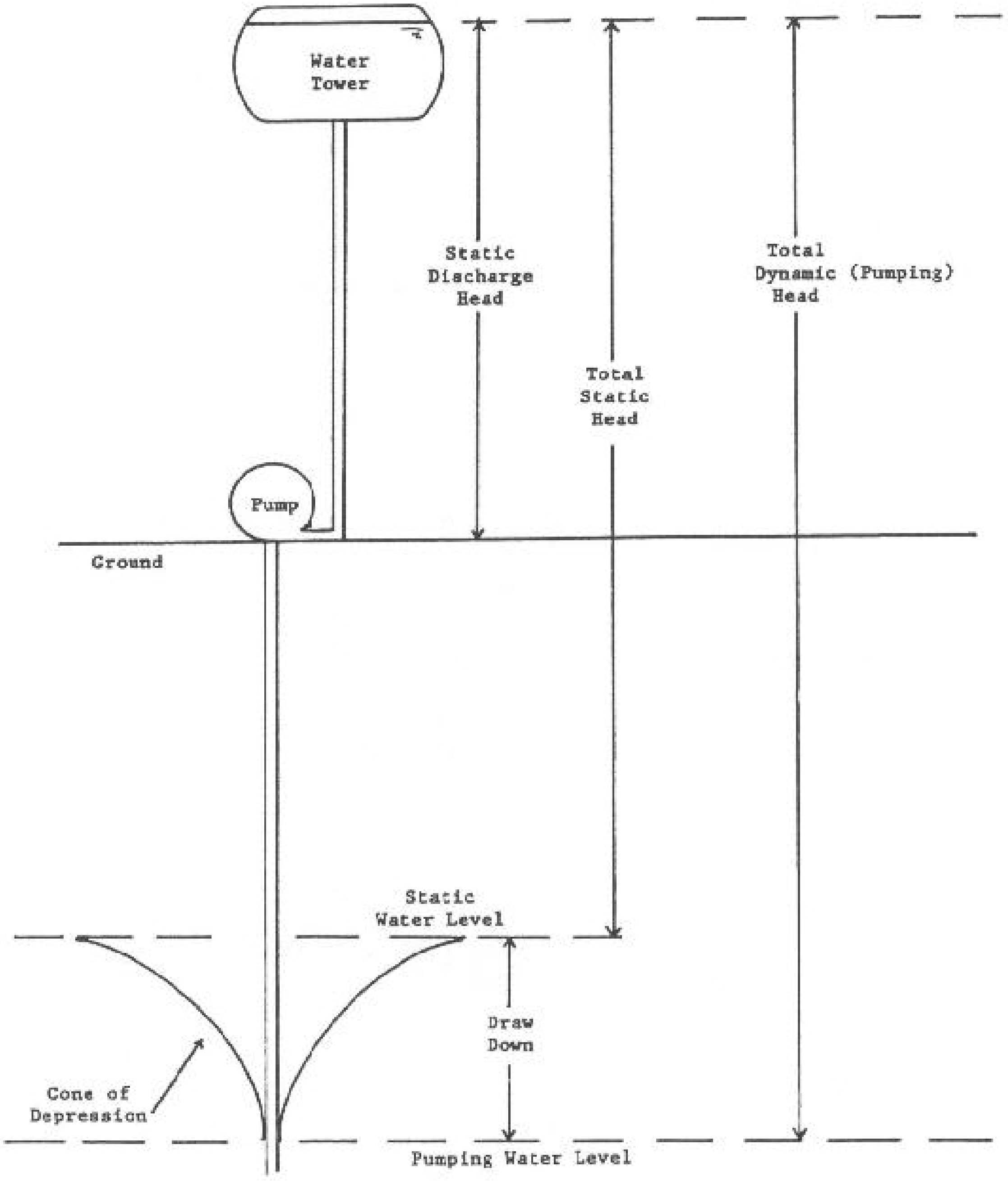
Booster Pumps

These are used to increase water pressure in the water distribution system.



PUMP SELECTION & PUMP CURVE

The selection of a pump for a particular condition should be approached with as much information as possible about the conditions under which it will operate. One piece of information necessary is the total dynamic head, which consists of the sum of all heads that the pump must overcome in its operation, the gpm to be moved, size of well casing (if needed), the revolutions per minute (rpm) of the power source, and the depth of setting.



With this information, the operator can make a decision of the type of impeller that would be the most efficient and use the least energy.

The following information may be found on a pump curve:

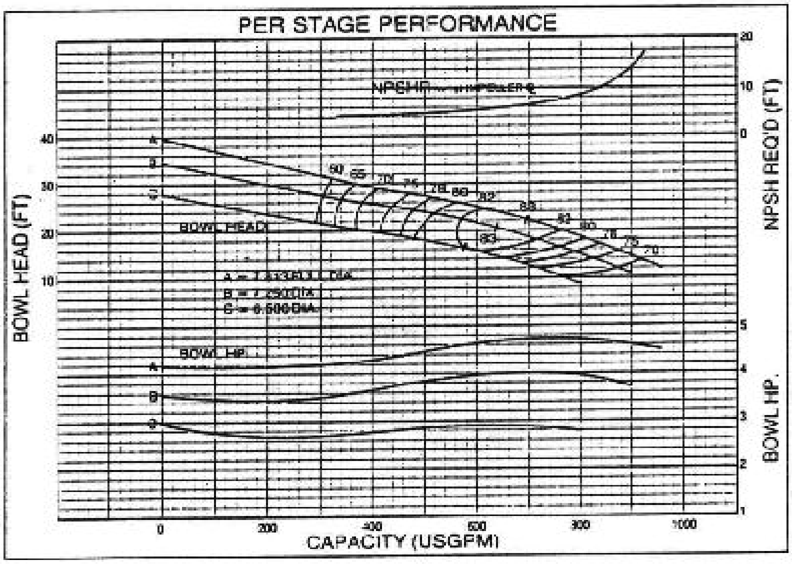
Size of Bowl
The pump curve contains the diameter of the bowl. If the bowl is too large, it may not fit into the well casing.

Size of Impeller
The size of the impeller will also be on the pump curve sheet. Shown by an A, B, or C on the curve, this indicates the trim, or size, of the impeller. The A curve shows the characteristics of a pump with the largest diameter impeller, with the impeller for the B and C curves decreasing in size.

Bowl Head
The curve indicates the head that one impeller will overcome. This information is contained along the right-hand side of the graph and is calibrated in feet rather than pounds per square inch (psi).

Capacity
The flow in gallons per minute is along the bottom of the graph.

Pump Efficiency
Efficiency should be a top priority in the selection of a pump. The pump efficiency is found by drawing a line from the gpm that is expected from the pump and a line from the head, in feet, that is expected. If the head is greater than one impeller can overcome, the bowls will have to be staged with additional bowls. This can change the pump’s efficiency. A pump with only one bowl usually has a greater loss than a pump with many bowls, or a staged pump.



PUMP DRIVES

The pump needs a means of rotating the impellers. The most common source of power is the electric motor, which is often the squirrel-cage type with a constant speed and torque. Electric motors are an attractive choice due to their reliability.

Information needed to select the correct size of electric motor for a particular application is the gpm, total head, motor efficiency, and pump efficiency.

As the motor rotates the shaft, it lifts a quantity of water from the well or reservoir to a higher elevation or pressure zone. The horsepower required is in direct proportion to the weight of the water being lifted each minute.

One horsepower is equal to 33,000 foot pounds per minute. This means that one horsepower will lift 33,000 pounds of water one foot in one minute. This formula is shown below (remember that a gallon of water weighs 8.34 pounds):

$$\text{MOTOR HP} = \frac{\text{GPM x 8.34 \#/gal x head}}{\text{33,000 ft lbs./min. x pump eff. x motor eff.}}$$

This may be simplified by dividing the 33,000 by 8.34 to give you 3960. Thus:

$$\text{MOTOR HP} = \frac{\text{GPM x HEAD}}{\text{3960 x P eff. x M eff.}}$$

The highest voltage available in the area should be used when selecting the motor since this will lower the amperage which, in turn, reduces the size of all the wiring that is required to operate it.

PUMP OPERATION AND MAINTENANCE

Both the pump and its motor need regular maintenance.

MOTOR MAINTENANCE

Information on the maintenance of the motor should be available in the manufacturer manual supplied with the motor. It includes the types of oils or greases to be used and how often the equipment should be lubricated.

Maintenance of the insulation inside of the motor is a difficult, but important, task. It needs to be kept dry, cool, and clean, free of contaminants such as dust, salts, chemicals, lint, and oil. It is important to clean the vents to keep them open.

Some insulation is porous and can absorb water, causing failure of the motor. Dirt and other contaminants attract moisture, as well, and reduce the life of the motor. The proper enclosure can eliminate most of the problems of moisture.

Contamination problems are often attributable to substandard greasing practices or to water contamination from flooding or excessive packing leakage.

Lubrication of the pump should follow the recommendations of the manufacturer. All fittings and grease cups should be cleaned before greasing to remove any dirt that has built up on them. The relief plug should be removed from the bearing. This allows the old grease to be removed from the bearing case as the new grease is pumped in. This practice prevents the old grease from entering the windings of the motor.

The motor's electric operating conditions--useful information for the operator--are easy to obtain. The voltage and amperage should be measured at least yearly. CAUTION SHOULD BE PRACTICED DUE TO THE DANGER OF ELECTRIC SHOCK. IT MAY BE ADVISABLE TO HAVE A QUALIFIED ELECTRICIAN TAKE THESE MEASUREMENTS FOR YOU. Measurements that change greatly could be an indication of problems with the motor or pump. A drop in voltage will result in a corresponding increase in the amperage.

PUMP MAINTENANCE

The only maintenance needed for a line shaft turbine pump is checking the packing gland for excessive leakage and repacking as needed. If the leakage at the packing gland is excessive, the operator should tighten the packing gland follower until the water loss is reduced, but the leakage should not be completely stopped since water serves as the coolant for the packing in the stuffing box.

When the follower cannot be tightened anymore, the packing has to be removed and new packing installed. NEW PACKING SHOULD NEVER BE ADDED ON TOP OF THE OLD.

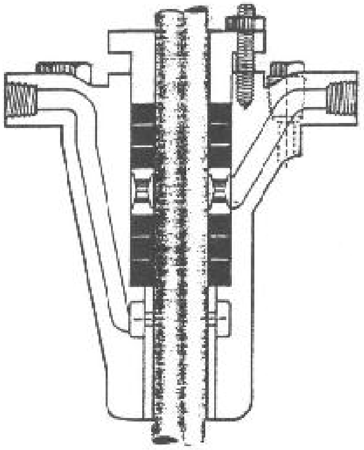
CAUTIONS WHEN SELECTING PUMP PACKING

Most types of pump packing have been developed to meet specific needs and are not usable in the water industry. Even so, there is a large selection of packings available for the waterworks operator to use. The most common types of packing used in the industry today are made of graphite or Teflon. The selection depends on the pressure and speed of the pump shaft. The following table shows the types of packing available:

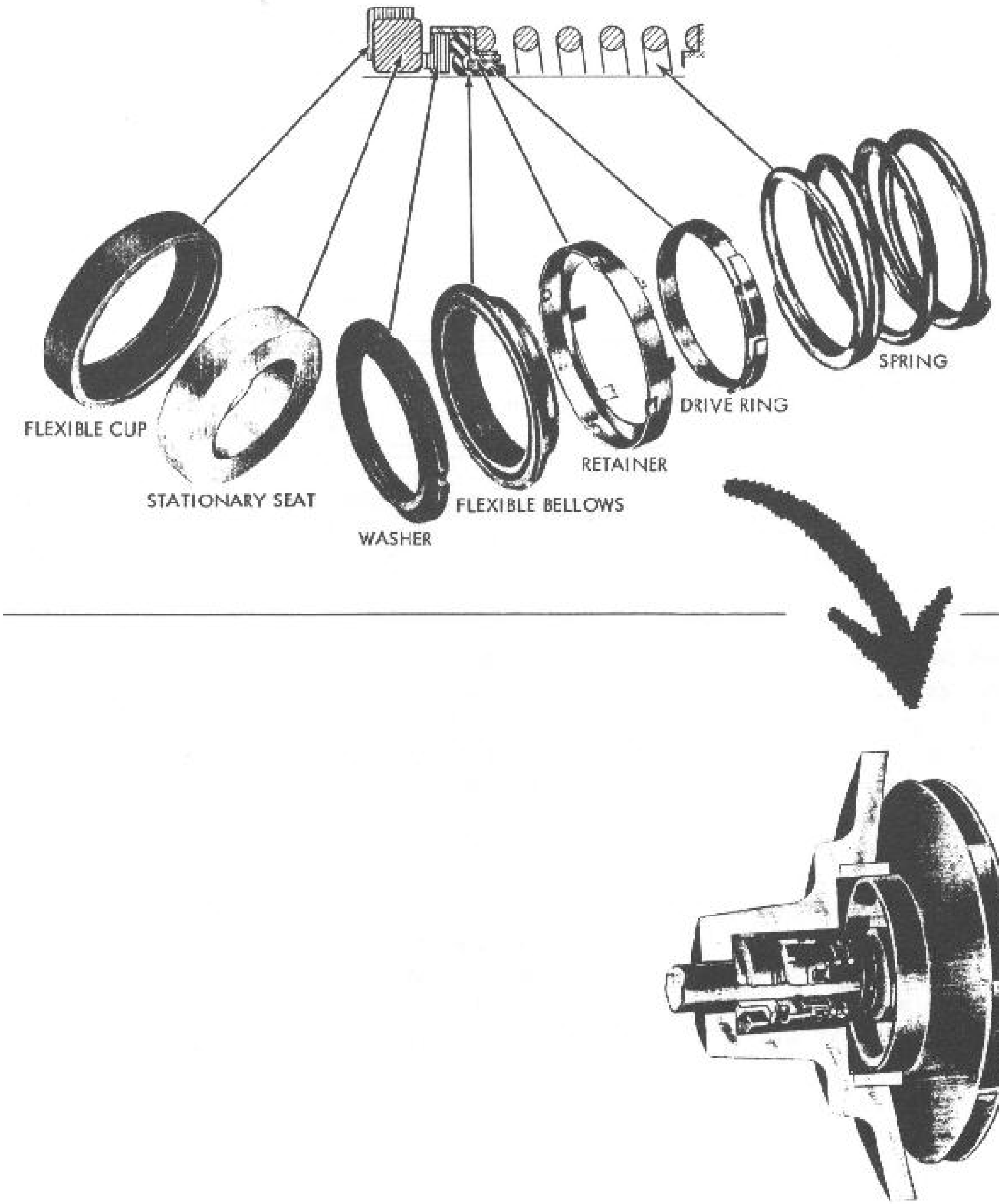
MATERIAL	pH RANGE	SHAFT SPEED, FT/MIN	TEMPERATURE LIMITS
Vegetable fibers	6-8	Variable	225° F
Cotton			
Flax			
Hemp			
Jute			
Ramie			
Mineral fibers		Variable	50° F
White asbestos………….	4-12		
Blue asbestos………….	2-10		
Pure Teflon………………	0-14	600 ft/min	600° F
Pure Graphite…………...	0-14	400 ft/min +	3000-5000° F

All of the old packing should be removed along with the lantern ring when repacking a pump. Proper tools should be used for the removal. Ice picks or screwdrivers may damage the sleeve or some other part of the stuffing box. The old packing should be inspected for any unusual wear.

The new packing used should be cut to fit around the shaft with no opening left at the packing joints. This can be done by wrapping the packing around a sleeve and cutting the packing into pieces. This will assure that the packing is the proper length and will fit the stuffing box. After the old packing has been removed from the pump, the stuffing box should be washed out with water to remove any other material. The new packing can then be installed. The second piece of packing should have the joint offset from the first packing to prevent water from escaping through the joints in the packing. This process should be followed until the stuffing box is full. The follower should then be installed on top of the packing and tightened lightly. The tightening should be continued after the pump is started until the leakage is controlled. It is considered controlled when the leakage is reduced to about 20 drops per minute.



It is now common to have a mechanical seal instead of packing. They are more expensive, but their maintenance is low.



Disinfection

The object of disinfection is to kill disease-causing organisms present in the water. With regard to water treatment, disinfection refers to the destruction of most intestinal or fecal bacteria. Sometimes disinfection is not complete. Some viruses and especially some protozoa, such as Giardia or cryptosporidium, could survive the disinfection process. The only method of complete protection is to sterilize the water by boiling it for a period of 15 to 20 minutes. This process kills most living organisms, but it is only practical as an emergency measure for the individual users.

DISINFECTION AGENTS

The methods of disinfection practical in public water supplies are chlorination, ozonation, use of ultra-violet light, and over-liming. Potassium permanganate, iodine, bromine, and silver are also used, but less frequently. Of these, only bromine has been found to be effective and economical in the treatment of water. Chlorination is so widely used that the terms disinfection and chlorination are almost the same in waterworks practice. Chlorination will be fully discussed later in this chapter.

Ozone is produced by passing a high voltage current through air. Disinfection is accomplished by introducing this ozone into the water to be disinfected. Ultra-violet (UV) treatment is accomplished by passing a thin film of water over a quartz-enclosed mercury vapor lamp. UV will sterilize almost completely but only when the water is clear. Its advantages are that no chemicals are used, no odors are formed, and there is no possibility of overdosage. UV will inactivate viruses completely but will not inactivate coliforms, Giardia, and cryptosporidium. Other disadvantages of UV are that, when used alone, a large lamp surface is required and it does not produce a residual to cope with subsequent contamination in the distribution system. The lamp can be costly to maintain.

Over-liming water, usually done in connection with softening, is destructive to intestinal bacteria, especially when the pH is over 10.3 for a period greater than 6 hours. A residual disinfectant must be used in conjunction with softening.

DISCOVERY AND EARLY CONCEPTS

The disinfection of water has been practiced for several hundred years, even though initially there was no understanding of the principals involved. Historical records show that the boiling of water had been recommended at least as early as 500 B.C.

Chlorine was identified as a chemical element in the early 1800s. Because of its characteristic color, the name chlorine was derived from the Greek word chlorous, meaning pale green. It was not until sometime later, however, that its value as a disinfectant was recognized.

The first record of chlorine being used directly for water disinfection was on an experimental basis, in 1896 in connection with filtration studies in Louisville, Kentucky. It was employed for a short time in 1897 in England, again on an experimental basis, to sterilize water distribution mains following a typhoid outbreak. Its first continuous use was in Belgium, beginning in 1902, for the dual objective of aiding coagulation and disinfection. The first permanent use in the United States was in Jersey City, New Jersey. The practice was contested in court, but the court found that it represented a public-health safeguard. This action paved the way for its rapid extension to other public water supplies in North America.

CHLORINATION

Originally, chlorination was the final treatment process after clarification and filtration. In some cases, it was the only treatment provided. In 1915, the influence of ammonia on the disinfection qualities of chlorine was discovered. This led to prolonging widespread adoption of combined treatment with chlorine and ammonia. The combination of chlorine and ammonia produced a more stable disinfection residual than chlorine alone. However, a combined chlorine and ammonia residual is not as effective as a free-chlorine residual.

The most effective chlorine residual is created by breakpoint-chlorination. This concept began to emerge in the early 1940s. It was reported that some waters exhibited a break in the chlorine residual curve upon addition of a supplementary amount of chlorine, creating a free chlorine residual. (This will be discussed more later on in the chapter) For most supplies, chlorinating to create a free available chlorine residual, or the practice of breakpoint chlorination, is the best form of disinfection. However, free chlorine may produce undesirable by-products, especially when water that contains organic chemicals is treated. In these cases, the system may have to switch to the use of chlorine with ammonia or the use of chlorine dioxide or ozone as the disinfectant.

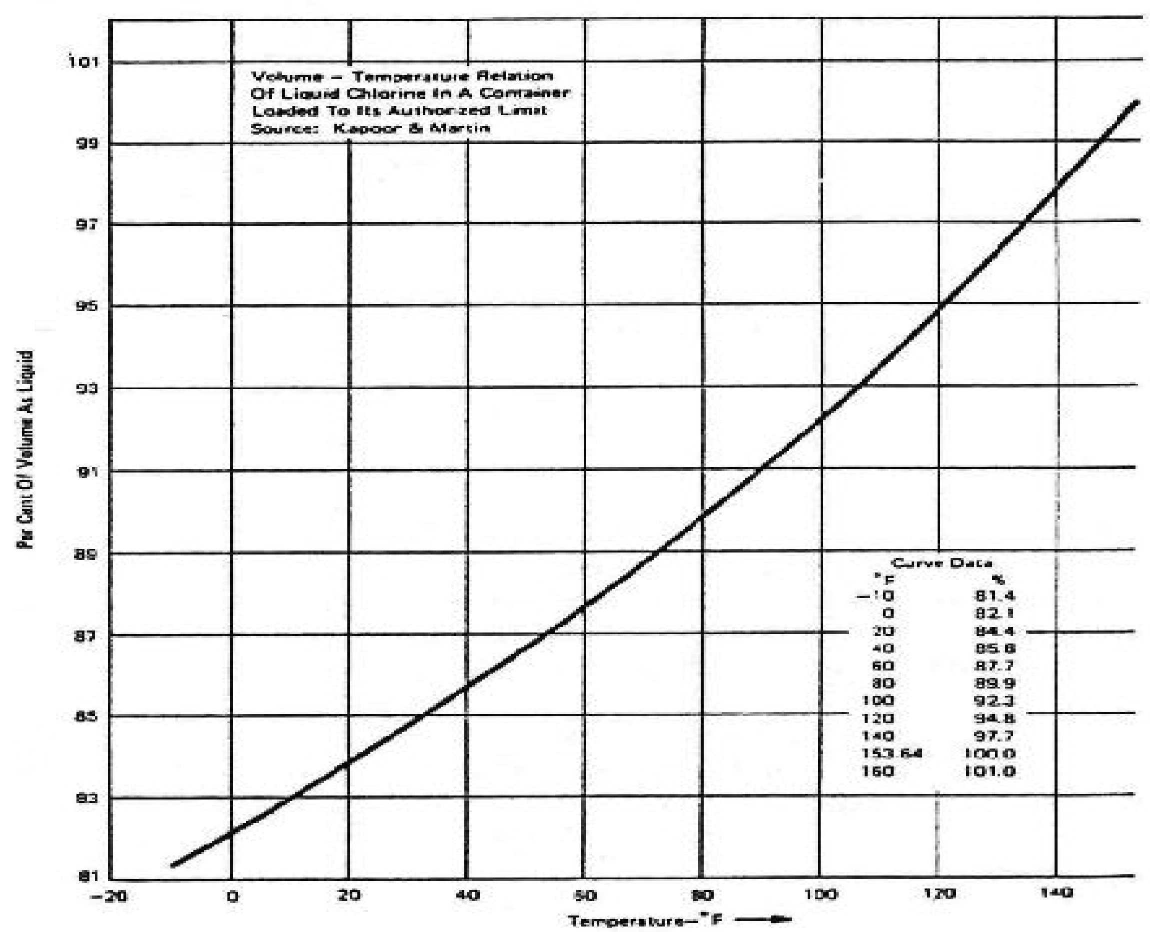
Improvements in chlorine disinfection materials and in chemical feeders contributed to the popularity and widespread adoption of chlorination. Disinfection dosages originally were based largely on the application of a fixed amount of chemical. No provisions were made for the effects of variations in water quality and the fluctuations in chlorine demand or in the amount of chlorine used by the water before a stable residual could be measured. Testing the residual amount of chlorine after the chlorination brought about the practice of varying the amount of feed. The testing of chlorine residual was originally done with the chemical orthotolidine (OTD), which was used until the mid- 1970s when the much safer DPD test procedure was developed as the standard. The OTD method should not be used as OTD is toxic and possibly carcinogenic.

Gaseous chlorine is the least expensive form of chlorine for water supplies. In small-water utility installations or for field-emergency or other specialized uses, other chlorine-containing compounds may be easier to use and more economical. Such materials are various hypochlorites or liquid bleach solutions, chlorinated lime, or chlorine dioxide.

Chlorine Gas Properties

At room temperature, elemental chlorine is a greenish-yellow gas about 2-1/2 times heavier than air. Therefore, it will sink to the floor if released from its container. It is sold to the water supplies as a compressed liquid that is amber in color and about 1 to 1-1/2 times heavier than water. If liquid chlorine is unconfined, it rapidly vaporizes to gas (one volume of liquid chlorine equals about 450 volumes of gas).

Chlorine confined in a container may exist as a gas, liquid, or both. The gas vapor pressure in the container (the 150 pound cylinder, the ton container, or the rail car) is a function of the temperature. It is independent of the volume of chlorine in the container. Thus, the gauge pressure of a container with one pound of chlorine is the same as a container with 100 pounds of chlorine at the same temperature.



Volume – Temperature Relation
Of Liquid Chlorine In A Container
Loaded To Its Authorized Limit
Source: Kapoor & Martin

Curve Data

°F	%
−10	81.4
0	82.1
20	84.4
40	85.8
60	87.7
80	89.9
100	92.3
120	94.8
140	97.7
153.64	100.0
160	101.0

Volume-Temperature Relation of Liquid Chlorine in a Container Loaded to Its Authorized Limit

Chlorine is only slightly soluble in water; its maximum solubility is approximately one percent at 49° C. At temperatures below this point it combines with water to form chlorine ice, a crystalline substance. When the water supply to a gas chlorinator is below normal room temperature, it may cool the chlorine gas to the point at which chlorine ice is formed and accumulates on the needle valve and gas outlet tube, resulting in erratic feed results. Because the vapor pressure of chlorine increases with rising temperatures, its solubility also decreases. At 212° F. chlorine is insoluble in water.

Chlorine dissolved in water forms a weak corrosive mixture of hydrochloric and hypochlorous acid. The corrosivity of chlorine solutions in water creates problems in handling chlorine spills and chlorine containers.

Chlorine reacts with many compounds. Because of its great affinity for hydrogen, it removes hydrogen from some compounds, such as hydrogen sulfide. It also reacts with ammonia or other nitrogen-containing compounds to form various mixtures of chloramines. It reacts with organic materials, sometimes with explosive violence. The operator should be cautious with chlorine compounds and avoid handling them with greasy or dirty scoops.

Although it is neither explosive nor flammable by itself, chlorine is capable of supporting the combustion of certain substances. It should be handled and stored away from compressed gases, such as ammonia and other flammable materials.

Most common metals are not affected at normal temperatures by dry chlorine, either gas or liquid. Chlorine is, however, reactive with aluminum and ignites carbon steel at temperatures above 450° F. Moist chlorine is corrosive to all common metals with the exception of gold, silver, platinum, titanium, and certain specialized alloys.

Physical Effects of Exposure to Chlorine Gas

Chlorine gas is primarily a respiratory irritant and concentrations in air above one ppm can usually be detected by most persons. Chlorine causes varying degrees of irritation of the skin, mucus membranes, and the respiratory system, depending on the concentration and the duration of exposure. Severe exposure can cause death, but the severe irritating effect makes it unlikely that anyone would remain in the chlorine-containing atmosphere unless trapped or unconscious.

Liquid chlorine may cause skin and eye burns upon contact with these tissues. Chlorine produces no known cumulative or chronic effect, and complete recovery usually can be expected to occur shortly following mild, short term exposure. An eight-hour time-weighted exposure of one ppm and a one-hour weighted exposure are the current federal Occupational Safety and Health Administration (OSHA) standards.

Hypochlorites

Hypochlorites are calcium or sodium salts of hypochlorous acid and are supplied either dry or in liquid form (as, for instance, in commercial bleach). The same residuals are obtained as with gas chlorine, but the effect on the pH of the treated water is different. Hypochlorite compounds contain an excess of alkali and tend to raise the pH of the water. Calcium hypochlorite tablets are the predominant form in use in the United States for swimming pools. Sodium hypochlorite is the only liquid hypochlorite disinfectant in current use. There are several grades and proprietary forms available. Pound-for-pound of available chlorine, hypochlorite compounds have oxidizing powers equal to gas chlorine and can be employed for the same purposes in water treatment. Gas chlorination requires a larger initial investment for feed equipment than what is needed for hypochlorite compounds.

Calcium hypochlorite materials used in the water industry are chemically different from those materials variously marketed for many years as bleaching powder, chloride of lime, or chlorinated lime. Materials now in common use are high-test calcium hypochlorites containing about 70 percent available chlorine and marketed under several trade names.

High-test calcium hypochlorites are white corrosive solids that give off a strong chlorine odor. Granular powdered or tablet forms are commercially available and all are readily soluble in water.

Sodium hypochlorite is sold only as a liquid and is normally referred to as liquid bleach. It is generally available in concentrations of 5 to 15 percent available chlorine. These solutions are clear, light yellow, strongly alkaline, and corrosive in addition to having a strong chlorine smell.

High-test hypochlorites, though highly active, are relatively stable throughout production, packaging, distribution, and storage. Storage at 86° F. for a year may reduce the available chlorine by about 10 percent. Storing at lower temperatures reduces the loss. All sodium-hypochlorite solutions are unstable to some degree and deteriorate more rapidly than the dry compounds. Most producers recommend a shelf life of 60 to 90 days. Because light and heat accelerate decomposition, containers should be stored in a dry, cool, and dark area.

Chlorine Dioxide

Chlorine dioxide is created by mixing solutions of sodium chlorite and chlorine. The advantages of chlorine dioxide are: it is a strong bactericide and viricide over a wide pH range; it forms a slight residual in the distribution system; it does not react with nitrogen to form chloramines; and it does not react with organic matter to form trihalomethanes (THMs). The disadvantages of chlorine dioxide are its high cost and its tendency to create chlorate and chlorite, which are potential toxins. Chlorine dioxide is used for taste and odor control as well as disinfection.

CHLORINATION PRACTICES

Early chlorination practices were developed for the purpose of disinfection. Combined chlorine and ammonia treatment was introduced to limit the development of objectionable tastes and odors often associated with marginal chlorine disinfection. Super chlorination was developed for the additional purpose of destroying objectionable taste and odor producing substances often associated with chlorine containing compounds. The discovery of breakpoint chlorination, followed by the recognition that chlorine residuals can exist in two distinct forms, led to the establishment of the two methods for water chlorination used today.

Use of Combined Residual Chlorination

Combined residual chlorination involves the addition of chlorine to water to produce, with natural ammonia present or with ammonia added, a combined available chlorine residual. Combined available chlorine forms have lower oxidation potentials than free available chlorine forms and are less effective as oxidants. They are also less effective as disinfectants. In fact, 25 times more combined available residual chlorine must be obtained to meet the same disinfectant level as a free available residual. The contact time has to be up to 100 times greater to obtain the same level of bacterial kill at the same pH and temperature conditions.

When a combined available chlorine residual is desired, the character of the water determines how it can be accomplished. These conditions may have to be considered:

1. If the water contains sufficient ammonia to produce the desired level of combined residual, the application of sufficient chlorine alone is all that is needed.
2. If the water contains too little or no ammonia, then addition of both chlorine and ammonia is required.
3. If the water has a free available chlorine, the addition of ammonia alone is all that is required. A combined chlorine residual should contain little or no free available chlorine.

The practice of combined residual chlorination is the most effective way of maintaining a stable residual throughout the distribution system to the point of consumer use. Combined residuals in the distribution system are generally longer-lasting and will carry farther into the system, but they are not as effective as free residuals are at disinfecting. The levels required by the regulatory agencies, when using combined residuals, are 1.0 ppm to 2.0 ppm.

Use of Free Residual Chlorination

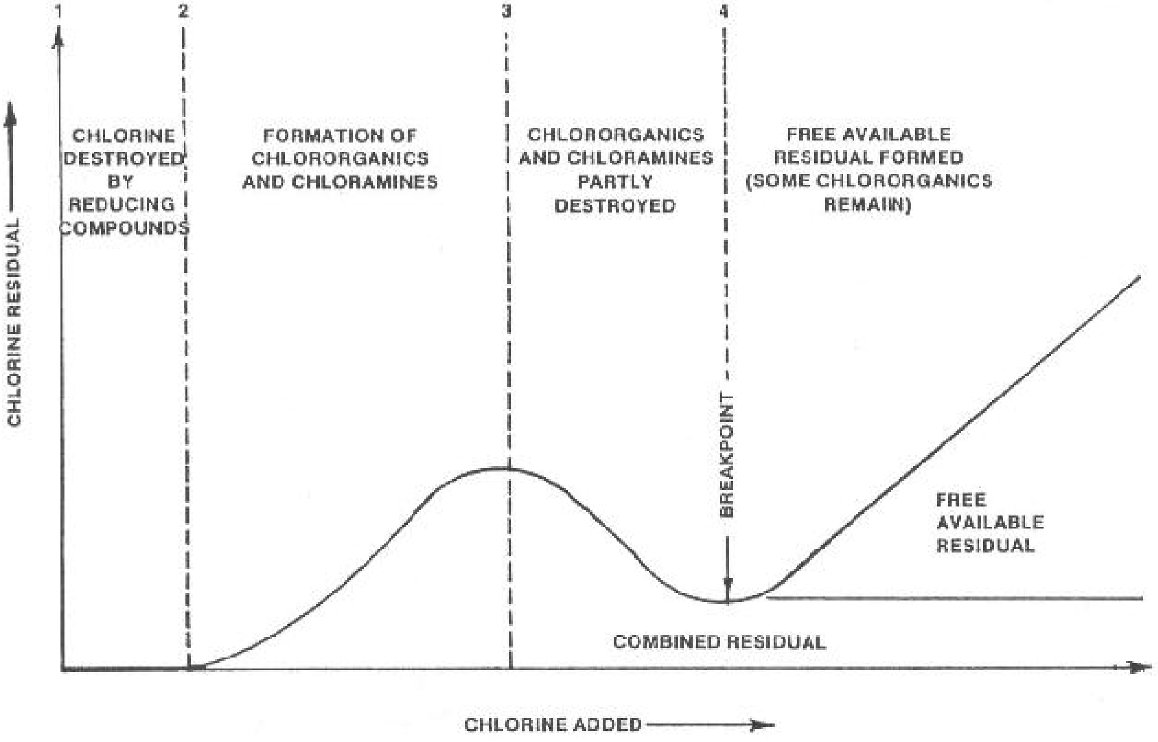
Free residual chlorination involves the application of chlorine to water to produce--either directly or by first destroying any naturally present ammonia--a free available chlorine residual and to maintain this residual through part or all of the water treatment plant and distribution system. Free available residual forms have higher oxidation potentials than combined available chlorine forms and are more effective as disinfectants.

When free available chlorine residuals are desired, the characteristics of the water will determine how this will be accomplished. This may have to be considered:

1. If the water contains no ammonia or other nitrogen compounds, any application of chlorine will yield a free residual once it has reacted with any bacteria, virus and other microorganisms present in the water.
2. If the water contains ammonia, it results in the formation of a combined residual, which must be destroyed by applying an excess of chlorine (see the breakpoint-chlorination curve).

Breakpoint Chlorination

Breakpoint chlorination is the name of the process of adding chlorine to water until the chlorine demand has been satisfied. Chlorine demand equals the amount of chlorine used up before a free available chlorine residual is produced. Further additions of chlorine will result in a chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint. Public water supplies normally chlorinate past the breakpoint.



Breakpoint chlorination

When chlorine is initially added to water, the following may happen:

1. If the water contains some iron, manganese, organic matter, and ammonia, the chlorine reacts with these materials and no residual is formed, meaning that no disinfection has taken place.
2. If additional chlorine is added at this point, it will react with the organics and ammonia to form chloramines. The chloramines produce a combined chlorine residual. As the chlorine is combined with other substances, it loses some of the disinfection strength. Combined residuals have poor disinfection power and may be the cause of taste and odor problems.
3. With a little more chlorine added, the chloramines and some of the chlororganics are destroyed.
4. With still more chlorine added, a free chlorine residual is formed, free in the sense that it can react quickly.

Free available chlorine is the best residual for disinfection. It disinfects faster and without the swimming-pool odor of combined residual chlorine. The free available residual forms at the breakpoint; therefore, the process is called breakpoint chlorination. The common practice today is to go just beyond the breakpoint to a residual of about .2 to .5 ppm.

A variety of reactions take place during chlorination. When chlorine is added to a water containing ammonia (NH_3), the ammonia reacts with hypochlorous acid (HOCL) to form monochloramine, dichloramine, and trichloramine. The formation of these chloramines depends on the pH of the water and the initial chlorine-ammonia ratio.

Ammonia + Hypochlorous acid ----> Chloramine + Water

NH_3 + $HOC1$-----------> NH_2C1 + H_20 Monochloramine

NH_2C1 + $HOC1$----------- > $NHC1_2$ + H_20 Dichloramine

$NHC1_2$ + $HOC1$----------- > $NC1_3$ + H_20 Trichloramine

At the pH of most natural water (pH 6.5 to 7.5*)*, monochloramine and dichloramine exist together. At pH levels below 5.5*,* dichloramine exists by itself. Below pH 4.0, trichloramine is the only compound found. The monochloramine and dichloramine forms have a definite disinfection power. Dichloramine is a more effective disinfecting agent than monochloramine. However, dichloramine is not recommended as a disinfectant due to the possibility of the formation of taste and odor compounds. Chlorine reacts with phenol and salicylic acid to form chlorophenol, which has an intense medicinal odor. This reaction is much slower in the presence of monochloramines.

Both the chlorine residual and the contact time are essential for effective disinfection. It is important to have complete mixing. The operator also needs to be aware that changes in the pH may affect the ability of the chlorine to disinfect the water. The operator must examine the application and select the best point of feed and the best contact time to achieve the results desired. The operator needs to consider:

1. Whether the injection point and the method of mixing is designed so that the disinfectant is able to get into contact with all of the water to be disinfected. This also depends on whether pre- and/or post-chlorination is being used.
2. Contact time. In situations of good initial mixing, the longer the contact time, the more effective the disinfection.
3. Effectiveness of upstream treatment processes. The lower the turbidity of the water, the more effective the disinfection.
4. Temperature. At higher temperatures the rate of disinfection is more rapid.
5. Dosage and type of chemical. Usually the higher the dose, the quicker the disinfection rate. The form of disinfectant (chloramine or free chlorine) and the type of chemical used influence the disinfection rate.
6. pH. The lower the pH, the better the disinfection.

Points of Chlorine Application

The points of application of chlorine must be selected carefully, considering the different reactions that may occur at different points of the water treatment process. The common application points are:

1. PRECHLORINATION

   Prechlorination is the application of chlorine ahead of any other treatment process. While prechlorination may increase the formation of trihalomethanes--potentially carcinogenic substances formed through the combination of chlorine and organics in the raw water--it provides the following benefits:

   a. Control of algae and slime growths.
   b. Control of mud ball formation in the filters.
   c. Improved coagulation.
   d. Reduction of tastes and odors.
   e. Increased safety factor in disinfection of heavily contaminated waters.

2. POSTCHLORINATION

Postchlorination is the application of chlorine after treatment and before it enters the distribution system. This is the primary point of disinfection and is normally the last application of any disinfectant. It is also the only point where chlorine is added in a water system where it has no other purpose except to disinfect.

3. TANKS AND RESERVOIRS

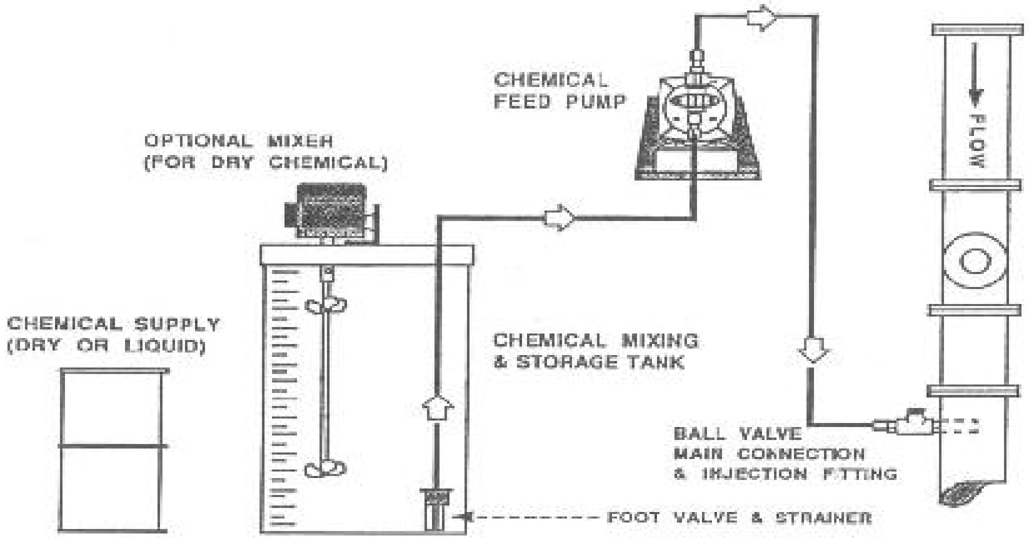
Usually tanks and reservoirs are not chlorinated continuously, but they must be disinfected after any maintenance has been done on the inside of the tank. A chlorine concentration of 50 ppm is required in the water used for this "super-chlorination." This chlorine must then be flushed out before the tank can be put back into service. Refer to AWWA Standard C652 for additional information on Tank and Reservoir disinfection.

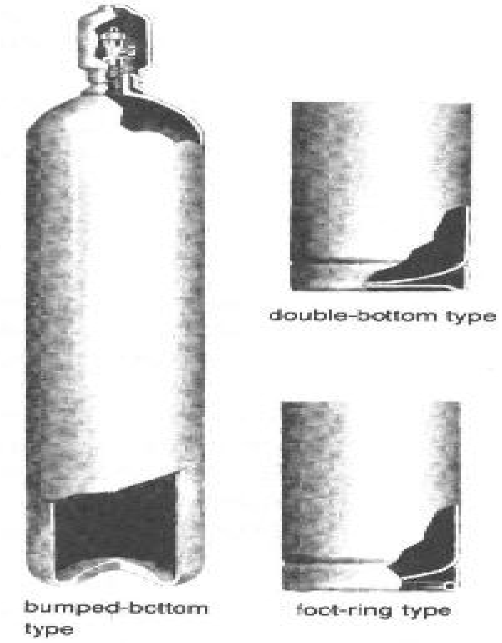
CHLORINE CONTAINER TYPES

The type of container used to transport chlorine will depend on the type of chlorine product used:

Hypochlorites

For hypochlorites to be mixed with water, a container made of plastic is required. The container size depends on the amount needed. Normally, it should hold a week's supply. The feed equipment for hypochlorites is often a diaphragm pump similar to the pump used to feed fluoride.





Gas Chlorine

Gas chlorine is normally shipped in 100-pound, 150-pound, or 2,000-pound (one ton) cylinders. If the demand is great enough, the chemical can be supplied in tank cars.

Cylinders containing 100 and 150 pounds of chlorine are convenient for small plants with capacities of less than 0.5 MGD. A fusible plug is placed in the valve below the valve seat as a safety device set to melt at 158 to 165 degrees F to prevent buildup of pressure and the possibility of rupture due to a fire or high surrounding temperatures.

Net Cylinder Contents	Approx. Tare, Lbs. *	Dimensions, Inches	
		A	B
100 Lbs.	73	8 ¼	54 ½
150 Lbs.	92	10 ¼	54 ½

*Stamped tare weight on cylinder shoulder does not include valve protection hood.

The following are safety procedures that should be observed when moving cylinders:

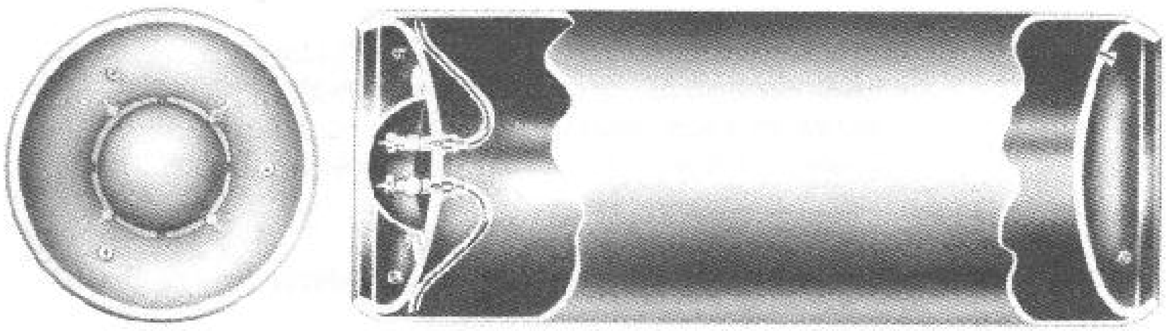
1. Always replace the protective cap when moving a cylinder.
2. Move cylinders with a properly balanced hand truck that has supports that fasten around the cylinder two-thirds of the way up on the cylinder.
3. The 100- and 150-pound cylinders can be rolled in a vertical position. Avoid lifting these cylinders except with approved equipment. Use a lifting clamp, cradle or carrier. Never lift with homemade chain devices, rope slings, or magnetic hoists and never lift the cylinder by its protective cap.
4. Keep cylinders away from direct heat and direct sunlight, especially in warm climates.
5. Transport and store cylinders in an upright position.
6. Firmly secure cylinders to an immoveable object when stored or in use.
7. Store empty cylinders separately from full cylinders, and label them clearly with information as to whether they are full or empty.

Never store chlorine near turpentine, ether, anhydrous ammonia, finely divided metals, hydrocarbons, or other materials that are flammable in air or will react violently with chlorine.

Ton containers are the most common type used in larger plants. This type of container holds 2,000 pounds (one ton or 1,000 kilos) of chlorine. The container itself weighs about 1,300 pounds, giving it a total weight of approximately 3,300 pounds when full. Ton containers are normally of the following construction:

Welded steel construction with a length of approximately 80 inches and an outside diameter of 30 inches. The ends of the ton containers are crimped inwardly to provide a substantial grip for the lifting clamps.

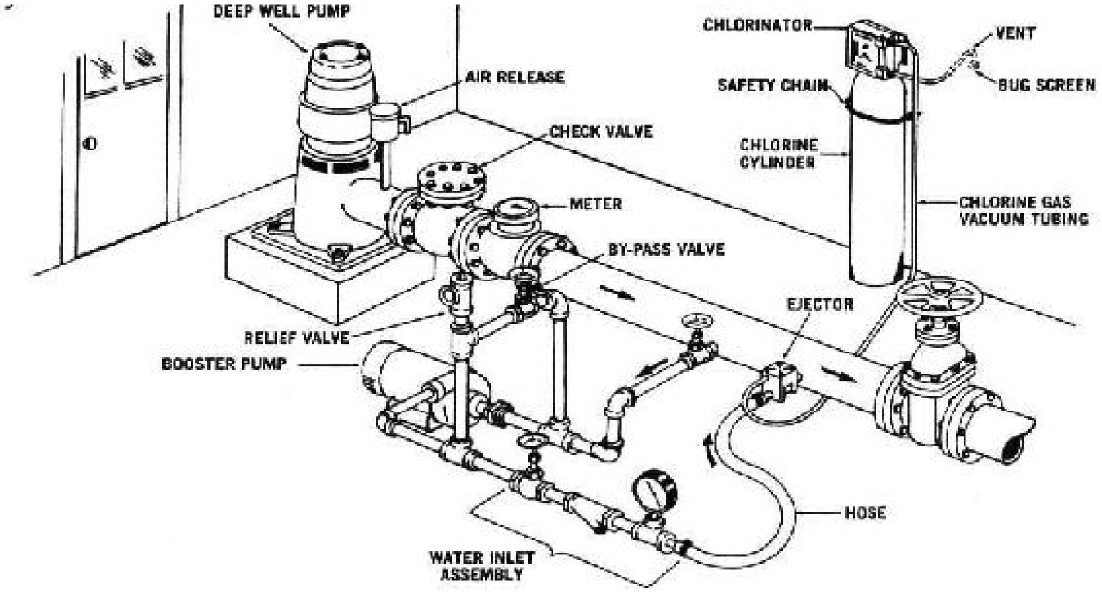
- Ton containers generally have about eight openings for valve and fusible plugs. Normally two valves are placed on one end of the cylinder, along with three fusible plugs. The other end of the cylinder contains three additional fusible plugs. The fusible plugs melt at 158 to 165° F., the same temperatures as the ones on the 150-pound cylinder.

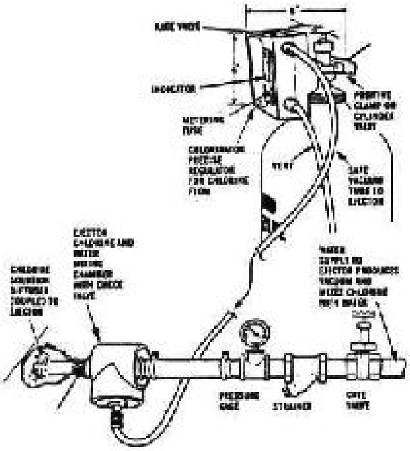


CHLORINATOR INSTALLATION

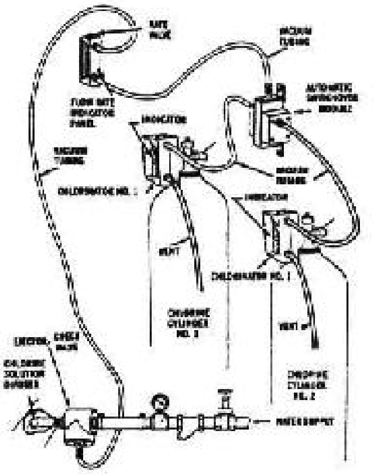
The chlorine room should have fans located either on the roof or in another place where it can push fresh air into the room and vent any chlorine out. The fans should be large enough to make one complete air change per minute. The intake for the vents should be located in the lower area of the room because chlorine is heavier than air and sinks to the floor. In some parts of Minnesota, the local fire marshal may require chlorine scrubber units to be installed. These units capture any chlorine gas or liquid that has escaped and neutralizes it with caustic soda before discharging it to the atmosphere.

Chlorine gas is removed from chlorinators. In smaller plants cylinder, the chlorine tanks by a valve and piping arrangement to the chlorine is withdrawn with equipment installed directly on the cylinder.

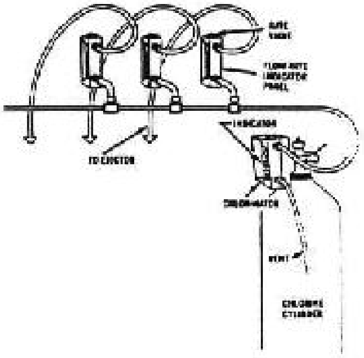




TYPICAL
INSTALLATION
BASIC SYSTEM



TYPICAL INSTALLATION
AUTOMATIC
SWITCHOVER SYSTEM



TYPICAL INSTALLATION
REMOTE AND
MULTI-POINT SYSTEMS

The operating vacuum to pull the chlorine gas out of the cylinders is provided by a hydraulic injector. The water used for the hydraulic injector is the plant's water supply. To get the

necessary water pressure for the injector, a small booster pump may have to be installed in the water line to the injector. The water supplied by this injector absorbs the chlorine gas; the resulting chlorine solution is conveyed to a chlorine diffuser through a corrosion resistant pipe. A vacuum regulator valve dampens the fluctuations for a smoother operation.

The primary advantage of vacuum-feed operation is safety. If a failure or breakage occurs in the vacuum system, the chlorinator either stops the flow of chlorine or allows air to enter the vacuum system rather than allowing chlorine to escape into the surrounding atmosphere. In case the chlorine inlet shutoff fails, a vent valve discharges the incoming gas to the outside of the chlorinator building.

MAKING CHLORINE CONNECTIONS

The outlet of a container valve has special threads. They are not ordinary tapered threads. The operator should use only the fittings and gaskets furnished by the chlorine supplier or chlorinator manufacturer when making connections to chlorine containers. Regular pipe thread fittings should not be used. A new gasket should always be used when making a new connection. The outlet threads on the container valve should always be inspected before being connected to the chlorine system. Containers with badly-worn outlet threads should be returned to the supplier. If a connecting nut is used, it should be inspected for corrosion. Since the threads on both the tank and the connecting nut could be worn, the use of a connecting yoke is recommended.

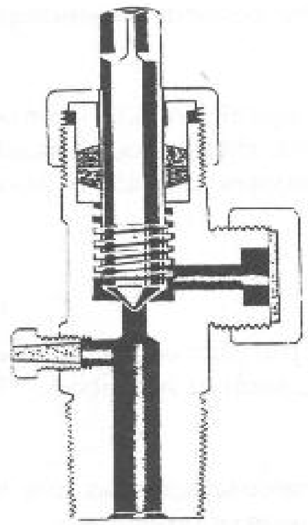
On pressurized systems, a flexible annealed copper line or pig tail coiled at least three times is recommended for the connection between chlorine containers and stationery piping. Care should be taken to prevent sharp bends in the tubing because this will weaken the tubing.

To simplify changing cylinders on a dual cylinder system, a shutoff valve is needed just beyond the cylinder being changed to control backflow from the other cylinder.

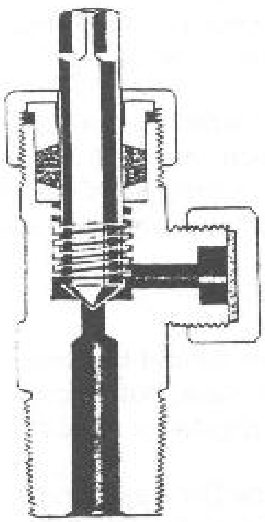
Leak-detection procedures should be followed after any connection of cylinders in the system. The connections should be checked with a 60 percent ammonia solution by applying only the vapors, not the liquid. A rag should be soaked with the ammonia solutions and held near the connections to the tank. If a leak is present, a smoky vapor will be given off from the leak. If a bottle of ammonia solution is used, only its vapors should be puffed near the suspected leak.

CHLORINE VALVES

Valve wrenches longer than six inches should not be used. Pipe wrenches or wrenches with an extension should not be used to open the valves. The valve should be opened by striking the wrench with the heel of the hand to rotate the valve stem in a counter-clockwise direction. Then it should be slowly opened one turn. If the valve cannot be opened in this manner, the packing nut should be loosened slightly and another attempt made. Then the valve should be opened and the packing nut retightened. If all attempts fail, the container should be returned to the supplier. Organic lubricants should not be used on any part of the chlorinator system as chlorine can react violently with organic material.



Standard Cylinder Valve



Standard Ton Container Valve

DEALING WITH CHLORINE LEAKS

Chlorine has the potential to cause serious injury, even death. Concentrations of 1,000 ppm, or one percent by volume, will kill in a very short time. Because the odor of gas chlorine is noticeable in very small amounts, it is generally easy to avoid the heavy concentrations that will cause injury. This characteristic makes chlorine less hazardous than other gases, such as hydrogen sulfide, which kills the sense of smell, and carbon monoxide, which cannot be smelled at all. If a person inhales chlorine, he or she may experience general restlessness, panic, severe irritation of the respiratory system, sneezing, and excessive amounts of saliva. These symptoms may be followed by coughing, retching, vomiting, and difficulty in breathing. People who have respiratory problems, such as asthma and certain types of chronic bronchitis, will have additional problems with chlorine inhalation. Liquid chlorine may cause severe irritation and blistering when in contact with the skin.

PROTECTION

All operators should be trained in the proper methods of handling chlorine. Chlorine is safe *if it is handled properly.* All operators should be trained in the use of self-contained breathing equipment, the methods for detecting leaks, and emergency procedures.

Self-contained air supplies and pressure-demand breathing equipment must fit and be used properly. People using this breathing equipment must first pass a physical exam and be trained in the proper use of the equipment.

It is important that trained backup personnel are available before a person enters an area with a chlorine leak. Protective clothing, such as a chemical suit, may be needed, depending on the concentration of the chlorine.

People who have worked in an area with a chlorine leak may be susceptible to skin irritation from their clothing, which may still be moist with chlorine. If this happens, these people should make sure their clothing is purged of chlorine--standing outside for a few minutes may allow the clothing to dry--before entering a confined space, such as a car or truck.

PLANNING AHEAD

All plant operations should be planned. In the case of a chlorine leak, the plan could include people not working in the plant, but who could be affected by a chlorine leak, such as neighbors. The plan must be practiced regularly. The following should be done:

1. Have the fire department and other available emergency response agencies tour the area to become familiar with the potential dangers and the location of emergency equipment. Give them a clearly marked map indicating the location of the chlorine storage area, chlorinators, and emergency equipment.
2. Have regular practice sessions in the use of respiratory, equipment, chemical suits, and chlorine repair kits. Involve all personnel who may respond to a chlorine-leak emergency.
3. Have a supply of ammonia solution available to detect chlorine leaks.
4. Write chlorine emergency procedures, including:
   a. Telephone numbers of the suppliers.
   b. List of key people who could help or who must be notified of the emergency.
   c. Local fire departments.
   d. Local police departments.
5. Follow established procedures when working with a leak:
   a. Never work alone during the emergency.
   b. Obtain help immediately. Quickly repair the problem; *they do not heal themselves.*
   c. Allow only authorized employees to work in the area, and make sure adequate equipment is readily available.
   d. If caught in an area with a chlorine leak, leave immediately. Do not breathe deeply. Walk out of the room with head up; do not crawl out. The effects depend on the length of exposure and the concentration of chlorine in the air.
   e. Use an ammonia solution to find small leaks. The vapor from the ammonia solution will generate a white vapor close to the leak.
   f. Develop emergency evacuation procedures with emergency personnel (police and fire departments) for the residents and businesses around the plant.
6. Post emergency procedures and practice them regularly.

7. Inspect equipment and make necessary repairs on a routine basis. At least twice each week, inspect the area where the chlorine containers are stored and where the chlorinators are operating.
8. At least once each week, inspect the emergency fans which will be needed in the event of a chlorine leak.
9. Conduct a health appraisal of all personnel who may have to respond to a chlorine emergency. Some may have physical problems that necessitate their removal from the emergency team.

MEASUREMENT OF CHLORINE RESIDUAL

The amount of chlorine residual in the water should be measured on a regular schedule. Tests should be done at least twice daily for small plants and more frequently for larger plants. Most large plants will have an automatic chlorine analyzer that automatically measures the residual.

Amperometric titration provides the most accurate measurement of chlorine. However, the equipment is not very portable, and it is not designed for work in the field. Most chlorine analysis is performed with the DPD method. Special DPD tablets that will change color in the presence of chlorine are added to a water sample. A color comparator or a colorimeter that automatically measures the intensity of the color is used to determine the concentration of chlorine residual in the water sample.

Chlorine residual measurements should be done on the distribution system at the areas farthest from the source of the water-treatment plant or the well. This ensures that the entire distribution system is receiving enough chlorine. If breakpoint chlorination is being practiced to obtain a free chlorine residual, the residual should be at least 0.2 to 0.5 ppm. If a combined-chlorine residual is being used for chlorination, the residual should be 1 to 2 ppm.

If the residual is low, the disinfection of the water system cannot be assumed to be complete and disease-causing bacteria (pathogens) may still be present in the water distributed.

DISINFECTION PROCEDURES WHEN CUTTING INTO OR REPAIRING EXISTING MAINS

The following procedures apply primarily when existing mains are wholly or partially dewatered. After the appropriate procedures have been completed, the existing main may be returned to service prior to completion of bacteriological testing in order to minimize the time customers are out of water. Leaks or breaks that are repaired with clamping devices while the mains remain full of pressurized water present little danger of contamination and require no disinfection.

Trench Treatment

When an existing main is opened, either by accident or by design, the excavation will likely be wet and may be badly contaminated from nearby sewers. Liberal quantities of hypochlorite applied to open trench areas will lessen the danger from such pollution. Tablets have the advantage in such because they dissolve slowly and continue to release hypochlorite as water is pumped from the excavation.

Swabbing With Hypochlorite Solution

The interior of all pipe fitting (particularly couplings and sleeves) used in making the repair shall be swabbed or sprayed with a 1 percent hypochlorite solution before they are installed.

Flushing

Thorough flushing is the most practical means of removing contamination introduced during repairs. If valve and hydrant locations permit, flushing toward the work location from both directions is recommended. Flushing shall be started as soon as the repairs are completed and shall be continued until discolored water is eliminated.

Slug Chlorination

When practical, in addition to the procedures above, the section of main in which the break is located shall be isolated, all service connections shut off, and the section flushed and chlorinated. Hypochlorite dose may be increased to as much as 300 mg/L and the contact time reduced to as little as 15 minutes. After chlorination, flushing shall be resumed and continued until discolored water is eliminated, and the water is free of noticeable chlorine odor.

Sampling

Bacteriological samples shall be taken after repairs are completed to provide a record of determining the procedure’s effectiveness. If the direction of flow is unknown, then samples shall be taken on each side of the main break. If positive bacteriological samples are recorded, then the situation shall be evaluated by the purchaser (or purchaser’s representative) who can determine corrective action, and daily sampling shall be continued until two consecutive negative samples are recorded.

Fluoridation

Fluoride is a naturally occurring element found in small but varying amounts in water, air, soil, plants, and animals. Water fluoridation is the deliberate addition of fluoride into drinking water in accordance with scientific and dental guidelines. When used appropriately, fluoride is a safe and effective agent that can be used to prevent dental cavity formation. However, fluoride above 2.0 parts per million (ppm) may result in enamel fluorosis in developing teeth. Scientific research on the subject began in the 1930s and continues today to establish optimal fluoride levels in drinking water.

REGULATIONS

Minnesota Statutes require all municipal water supplies to maintain a fluoride concentration of 0.9 ppm to 1.5 ppm, with an optimum level of 1.2 ppm. The Safe Drinking Water Act established a fluoride Maximum Contaminant Level (MCL) of 4.0 ppm to protect against crippling skeletal fluorosis and a Secondary MCL (SMCL) of 2.0 ppm to protect against enamel fluorosis.

Fluoride must be fed with equipment that conforms to Minnesota standards, and to prevent an overfeed of fluoride; it must be fed through a break box. Municipal water supplies must test for fluoride concentration daily using an approved analytical method. Records of these results must be kept by the water supplier and reports submitted monthly to MDH. A quarterly fluoride water sample must be submitted to MDH every three months. This sample serves to verify that optimum fluoride levels are being maintained and to check the water supplier's testing equipment accuracy.

FLUORIDE CHEMICALS

The most commonly used fluoride compound is hydrofluosilicic acid. Other commonly used fluoride compounds are sodium fluorosilicate and sodium fluoride.

Fluoride compounds must conform to American National Standards Institute / NSF International and American Water Works Association standards. The water supplier should insist that the chemical supplier furnish only compounds that meet these standards. The water supplier should also periodically request Material Safety and Data Sheets and chemical composition test results from the chemical supplier.

Several factors must be considered in selecting a fluoride chemical. For suppliers that use a powder or crystal form, the solubility of the chemical in water is important since the chemical must dissolve readily in water and remain in the solution. Operator safety and ease of handling must also be considered, as well as storage and feeding requirements and, of course, cost.

Hydrofluosilicic acid must be handled cautiously. It is very dangerous, can cause burns, and produces acidic fumes that must be vented to the atmosphere. These acidic fumes can etch glass on gauges, corrode electrical equipment and irritate skin. Sodium fluoride is the easiest chemical to feed because of its uniform solubility in water.

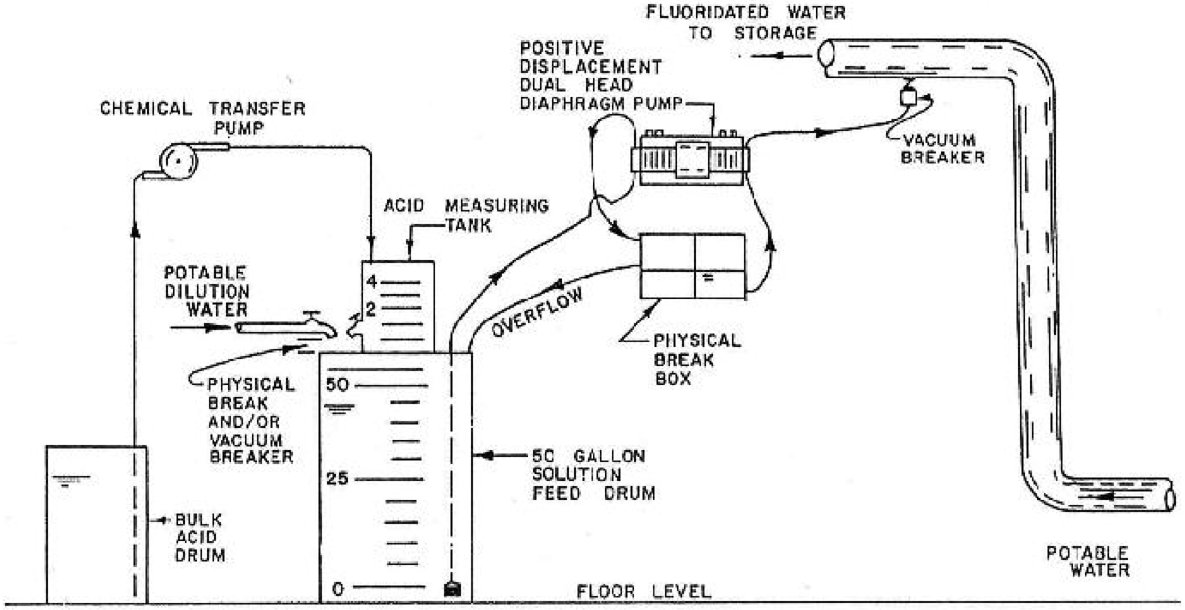
	Sodium Silicofluoride Na_2SIF_6	Sodium Fluoride NaF	Hydrofluosilicic Acid H_2SIF_6
Form	Molecular Weight	Commercial purity %	Fluoride Ion %
powder	188.1	98-99	60.7 (100%)
powder or crystal	42	95-98	45.3 (96%)
liquid	144.1	22-30	79.2 (100%)
Purity %	Density	Solubility in water %	pH of saturated solution
59.8 (98.5%)	55–72 lb/ft^3	0.76	3.5
43.4 (96%)	65–90 lb/ft^3	4.95	7.6
23.8 (30%)	10.5 lb/gal	100	1.2

FLUORIDATION SYSTEMS

Fluoride can be added to water in liquid or powder form. In liquid form, a chemical pump adds the fluoride in a controlled dosage. In powder form, a dry feeder adds the chemical to a water solution which is then added to the water.

Type of Feeder	Chemical Used	General Rate Range
Gravimetric (dry feeder)	Na_2SIF_6	2 to 5,000 pounds per hour (lb/hr)
Volumetric (dry feeder)	Na_2SiF_6	0.02 to 5,000 lbs/hr
Piston or centrifugal metering pump	H_2SIF_6 NaF	18 to 5,000 lbs/ hr
Diaphragm metering Pump – mechanical	H_2SIF_6 NaF	9 to 2,500 gallons per day (gal/d)
Diaphragm metering Pump – Electronic	H_2SIF_6 NaF	0.2 to 96 (gal/d)
Peristaltic metering Pump	NaF	0.5 to 85 (gal/d)

HYDROFLUOSILIC ACID FEED



A typical hydrofluosilicic feed system includes:

Displacement Pump

A dual head or 2 single headed positive displacement pump designed of a corrosion-resistant material. If the pump discharges to an open tank with an airbreak such as a clearwell or filter, the double-head pump is not required. The airbreak will prevent any chance of back siphonage.

Break Box

A break box is required to prevent an overfeed of fluoride chemical. This is a single compartment tank with one head of the pump discharging into one side and the second head using that same compartment as the suction for the pump that discharges to the feed point. This box must be made from acid resistant material that can withstand the corrosion of the hydrofluosilicic acid. There is an overflow line back to the day tank. (Corrosion-resistant shelving should be used for mounting feed pumps and the breakbox).

Day tank

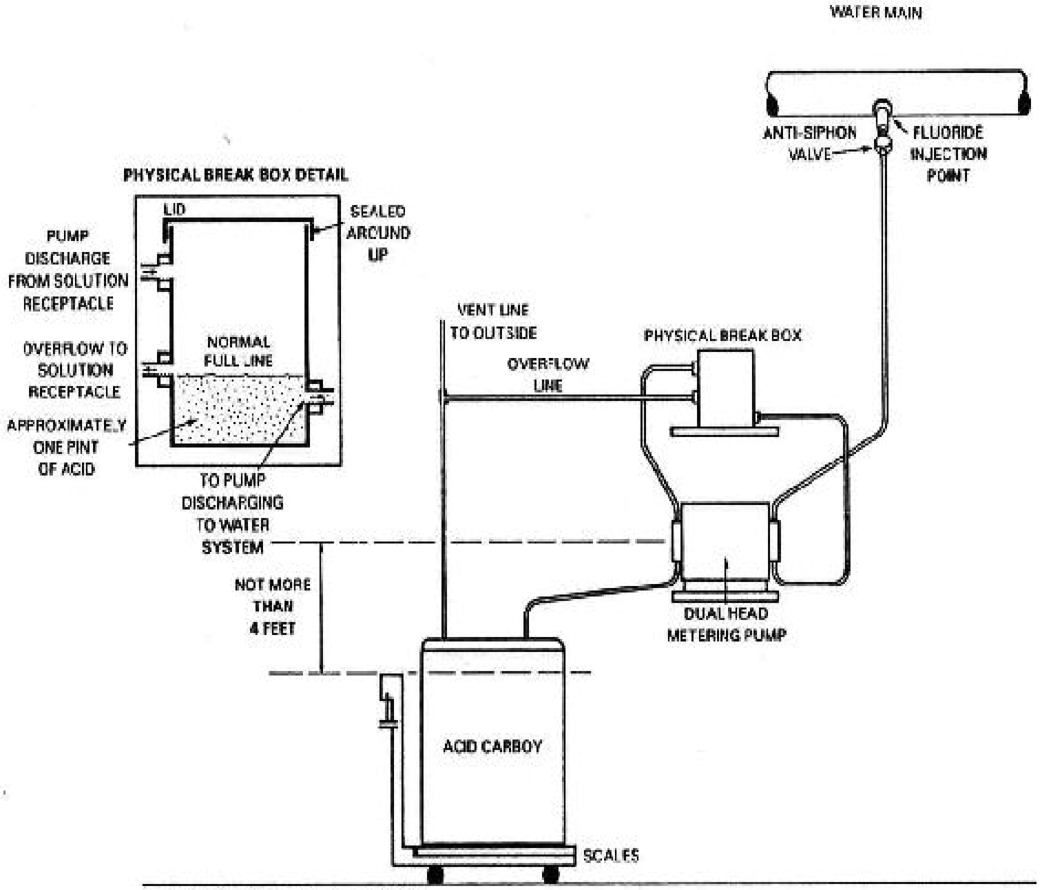
The solution or day tank is generally a calibrated polyethylene tank that can withstand the corrosivity of an acid. This tank generally holds at least 50 gallons of fluoride solution. It should be calibrated in one-gallon units. The solution tank should be sealed and vented to the outside.

Chemical

Whenever possible, full-strength chemical should be fed. If it isn't, a method for diluting the acid with water is needed. The dilution can be done manually; otherwise, a transfer pump is required to move the acid needed to make up the solution from the storage tank to the dilution tank. A water source is also needed and must be protected from cross-connection.

Safety and Ventilation

When working on the fluoridation system, the operator needs to use safety equipment consisting of neoprene apron, gloves, and goggles. Ventilation must be provided. An exhaust fan and solution-tank vents help protect against indoor acid fumes which could etch glass and corrode electrical equipment. All tank vents should be terminated outside the building.



*Courtesy of Minnesota State Department of Health

Amount of Fluoride in Hydrofluosilicic Acid

The weight of a hydrofluosilicic acid solution is found by multiplying the weight per gallon by the percent of purity (a gallon of hydrofluosilicic acid has a density of 10.3 pounds per gallon). Most commercially available hydrofluosilicic acid contains 23-25 % pure acid.

$$\begin{aligned}\text{Weight of pure acid} &= \text{Weight per gallon x percent purity}\\ &= \text{10. 3 lb hydrofluosilicic acid solution/gal x 0.24}\\ &= \text{2.47 lb hydrofluosilicic acid/gal}\end{aligned}$$

Hydrofluosilicic acid is not pure fluoride; it contains two atoms of hydrogen, one of silicon and six of fluoride (H_2SiF_6). The percent of pure fluoride in the acid is found by calculating the molecular weight of the acid and dividing the molecular weight of the fluoride by the total molecular weight of the acid.

$$\text{Percent pure fluoride} = \frac{\text{Atomic weight of fluoride atoms within molecule}}{\text{Molecular weight of hydrofluosilicic acid } (H_2SiF_6)}$$

$$= \frac{(\text{6 F atoms x 19 F atomic weight})}{((2 \text{ x } 1) + (1 \text{ x } 28.1) + (6 \text{ x } 19))} \text{ x } 100\% = 79\%$$

Feed calculations

The size of the feed pump is determined by:

- The required rate of feed from the well or plant (gallons treated).
- The natural fluoride concentration in the raw water.
- The percentage of purity and availability of fluoride in the chemical.

Example

Assume a well pump has a flow of 1,000 gallons per minute (gpm) and runs for 24 hours. The fluoride concentration needed is 1.2 parts per million (ppm); the natural fluoride concentration is 0.1 ppm. A 25 percent hydrofluosilicic acid solution having a pure fluoride content of 79 percent and a density of 10.4 pounds per gallon is used. How many gallons of acid per day must be added to raise the concentration to 1.2 ppm?

$$\text{Pounds fluoride} = \frac{\text{gallons to be treated}}{1{,}000{,}000} \text{ x 8.34 lb/gal x concentration (dosage)}$$

$$= \frac{\text{1,000 gal/min x 1,440 min/day}}{\text{1,000,000 gallons/Mgal}} \text{ x 8.34 x (1.2 ppm - 0.1 ppm)}$$

$$= \frac{\text{12.01 Mlb}}{\text{Day}} \text{ x 1.1 ppm}$$

$$= \text{13.21 pounds per day pure fluoride needed}$$

$$\text{Pounds fluoride per gallon} = \text{weight/gallon x (\% acid/100) x (\% purity/100)}$$

$$= 10.4 \text{ lb/gal} \times 0.25 \times 0.79$$

$$= 2.05 \text{ \# fluoride/gallon}$$

$$\text{Gallons per day} = \frac{\text{pounds per day}}{\text{pounds per gallon}}$$

$$= \frac{13.21 \text{ pounds per day}}{2.05 \text{ pounds per gallon}}$$

$$= 6.44 \text{ gallons hydrofluosilicic acid solution per day}$$

The pump purchased should be sized so that the required amount of acid per day is in the mid-range of its capacity. This will give a more accurate feed. If the water flow is less than 100 gpm, acid may be diluted; however, in most cases--even with a low flow--a pump small enough to feed accurately can be purchased. Dilution is not recommended. The pump should be sized to accommodate low flow. The chemical feed equipment must be wired to start and stop with the well pump so that chemical is fed only when water flows.

Operation and Maintenance

Operation of the pumping equipment is simple, but anything mechanical occasionally breaks down. In most cases, diaphragm pumps are operated by either electronic or mechanical controls. Electronic pumps are becoming more popular because of their reliability and versatility. Electronic pumps can accurately deliver very small volumes because both the length of the stroke and its frequency can be finely adjusted. Mechanical pumps are typically immersed in oil and require more maintenance.

When the pump operating the diaphragm moves a given distance for each stroke, it opens the check on the suction side, allowing a given amount of acid to flow into the pump. The amount of acid will depend on the volume of the cavity that the diaphragm movement creates. When the diaphragm reverses the stroke to expel the acid, the suction check closes and the discharge check opens, allowing the acid to flow away from the pump.

Maintenance of the pumping equipment involves the replacement of the check valve balls, diaphragm gaskets, and related parts. Most operators should be able to repair the pump without too much trouble; however, if the power source is the problem, it may require an electrician or the pump supplier's service representative.

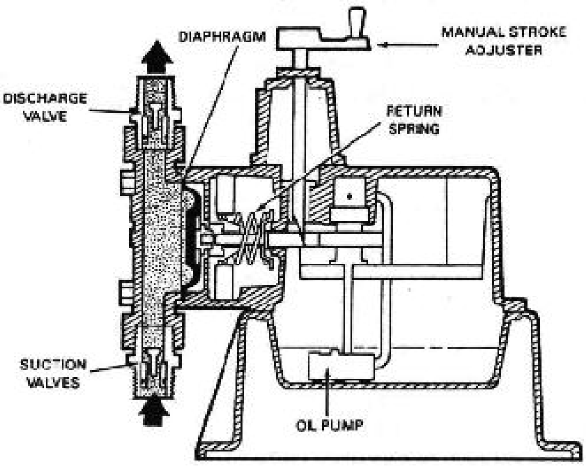
Installation

Prior to the start-up of the equipment, the operator should make sure:

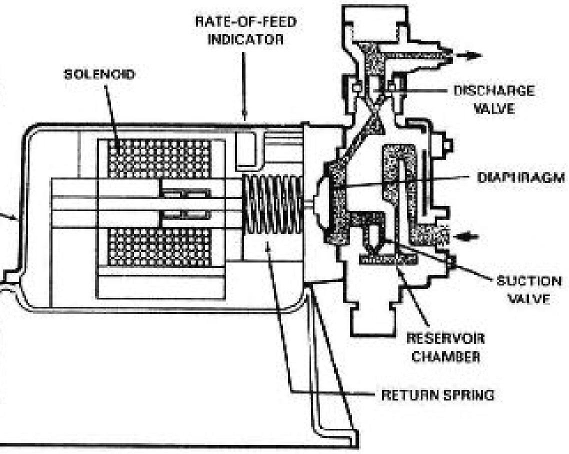
- Chemical is injected into the water system at the lower half of a discharge pipe located downstream of the pump. The injection pipe located in the lower half of the pipe will prevent corrosion of the pipe.

- Power supply for the feed pump is activated by the well or water-pumping equipment so the fluoride pump will start and stop the same time as the water pump.
- All valves on discharge side of feed pump are open to allow chemical flow.

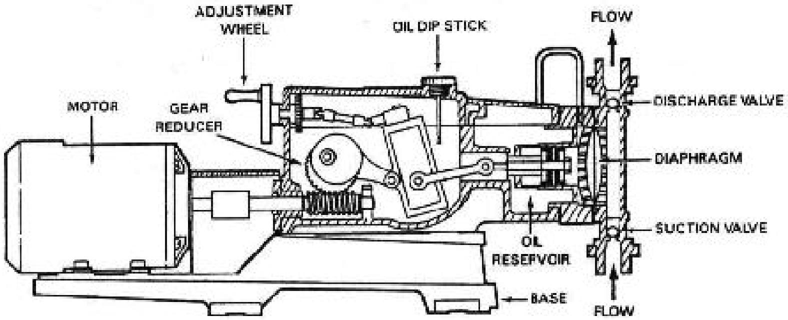
DIAPHRAGM METERING PUMP



TYPICAL ELECTRONIC METERING PUMP

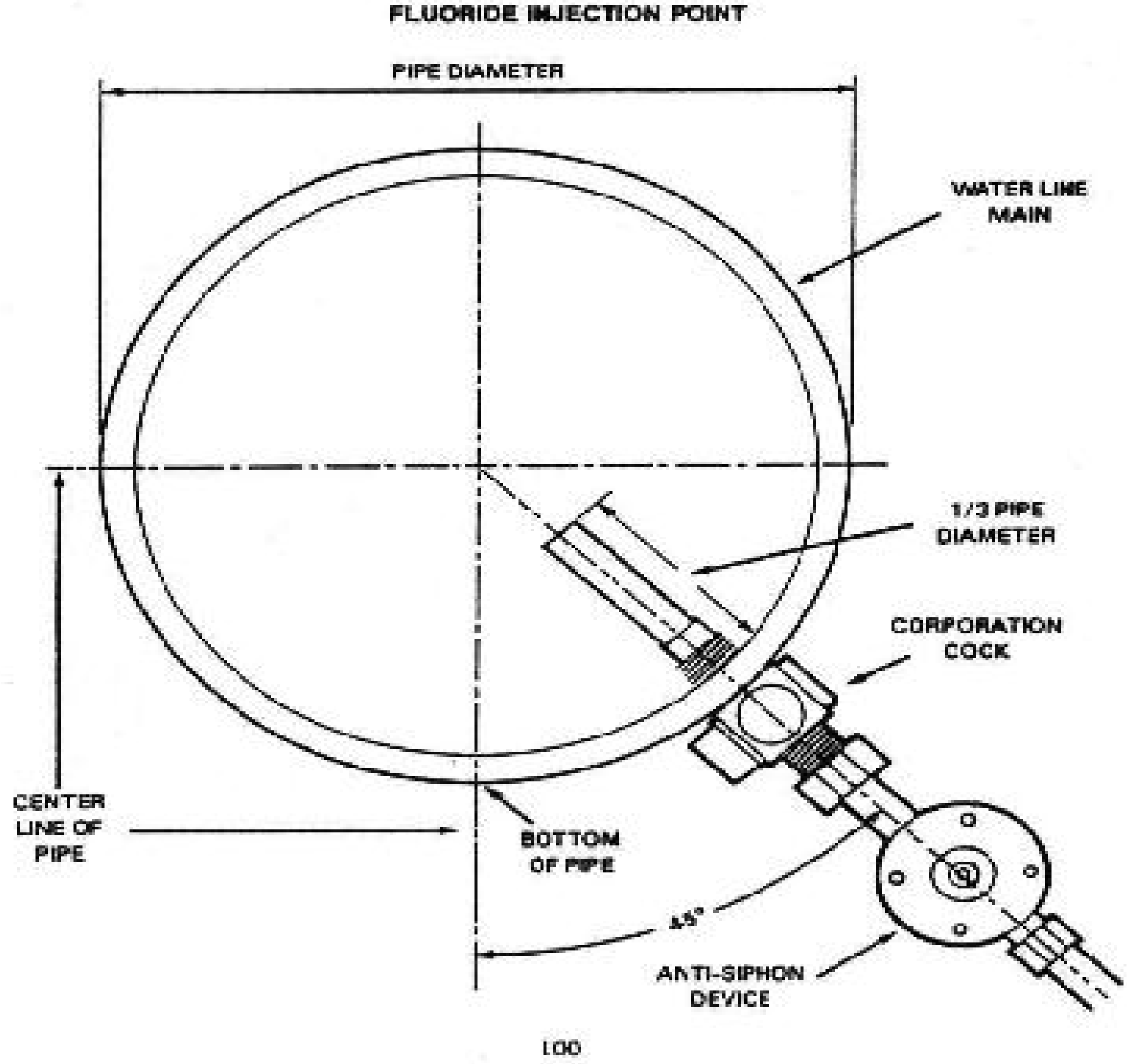


TYPICAL HYDRAULIC DIAPHRAGM METERING PUMP



Once these items are checked, and corrected, an operator should:

- Prime the feed pump with potable water, and run the pump at full capacity until all air has been bled from the lines.
- Use a graduated cylinder and stop watch to calibrate the feed rate of the pump and make any necessary adjustments.
- After the feed has started, check the water samples for the proper fluoride concentration. These samples should be taken at least 100 feet from the point of fluoride application.



Troubleshooting

If low fluoride concentration is detected, and if the problem is determined to be related to low pump output (not an error in the feed calculations), the following possible causes should be investigated:

- Low pump setting - An increased pump setting may solve the output problem.
- Trapped air or loss of prime - If air is found in the chemical feed lines, determine how it entered. It might be due to a faulty seal, a tubing or fitting leak, air suction due to a depleted feed solution supply, or other similar causes.
- Ruptured diaphragm - A ruptured diaphragm should be replaced immediately since an acid leak can cause internal pump damage.
- Clogged tubing or valves - Make sure liquid flows freely through the system.

If the pump is operating properly and a low concentration is detected, the cause must lie in the feed solution or water pumpage rate and you should check:

- Proper feed dilutions - Prepare a small amount of the proper solution concentration. Feed this into the system and test for the actual fluoride concentration.
- Pump rate - Check the meter with a stop watch for a given length of time.

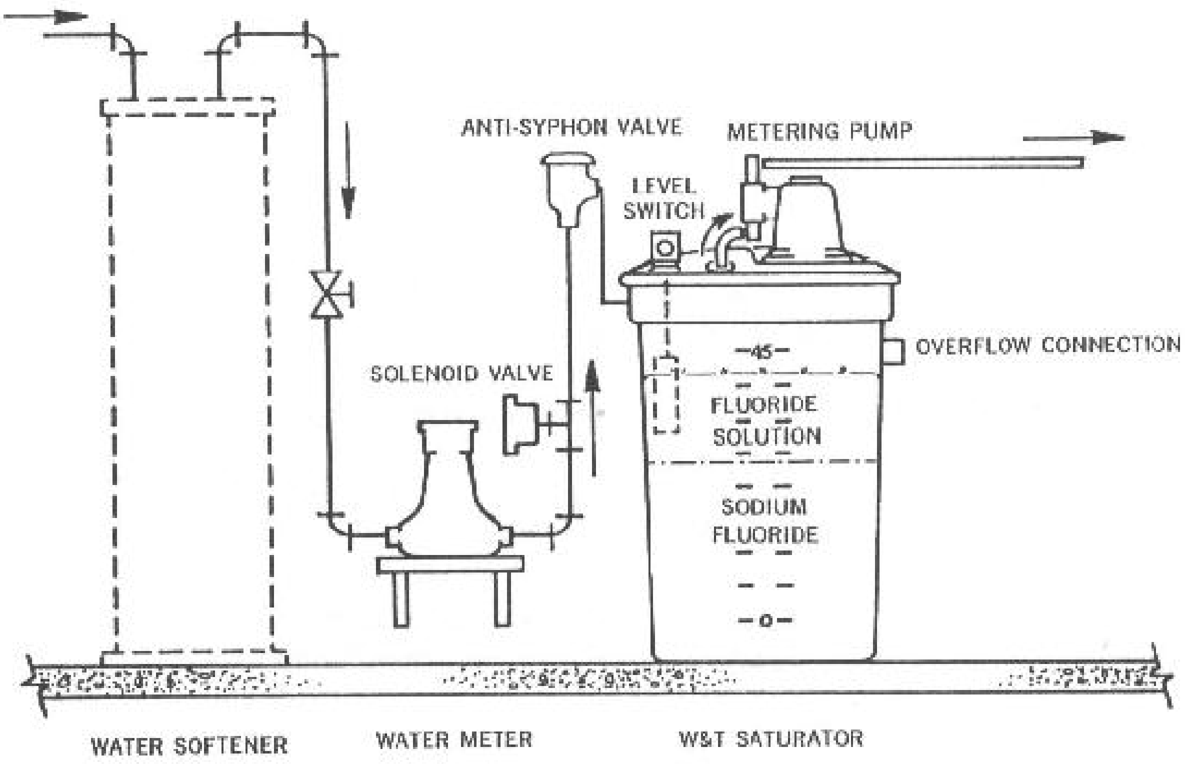
If the pump is operating properly and a high concentration is detected, the cause may be high pump output. The pump setting is too high or the fluoride solution is being siphoned into the water piping. Siphoning is less likely to be the problem since most solutions are added at the discharge side of a well pump against higher pressure. However, siphoning might occur if pressure is lost in the water system. A break box in provided in the feed system to safeguard against excessive feed due to siphoning action.

SODIUM FLUORIDE FEED

In a fluoride saturator, the incoming water becomes saturated with sodium fluoride as it percolates up through the granulated sodium fluoride bed. This provides a 4% sodium fluoride solution. This solution is injected into the water supply at a rate calculated to maintain a fluoride concentration of 1.2 ppm.

Installation

To prevent scale formation, a softener should be used to soften the makeup water for the saturator when the hardness exceeds 75 ppm as calcium carbonate or 4.4 grains. This softened incoming water should then go through a water meter, a solenoid valve, or a flow control valve and a backflow preventer. The water is piped into the saturator through a diffuser system. A constant water level is maintained inside the saturator by means of a float connected to a liquid level switch. The upward flow rate should not exceed 2 gpm. The tank should be filled manually each day while recording the amount used so that the level remains constant.



Operation and Maintenance

To operate the saturator, the following steps should be taken:

- Mark the outside of the saturation tank at the five-inch level. This is the minimum depth of sodium fluoride needed in the tank to maintain a four-percent solution. Add additional sodium fluoride when it reaches this line.
- Turn on the power source for the valves to allow the water to fill the tank and begin to dissolve the sodium fluoride. The flow of water should shut off automatically when the proper level is reached in the saturator. There should be a minimum of 1 foot of water above the sodium fluoride bed.
- Submerge the chemical feed pump suction line just below the water surface and start the pump. Set the pump at the desired feed rate (which will have to be calculated).

The saturator should be cleaned periodically according to the following procedures:

- Allow the system to operate without adding chemical until the fluoride bed is depleted to a point that the diffuser is exposed.

- Disconnect the power to the level control. Allow the chemical pump to run until only about one foot or less of solution remains above the fluoride bed.
- Remove the cover from the saturator.
- Remove the drain plug and allow the tank to drain. Agitation or stirring may be necessary to loosen the hardened material. Be careful not to damage the diffuser. The diffuser assembly can be removed if it is not embedded in the fluoride bed.
- If you are draining to a septic system or gravel pocket from a floor drain you should dilute the solution with running water while draining or, consider draining to a municipal sanitary sewer system.
- Rinse the inside of the tank to remove any built up deposits.

CHEMICAL HANDLING AND SAFETY

Operating a fluoridation system, especially one using hydrofluosilicic acid, involves handling corrosive liquids. Hazards may be reduced greatly by following some simple safety precautions and general housekeeping rules:

- Appropriate personal protective equipment must be used when handling chemicals or working with fluoridation equipment. These include such items as face shields, neoprene goggles, gloves, and aprons.
- Splashed acid is dangerous to the body, especially the eyes. An eye-wash station and deluge shower must be present at all fluorosilicic acid installations, and should be located as close as possible to the fluoridation equipment.
- Keep storage containers and tanks clearly labeled and chemicals separated.
- Keep your chemical area clean and free of obstructions. An accident is less likely in a clean area.

OPERATIONAL REPORTS

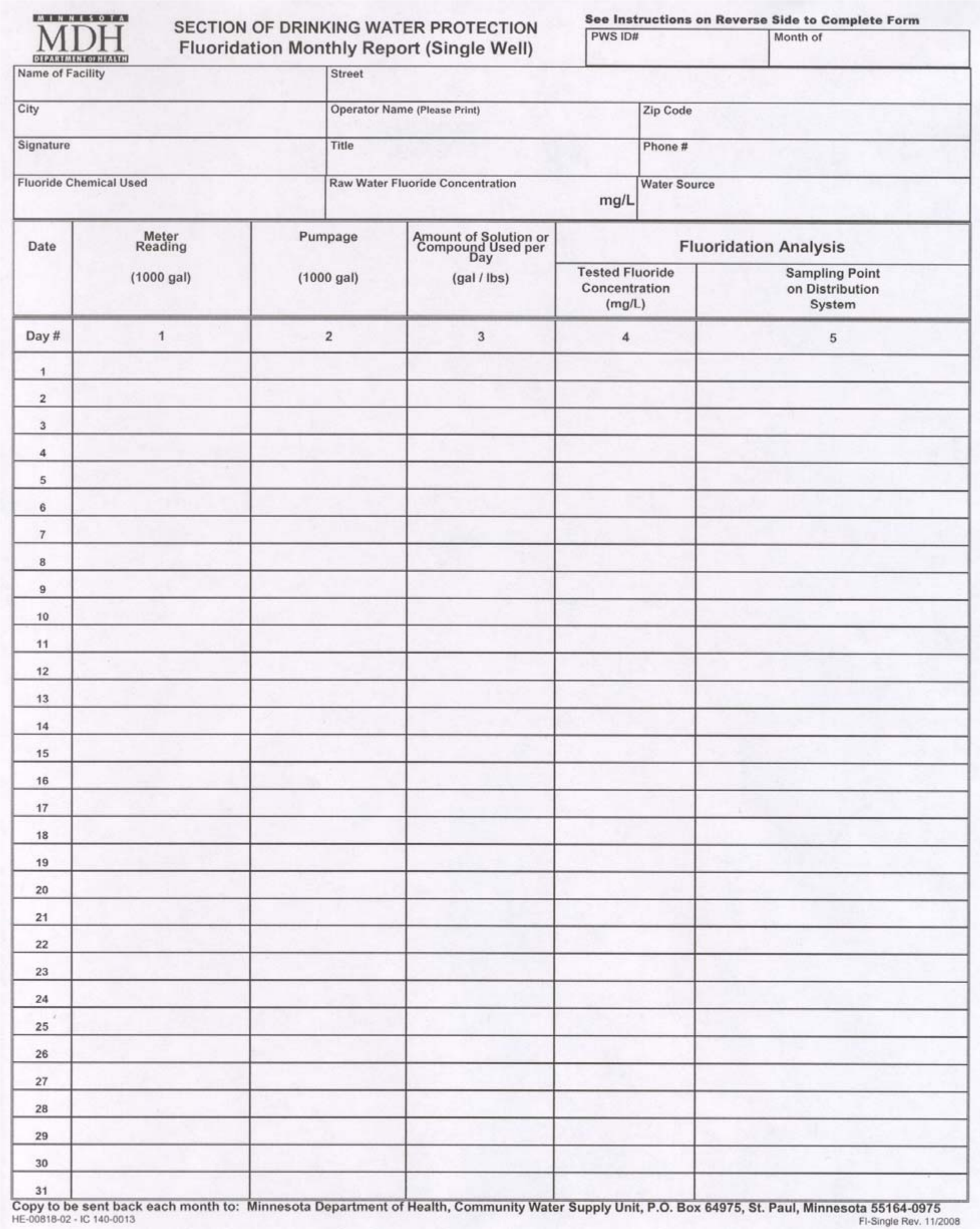
MDH requires a monthly operation report from each water supply regarding operation of fluoridation systems. It is recommended that water systems test the natural background fluoride concentration of their water sources regularly, and perform the following daily.

- Analyze distribution system sample fluoride concentrations.
- Calculate finished water pump flows from meter readings.
- Calculate fluoride amount used.
- Record findings on the MDH Monthly Fluoridation Report, which must be submitted to MDH the beginning of each month.

FLUORIDE TESTING

The SPADNS method, measures the change of color intensity in the SPADNS reagent when a sample containing fluoride is added. The change can be measured by comparison with color standards provided with a SPADNS test kit or by photometric measurements using a color meter. Some chemicals other than fluoride may interfere with the SPADNS test result and cause faulty readings. Polyphosphate is the most common chemical used in drinking water that will give you a false high reading.

Fluoride electrode and a meter indicate the fluoride concentration. Other chemicals usually do not interfere with this test method.



MINNESOTA MDH DEPARTMENT of HEALTH

SECTION OF DRINKING WATER PROTECTION
Fluoridation Monthly Report (Single Well)

See Instructions on Reverse Side to Complete Form

PWS ID#	Month of	
Name of Facility	Street	
City	Operator Name (Please Print)	Zip Code
Signature	Title	Phone #
Fluoride Chemical Used	Raw Water Fluoride Concentration mg/L	Water Source

Date	Meter Reading (1000 gal)	Pumpage (1000 gal)	Amount of Solution or Compound Used per Day (gal / lbs)	Fluoridation Analysis	
				Tested Fluoride Concentration (mg/L)	Sampling Point on Distribution System
Day #	1	2	3	4	5
1					
2					
3					
4					
5					
6					
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8					
9					
10					
11					
12					
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Copy to be sent back each month to: Minnesota Department of Health, Community Water Supply Unit, P.O. Box 64975, St. Paul, Minnesota 55164-0975

HE-00818-02 - IC 140-0013

FI-Single Rev. 11/2008

INSTRUCTIONS FOR FILLING OUT THE FLUORIDATION MONTHLY REPORT (Single Well)

Column Number	
1	**Daily water meter reading in thousands of gallons.**
2	**Pumpage in thousands of gallons: daily meter reading minus the previous day's meter reading.**
3	**The total number of gallons of fluoride solution used per day or the total pounds of fluoride compound used if you are using sodium fluorosilicate.**
4	**Your tested fluoride concentration of the treated water. These tests are to be run daily. Do not composite samples.**
5	**Sample location: the sample is to be taken on the distribution system and at different locations each day.**

NOTE: THE RAW WATER FLUORIDE CONCENTRATION SHOULD BE TESTED MONTHLY.

COMMENTS: ______________________________

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Send Fluoridation Monthly Report (Single Well) to:

Minnesota Department of Health
Community Water Supply Unit
PO Box 64975
Saint Paul, MN 55164-0975

11

Aeration

Aeration brings water and air in close contact in order to remove dissolved gases (such as carbon dioxide) and oxidizes dissolved metals such as iron, hydrogen sulfide, and volatile organic chemicals (VOCs). Aeration is often the first major process at the treatment plant. During aeration, constituents are removed or modified before they can interfere with the treatment processes.

Aeration brings water and air in close contact by exposing drops or thin sheets of water to the air or by introducing small bubbles of air (the smaller the bubble, the better) and letting them rise through the water. The scrubbing process caused by the turbulence of aeration physically removes dissolved gases from solution and allows them to escape into the surrounding air.

Aeration also helps remove dissolved metals through oxidation, the chemical combination of oxygen from the air with certain undesirable metals in the water. Once oxidized, these chemicals fall out of solution and become particles in the water and can be removed by filtration or flotation.

The efficiency of aeration depends on the amount of surface contact between air and water, which is controlled primarily by the size of the water drop or air bubble.

Oxygen is added to water through aeration and can increase the palpability of water by removing the flat taste. The amount of oxygen the water can hold depends primarily on the temperature of the water. (The colder the water, the more oxygen the water can hold).

Water that contains excessive amounts of oxygen can become very corrosive. Excessive oxygen can also cause problems in the treatment plant i.e. air binding of filters.

CHEMICALS REMOVED OR OXIDIZED BY AERATION

Constituents commonly affected by aeration are:

- Volatile organic chemicals, such as benzene (found in gasoline), or trichloroethylene, dichloroethylene, and perchloroethylene (used in dry-cleaning or industrial processes)
- Ammonia
- Chlorine
- Carbon dioxide
- Hydrogen sulfide
- Methane
- Iron and Manganese

Carbon Dioxide

Surface waters have low carbon dioxide content, generally in the range of 0 to 2 mg/l. Water from a deep lake or reservoir can have high carbon dioxide content due to the respiration of microscopic animals and lack of abundant plant growth at the lake bottom.

Concentration of carbon dioxide varies widely in groundwater, but the levels are usually higher than in surface water. Water from a deep well normally contains less than 50 mg/l, but a shallow well can have a much higher level, up to 50 to 300 mg/l.

Excessive amounts of carbon dioxide (above 5-15 mg/L) in raw water can cause three operating problems:

- Increases the acidity of the water, making it corrosive. Carbon dioxide forms a “weak” acid, H_2C0_3 (carbonic acid).
- Tends to keep iron in solution, thus making iron removal more difficult.
- Reacts with lime added to soften water, causing an increase in the amount of lime needed for the softening reaction.

Most aerators can remove carbon dioxide by the physical scrubbing or sweeping action caused by turbulence. At normal water temperatures, aeration can reduce the carbon dioxide content of the water to as little as 4.5 mg/l.

Hydrogen Sulfide

Hydrogen sulfide can present dangerous problems in water treatment. Brief exposures (less than 30 minutes) to hydrogen sulfide can be fatal if the gas is breathed in concentrations as low as 0.03 percent by volume in the air. The Immediate Dangerous to Life and Health level for hydrogen sulfide is 300 ppm.

Hydrogen sulfide occurs mainly in groundwater supplies, and may be caused by the action of iron or sulphur reducing bacteria in the well. The rotten-egg odor often noticed in well waters is caused by hydrogen sulfide. Hydrogen sulfide in a water supply will disagreeably alter the taste of coffee, tea, and ice. Occasional disinfection of the well can reduce the bacteria producing the hydrogen sulfide.

Serious operational problems occur when the water contains even small amounts of hydrogen sulfide:

- Disinfection of the water can become less effective because of chlorine demand exerted by the hydrogen sulfide.
- Corrosion to piping systems and the water tanks, water heaters, and copper alloys.

Aeration is the most common choice for removal of hydrogen sulfide from water. Hydrogen sulfide has a low boiling point and vaporizes easily. The turbulence from the aerator will easily displace the gas from the water; however the designer of the system needs to consider how the gas is discharged from the aerator. If the gas accumulates directly above the water, the process will be slowed and corrosive conditions can be created.

Methane

Methane is a colorless gas that is highly flammable and explosive and can be found in groundwater. It may be formed by the decomposition of organic matter. It can be found in water from aquifers that are near natural-gas deposits. Methane tends to make the water taste like garlic. The gas is only slightly soluble in water, has a low boiling point, vaporizes easily, and therefore is easily removed by the aeration of the water.

Iron and Manganese

Iron and manganese minerals are commonly found in soil and rock and can dissolve into groundwater as it percolates through soil and rock.

Water containing more than 0.3 mg/l of iron will cause yellow to reddish-brown stains of plumbing fixtures or almost anything that it contacts. If the concentration exceeds 1 mg/l, the taste of the water will be metallic and the water may be turbid.

Manganese in water, even at levels as low as 0.1 mg/l, will cause blackish staining of fixtures and anything else it contacts. Manganese concentration levels that can cause problems are 0.1 mg/l and above.

If the water contains both iron and manganese, staining could vary from dark brown to black. Typical consumer complaints are that laundry is stained and that the water is red or dirty. Water containing iron and manganese should not be aerated unless filtration is provided.

Oils and Algae By-Products

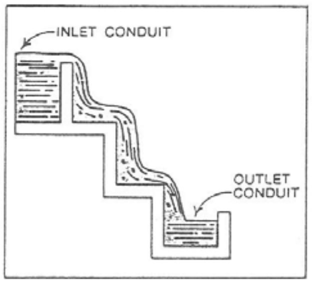
Many taste and odor problems in surface water could be caused by oils and by-products that algae produce. Since oils are much less volatile than gases, aeration is only partially effective in removing them.

TYPES OF AERATORS

Aerators fall into two categories. They either introduce air to water, or water to air. The water-in-air method is designed to produce small drops of water that fall through the air. The air-in-water method creates small bubbles of air that are injected into the water stream. All aerators are designed to create a greater amount of contact between air and water to enhance the transfer of gases and increase oxidation.

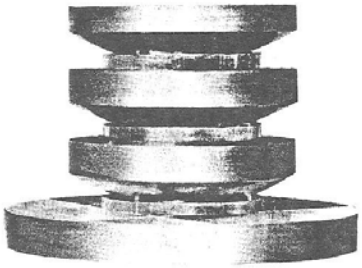
Water-Into-Air Aerators

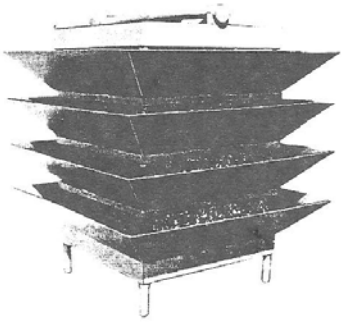
Cascade Aerators
A cascade aerator (one of the oldest and most common aeratrors) consists of a series of steps that the water flows over (similar to a flowing stream). In all cascade aerators, aeration is accomplished in the splash zones. Splash zones are created by placing blocks across the incline. (They are the oldest and most common type of aerators.) Cascade aerators can be used to oxidize iron and to partially reduce dissolved gases.



Cone Aerators

Cone aerators are used primarily to oxidize iron and manganese from the ferrous state to the ferric state prior to filtration. The design of the aerator is similar to the cascade type, with the water being pumped to the top of the cones and then being allowed to cascade down through the aerator.



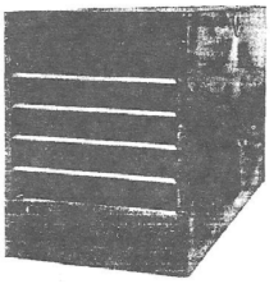


Slat and Coke Aerators

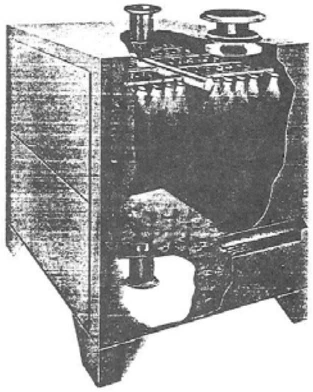
Slat and coke trays are similar to the cascade and cone aerators. They usually consist of three-to-five stacked trays, which have spaced wooden slats in them. The trays are then filled with fist-sized pieces of coke, rock, ceramic balls, limestone, or other materials. The primary purpose of the materials is providing additional surface contact area between the air and water.

Draft Aerators

Draft aerators are similar to other water-into-air aerators, except that the air is induced by a blower. There are two basic type of draft aerators. One has external blowers mounted at the bottom of the tower to induce air from the bottom of the tower. Water is pumped to the top and allowed to cascade down through the rising air. The other, an induced-draft aerator, has a top-mounted blower forcing air from bottom vents up through the unit to the top. Both types are effective in oxidizing iron and manganese before filtration.



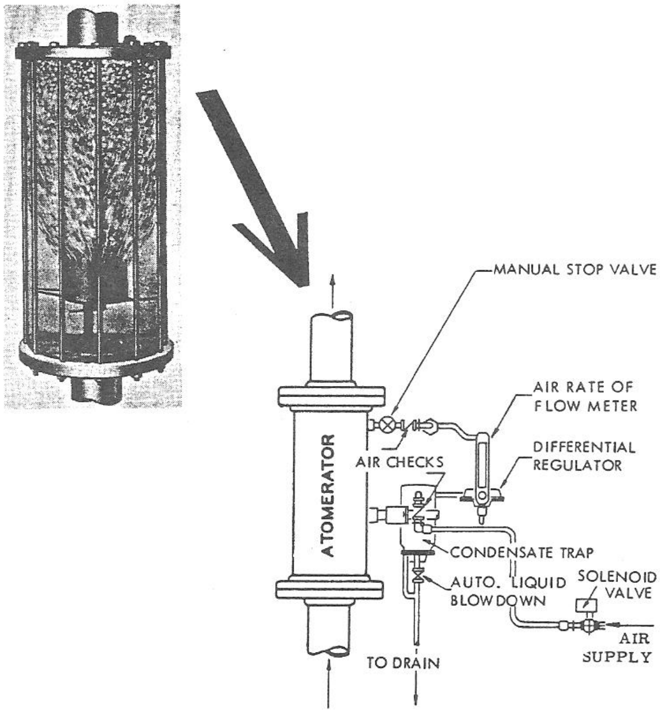
Spray Aerators



Spray aerators have one or more spray nozzles connected to a pipe manifold. Water moves through the pipe under pressure, and leaves each nozzle in a fine spray and falls through the surrounding air, creating a fountain affect. Spray aeration is successful in oxidizing iron and manganese and increases the dissolved oxygen in the water.

Air-Into-Water Aerators

Pressure Aerators



There are two basic types of pressure aerators. One uses a pressure vessel; where water to be treated is sprayed into high-pressure air, allowing the water to quickly pick up dissolved oxygen.

The other is a pressure aerator commonly used in pressure filtration Air is injected into the raw water piping and allowed to stream into the water as a fine bubble, causing the iron to be readily oxidized.

The higher the pressure, the more readily the transfer of the oxygen to the water. The more oxygen that is available, the more readily the oxidation of the iron or manganese.

Centrifugal Aerators

Centrifugal aerators create enhanced conditions for dissolving gas into liquid phase, including bubble size, and bubble size distribution and duration of interaction with liquid. Centrifugal aerators combine several elements: 1. High turbulence swirling flow of liquid; 2. Orthogonal flow of liquid and gas; 3. Constant pressure inside the vessel; 4. Optimum flow velocity generating centrifugal forces thereby extending diffusion rate within the vessel; and 5. Very small pores, through which gas permeates into the liquid and is sheered off into liquid phase, thereby forming small bubbles.

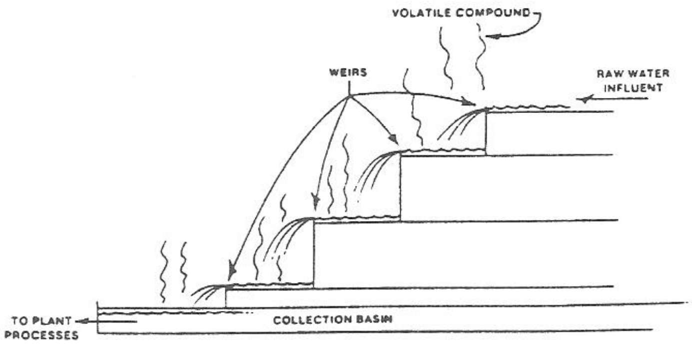
AIR STRIPPING

Air stripping can be quite effective in removing volatile organic chemicals (VOCs) from water.

Air stripping has been shown to be capable of removing up to 90 percent of the most highly volatile VOCs. Water flows over cascade aerators, or in specially designed air-stripping towers. In the air stripping towers, water flows down over a support medium or packing, while air is being pumped into the bottom of the tower.

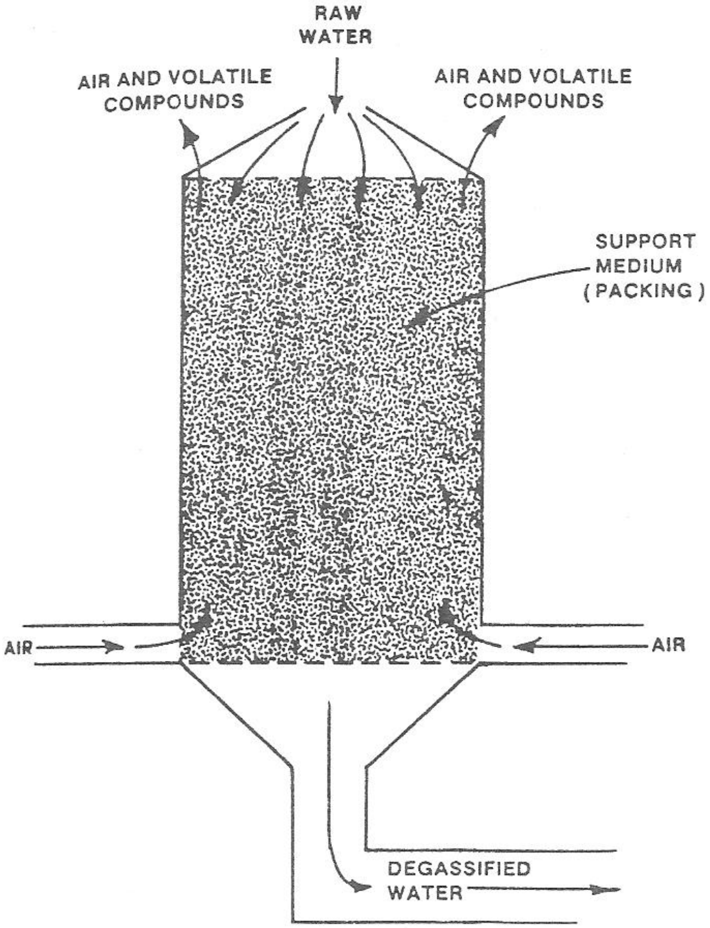
OPERATING CONSIDERATIONS

Aeration raises the dissolved oxygen content of the water. If too much oxygen is injected into the water, the water becomes supersaturated, which may cause corrosion or air binding in filters. Other problems with aeration may include slow removal of the hydrogen sulfide from the towers, algae production, clogged filters, and overuse of energy in some aerators.



Corrosion

A certain amount of dissolved oxygen is present in raw and treated waters. However, dissolved oxygen can cause corrosion. Corrosion can occur whenever water and oxygen come into contact with metallic surfaces. Generally, the higher the dissolved oxygen concentration, the more rapid the corrosion. The solution to this problem is to not over-aerate. This may be difficult because no definite rule exists as to what constitutes over-aeration. The amount of aeration needed will vary from plant to plant and will also vary with the season.



False Clogging of Filters (Air Binding)

Filters in water containing a high amount of dissolved oxygen will have a tendency to release the oxygen in the filter as it passes through. The process can continue until the spaces between the filter media particles begin to fill with bubbles. Called air binding, this causes the filter to behave as though it is plugged and in need of backwashing.

Slow Removal of Hydrogen Sulfide

Hydrogen sulfide is most efficiently removed, not by oxidation, but by the physical scrubbing action of aeration. This removal is dependent on the pH of the water. At a pH of 6 or less, the hydrogen sulfide is easily removed. If the water has a high pH, the hydrogen sulfide will ionize, precluding removal by aeration.

Three basic control tests are required for aeration:

- Dissolved oxygen - The concentration of dissolved oxygen can be used to determine if the water is over or under-aerated. The pH test will give an indication of the amount of carbon dioxide removed.
- pH - pH increases as carbon dioxide is removed. pH can also be used to monitor the effective range for hydrogen sulfide, iron, and manganese removal.
- Temperature - The saturation point of oxygen increases as the temperature decreases. As water temperature drops, the operator must adjust the aeration process to maintain the correct dissolved oxygen level.

Notes:

Coagulation and Flocculation

Groundwater and surface water contain both dissolved and suspended particles. Coagulation and flocculation are used to separate the suspended solids portion from the water.

Suspended particles vary in source, charge, particle size, shape, and density. Correct application of coagulation and flocculation depends upon these factors. Suspended solids in water have a negative charge and since they have the same type of surface charge, they repel each other when they come close together. Therefore, suspended solids will remain in suspension and will not clump together and settle out of the water, unless proper coagulation and flocculation is used.

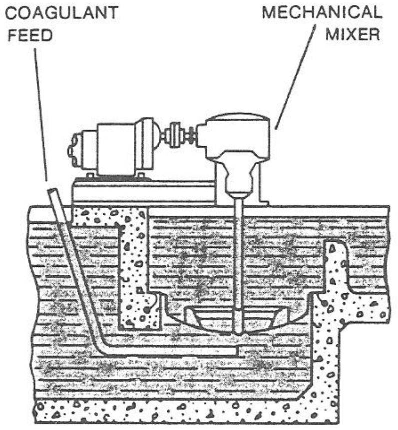
Coagulation and flocculation occurs in successive steps, allowing particle collision and growth of floc. This is then followed by sedimentation (see Sedimentation Chapter). If coagulation is incomplete, flocculation step will be unsuccessful, and if flocculation is incomplete, sedimentation will be unsuccessful.

COAGULATION

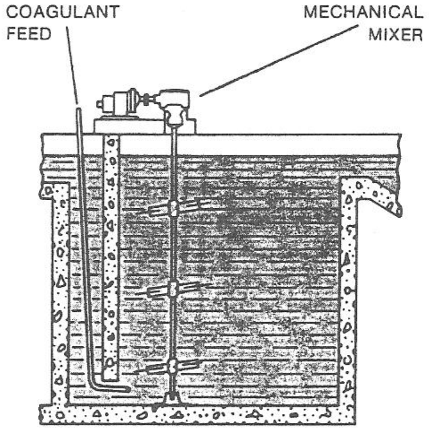
Coagulant chemicals with charges opposite those of the suspended solids are added to the water to neutralize the negative charges on non-settlable solids (such as clay and color-producing organic substances).

Once the charge is neutralized, the small suspended particles are capable of sticking together. These slightly larger particles are called microflocs, and are not visible to the naked eye. Water surrounding the newly formed microflocs should be clear. If not, coagulation and some of the particles charge have not been neutralized. More coagulant chemicals may need to be added.

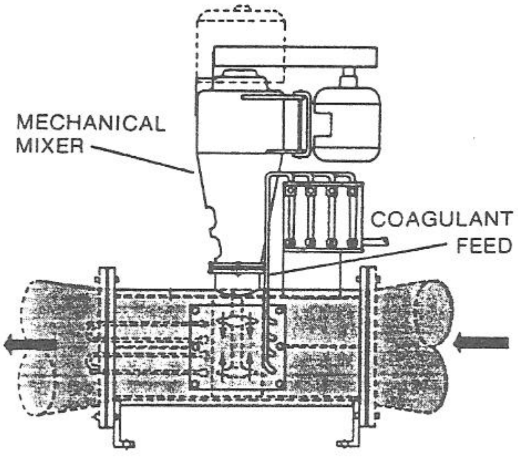
A high-energy, rapid-mix to properly disperse coagulant and promote particle collisions is needed to achieve good coagulation. Over-mixing does not affect coagulation, but insufficient mixing will leave this step incomplete. Contact time in the rapid-mix chamber is typically 1 to 3 minutes.



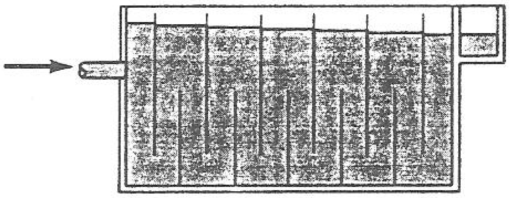
Mechanical Mixing Chamber



Mechancial Mixing Chamber



In-Line Mixer

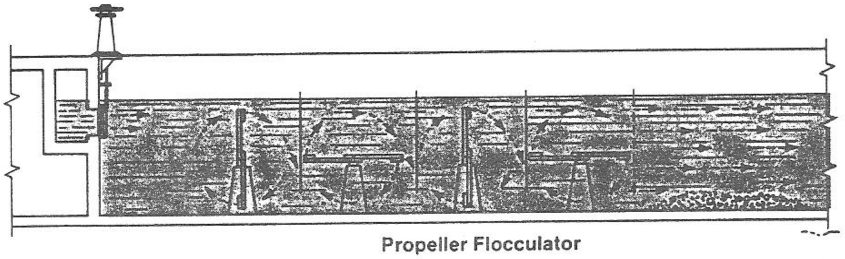


Baffled Chamber

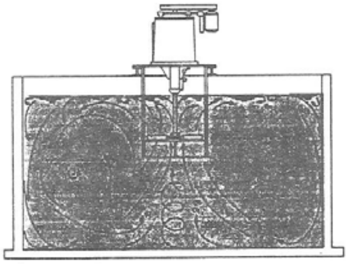
FLOCCULATION

Flocculation, a gentle mixing stage, increases the particle size from submicroscopic microfloc to visible suspended particles. Microfloc particles collide, causing them to bond to produce larger, visible flocs called pinflocs. Floc size continues to build with additional collisions and interaction with added inorganic polymers (coagulant) or organic polymers. Macroflocs are formed and high molecular weight polymers, called coagulant aids, may be added to help bridge, bind, and strengthen the floc, add weight, and increase settling rate. Once floc has reached it optimum size and strength, water is ready for sedimentation.

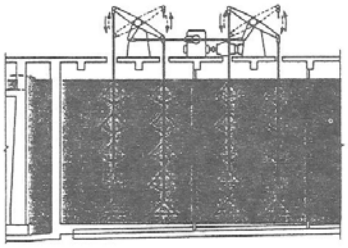
Design contact times for flocculation range from 15 or 20 minutes to an hour or more, and flocculation requires careful attention to the mixing velocity and amount of mix energy. To prevent floc from tearing apart or shearing, the mixing velocity and energy are usually tapered off as the size of floc increases. Once flocs are torn apart, it is difficult to get them to reform to their optimum size and strength. The amount of operator control available in flocculation is highly dependent upon the type and design of the equipment.



Propeller Flocculator



Turbine Flocculator

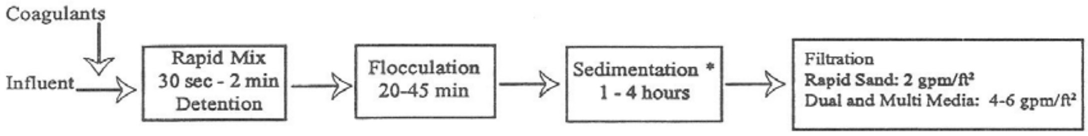


Walking Beam Flocculator

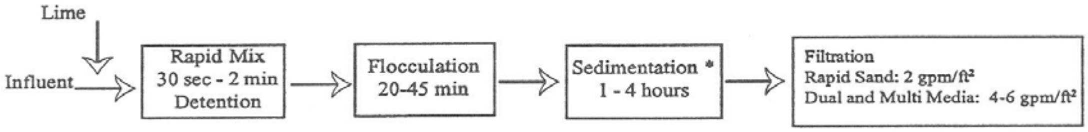
CONVENTIONAL PLANTS

Conventional plants separate coagulation (or rapid-mix) stage from flocculation (or slow-mix) stage. These stages are followed by sedimentation, and then filtration. Plants designed for direct filtration route water directly from flocculation to filtration. These systems typically have a higher raw-water quality. Conventional plants can have adjustable mixing speeds in both the rapid-mix and slow-mix equipment. Multiple feed points for coagulants, polymers, flocculants, and other chemicals can be provided and there is generally enough space to separate the feed points for incompatible chemicals.

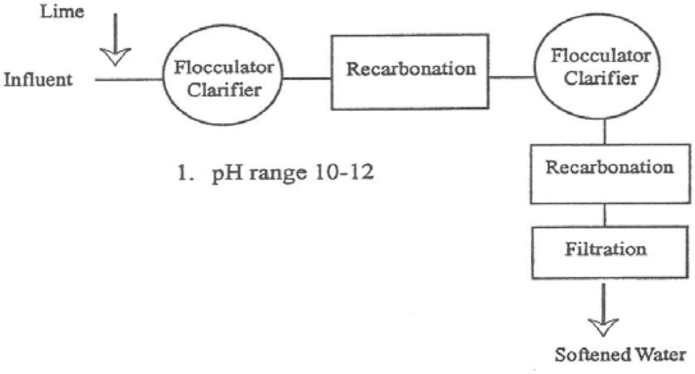
Conventional plants have conservative retention times and rise rates. This usually results in requirements for large process basins and a large amount of land for the plant site. On-site pilot plant evaluation, by a qualified engineer familiar with the water quality, is recommended prior to design.



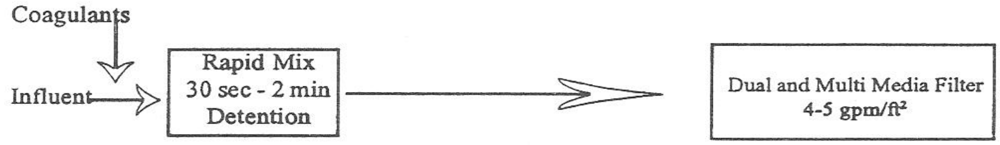
*or alternate solids removal process



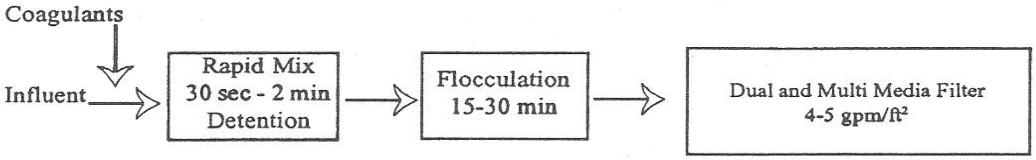
1. pH range 9-10
2. Or alternate solids removal process



1. pH range 10-12



*or alternate solids removal process



Retention (or detention) time is the amount of time that water spends in a process. It is calculated by dividing the liquid volume (in gallons) of a basin by the plant flow rate (gallons per minute). Actual detention time in a basin will be less than the calculated detention time because of "dead areas" and short circuiting, which could be due to inadequate baffling.

$$\text{Retention time} = \frac{\text{basin volume (gallons)}}{\text{gpm flow}}$$

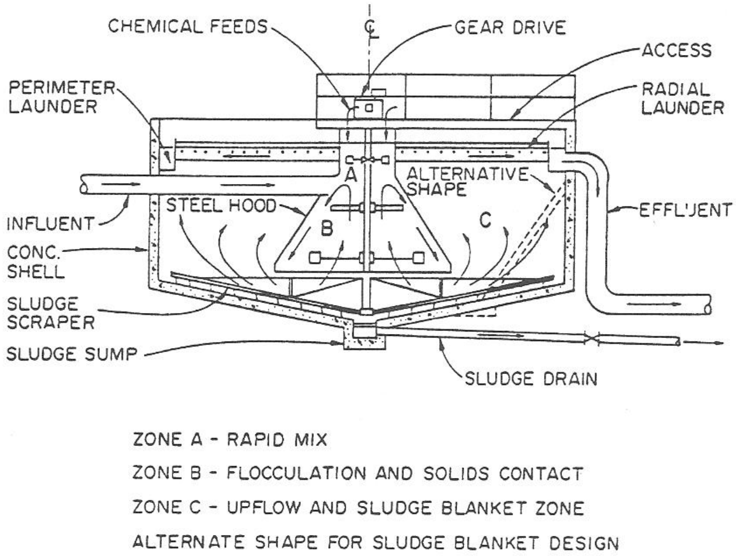
Rise rate is calculated by dividing the flow in gallons per minute by the net water surface area of the basin in square feet.

$$\text{Rise Rate} = \frac{\text{gpm flow}}{\text{surface area}}$$

COAGULATION, FLOCCULATION, AND SEDIMENTATION COMBINED

Some designs incorporate coagulation, flocculation, and sedimentation a single unit (either upflow solids contact units or sludge blanket units). Most upflow solids contact units use recirculation of previously formed floes to enhance floc formation and maximize usage of treatment chemicals. Sludge blanket units force newly forming flocs to pass upward through a suspended bed of floc.

In both styles of units, the cross-sectional surface of the basin increases from bottom to top, causing water flow to slow as it rises, and allowing floc to settle out. Combination units generally use higher rise rates and shorter detention time than conventional treatment. Numerous manufacturers market proprietary units based on these design concepts. These units are more compact and require less land for plant site location. On-site pilot plant evaluation, by a qualified engineer familiar with the water quality, is recommended prior to design.



Typical proprietary design of solids contact reactor unit.

COAGULANT SELECTION

The choice of coagulant chemical depends upon the type of suspended solid to be removed, raw water conditions, facility design, and cost of chemical. Final selection of coagulant (or coagulants) should be made with jar testing and plant scale evaluation. Consideration must be given to required effluent quality, effect upon down stream treatment process performance, cost, method and cost of sludge handling and disposal, and cost of the dose required for effective treatment.

Inorganic Coagulants

Inorganic coagulants such as aluminum and iron salts are the most commonly used. When added to water, these highly charged ions to neutralize the suspended particles. The inorganic hydroxides that are formed produce short polymer chains which enhance microfloc formation.

Inorganic coagulants usually offer the lowest price per pound, are widely available, and, when properly applied, are effective in removing most suspended solids. They are also capable of removing a portion of the organic precursors which may combine with chlorine to form disinfection by-products. Inorganic coagulants produce large volumes of floc which can also entrap bacteria as they settle.

Inorganic coagulants may alter the pH of the water since they consume alkalinity. When applied in a lime soda ash softening process, alum and iron salts generate demand for lime and soda ash. They also require corrosion-resistant storage and feed equipment. It is important to note that large volumes of settled floc must be disposed of in an environmentally acceptable manner.

Alum, ferric sulfate, and ferric chloride, lower the alkalinity, and pH reactions for each follow:

Alum

$$A1_2(SO_4)_3 + 3\,Ca(HCO_3)_2 \dashrightarrow 2\,Al(OH)_3 + 3CaSO_4 + 6\,CO_2$$

Aluminum Sulfate	+	Calcium Bicarbonate (present in the water to treat)	gives	Aluminum Hydroxide	+	Calcium Sulfate	+	Carbon Dioxide

Ferric Sulfate

$$Fe_2(SO_4)_3 + 3\,Ca(HCO_3)_2 \dashrightarrow 2\,Fe(OH)_3 + 3CaSO_4 + 6\,CO_2$$

Ferric Sulfate	+	Calcium Bicarbonate (present in the water to treat)	gives	Ferric Hydroxide	+	Calcium Sulfate	+	Carbon Dioxide

Ferric Chloride

$$2\,Fe\,Cl_3 + 3\,Ca(HCO_3)_2 \dashrightarrow 2\,Fe(OH)_3 + 3CaCl_2 + 6CO_2$$

Ferric Chloride	+	Calcium Bicarbonate (present in the water to treat)	gives	Ferric Hydroxide	+	Calcium Chloride	+	Carbon Dioxide

Polymers

Polymers (long-chained, high-molecular-weight, organic chemicals) are becoming more widely used. These can be used as coagulant aids along with the regular inorganic coagulants. Anionic (negatively charged) polymers are often used with metal coagulants. Low-to-medium weight cationic (positively charged) polymers may be used alone, or in combination with alumor ferric coagulants to attract suspended solids and neutralize their surface charge. Manufacturers can produce a wide range of polymers that meet a variety of source-water conditions by controlling the amount and type of charge and the polymers molecular weight.

Polymers are effective over a wider pH range than inorganic coagulants. They can be applied at lower doses, and do not consume alkalinity. They produce smaller volumes of more concentrated, rapidly settling floc. Floc formed from use of a properly selected polymer will be more resistant to shear, resulting in less carryover and a cleaner effluent.

Polymers are generally several times more expensive in price per pound than inorganic coagulants. Selection of the proper polymer requires considerable jar testing under simulated plant conditions, followed by pilot or plant-scale trials. All polymers must also be approved for potable water use by regulatory agencies.

Sedimentation

Sedimentation, or clarification, is the processes of letting suspended material settle by gravity. Suspended material may be particles, such as clay or silts, originally present in the source water. Suspended material or floc is typically created from materials in the water and chemicals used in coagulation or, in other treatment processes, such as lime softening (see Lime Softening chapter).

Sedimentation is accomplished by decreasing the velocity of the water to a point which the particles will no longer remain in suspension. When the velocity no longer supports the particles, gravity will remove them from the water flow.

PARTICLE SIZE

The size and type of particles to be removed have a significant effect on the operation of the sedimentation tank. Sand or silt can be removed very easily because of their density. The velocity of the water-flow channel can be slowed to less than one foot per second and most of the sand and silt will be removed by simple gravitational forces. In contrast, colloidal material (small particles that stay in suspension and make the water seem cloudy) will not settle until the material is coagulated and flocculated by adding a chemical, such as iron salt or aluminum sulfate.

The shape of the particle also affects its settling characteristics. A round particle, for example, will settle much more readily than a particle that has ragged or irregular edges. All particles also tend to have a slight electrical charge. Particles with the same charge tend to repel each other. This repelling action keeps the particles from congregating into flocs and settling.

WATER TEMPERATURE

When water temperature decreases, the rate of settling becomes slower. The result is that, as the water cools, detention time in the sedimentation tank must increase and the operator must make changes to the coagulant dosage to compensate for the decreased settling rate. In most cases, temperature does not have a significant effect on treatment. A water treatment plant has the highest flow demand in the summer when the temperatures are highest and settling rates are the best. When water is colder, the flow in the plant is at its lowest and, in most cases; detention time in the plant is increased so floc has time to settle in the sedimentation basin.

CURRENTS

Several types of water currents may occur in the sedimentation basin. Density currents are caused by the weight of solids, the concentration of solids, and the temperature of the water. Eddy currents are produced by the velocity and flow of the water coming into the basin and leaving the basin. Currents can be beneficial in that they promote sedimentation of the particles. However, currents also tend to distribute floc unevenly throughout the basin; as a result, do settle at an even rate. Current problems can be reduced by proper design of the basin and installation of baffles can help prevent currents from short circuiting the basin.

SEDIMENTATION BASIN ZONES

Most sedimentation tanks are divided into these separate zones:

Inlet Zone

The inlet or influent zone should distribute flow uniformly across the inlet to the tank. The normal design includes baffles that gently spread the flow across the total inlet of the tank and prevent short circuiting in the tank. (Short circuiting is the term used for a situation in which part of the influent water exits the tank too quickly, by flowing across the top or along the bottom of the tank.) The baffle is sometimes designed as a wall across the inlet, with holes perforated across the width of the tank.

Settling Zone

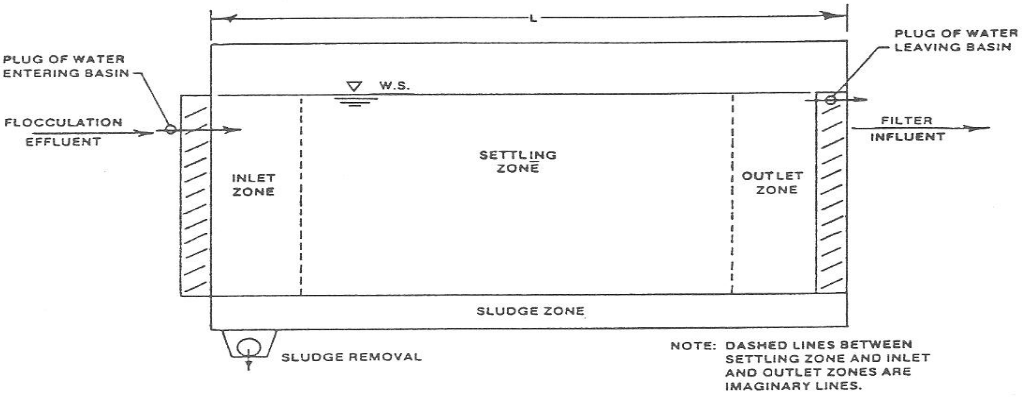
The settling zone is the largest portion of the sedimentation basin. This zone provides the calm area necessary for the suspended particles to settle.

Sludge Zone

The sludge zone, located at the bottom of the tank, provides a storage area for the sludge before it is removed for additional treatment or disposal. Basin inlets should be designed to minimize high flow velocities near the bottom of the tank. If high flow velocities are allowed to enter the sludge zone, the sludge could be swept up and out of the tank. Sludge is removed for further treatment from the sludge zone by scraper or vacuum devices which move along the bottom.

Outlet Zone

The basin outlet zone (or launder) should provide a smooth transition from the sedimentation zone to the outlet from the tank. This area of the tank also controls the depth of water in the basin. Weirs set at the end of the tank control the overflow rate and prevent the solids from rising to the weirs and leaving the tank before they settle out. The tank needs enough weir length to control the overflow rate, which should not exceed 20,000 gallons per day per foot of weir.



Sedimentation basin zones

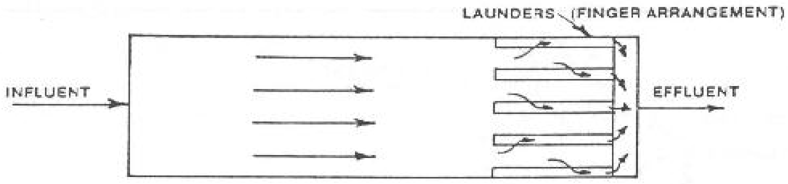
SELECTION OF BASIN

There are many sedimentation basin shapes including rectangular, circular, and square.

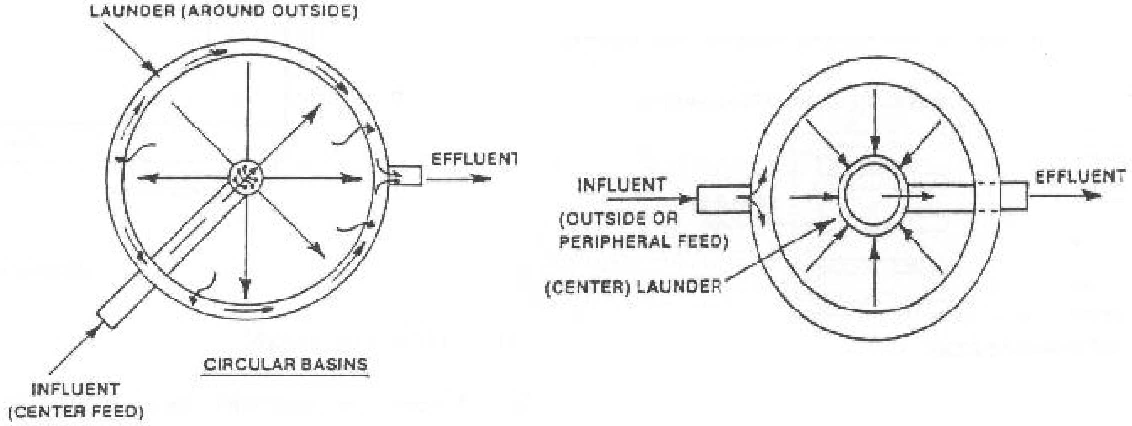
Rectangular Basins

Rectangular basins are commonly found in large-scale water treatment plants. Rectangular tanks are popular as they tend to have:

- High tolerance to shock overload
- Predictable performance
- Cost effectiveness due to lower construction cost
- Lower maintenance
- Minimal short circuiting



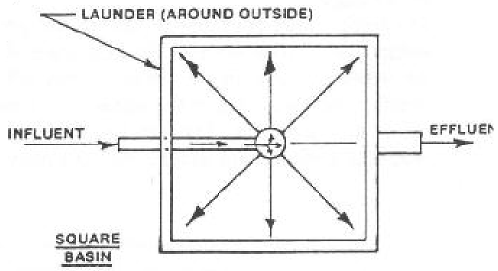
RECTANGULAR BASIN



CIRCULAR BASINS

Circular and Square Basins

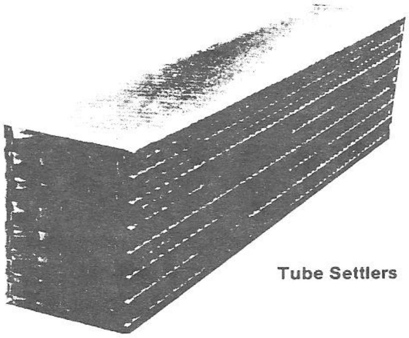
Circular basins are often referred to as clarifiers. These basins share some of the performance advantages of the rectangular basins, but are generally more prone to short circuiting and particle removal problems. For square tanks the design engineer must be certain that some type of sludge removal equipment for the corners is installed.

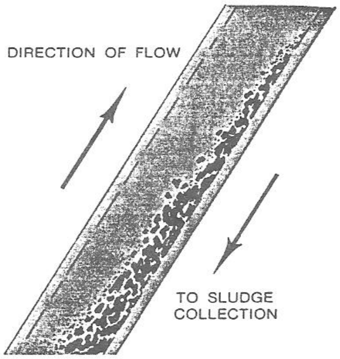


SQUARE BASIN

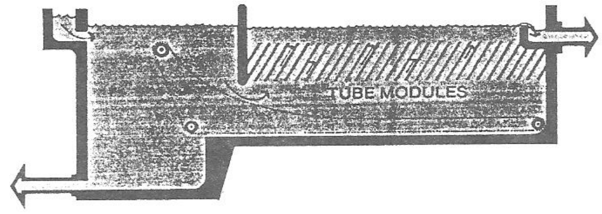
HIGH-RATE TUBE SETTLERS

High rate tube settlers are designed to improve the characteristics of the rectangular basin and to increase flow through the tank. The tube settlers consist of a series of tubes that are installed at a 60 degree angle to the surface of the tank. The flow is directed up through the settlers. Particles have a tendency to flow at an angle different than the water and to contact the tube at some point before reaching the top of the tube. After particles have been removed from the flow and collected on the tubes, they tend to slide down the tube and back into the sludge zone.

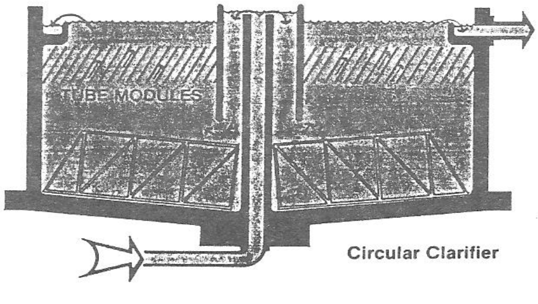

Tube Settlers



Counter-Current Flow in Tubes



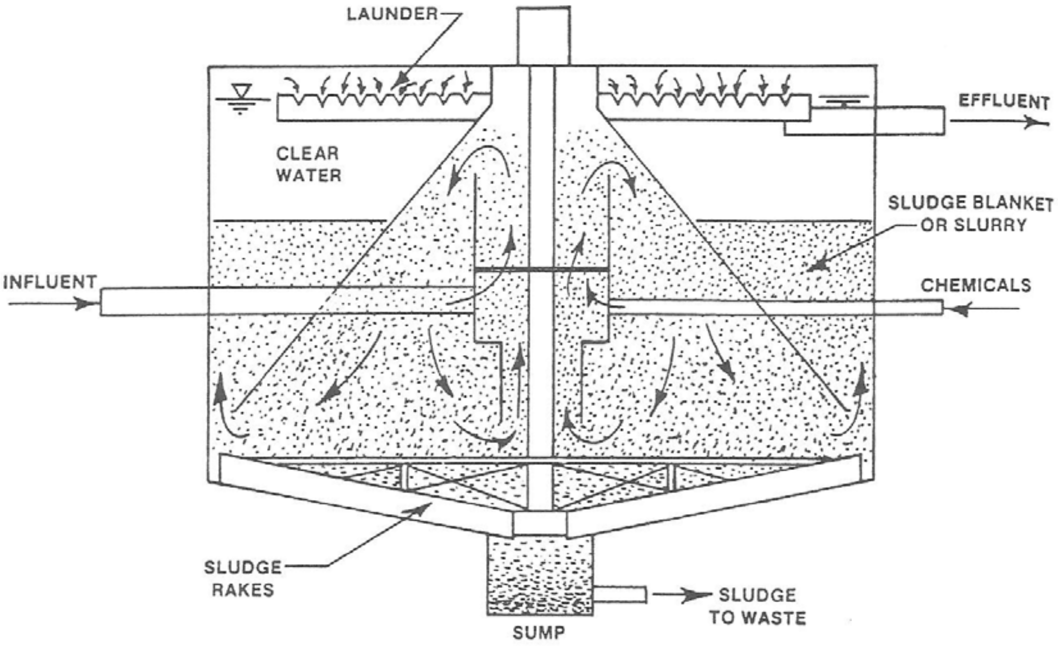
Rectangular Clarifier



Circular Clarifier

SOLIDS CONTACT UNIT

A solids contact unit combines coagulation, flocculation, and sedimentation in one unit. These units are also called upflow clarifiers or sludge-blanket clarifiers. These units are used primarily with lime-soda ash to settle floc formed during water softening. Flow is usually in an upward direction through a sludge blanket or slurry of flocculated suspended solids.



Solids-contact unit

NOTES:

Iron and Manganese

Iron and manganese control is the most common type of municipal water treatment in Minnesota. Iron and manganese occur naturally in groundwater. Neither element causes adverse heath effects at concentrations typically found in Minnesota. These elements are, in fact, essential to the human diet.

Water containing excessive amounts of iron and manganese can stain clothes, discolor plumbing fixtures, and sometimes add a “rusty” taste and look to the water. Surface water generally does not contain large amounts of iron or manganese, but iron and manganese are found frequently in water systems that use groundwater.

The Safe Drinking Water Act secondary standards (aesthetic, not health related) for iron in drinking water is 0.3 parts per million (ppm) and 0.05 ppm for manganese. If water contains more than 0.05 ppm iron, or 0.01 ppm manganese, the operator should implement an effective hydrant-flushing program in order to avoid customer complaints.

BACTERIA AND IRON AND MANGANESE

Iron and manganese in water also promote the growth of bacteria (including iron bacteria). These organisms obtain energy for growth from the chemical reaction that occurs when iron and manganese mix with dissolved oxygen. These bacteria form thick slime growths on the walls of the piping system and on well screens. These shines tend to be are rust-colored from iron and black-colored from manganese. Variations in flow can cause these slime growths to separate from pipe walls, resulting in dirty water in the system.

The growth of iron bacteria can be controlled by chlorination. However, when water containing iron is chlorinated, the iron is converted from the ferrous state to the ferric state--in other words, rust--and manganese is converted into black manganese dioxide. These materials form a coating on the inside of the water main and, when they break loose, a customer will sometimes complain of “dirty” water.

Iron bacteria will use even small amounts of iron present in the ferrous state, oxidize it, and then use the energy. Manganese is also used by other bacteria to form organics, which contribute to the iron bacteria slime in the well and/or water system.

Iron bacteria are found any where a food source of iron is available. The presence of one bacterium is all that is needed to start an infestation in a well or a distribution system.

IRON AND MANGANESE CONTROL

Methods to control iron and manganese in distribution systems include arranging for alternate water sources, adding phosphate to the water to keep iron and manganese in solution, and oxidizing and removing both by filtration.

Alternate Sources

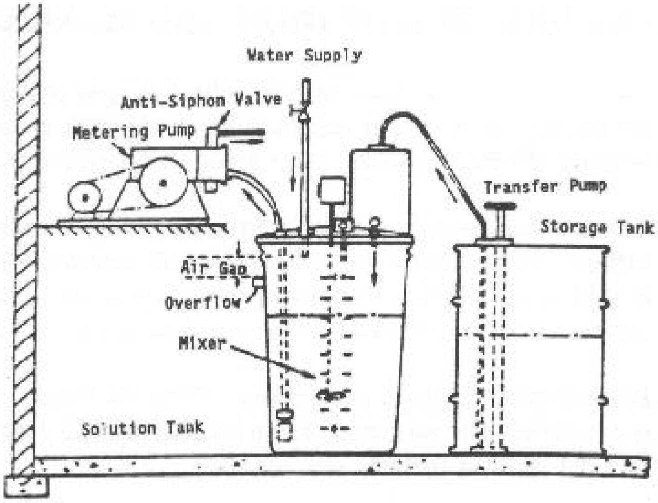
In some situations, abandoning a well and drilling a new one into an aquifer with a lower iron or manganese concentration may be cost-effective. It may also be possible to blend the water from the well with the high concentrations with water from another source with lower concentrations.

Phosphate Treatment

Phosphate can be added at the source to mask the effects of elevated iron concentrations in the distribution system. This is effective when the water contains less than 0.3 ppm of iron or 0.1 ppm of manganese. Phosphate delays the precipitation of oxidized manganese and iron, thereby greatly reducing the layer of scale that forms on the pipe. The effect is called sequestration. The iron or manganese ion is surrounded by a chain of phosphate molecules and is not allowed to precipitate in the water.

Pyrophosphate, tripolyphosphate, and metaphosphate may be effective as iron and manganese sequestering agents. However, the most effective seems to be sodium phosphate in low concentrations. The proper dose and type of phosphate should be selected only after bench-scale testing is performed by a qualified technician or consultant.

Phosphate feed points should be separated from the chlorine injection point by as much distance as possible. The phosphate feed point should also be ahead of the chlorine injection point. If phosphate is fed after chlorine, there is a possibility the iron and manganese will be oxidized by the chlorine before sequestering can take place causing iron and manganese precipitates to be pumped out into the distribution system.



Feed equipment used for phosphate addition is similar to equipment used to feed fluoride. It consists of a storage tank, solution tank, feed pump, and controller to pace the feed rate. The storage tank and solution tank must contain at least 10 ppm of free chlorine residual to prevent bacterial growth in the phosphate solution (phosphate is an excellent food source for bacteria).

Phosphate solutions can be made up from powder in a saturator similar to the one used to make dry-fluoride solutions (see Fluoridation). Phosphate solutions containing more than one-half pound of phosphate per gallon (60 ppm) may be very viscous. It is important that any solution be fed within 48 hours of its production. Polyphosphates tend to break down into orthophosphate, which is much less effective in preventing manganese deposits.

The amount of phosphates required to sequester iron and manganese generally has to be approximately two parts actual phosphate (as product) for one part of iron and manganese. It is also important to remember that a chlorine residual must be maintained throughout the distribution system to control bacterial growth. The chlorine residual should be greater than 0.2 ppm at the most distant part of the system.

If the total detention time in the distribution system exceeds 72 hours, the phosphates may break down and release the iron and manganese in the outer portions of the system. If the detention is exceeded, the iron or manganese problem may not be resolved with phosphate.

Removal by Ion Exchange

Ion exchange may also remove iron and manganese (typically used in home softening). If the water has not been exposed to oxygen, the resins in the softener will remove the iron and manganese ions from the water. If the water contains any dissolved oxygen, the resin can be fouled with iron and manganese deposits. The resin can be cleaned, but the process is expensive and the capacity of this resin is reduced with each cleaning. This method is not recommended for municipal treatment.

Removal by Iron and Manganese Filtration

Removing iron and manganese from drinking water instead of sequestration it is recommended if the water contains over 0.3 ppm of iron or 0.05 ppm of manganese. These elements can be removed during softening with lime, but most commonly iron and manganese is removed by filtration after oxidation (with air, potassium permanganate, or chlorine).

Gravity and pressure filters are both used, with pressure filters being the more popular.

The operator should frequently check to see that all the iron in the water entering the filter has been converted to the ferric (or insoluble particulate) state. The operator collects a water sample, passes it through a filter paper, and runs an iron test on the clean, filtered water (filtrate). If no iron is present, it has all been oxidized and is being removed in the filtration process. If iron is found in the filtrate, oxidation has not been complete and some of the iron will pass through the filter and end up in the treated water. In this case, the operator should consider adjustments to the oxidation process.

Most iron removal filters are designed so that the filters are backwashed based on head-loss on the filter. If iron breakthrough is a problem, the filters will have to be backwashed more frequently. Accurate records will reveal when breakthrough is expected so that the operator can backwash before it is likely to occur.

Oxidation with aeration

Iron is easily oxidized by atmospheric oxygen. Aeration provides the dissolved oxygen needed to convert the iron and manganese from ferrous and manganous (soluble) forms to insoluble oxidized ferric and manganic forms. It takes 0.14 ppm of dissolved oxygen to oxidize 1 ppm of iron, and 0.27 ppm of dissolved oxygen to oxidize 1 ppm of manganese.

Aeration requires careful control of the water flow through the process (see Aeration chapter). If water flow is too great, not enough air is applied to oxidize the iron and manganese. If water flow is too small, the water can become saturated with dissolved oxygen and, consequently, become corrosive to the distribution system. Corrosive water may lead to increased lead and copper levels at customers' taps.

During aeration, slime growths may develop on the aeration equipment, and if these growths are not controlled, they can produce taste and odor problems in the water. The growth of slime can be controlled by adding chlorine at the head of the treatment plant. The process should be inspected regularly to catch problems early.

A detention basin can be provided after aeration to allow complete oxidation. These basins should be cleaned regularly to avoid sludge accumulation. Detention time can also be provided with head on the filters rather than requiring a separate tank. Detention time before filtration should be at least 20 minutes, more if possible. The pH of the water influences how much time is needed for the reaction to be completed. After oxidation of the iron and manganese, the water must be filtered to remove the precipitated iron and manganese.

Oxidation of iron and manganese with air is by far the most cost-effective method since there is no chemical cost; however, there are disadvantages. The oxidation process can be slowed and the reaction tank has to be quite large (if there are high levels of manganese). In addition, small changes in water quality may affect the pH of the water and the oxidation rate may slow to a point where the plant capacity for iron and manganese removal is reduced.

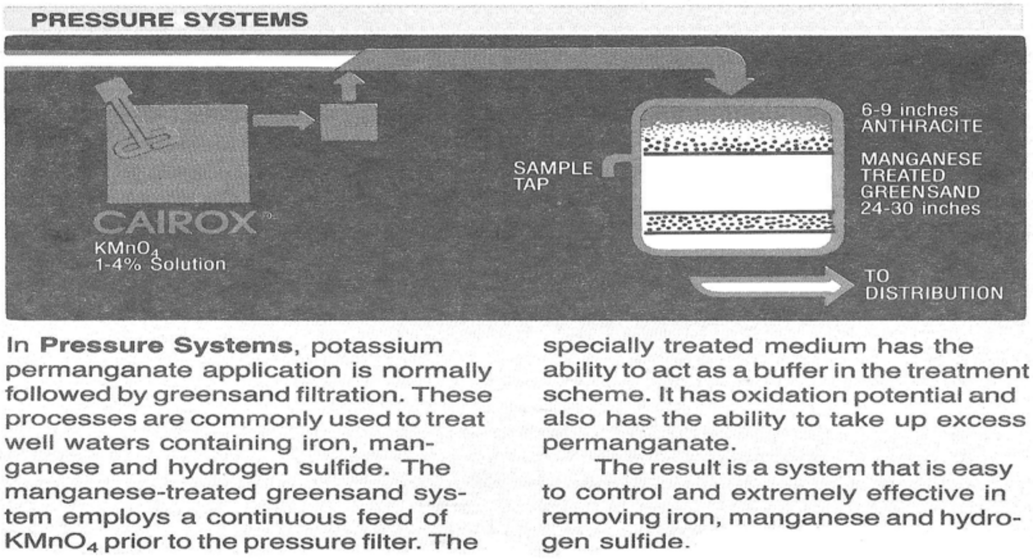
Oxidation with chlorine

Iron and manganese in water can also be oxidized by chlorine, converting to ferric hydroxide and manganese dioxide. The precipitated material can then be removed by filtration. The higher the amount of chlorine fed, the more rapid the reaction. Most treatment plants use 1 – 2 parts of chlorine to 1 part of iron to achieve oxidation.

When using this process on water containing organics such as Total organic carbon (TOC) or natural organic material (NOM), the likelihood of creating disinfection by-products (DBPs) increases.

Oxidation with permanganate

Using potassium permanganate to oxidize iron or manganese is fairly common in Minnesota. Potassium permanganate oxidizes iron and manganese into their insoluble states. The dose must be great enough to oxidize all of the manganese, but not too great as this will produce a pink color in the water in the distribution system. Observing water being treated will indicate if adjustments to the chemical feeders are needed. Potassium permanganate is typically more effective at oxidizing manganese than aeration or chlorination.

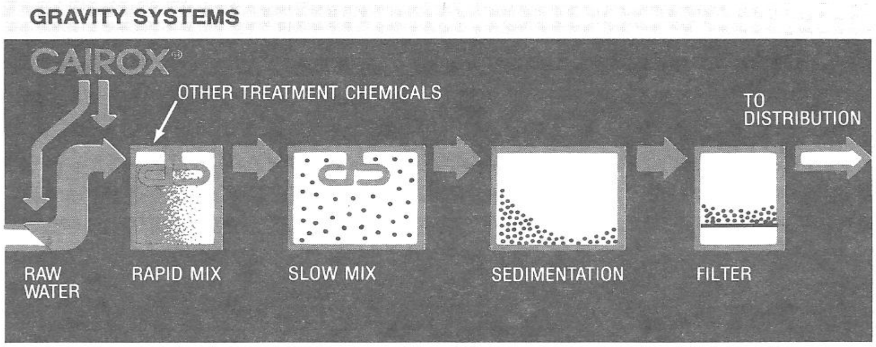


In **Pressure Systems**, potassium permanganate application is normally followed by greensand filtration. These processes are commonly used to treat well waters containing iron, manganese and hydrogen sulfide. The manganese-treated greensand system employs a continuous feed of $KMnO_4$ prior to the pressure filter. The specially treated medium has the ability to act as a buffer in the treatment scheme. It has oxidation potential and also has the ability to take up excess permanganate.

The result is a system that is easy to control and extremely effective in removing iron, manganese and hydrogen sulfide.

When oxidizing with potassium permanganate, the operation of the filters becomes important since the reaction also continues to take place in the filter media. The normally-used filter media (sand) will remove iron and manganese if the combined concentration is below 1 ppm. Higher concentrations require different type of filter materials (greens and others) and different methods of operation.

Potassium permanganate is often used with manganese greensand, a granular material that is charged with potassium permanganate after the backwashing process. This method allows the oxidation process to be completed in the filter itself and is a buffer to help avoid pink water in distribution. After the filter is backwashed, it regenerates for a period of time with a high level of permanganate before it is put back into operation.



Notes:

Hardness

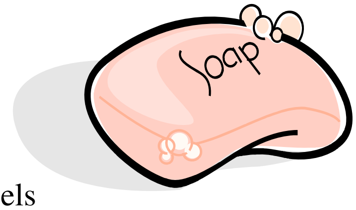
Removing hardness from water is called softening and hardness is mainly caused by calcium and magnesium salts. These salts are dissolved from geologic deposits through which water travels. The length of time water is in contact with hardness producing material helps determine how much hardness there is in raw water.

The two basic methods of softening public water supplies are chemical precipitation and ion exchange. Other methods can also be used to soften water, such as electrodialysis, distillation, freezing, and reverse osmosis. These processes are complex and expensive and usually used only in unusual circumstances.

Water becomes hard by being in contact with soluble, divalent, metallic cations. The two main cations that cause water hardness are calcium (Ca^{2+}) and magnesium (Mg^{2+}). Calcium is dissolved in water as it passes over and through limestone deposits. Magnesium is dissolved as water passes over and through dolomite and other magnesium bearing formations. Because groundwater is in contact with these geologic formations for a longer period of time than surface water, groundwater is usually harder than surface water.

Although strontium, aluminum, barium, iron, manganese, and zinc also cause hardness in water, they are not usually present in large enough concentrations to contribute significantly to total hardness.

OBJECTIONS TO HARD WATER



Hardness was originally defined as the capacity of water to precipitate soap. Calcium and magnesium precipitate soap, forming a curd which causes “bathtub ring” and dingy laundry (yellowing, graying, loss of brightness, and reduced life of washable fabrics), feels unpleasant on the skin (red, itchy, or dry skin), and tends to waste soap. To counteract these problems, synthetic detergents have been developed. These detergents have additives known as sequestering agents that “tie-up” the hardness ions so they cannot form troublesome precipitates.

Hard water forms scale, usually calcium carbonate, which causes a variety of problems. Left to dry on the surface of glassware, silverware, and plumbing fixtures (shower doors, faucets, and sink tops), hard water leaves an unsightly scale called water spots. Scale that forms inside water pipes eventually reduces water pipe carrying capacity. Scale that forms within appliances, pumps, valves, and water meters causes wear on moving parts.

When hard water is heated, scale forms much faster. This creates an insulation problem inside boilers, water heaters, and hot-water lines, and increases water heating costs.

The degree of hardness consumers consider objectionable depends on the degree of hardness to which consumers have become accustomed, as described here:

Soft:	0 to75 mg/L as $CaCO_3$
Moderate:	75 to 150 mg/L as $CaCO_3$
Hard:	150 to 300 mg/L as $CaCO_3$
Very Hard:	Above 300 mg/L as $CaCO_3$

Water should have a total hardness of less than 75 to 85 mg/l as $CaCO_3$ and a magnesium hardness of less than 40 mg/l as $CaCO_3$ to minimize scaling at elevated temperatures.

Many systems allow hardness in finished water to approach 110 to 150 mg/L to reduce chemical costs and sludge production. Use of synthetic detergents has reduced the importance of hardness for soap consumption; however, industrial requirements for high quality feed water for high pressure boilers and cooling towers have generally increased. As industrial waste treatment costs increase, demand for higher quality potable water has increased dramatically. Industries purchasing water from municipal supplies often add water treatment, depending on the quality of the municipal supply and the intended plant or process use.

HARDNESS MEASUREMENTS

Water hardness is unfortunately, expressed in several different units and it is often necessary to convert from one unit to another when making calculations. Most commonly used units include grains per gallon (gpg), parts per million (ppm), and milligrams per liter (mg/L).

Grains per gallon is based on the old English system of weights and measures, and is based on the average weight of a dry kernel of grain (or wheat). Parts per million is a weight to weight ratio, where one ppm of calcium means 1 pound of calcium in 1 million pounds of water (or 1 gram of calcium in 1 million grams of water). Milligrams per liter (mg/L) are the same as ppm in the dilute solutions present in most raw and treated water (since pure water weights 1000 grams per liter).

To Convert	To	Multiply by
Grains per gallon	Milligrams per liter	17.12
Milligrams per liter	Grains per gallon	0.05841

Since calcium carbonate is one of the more common causes of hardness, total hardness is usually reported in terms of calcium carbonate concentration (mg/L as $CaCO_3$), using either of two methods:

Calcium and Magnesium Hardness

Hardness caused by calcium is called calcium hardness, regardless of the salts associated with it. Likewise, hardness caused by magnesium is called magnesium hardness. Since calcium and magnesium are normally the only significant minerals that cause hardness, it is generally assumed that:

Total Hardness = **Calcium Hardness** + **Magnesium Hardness**
(mg/L as $CaCO_3$) (mg/L as $CaCO_3$) (mg/L as $CaCO_3$)

= 2.50 X Calcium conc. (mg/L as Ca^{2+}) + 4.12 X Magnesium conc. (mg/L as Mg^{2+})

Carbonate and Non-carbonate Hardness

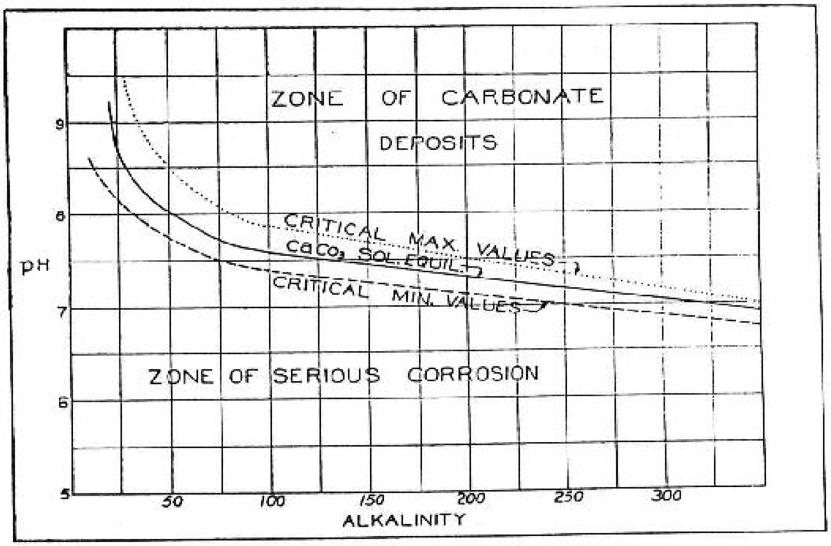
Carbonate hardness is primarily caused by the carbonate and bicarbonate salts of calcium and magnesium. Non-carbonate hardness is a measure of calcium and magnesium salts other than carbonate and bicarbonate salts (such as calcium sulfate, $CaSO_4$, or magnesium chloride, $MgCl_2$). Total hardness (which varies based on alkalinity) is expressed as the sum of carbonate hardness and non-carbonate hardness:

Total hardness = **Carbonate hardness** + **Non-carbonate hardness**
(mg/L as $CaCO_3$) (mg/L as $CaCO_3$) (mg/L as $CaCO_3$)

ALKALINITY

Alkalinity is a measure of water's capacity to neutralize acids, and is important during softening. Alkalinity is the result of the presence of bicarbonates, carbonates, and hydroxides of calcium, magnesium, and sodium. Many of the chemicals used in water treatment, such as alum, chlorine, or lime, cause changes in alkalinity. Determining alkalinity is required when calculating chemical dosages for coagulation and water softening. Alkalinity is also used to calculate corrosivity of water and estimate carbonate hardness.

Alkalinity (expressed as calcium carbonate $CaCO_3$)= bicarbonate ion concentration [HCO_3] + carbonate ion concentration[$C0_3$] + hydroxyl ion concentration [OH]



Notes:

Lime Softening

Chemical precipitation is one of the more common methods used to soften water. Chemicals normally used are lime (calcium hydroxide, $Ca(OH)_2$) and soda ash (sodium carbonate, Na_2CO_3). Lime is used to remove chemicals that cause carbonate hardness. Soda ash is used to remove chemicals that cause non-carbonate hardness.

When lime and soda ash are added, hardness-causing minerals form nearly insoluble precipitates. Calcium hardness is precipitated as calcium carbonate ($CaCO_3$). Magnesium hardness is precipitated as magnesium hydroxide ($Mg(OH)_2$). These precipitates are then removed by conventional processes of coagulation/flocculation, sedimentation, and filtration. Because precipitates are very slightly soluble, some hardness remains in the water--usually about 50 to 85 mg/l (as $CaCO_3$). This hardness level is desirable to prevent corrosion problems associated with water being too soft and having little or no hardness.

LIME ADDITION

Hardness		Lime		Precipitate
CO_2.	+	$Ca(OH)_2$	->	$CaCO_3 + H_2O$
$Ca(HCO_3)_2$	+	$Ca(OH)_2$	->	$2CaCO_3 + 2H_20$
$Mg(HCO_3)_2$	+	$Ca(OH)_2$	->	$CaCO_3 + MgCO_3 + 2H_20$
$MgCO_3$	+	$Ca(OH)_2$	->	$CaCO_3 + Mg(OH)_2$

CO_2 does not contribute to the hardness, but it reacts with the lime, and therefore uses up some lime before the lime can start removing the hardness.

LIME AND SODA ASH ADDITION

		Lime				
$MgSO_4$	+	$Ca(OH)_2$	->	$Mg(OH)_2$	+	$CaSO_4$
		Soda ash		Precipitate		
$CaSO_4$	+	Na_2CO_3	->	$CaCO_3$	+	Na_2SO_4

CO_2 = carbon dioxide, $Ca(OH)_2$ = calcium hydroxide or hydrated lime, $CaCO_3$ = calcium carbonate, $Ca(HCO_3)_2$ = calcium bicarbonate, $Mg(HCO_3)_2$ = magnesium bicarbonate, $MgCO_3$ = magnesium carbonate, $Mg(OH)_2$ = magnesium hydroxide, $MgSO_4$ = magnesium sulfate, $CaSO_4$ = calcium sulfate, H_20 - water. Na_2CO_3 = sodium carbonate or soda ash

For each molecule of calcium bicarbonate hardness removed, one molecule of lime is used. For each molecule of magnesium bicarbonate hardness removed, two molecules of lime are used. For each molecule of non-carbonate calcium hardness removed, one molecule of soda ash is used. For each molecule of non-carbonate magnesium hardness removed one molecule of lime plus one molecule of soda ash is used.

CONVENTIONAL LIME-SODA ASH TREATMENT

When water has minimal magnesium hardness, only calcium needs to be removed. Only enough lime and soda ash are added to water to raise pH to between 10.3 and 10.6, and calcium hardness will be removed from the water (but minimal magnesium hardness will be removed).

EXCESS LIME TREATMENT

When magnesium hardness is more than about 40 mg/l as $CaCO_3$, magnesium hydroxide scale deposits in household hot-water heaters operated at normal temperatures of 140 to 150° F. To reduce magnesium hardness, more lime must be added to the water. Extra lime will raise pH above 10.6 to help magnesium hydroxide precipitate out of the water.

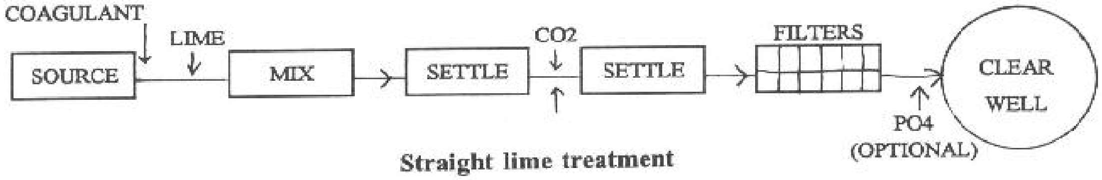
SPLIT TREATMENT

When water contains high amounts of magnesium hardness, split treatment may be used. Approximately 80 percent of the water is treated with excess lime to remove magnesium at a pH above 11, after which it is blended with 20 percent of the source water. Split treatment can reduce the amount of carbon dioxide required to re-carbonate the water as well as offer a savings in lime feed.

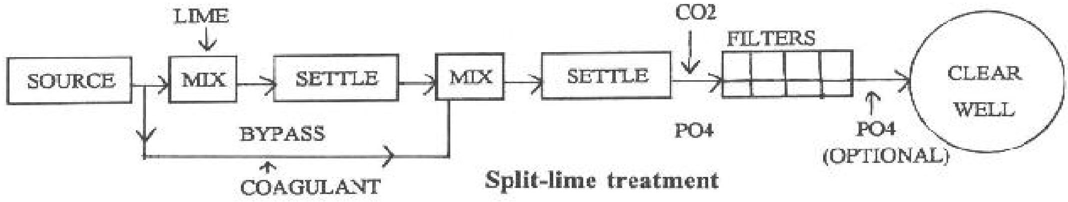
Since the fraction of the water that is treated contains an excess lime dose, magnesium is almost completely removed from this portion. When this water is mixed with the water that does not undergo softening, the carbon dioxide and bicarbonate in that water re-carbonates the final blend. Split treatment reduces the amount of chemical needed to remove hardness from water by 20 to 25 percent (a significant savings).

DESIGN CONSIDERATIONS

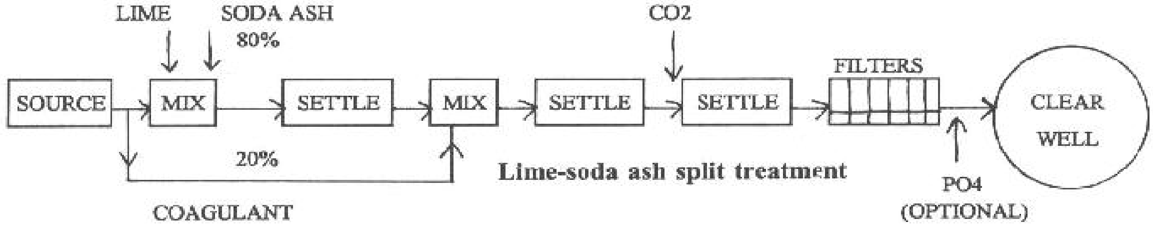
In lime soda-ash softening plants, the softening process may be carried out by a sequence of rapid mix, flocculation, and sedimentation or in a solids contactor. In the solids contactor the rapid mix, flocculation, and sedimentation occur in a single unit. The process begins with the mixing of the chemicals into the water, followed by violent agitation, termed rapid mixing. This allows chemicals to react with, and precipitate calcium or magnesium hardness in the water.



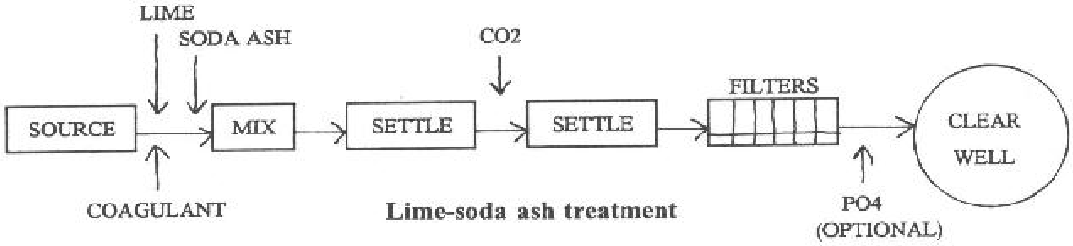
Straight lime treatment



Split-lime treatment



Lime-soda ash split treatment



Lime-soda ash treatment

Flocculation allows flocs to contact other flocs and grow large enough to settle in the sedimentation stage. Water is mixed gently with a small amount of energy. Most flocculators are compartmentalized, allowing for a tapered mix, so less energy must applied as the flocs grow in size.

Detention time in the flocculator is important to allow particles to come in contact with each other. The minimum time recommended is 30 minutes for conventional water softening.

Sludge returned to the head of the flocculator reduces the amount of chemical needed and provides seed flocs for the precipitation. The estimated return sludge is 10 to 25 percent of the source water.

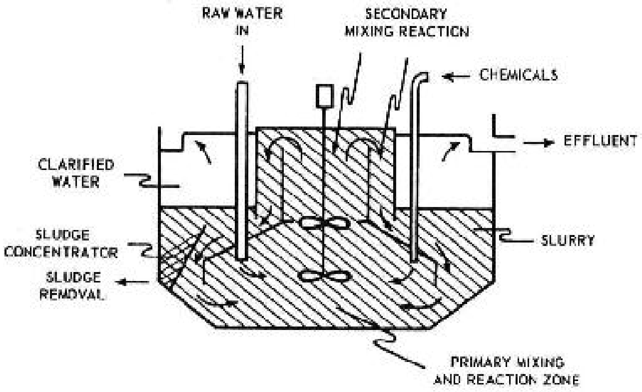
Sedimentation follows flocculation. Settling rates for these tanks are a function of particle size and density. Detention times in the settling basins range from 1.5 hours to 3.0 hours, and they can be rectangular, square, or circular (some designs incorporate inclined tube settlers).

Sedimentation can also occur in the solids-contact unit, in which the water is mixed with chemicals and flocculated in the center of the basin, then forced down and trapped for removal in a sludge blanket in the bottom of the tank.

Sludge Removal

Residue created from lime-soda ash softening is normally very high in calcium carbonate or a mixture of calcium carbonate, and magnesium hydroxide. Calcium carbonate sludges are normally dense, stable inert, and dewater readily. Solids content in the sludge range from 5 to 30 total solids with a pH greater than 10.5.

Lime-soda ash sludges may be treated with lagooning, vacuum filtration, centrifugation, pressure filtration, recalcination, or land application. The most common method is storage of sludge in lagoons and application to farmland or landfills disposal.



FUNCTIONAL DRAWING OF
SOLIDS CONTACT UNIT
USED FOR WATER SOFTENING

Calculations

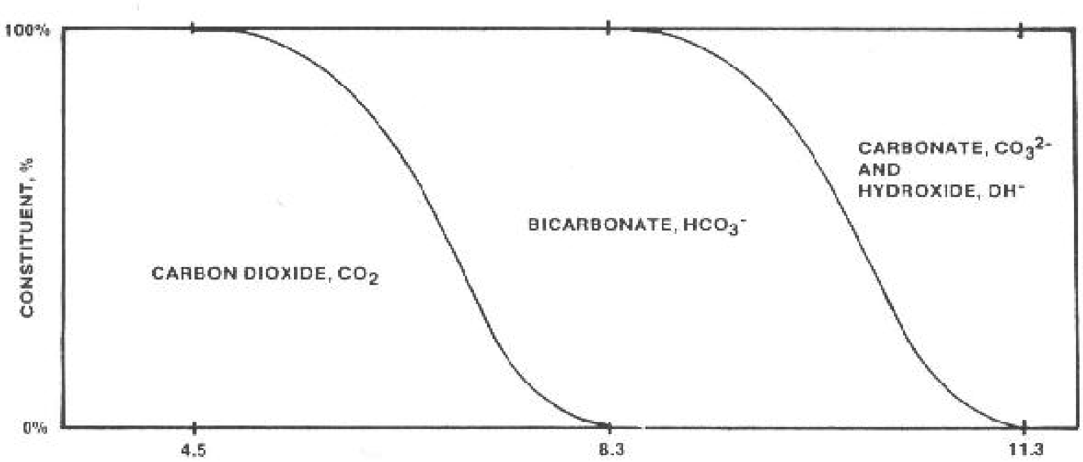
There are two methods for calculating lime and soda ash dosages (conventional dosage method and conversion factor method). The conventional method, although much longer, is helpful in understanding the chemical and mathematical relationships involved in softening. The conversion factor method is simpler, quicker, and more practical for daily operations.

In both calculation methods, lime and soda ash dosages depends on carbonate and non-carbonate hardness in the water. Lime is used to remove carbonate harness, and both lime and soda ash are used to remove non-carbonate hardness. If total hardness is less than or equal to total alkalinity, there is no non-carbonate hardness (only carbonate hardness). If total hardness is greater than total alkalinity, non-carbonate hardness equals the difference between total hardness and total alkalinity (and carbonate hardness equals total alkalinity).

If total hardness is equal to or less than total alkalinity, then:

> Lime Dosage = the carbon dioxide concentration [CO_2] + the total hardness concentration [Total Hardness] + the magnesium concentration [Mg] + [Excess]

Optimum chemical dosages can be evaluated with a jar test.



Relationship between pH and alkalinity (HCO_3^-, CO_3^{2-} and OH^-)

Alkalinity (mg/l as $CaCO_3$) is the capacity of water to neutralize acids. This is determined by the content of carbonate, bicarbonate and hydroxide. Alkalinity is a measure of how much acid can be added to a liquid without causing any significant change in pH.

When pH is less than 8.3, all alkalinity is in the bicarbonate form and is commonly referred to as natural alkalinity. When pH is above 8.3, alkalinity may consist of bicarbonate, carbonate, and hydroxide. As pH increases the alkalinity progressively shifts to carbonate and hydroxide forms. Total alkalinity is the sum of bicarbonate, carbonate, and hydroxide alkalinity. Various chemicals effect water differently:

Lowers Alkalinity:	**Increases Alkalinity:**
Aluminum sulfate	Calcium hypochlorite
Carbon dioxide	Caustic soda
Chlorine gas	Hydrate lime
Ferric Chloride	Soda ash
Ferric Sulfate	Sodium Aluminate
Sulfuric acid	

The following table gives molecular weights for common chemicals:

Quicklime (CaO)……………………	56
Hydrate Lime ($CaOH$)………………	74
Magnesium (Mg)……………………	24.3
Carbon Dioxide ($C0_2$)……………….	44
Magnesium Hydroxide ($Mg(OH)_2$)...	58.3
Soda Ash ($NaCO_3$)…………………	106
Alkalinity (as $CaCO_3$)………………	100
Hardness (as $CaCO_3$)……………….	100

Quicklime dosage can be calculated with the following formula:

$$\text{Quicklime (CaO) mg/l} = \frac{(A + B + C + D) + \%\ \text{EXCESS}}{\text{purity of lime as a decimal}}$$

A = Carbon Dioxide in source water
= mg/l CO_2 x ($\underline{CaO}/CO_2$)
= mg/l CO_2 x 56/44
= mg/l CO_2 x 1.27

B = Bicarbonate alkalinity removed
= mg/l as $CaCO_3$ x ($\underline{CaO}/CaCO_3$)
= mg/l x 56/100
= mg/l alkalinity x .56

C = Hydroxide alkalinity in softener effluent
= mg/l hydroxide alkalinity x ($\underline{CaO/}CaCO_3$)
= mg/l hydroxide alkalinity x 56/100
= mg/l hydroxide alkalinity x .56

D = Magnesium removed in softening
= Mg/l as Mg^{2+} x ($\underline{CaO}/Mg(OH)_2$
= Mg/l as Mg^{2+} x 56/24.3
= Mg/l as Mg^{2+} x 2.30

If hydrated lime (CaOH) is used in place of quicklime, the molecular weight of quicklime of 56 should be replaced with the weight of hydrated lime (74).

When treating water that contains non-carbonate hardness, soda ash is required. The amount of soda ash can be estimated by using the following formula:

Soda Ash ($NaCo_3$) mg/l = mg/l Non Carbonate Hardness as $CaCO_3$ x $Na^2CO_3/CaCO_3$

= mg/l Non-Carbonate Hardness as $CaCO_3$ x 106/100

= mg/l Non-Carbonate Hardness as $CaCO_3$ x 1.06

After softening, pH of the water is generally above 10. If left at this pH, water will plate filter sand and cause problems in the distribution system. Carbon dioxide (through re-carbonation), is added to lower the pH. The amount of carbon dioxide (CO_2) required can be estimated:

$$\text{Total } CO_2\ (\text{mg/l}) = Ca(OH)_2\ (\text{mg/l}) \times \frac{CO_2}{Ca(OH)_2} + Mg(OH)\text{residual} \times \frac{CO_2}{Mg(OH)_2}$$

Total CO_2 = $Ca(OH)_2$ mg/l x 44/74 + $Mg(OH)_2$ residual x 44/58.3

Total CO_2 = $Ca(OH)_2$ mg/l x .59 + $Mg(OH)_2$ residual x .75

Conversion Method

Equivalent weight conversions required in the conventional method have been combined into single factors shown in the table below. These factors, multiplied by the concentration of the corresponding material, will give the lime or soda ash dosage needed to remove material in units of milligrams per liter or pounds per million gallons. The total dosage is the sum of all material removed from the water, such as the carbon dioxide, bicarbonate alkalinity, and the magnesium, plus the amount of excess that is required to reduce the hardness in the water. The total soda-ash dosage is found in the same manner by finding the sum of the amounts needed to remove the non-carbonate material from the water. An additional calculation is needed to adjust for the purity of the lime or soda-ash used.

	Converting to:			
	Lime (CaO)		Soda Ash	
	mg/l	lb/MG	mg/l	lb/MG
Carbon Dioxide (mg/l as $CaCO_3$)	1.27	10.63	---	---
Bicarbonate Alkalinity (mg/l as $CaCO_3$)	0.56	4.67	---	---
Magnesium as Mg (mg/l as $CaCO_3$)	2.31	19.24	---	---
Excess as $CaCO_3$ (mg/l as $CaCO_3$)	0.56	4.67	---	---
Non-carbonate Hardness (mg/l as $CaCO_3$)	---	---	1.06	8.83
Excess Soda ash (mg/l as $CaCO_3$)	---	---	1.06	8.83

Example:

The following test results were provided by the laboratory:

CO_2 concentration	25 mg/l as CO_2
HCO_3 (bicarbonate) concentration	205 mg/l as $CaCO_3$
Mg (magnesium) concentration	9 mg/l as Mg
non-carbonate hardness concentration	95 mg/l as $CaCO_3$

Assuming no excess lime is added, find correct dosages for lime (containing 90% pure CaO) and soda ash (containing 99% pure Na_2CO_3) required to remove all hardness.

CO_2	25 mg/l x 1.27	=	31.75 mg/l as CaO
HCO_3	205 mg/l x 0.56	=	114.80 mg/l as CaO
Mg	9 mg/l x 2.31	=	20.79 mg/l as CaO
TOTAL		=	167.34 mg/l as CaO

Then adjust lime dosage for purity:

Actual Lime Dose = $\frac{167.34\ \text{mg/l}}{.90}$ = 185.93 mg/l

Next, find soda ash dosage:

Soda Ash Dosage = 95 mg/l x 1.0 = 100.7 mg/l as Na_2CO_3

Actual Dosage = $\frac{100.7\ \text{mg/l}}{.99}$ = 101.7 mg/l as Na_2CO_3

Recarbonation

After adding lime and/or soda ash, treated water will generally have a pH greater than 10. It is necessary to lower the pH to stabilize the water and prevent deposition of carbonate scale on filter sand and distribution piping. Recarbonation is the most common process used to reduce pH. This procedure adds carbon dioxide to water after softening. Generally, enough carbon dioxide is added to reduce the pH of the water to less than 8.7. The amount of carbon dioxide added is determined using a saturation index. The Langelier Index (LI) is the most common stabilization index used, but some plants instead use the Rizner Index, (reciprocal of the Langelier Index). The Langelier Index is expressed as pH of stabilization (pHs) minus actual pH measured (pHs - pH). When the Langelier Index is positive, pipes tend to become coated with scale. When it is negative, the water tends to be corrosive.

When low magnesium water is softened, no excess lime needs to be added. After softening, water becomes supersaturated with calcium carbonate and has a pH between 10.0 and 10.6. When carbon dioxide is added, the excess calcium carbonate is converted back to permanent hardness or calcium bicarbonate by the following formula:

Ca^{2+} (calcium ion) + CO_3^{2-} (carbonate ion) + CO_2 (carbon dioxide) + H_2O (water)
= $2HCO_3^-$ (bicarbonate ions)

When high magnesium water is softened, excess lime needs to be added to raise the pH above 11, and magnesium hydroxide precipitates out. After treatment, enough carbon dioxide must be added to neutralize the excess hydroxide ions, as well as convert carbonate ions to bicarbonate ions. The first stage of this reaction reduces the pH to between 10.0 and 10.5. In this range, calcium carbonate is formed and magnesium hydroxide that did not precipitate, or did not settle out, is converted to magnesium carbonate.

Ca^{2+} (calcium ion) + 2 OH^- (hydroxyl ions) + CO_2 (carbon dioxide) <----> $CaCO_3$ (calcium carbonate) + H_2O (water)

Mg^{2+} magnesium ion) + 2 $0H^-$ (hydroxyl ions) + CO_2 (carbon dioxide) <----> $MgCO_3$ (magnesium carbonate) + H_20 (water)

Additional carbon dioxide needs to be added to lower the pH to between 8.4 and 8.6. The previously formed calcium carbonate re-dissolves and carbonate ions are converted to bicarbonate ions as shown below:

$CaCO_3$ (calcium carbonate) + H_20 (water) + CO_2 (carbon dioxide) <----> Ca^{2+} (calcium ion) + $2HCO_3^-$ (bicarbonate ions)

Mg^{2+} (magnesium ion) + CO_3^{2+} (carbonate ion) + CO_2 (carbon dioxide) + H_20 (water) <----> Mg^{2+} (magnesium ion) + 2 HCO_3^- (bicarbonate ions)

For treatment of low magnesium water (where excess-lime addition is not required) single-stage recarbonation is used. The water is mixed with lime or soda ash in the rapid-mix basin, resulting in a pH of 10.2 to 10.5. If non-carbonate hardness removal is required, soda ash will also be added at this step. After rapid mixing, the resulting slurry is mixed gently for a period of 30 to 50 minutes to allow the solids to flocculate. After flocculation, the water is allowed to flow into a sedimentation basin where the solids will be removed by sedimentation. Following sedimentation the clear water flows to the recarbonation basin where carbon dioxide is added to reduce the pH to between 8.3 and 8.6. Any particles remaining in suspension after recarbonation are removed by filtration.

Two-Stage Softening

Two-stage softening is sometimes used for treatment of high magnesium water (where excess lime is required). Excess lime is added in the first stage to raise pH to 11.0 or higher for magnesium removal. Following first stage treatment, carbon dioxide is added to reduce the pH to between 10.0 and 10.5, the best value for removal of calcium carbonate. If non-carbonate hardness removal is needed, soda ash will be added at this point. After second stage treatment, the water flows to a secondary recarbonation tank, where pH is reduced to between 8.3 and 8.6.

Single-Stage Softening

Single-stage recarbonation is the one most commonly practiced (Because of the high capital cost for building this type of two-stage treatment train). There are some benefits to using the two-stage method, including reduced operating cost since less carbon dioxide is needed. Better finished water quality is usually obtained through the two-stage process.

Notes:

Ion Exchange Softening

Ion-exchange is used extensively in small water systems and individual homes. Ion-exchange resin, (zeolite) exchanges one ion from the water being treated for another ion that is in the resin (sodium is one component of softening salt, with chlorine being the other). Zeolite resin exchanges sodium for calcium and magnesium. The following chemical reactions show the exchange process, where X represents zeolite, the exchange material.

Removal of carbonate hardness:

$$Ca(HCO_3)_2 + Na_2X \text{ ------> } CaX + 2NaHCO_3$$

$$Mg(HCO_3)_2 + Na_2X \text{ ------> } MgX + 2NaHCO_3$$

Removal of non-carbonate hardness:

$$\begin{array}{llll} CaSO_4 & + \; Na_2X & \text{----->} & CaX + Na_2SO_4 \\ CaCl_2 & + \; Na_2X & \text{------>} & CaX + CaCl_2 \\ MgSO_4 & + \; Na_2X & \text{------>} & MgX + Na_2SO_4 \\ MgCL_2 & + \; Na_2X & \text{------>} & MgX + 2NaC1 \end{array}$$

These reactions represent cation exchange, the exchange of positive ions. To replenish the sodium ions used, units need to be regenerated with material containing high amounts of sodium, normally salt brine. This allows the resin to be reused many times.

Ion-exchange does not alter the water's pH or alkalinity. However, the stability of the water is altered due to the removal of calcium and magnesium and an increase in dissolved solids. For each ppm of calcium removed and replaced by sodium, total dissolved solids increase by 0.15 ppm. For each ppm of magnesium removed and replaced by sodium, total dissolved solids increase by 0.88 ppm.

Measurements used to express water hardness in ion-exchange differ from units used in lime-soda softening. Hardness is expressed as grains per gallon rather than mg/l of calcium carbonate.

1 grain/gallon 17.12 mg/l

If water contains 10 grains of hardness, would hardness be expressed 171.2 mg/l?

10 grains x 17.12 mg/l / grain
= 171.2 mg/l of hardness

ADVANTAGES OF ION-EXCHANGE SOFTENING

Compared with lime-soda ash softening, ion-exchange has certain advantages. It is compact and has a low capital cost. The chemicals used are safer for the operator to handle and operation is much easier. It can be almost totally automated. Because resins have the ability to remove all hardness from the water, treated water must be blended with water that has been by-passed around the softener (or adjustments made) to obtain a hardness level the operator needs to maintain.

Many systems have found ion-exchange to be the most cost effective way to produce quality water for their customers. If zeolite units are used to soften surface water, it must be preceded by surface water treatment.

EQUIPMENT AND OPERATION

Ion-Exchange Resins

Natural green sand called glauconite has very good exchange capabilities and was once widely used. Synthetic zeolites, known as polystyrene resins, are most commonly used now. Cost is reasonable, and it is easy to control the quality of the resin. They also have much higher ion exchange capacities than the natural material.

The ability of the resin to remove hardness from the water is related to the volume of resin in the tank. Softeners should remove about 50,000 grains of hardness per cubic foot of resin. Resins hold hardness ions until they are regenerated with a salt brine solution. The hardness ions are exchanged for sodium ions in the salt brine.

Example:

If water contains 10 grains per gallon of hardness, how many gallons of water would the resin remove? The tank holds 500 cubic feet of resin with capability of removing 45,000 grains per gallon per cubic foot.

$$\text{Gallons} = \frac{\text{cubic feet x grains per cubic foot}}{\text{grains per gallon}}$$

$$= \frac{\text{500 cubic feet x 45,000 grains/cubic foot}}{\text{10 grains per gallon}}$$

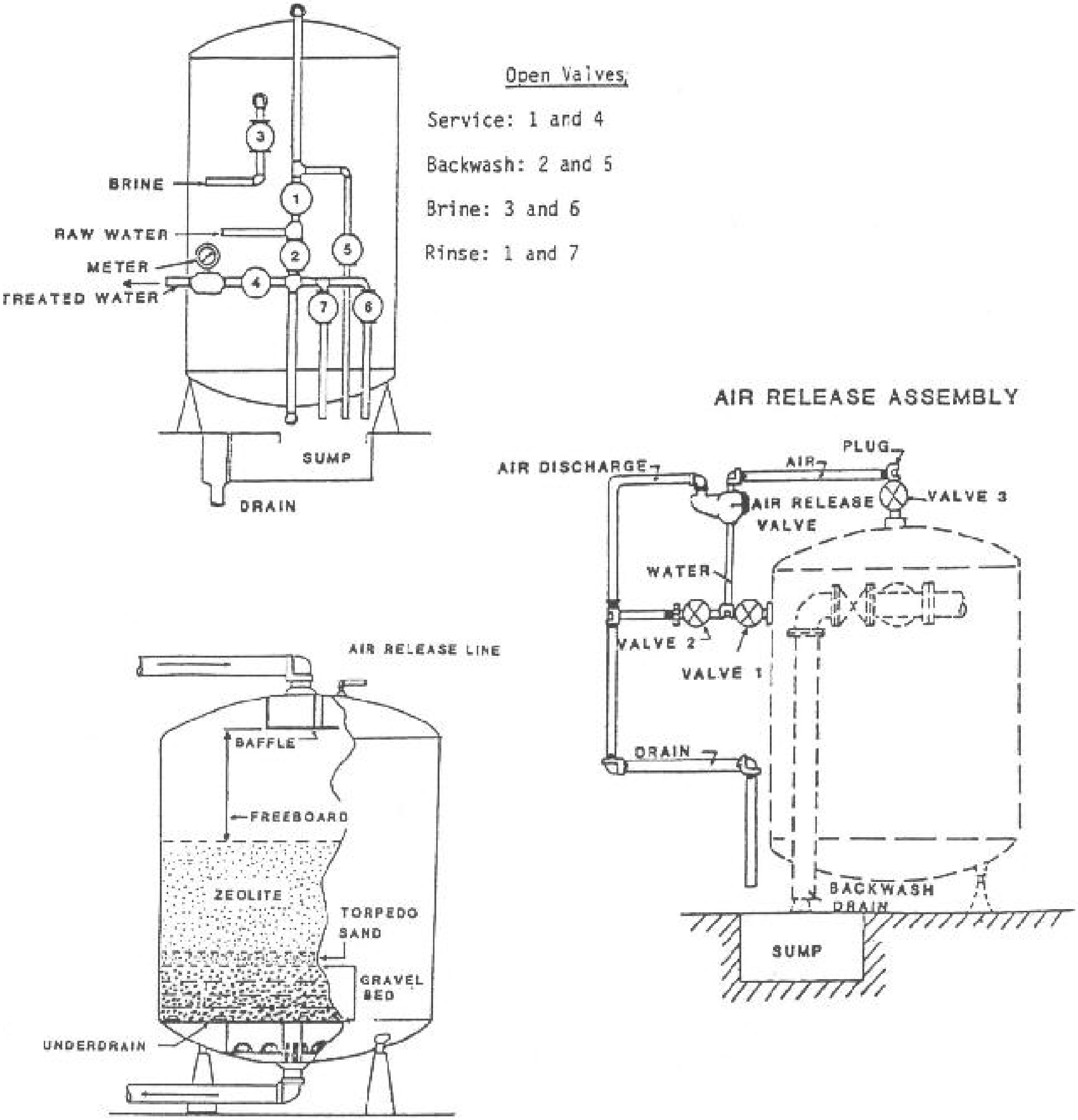
$$= \frac{\text{22,500,000 grains}}{\text{10 grains/gallon}}$$

$$= \text{2,250,000 gallons before requiring regeneration}$$

Ion-Exchange Units

These units resemble pressure filters. The interior is generally treated to protect the tank against corrosion from the salt. The units are normally of the downflow type, and the size and volume of the units are dictated by the hardness of the water and the volume of treated water needed to be produced between each regeneration cycle. Resin is supported by an underdrain system that removes the treated water and distributes brine evenly during regeneration. Minimum depth of resin should be no less than 24 inches above the underdrain.

Zeolite Softening Units



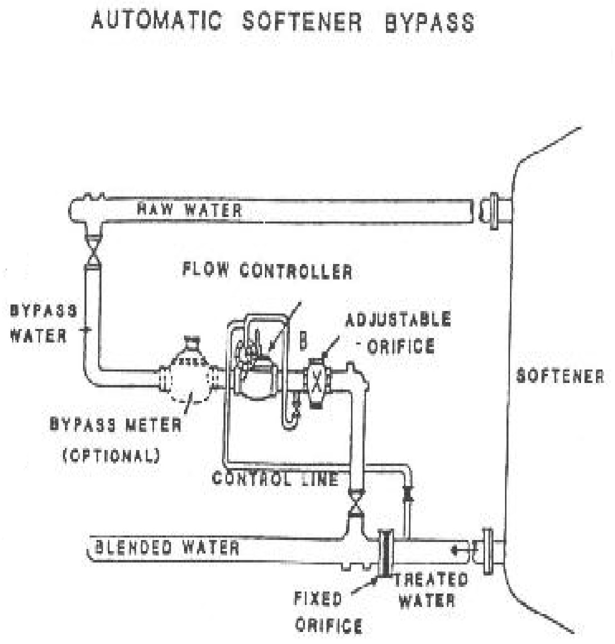
Salt Storage

Salt is stored as a brine, ready to be used for regeneration of the resin. The amount of salt needed ranges from 0.25 to 0.45 pounds for every 1,000 grains of hardness removed. The tank should be coated with a salt-resistant material to prevent corrosion of the tank walls.

Salts need to meet the AWWA or NSF standards for sodium chloride. Rock or pellet salt is the best for preparing brine and road salt is not acceptable, due to the dirt that it contains.

Salt storage tanks should be covered to prevent contamination. A raised curb should be provided at each access hatch to prevent contamination by flood water or rain.

Filling a salt storage tank with water first and then adding salt is the preferred method for making brine. The brine is heavier than water and settles to the bottom of the tank. The brine is usually pumped from the tank to the ion-exchange units. When making brine, water must be added through an air gap to avoid back siphonage of the brine to the water system.



Brine Feeding Equipment

Concentrated brine contains approximately 25 percent salt. The brine should be diluted to about 10 percent before added to the softener. It is generally injected with a venturi or a metering pump. Solubility of salt decreases with a rise in temperature, which forces salt out of solution. Water that remains after the salt has separated out of the solution is subject to freezing. Therefore, brine piping should be protected from cold temperatures.

Devices for Blending

A properly operated ion-exchange unit produces water with zero hardness, but with high corrosivity. Since a total hardness of 85 to 100 mg/l is the most desirable, treated water from the ion-exchange unit is generally blended with source water to raise hardness in the finished water. Blending is normally accomplished by metering both the effluent from the softener and added raw water. Meters are installed in both lines so that the operator can adjust and monitor the blend.

Softening Cycle

The length of the softening cycle ends when 1 to 5 mg/l of hardness is detected in the effluent (loading rates for synthetic resins are in the area of 10 to 15 gpm/square foot of media surface area). Almost all softening units have an alarm on the water meter to indicate when a certain amount of water has passed through the exchange unit.

Backwash Cycle

Once hardness breaks through, the softener must be regenerated. In down-flow units, the resin must first be backwashed to loosen the resin (it becomes compacted by the weight of the water), and to remove any other material that has been filtered out of the water by the resin. The backwash rate is normally 6 to 8 gpm/square foot of zeolite bed area. The operator needs to apply enough backwash water to expand the resin bed by about 50 percent. The backwash water is usually discharged to a box containing orifice plates that measure the flow rate. Distributors at the top of the unit provide for uniform water distribution and uniform wash-water collection. Underdrains provide uniform distribution of the backwash water on the bottom of the resin.

Regeneration

Concentrated brine is pumped to the unit from the storage basin. Brine is diluted through the injector to a solution containing about 10 percent salt before it is passed through the resin. The time required for regeneration is about 20 to 35 minutes. The flow rate of brine through the resin is measured in gallons per minute per cubic foot of media. The brine needs to be in contact with the resin long enough to allow for complete exchange of hardness ions on the resin with sodium ions in the brine. It is better to allow too much time than to not allow enough. If the resin is not totally recharged, the next softening run will be short.

Rinse Cycle

The rinse cycle removes remaining brine from the tank. The total amount of rinse water needed is 20 to 35 gallons per cubic foot of resin. The rinse is started at a slow rate (-2 gpm/square foot of surface area-) and continues until the chloride concentration of the effluent (which should be monitored frequently) is quite low.

Disposal of Brine

The volume of brine used during a regeneration cycle, (together with the rinse water that follows) varies from 1.5 to 7 percent of the amount of water softened by the unit. The chloride concentration in this wastewater could be as high as 35,000 to 45,000 mg/l. Chlorides will upset a wastewater treatment plant, and disposal methods have to comply with Minnesota Pollution Control Agency requirements.

Resin Breakdown

Synthetic resins normally last 15 to 20 years, but certain conditions can cause resin to breakdown earlier. Oxidation by chlorine is probably the most common cause of resin breakdown. When chlorine is used to oxidize iron in the water, the chlorine should be removed before ion exchange.

Iron Fouling

Iron will significantly affect the ability of resins to remove hardness ions. Ferrous iron can be oxidized during softening and precipitate out as iron oxide on the resin, and no amount of brine will remove the iron fouling. If iron oxide is formed before ion exchange unit, it can be filtered out by the resin and removed during the backwashing of the unit. Normally if the iron concentration in the source water is high, iron removal is provided ahead of the exchange unit to prevent fouling of the unit.

Suspended Material

Turbidity, organic chemicals, and bacterial slimes resins resulting in the loss of some of the resin exchange capacity. The best solution is to remove of the suspended matter with coagulation, sedimentation, and filtration before the softening process.

Unstable Water

Water that has been softened by ion exchange will be corrosive and should be stabilized to prevent corrosion from taking place in the distribution system. Blending with raw water or adding phosphates or other chemicals to reduce the corrosivity of the water.

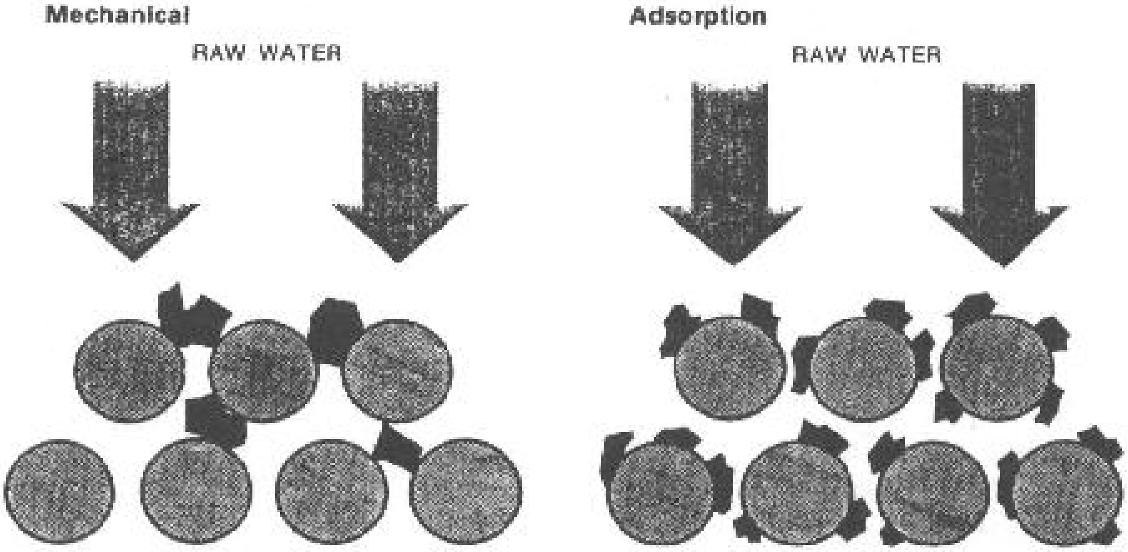
TESTING

Testing should include total hardness of raw and treated water, chloride concentration in the rinse water, and Langelier Index (pH of stability [pHs] - pH measured). If the Langelier Index is positive, a calcium scale will tend to coat the pipes in the distribution system. If the Langelier Index is negative, the water will tend to be corrosive.

Filtration

Filtration plays an important role in the natural treatment of groundwater as it percolates through the soil. It is also a major part of most water treatment. Groundwater that has been softened, or treated through iron and manganese oxidation, requires filtration to remove floc created by coagulation or oxidation processes. Since surface water is subject to run-off and does not undergo natural filtration, it must be filtered to remove particles and impurities.

Filtration can be compared to a sieve or micro-strainer that traps suspended material between the grains of filter media. However, since most suspended particles can easily pass through the spaces between grains of the filter media, straining is the least important process in filtration. Filtration primarily depends on a combination of complex physical and chemical mechanisms, the most important being adsorption. Adsorption is the process of particles sticking onto the surface of the individual filter grains or onto the previously deposited materials. Forces that attract and hold particles to the grains are the same as those that work in coagulation and flocculation. In fact, coagulation and flocculation may occur in the filter bed, especially if coagulation and flocculation before filtration was not properly controlled. Incomplete coagulation can cause serious problems in filter operation.



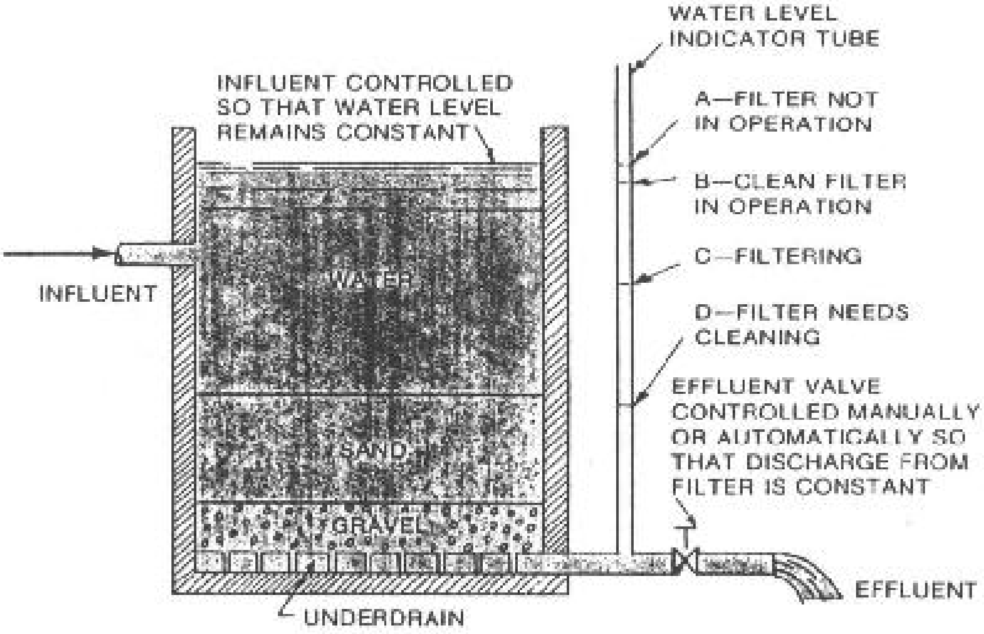
Large particles become lodged and cannot continue downward through the media.

Particles stick to the media and cannot continue downward through the media.

The Two Removal Mechanisms

TYPES OF FILTERS

Several types of filters are used for water treatment. Early slow sand filters typically have filter rates of 0.05 gpm/ft^2 of surface area and require large filter areas. The top several inches of the sand has to be removed regularly--usually by hand--due to the mass of growing material 'schmutzdecke' that collects in the filter. Sand removed is usually washed and returned to the filter. These filters are still in use in some small plants, especially in the western United States as well as in many developing countries. They may also be used as a final step in wastewater treatment.

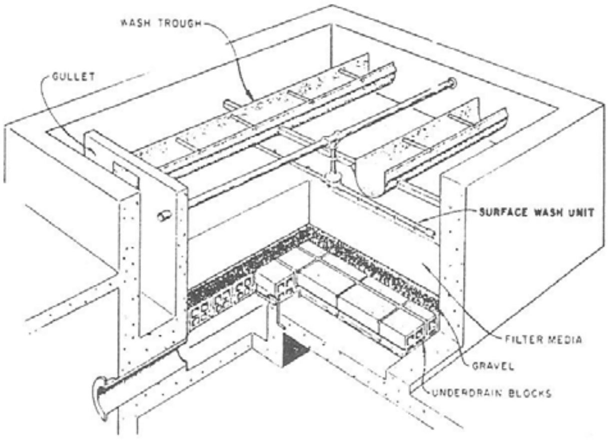


Modern filters are classified as: Gravity Filters (Rapid Sand or High Rate-Dual media-Multi-media) or Pressure Filters (Sand or Multi-media).

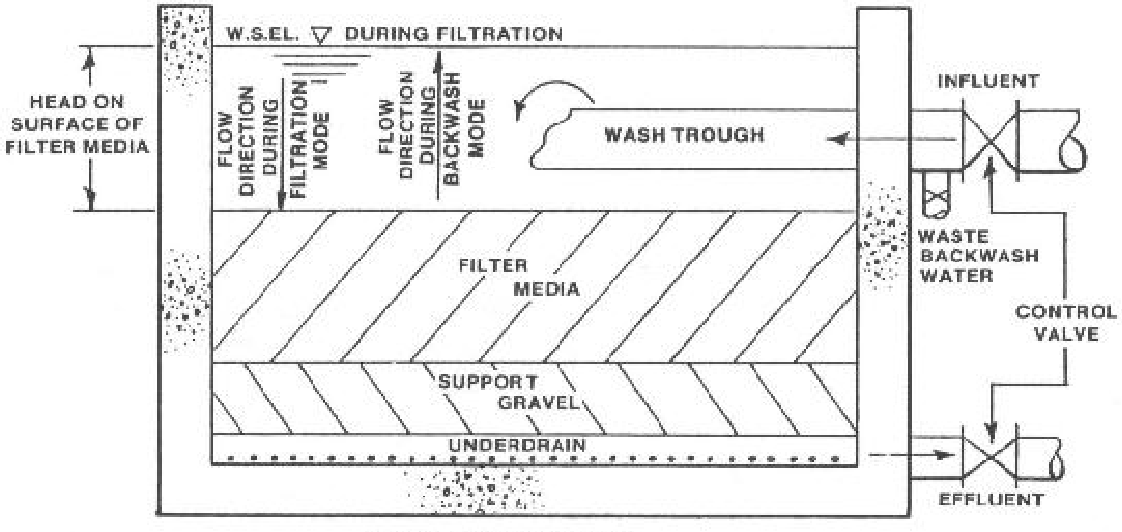
RAPID SAND FILTERS

Rapid sand filters have filter rates 40 times those of slow sand filters. The major parts of a rapid sand filter are:

- Filter tank or filter box
- Filter sand or mixed-media
- Gravel support bed
- Underdrain system
- Wash water troughs
- Filter bed agitators



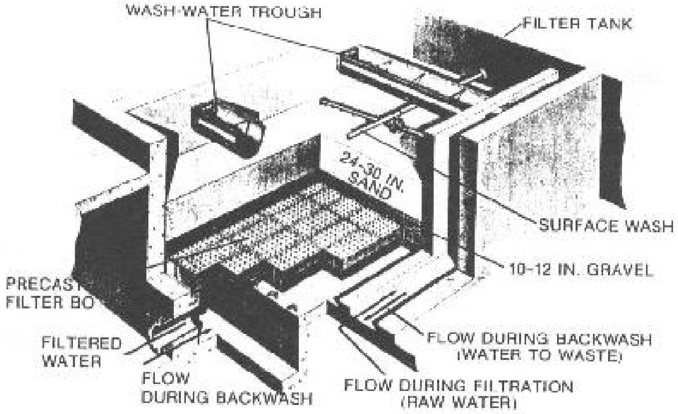
The filter tank is generally constructed of concrete and is most often rectangular. Filters in large plants are usually constructed next to each other in a row, allowing piping from the sedimentation basins to feed the filters from the central pipe gallery. Some smaller plants are designed with filters forming a square of four filters with a central pipe gallery feeding the filters from a center wall.

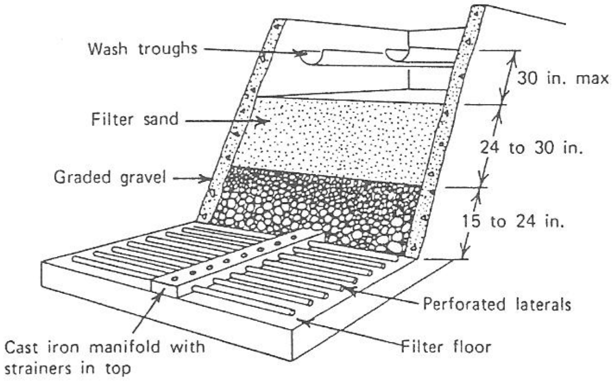


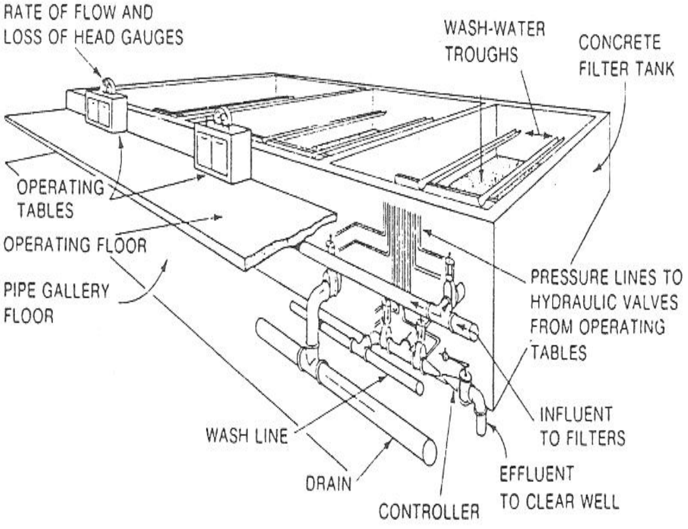
GRAVITY FILTER MODULE

Filter Sand

The filter sand used in rapid sand filters is manufactured specifically for the purpose of water filtration. Most rapid sand filters contain 24-30 inches of sand, but some newer filters are deeper. The sand used is generally 0.4 to 0.6 mm in diameter. This is larger than the sand used in slow rate filtration. The coarser sand in the rapid filters has larger voids that do not fill as easily.







Battery of three filters.

Graded Gravel

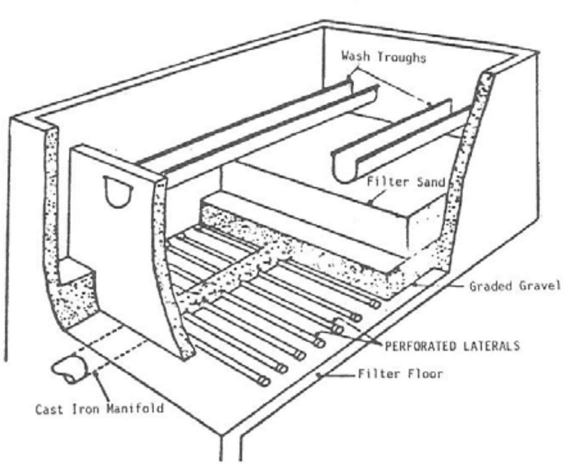
Gravel installed under the sand layer(s) in the filter prevents filter sand from being lost during filtration. The under-gravel also distributes the backwash water evenly across the total filter. This under-gravel supports the filter sand and is usually graded in three to five layers, each generally 6-18 inches in thickness, depending on the type of underdrain used.

Underdrain

The filter underdrain can be one of many types, such as:

- Pipe laterals
- False floor
- Leopold system
- Porous plates or strainer nozzles

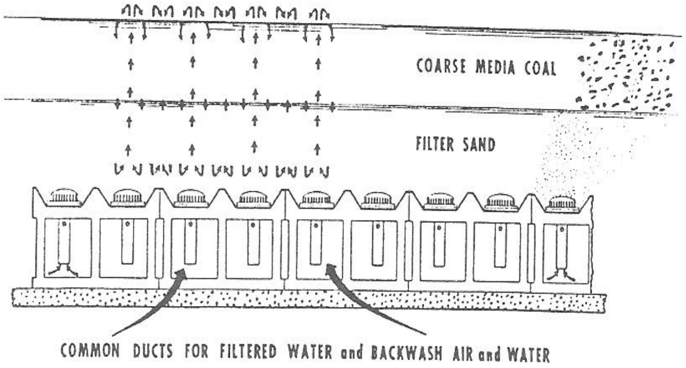
Pipe Laterals



A pipe lateral system uses a control manifold with several perforated laterals on each side. Piping materials include cast iron, asbestos cement, and PVC. The perforations are usually placed on the underside of the laterals to prevent them from plugging with sand. This also allows backwash to be directed against the floor, which helps keep gravel and sand beds from being directly disturbed by the high velocity water jets.

False Floor

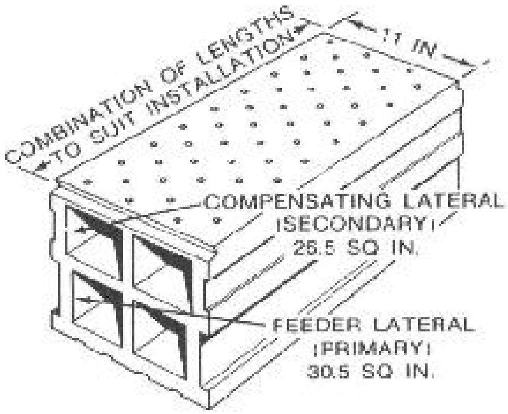
The false floor design of a filter underdrain is used together with a porous plate design, or with screens that retain sand when there is no undergravel layer. This type of underdrain allows the open space under the floor to act as a collection area for the filtered water and distribution of backwash water.

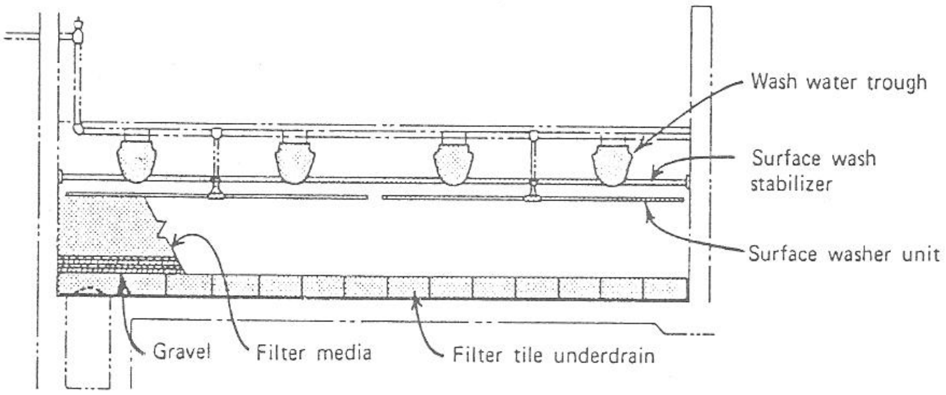


False Floor Underdrain (without gravel)

Leopold System

The Leopold system consists of a series of clay or plastic blocks that form the channels to remove the filtered water from the filter and distribute the backwash water. This type of underdrain is generally used with an undergravel layer, although some new designs allow for sand retention without gravel.





Washwater Troughs

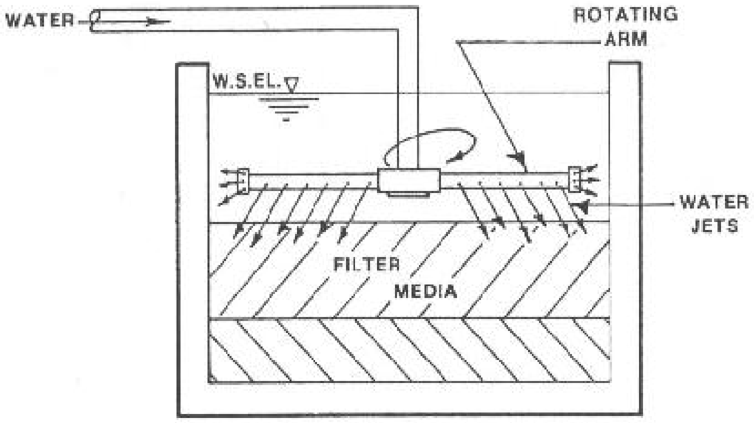
Washwater troughs above the filter media collect backwash water and carry it to the drain system. Proper placement of these troughs is important to ensure filter media is not carried into the troughs during the backwash and removed from the filter. Wash troughs must be installed at the same elevation, so they remove backwash evenly from the filter and an even head is maintained across the entire filter. These backwash troughs are constructed from concrete, plastic, fiberglass, or other corrosion-resistant materials.

Surface Wash

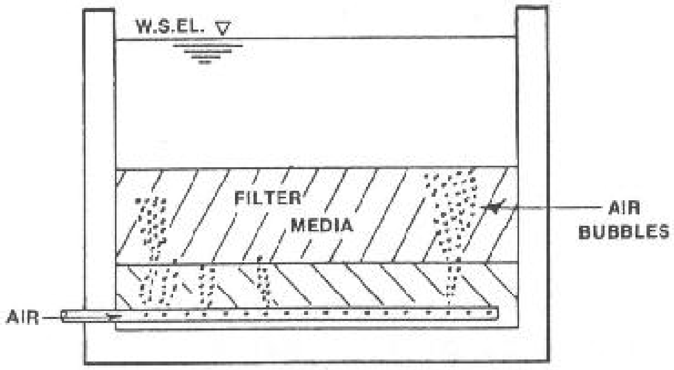
The upper six-to-ten inches of filter media remove most of the suspended material from the water. It is important that this layer is thoroughly cleaned during the backwash cycle. Normal backwashing does not, in most cases, clean this layer completely, and agitation is needed to break up the top layers of the filter to help backwash water remove any material caught there.

The surface wash system consists of a series of pipes installed in the filter to introduce high velocity water or air jet action into the upper layer of the filter. This jet action is generally supplied by rotating arms activated during backwashing.

A newer design of surface wash uses compressed air to mix the upper layer and loosen particles from the sand, so backwash water can remove the particles more easily. This air wash generally is turned on before the backwash cycle. If both are used at the same time, some sand may be washed away. The compressed air rate can be two-to-five cubic feet per minute per square foot (cfm/ft^2) of filter surface, depending on the filter.



ROTARY SURFACE WASH

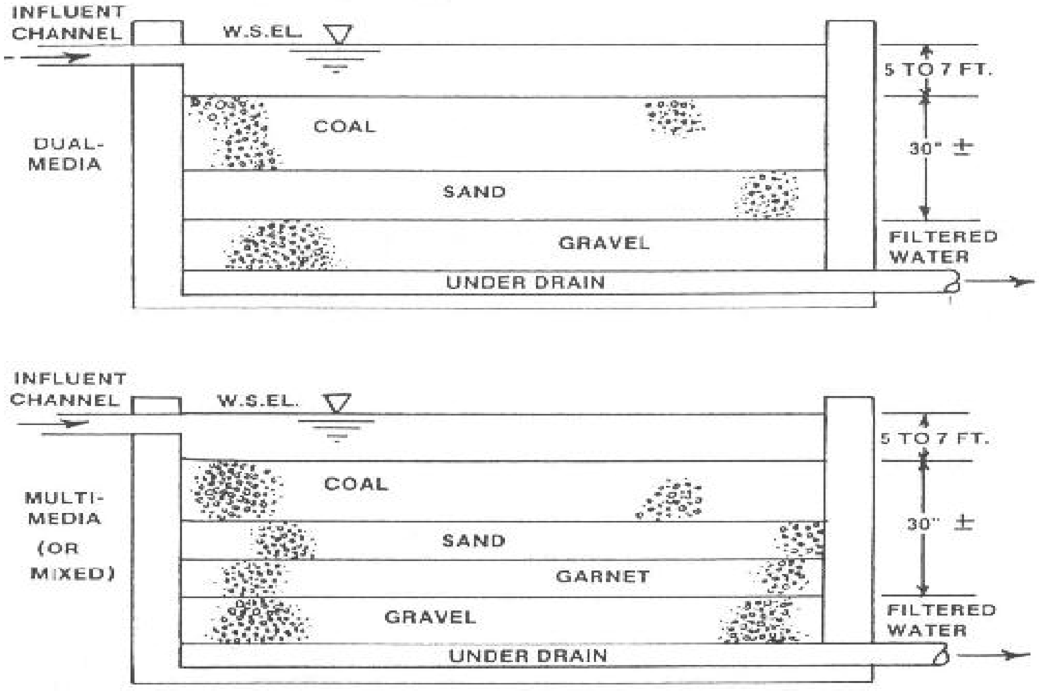


AIR WASH

HIGH RATE FILTERS

High rate filters, which operate at three-to-four times the rate of rapid sand filters, use a combination of filter media, not just sand. Media combinations are generally sand and anthracite coal. Multi-media or mixed-media filters generally use sand, anthracite coal, and garnet.

In rapid sand filters, fine sand grains are at the top of the sand layer with larger grains farther down the filter. As a result, the filter removes most suspended material in the first few inches of the filter. In the high rate filter, the media size decreases and the top layers consists of a coarse material with the finer material farther down, allowing the suspended material to penetrate deeper into the filter. This allows for longer filter runs at higher rates than is possible with rapid sand filters.

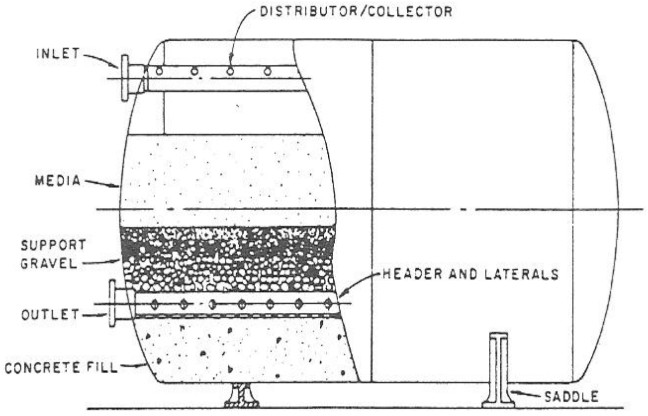


High Rate Filter Configurations

Filter media used in a high rate filter depends on the raw-water quality, raw-water variations, and chemical treatment used. Pilot studies help the operator evaluate which material, or combination of materials, will give the best result.

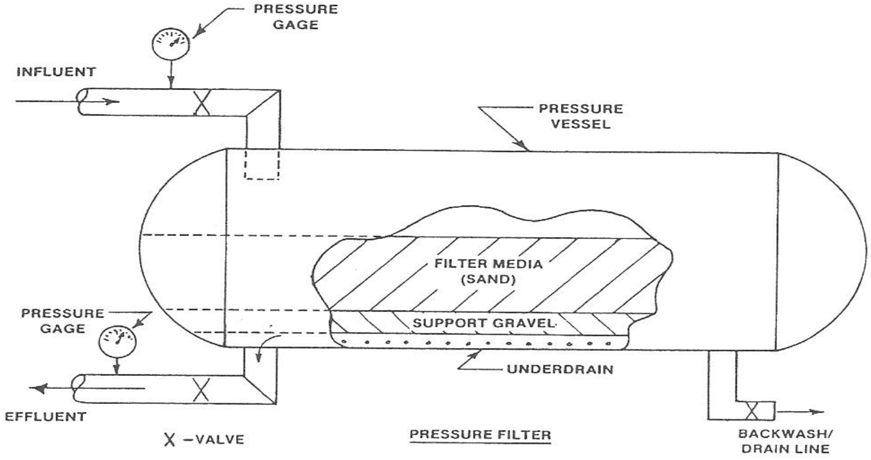
PRESSURE FILTERS

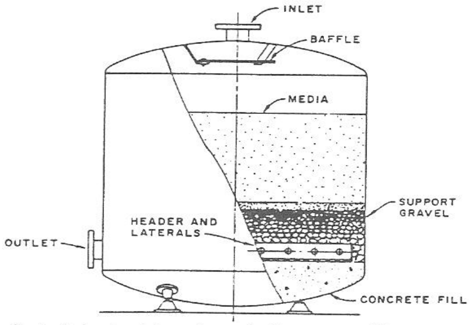
Pressure filters fall into two categories: pressure sand and diatomaceous earth filters. Pressure filters are used extensively in iron and manganese removal plants.



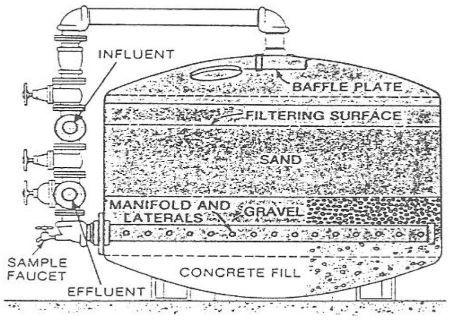
A pressure sand filter is contained under pressure in a steel tank, which may be vertical or horizontal, depending on the space available. As with gravity filters, the media is usually sand or a combination of media, and filtration rates are similar to gravity filters.

Groundwater is first aerated to oxidize the iron or manganese, and then pumped through the filter to remove the suspended material.

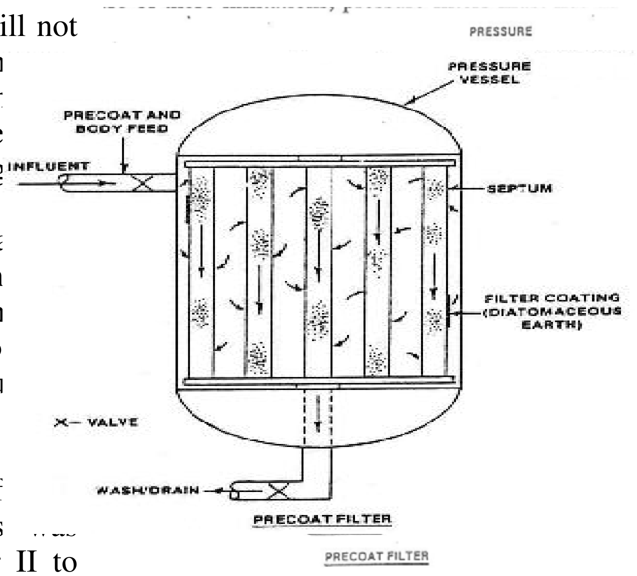




Typical horizontal and vertical pressure filters.



Vertical Pressure Sand Filter

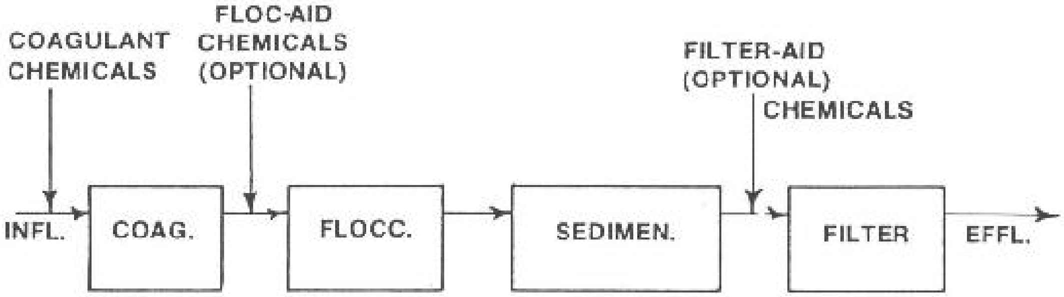


Because water is under pressure, air binding will not occur in the filter. However, pressure filters h major disadvantage in that the backwash canr observed; in addition, cracking of the filter be occur quite easily, allowing the iron and mang particles to go straight through the filter. When pressure filters for iron and manganese remova operator must regularly measure the iron manganese concentration of the filter effluen backwash the filter before breakthrough o Because of these limitations, pressure filters mu be used to treat surface water.

Diatomaceous earth filters are commonly used f treatment of swimming pools. The process developed by the military during World War II to remove microorganisms that cause amoebic dysentery from water used in the field.

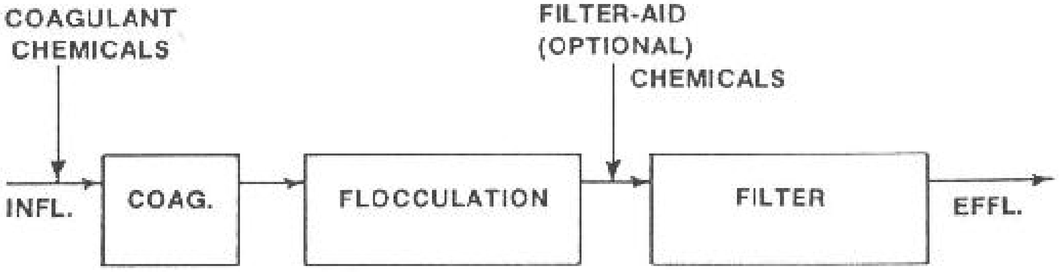
FILTRATION

Conventional filtration, the traditional design for many years, provides effective treatment for just about any range of raw-water turbidity. Its success is due partially to the clarification that precedes filtration and follows coagulation and flocculation. Clarification (or flocculation/sedimentation) includes any solid/liquid separation process following coagulation, where accumulated solids are removed. Clarification, if operated properly, should remove most of the suspended material. After clarification, the water passing through to the filters should not have any turbidity higher than 10-15 Nephelometric Turbidity Units (NTUs).



CONVENTIONAL FILTRATION

In direct filtration, no clarification follows the coagulation phase. Direct filtration is designed to filter water with an average turbidity of less than 25 NTU. Dual and multi-media filters are used with direct filtration. They are able to remove more suspended material per cubic foot of filter media than sand filters. Direct filtration plants have a lower capitol cost. However, the process cannot handle large variations in raw water turbidity.



DIRECT FILTRATION

Water (either from the source or, more commonly, from pre-treatment processes) is applied to the top of the filter; it then flows downward. The water level above the filter bed is usually kept at two-to-six feet. When the filtration is started after being backwashed, there will be little head loss. In filters with a control valve installed on the filter effluent pipe, the filter flow is restricted during this time. The control valve also has the important function of preventing filter surges,

which could disturb the media and force floc through the filter.

The rate of flow on a filter depends on the type of filter. A rapid sand filter will have a flow of 2-3 gpm/square foot of filter area. The high rate filter may have 4-6 gpm/square foot applied to the surface. A constant rate flow valve is almost fully closed when a filter is clean so that the desired water level on top of the filter is maintained. As the filter becomes dirty with suspended material, the valve opens gradually until the increase in the water level above the filter indicates that the filter needs backwashing.

In filters with variable declining rate flow control, filters are allowed to take on as much water as they can handle. As the filters become dirty, the headloss and the depth of the water on the surface increase until the filters need backwashing. This method is generally preferred because it requires less operator attention. With this method, a filter accepts as much flow as it can handle. As the filter becomes dirty, the flow through the filter becomes less and, if the plant has more than one filter, additional flow redistributes across the other filters. A flow restrictor is placed in the filter effluent pipe to prevent a filter inflow that is too great for the filter.

Regardless of the method of control, the filter eventually fills with suspended material. At some time, usually after 15 to 30 hours, it will need to be backwashed to clean the media.

Control of filter operations requires a rate of flow controller, loss of head indicator, and in-line turbidimeter, as described below.

Rate of Flow Controllers

Flow rates through filters are controlled by one of two different methods:

Declining Rate

This method of control is used where the head loss through the plant is quite large. It allows the filter head to increase until the filter becomes plugged with particles and the head loss is too great to continue operation of the filter. The rate through the filter is much greater in the beginning of a filter run than at the end when the filter is dirty. This method tends to be the most commonly installed in new filter plants.

Constant Rate

This type of control monitors the level of water on the top of the filter and attempts to control this level from the start of the operation to the end. This is accomplished by the controller operating a valve on the effluent of the filter. The valve will be nearly closed at the start of the filter run and fully open at the end. This design is used when the head or pressure on the filter is limited.

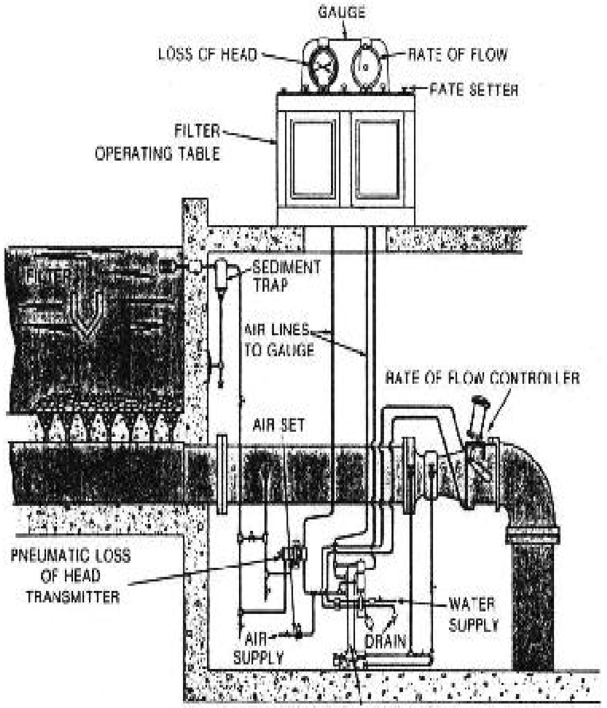
Both controllers consist of a venturi tube or some other type of metering device as well as a valve to control the flow from the filter. In most cases, the valve is controlled by an automatic control device, often an air-actuated type valve that is controlled by the flow tube controller.

Loss of Head Indicator

As filtration proceeds, an increasing amount of pressure, called head loss across the filter, is required to force the water through the filter. Head loss should be continuously measured to help determine when the filter should be backwashed. Usually the difference in the head is measured by a piezometer connected to the filter above the media and the effluent line.

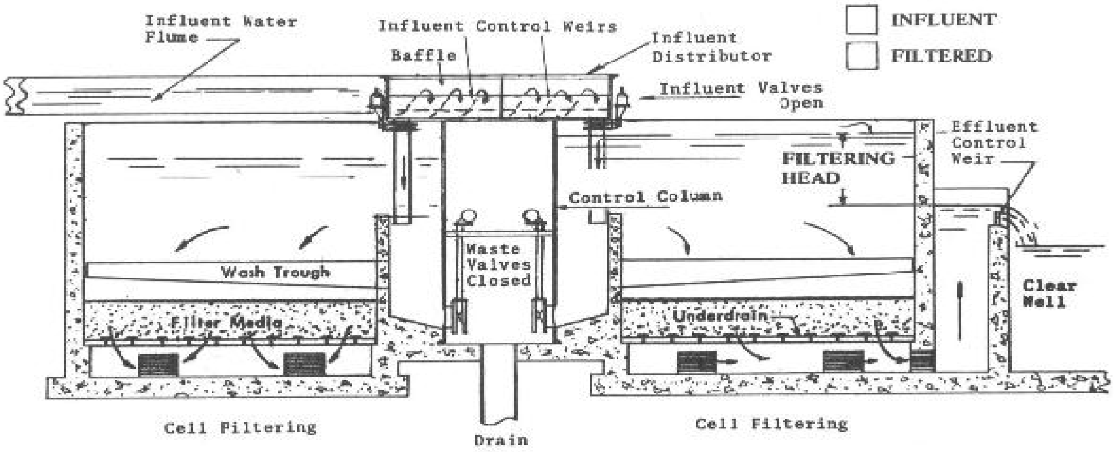
In-line Turbidimeter

Turbidity in water is caused by small suspended particles that scatter or reflect light so that the water appears to be cloudy. Turbidity of the filtered water may shelter bacteria, preventing chlorine from reaching it during the final disinfection process. The turbidity of the filtered water is one of the factors that determines the length of a filter run. At some point, the suspended material will start to break through the filter media and increase the turbidity of the filter effluent. At this time, the filter should be backwashed. Continuous turbidity monitors provide information about when the filter is approaching this point so that the operators can start the backwash before the turbidity is too great. Turbidity measurements will also indicate whether the coagulation and other treatment processes are operating properly.



RATE OF FLOW DIAPHRAGM PENDULUM PILOT VALVE CONTROL UNIT WITH PNEUMATIC TRANSMITTER

FILTER CYCLE



BACKWASH CYCLE

Proper backwashing is a very important step in the operation of a filter. If the filter is not backwashed completely, it will eventually develop operational problems. If a filter is to operate efficiently, it must be cleaned before the next filter run. Treated water is used for the backwash cycle, and is generally taken from elevated storage tanks or pumped in from the clear well.

During filtration, the filter media becomes coated with floc, which plugs the voids between the filter grains, making the filter difficult to clean. The media must be expanded to clean the filter during the backwash. This expansion causes the filter grains to violently rub against each other, dislodging the floc from the media. The filter backwash rate has to be great enough to expand and agitate the filter media and suspend the flocs in the water for removal. However, if the filter backwash rate is too high, media will be washed from the filter into the troughs and out of the filter. A normal backwash rate is between 15 to 23 gpm per square foot of filter surface area.

In most cases the filter backwash rate will not break up the mass on the top of the filter. The design engineer will recommend the installation of a surface wash of some type, the most common being a set of rotary arms that are suspended above the media during filtration. During filter backwash, the media expands upwards and around the washing arms. A newer method of surface wash involves using air scour before the water wash. This is a very efficient method but requires the installation of a large air blower to produce the air. The normal design for the air wash will be 2-5 cubic feet of air per square foot of filter area.

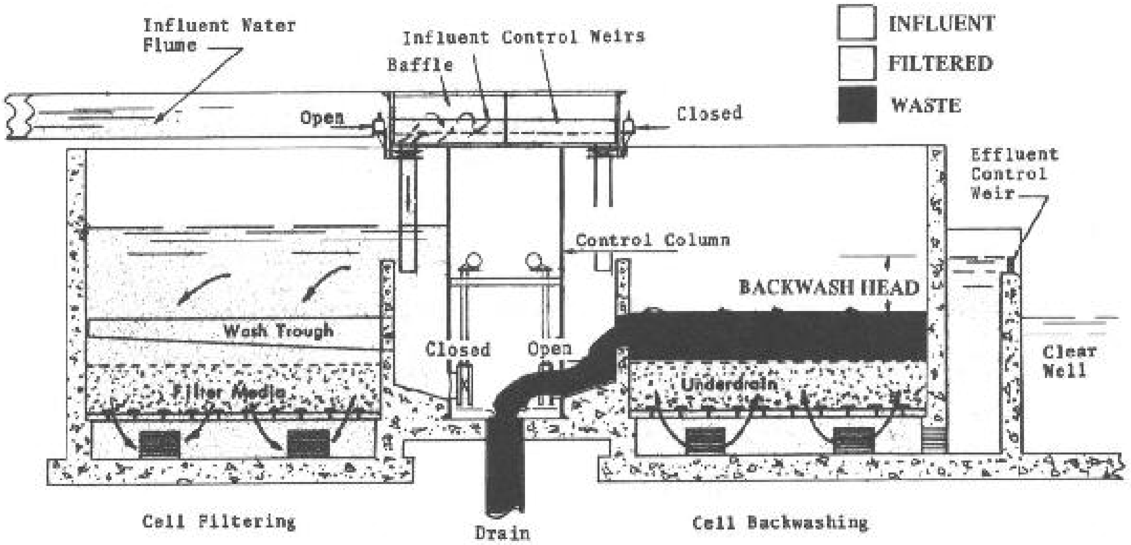
The filter should be backwashed when the following conditions have been met:

- The head loss is so high that the filter no longer produces water at the desired rate; and/or
- Floc starts to break through the filter and turbidity in the filter effluent increases; and/or
- A filter run reaches a given hour of operation.
- If a filter is taken out of service for some reason, it must always be backwashed prior to being put back on-line.

The decision to backwash the filter should not be based on only one of the above conditions. If a filter is not backwashed until the head loss exceeds a certain number of feet, the turbidity may break through and cause the filter to exceed the standard of 0.5 NTU of turbidity. Similarly, depending on filter effluent- turbidity alone can cause high head loss and decreased filter flow rate, which can cause the pressure in the filter to drop below atmospheric pressure and cause the filter to air bind and stop filtering.

If the water applied to a filter is very good quality, the filter runs can be very long. Some filters can operate longer than one week before needing to be backwashed. However, this is not recommended as long filter runs can cause the filter media to pack down so that it is difficult to expand the bed during the backwash.

The normal method for backwashing a filter involves draining the water level above the filter to a point six inches above the filter media. The surface wash is then turned on and allowed to operate for several minutes to break up the crust on the filter. After that, the backwash valve is opened, allowing backwash water to start flowing into the filter and start carrying suspended material away from the filter. For a filter with an air wash instead of a water-surface wash, the filter backwash water and the air wash should not be used together. This would be possible only if some means of controlling the media carryover is installed.



The time elapsed from when the filter wash is started until full flow is applied to the filter should be greater than one minute. After a few minutes, the filter backwash valve should be fully opened to allow full expansion of the filter media. Generally, this expansion will be 20-40 percent over the normal filter bed volume. The expansion needed will depend on how much agitation is needed to suspend the filter media to remove to suspended material trapped in the filter.

With a multi-media filter, the rate must be high enough to scrub the interface between the coal and the sand, where the highest amount of suspended solids will be removed from the media. The filter will be washed 10-15 minutes, depending on the amount of solids that must be removed. The best way to determine how long the filter should be washed is to measure the turbidity of the backwash water leaving the filter. In some cases, a filter is washed too long. This could be costly. Too much backwash water is used, and it must be treated after use. Backwash valves must be opened slowly. Opening the valves too rapidly can cause serious damage to the filter underdrain, filter gravel, and filter media.

Water from the filter backwash cannot be returned directly to the environment. Normally the water is discharged into a backwash tank and allowed to settle. The supernatant, or cleared liquid, is then pumped back to the head of the treatment plant at a rate not exceeding ten percent of the raw water flow entering the plant. The settled material is pumped to a sewer or is treated in the solids-handling process of the plant. This conserves most of the backwash water and eliminates the need to obtain a pollution discharge permit from the Minnesota Pollution Control

Agency for the disposal of the filter backwash water.

Since backwash is a very high flow operation, the surges that are created from the backwash coming from the filter must not be allowed to enter the head of the plant. Therefore, the spent backwash water must be stored in storage tanks and returned slowly to the treatment process.

FILTER TO WASTE

When filtration is started after backwash, the filtered water should be wasted until the turbidity in the effluent meets standards. Depending on the type of filter, this may last from two to 20 minutes. This wasting is needed as some suspended material remains in the filter media following the backwash. The media needs to become somewhat sticky again to start to capture the suspended material. Also, the filtration rate is higher in a clean filter, causing more material to be swept from the filter during the start-up. Filtration should always be started slowly after a backwash to prevent breakthrough of suspended material.

FILTER AIDS

When water passes through a filter, the floc sometimes is torn apart into smaller particles that penetrate deeply into the filter media, causing premature turbidity breakthrough. This requires more frequent filter backwashing of the filter and large volumes of backwash water to be able to remove the floc that has penetrated deeply into the filter bed.

A filter aid is a material that adds strength to the floc and prevents its breakup. Generally, a polymer is used as a filter aid because it creates strong bonds with the floc. Polymers are water soluble, organic compounds that can be purchased in either wet or dry form.

Polymers have very high molecular weight and cause the floc to coagulate and flocculate quickly. Polymers can have positive or negative charges, depending on the type needed to cause attraction to the specific floc filtered.

When used as a filter aid, the polymer strengthens the bonds and prevents the shearing forces in the filter from breaking the floc apart. For best results, the polymer should be added just ahead of the filter. A normal dose of polymer for filter aiding will be less than 0.1 ppm, but the exact dose will be decided by the result of a jar test and by experimentation in the treatment plant. Too much polymer will cause the bonds to become too strong, which may then cause the filter to plug, especially the top few inches of the filter media.

FILTER OPERATING PROBLEMS

There are three major types of filter problems. They can be caused by chemical treatment before the filter, control of filter flow rate, and backwashing of filters.

Chemical Addition Before Filter

Coagulation and flocculation stages of the water treatment must be monitored continuously.

Adjustments in the amount of coagulant added must be made frequently to prevent the filter from becoming overloaded with suspended material. This overload may cause the filter to prematurely reach its maximum headloss.

If there is early turbidity breakthrough in the filter effluent, more coagulant may have to be added to the coagulation process. There may be a need for better mixing during the coagulation or the addition of more filter aid. If there is a rapid increase in filter head loss, too much coagulant may be clogging the filter. Less coagulant or less filter aid should be used. The operator needs to learn to recognize these problems and choose the proper corrections.

Control of Filter Flow Rate

When a filter is subjected to rapid changes in flow rate, the turbidity of the effluent may be affected, and the dirtier the filter media, the greater the effect.

When a plant flow changes, the filter flow also has to change to produce the water needed. If an increase is necessary, the flow should, if possible, be increased gradually over a ten-minute period to reduce the impact on the filter. Addition of filter aids may also reduce the impact on the filter effluent.

During backwashing, one of the filter cells will be temporarily out of service, and the remaining filter cells must pick up the additional flow. This can cause an abrupt change in flow that will cause turbidity breakthrough. This problem can be avoided by keeping one filter in reserve to accept this additional flow. If the plant has a backwash storage basin, this will also prevent surges to the filters.

Many plants are not operated continuously, and the start-up at the beginning of the day will cause a surge to the filter(s). The filters should be backwashed before putting them back into operation or operated to waste until the effluent meets the standards.

Backwashing of Filters

Backwashing of the filters is the single most important operation in the maintenance of the filters. If the filter is not backwashed effectively, problems may occur that may be impossible to correct without totally replacing the filter media. These problems could be caused by improper backwashing procedures:

Mud Balls

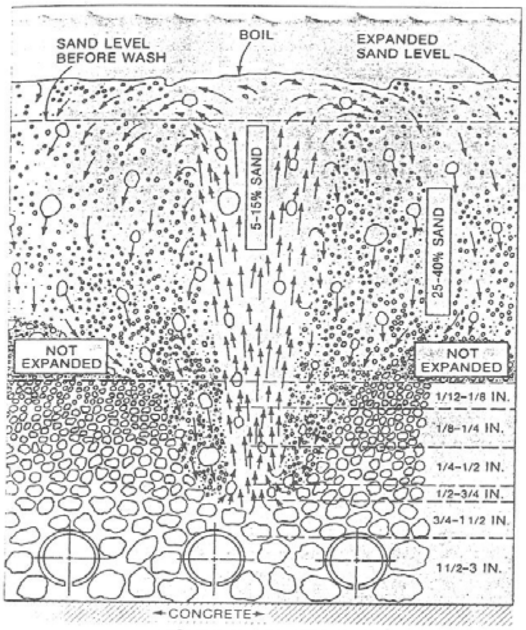
Mud balls are formed by the filter media cementing together with the floc that the filter is supposed to remove. If the filter is backwashed effectively, the mud balls are broken apart and removed. As the balls gain weight, they will settle to the bottom of the filter and occupy valuable filter volume. This will cause the flow to increase in the areas of the filter that have not been plugged. Additional problems, such as filter cracking and separation of the media from the filter walls may also be the result of mud-ball formation.

Filter Bed Shrinkage

Filter bed shrinkage or compaction can result from ineffective backwashing. Media grains in a clean filter rest directly against each other with very little compaction. Filter media in a dirty filter are surrounded by a soft layer which causes it to compact. This causes filter bed cracking and separation of the filter media from the walls of the filter. When the filter is cracked, it is obvious that the filter will short circuit. The flow will seek the crack and go straight through, resulting in excessive turbidity in the effluent.

Separation of Gravel

Separation of the gravel is caused by the backwash valve opening too quickly; as a result, the supporting gravel is forced to the top of the filter. This could also be caused by the filter underdrain being plugged, causing uneven distribution of the backwash water. When this happens, a boil occurs from the increased velocity in the filter. The filter media will start washing into the filter underdrain system and be removed from the filter. If displacement has occurred, the filter media must be removed from the filter and the filter rebuilt by the placement of each grade of media in its proper place.



A Sand Boil in a Filter Bed

Air Binding

Air binding of the filter is not common as long as the filter is washed regularly. Air binding is the result of pressure in the filter becoming negative during operation. This causes the air dissolved in the water to come out of the solution and become trapped in the filter, resulting in resistance and short filter runs. This negative head generally occurs in a filter that has less than five feet of head above the unexpanded filter bed. If a filter head of five feet is not possible, filter backwash should be started at a lower head loss than normal.

Air binding can also be caused by the water being cold and super-saturated with air. This air bubbles out as the water warms up. It is not possible for the operator to control this situation. If it happens, the filter must be backwashed more frequently to correct the filter air binding.

Media Loss

Media loss is normal in any filter. Some are lost each time the filter is backwashed, especially if the filter surface wash is used. If a large amount of media is being lost, the method of washing should be inspected and corrected. The bed should not have to be expanded more than 20 percent during the backwash cycle. It may help to turn off the surface wash approximately two minutes before the end of the backwash. If this does not correct the problem, the filter troughs may have to be raised to prevent the excessive media loss.

After a well-operated filter backwash, the filter should be level and smooth with no cracks or mud balls at the surface. A good bed will appear to move laterally during the backwash and there will be no boils at the surface. The filter should clear up evenly cleaning. If some areas are not clean, there could be an under-drain problem.

Membrane Filtration

A membrane is a thin layer of semi-permeable material that separates substances when a driving force is applied across the membrane. Membrane processes are increasingly used for removal of bacteria, microorganisms, particulates, and natural organic material, which can impart color, tastes, and odors to water and react with disinfectants to form disinfection byproducts.

As advancements are made in membrane production and module design, capital and operating costs continue to decline. The membrane processes discussed here are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO).

MICROFILTRATION

Microfiltration is loosely defined as a membrane separation process using membranes with a pore size of approximately 0.03 to 10 micronas (1 micron = 0.0001 millimeter), a molecular weight cut-off (MWCO) of greater than 1000,000 daltons and a relatively low feed water operating pressure of approximately 100 to 400 kPa (15 to 60psi) Materials removed by MF include sand, silt, clays, Giardia lamblia and Crypotosporidium cysts, algae, and some bacterial species. MF is not an absolute barrier to viruses. However, when used in combination with disinfection, MF appears to control these microorganisms in water.

There is a growing emphasis on limiting the concentrations and number of chemicals that are applied during water treatment. By physically removing the pathogens, membrane filtration can significantly reduce chemical addition, such as chlorination.

Another application for the technology is for removal of natural synthetic organic matter to reduce fouling potential. In its normal operation, MF removes little or no organic matter; however, when pretreatment is applied, increased removal of organic material can occur. MF can be used as a pretreatment to RO or NF to reduce fouling potential. Both RO and NF have been traditionally employed to desalt or remove hardness from groundwater.

ULTRAFILTRATION

Ultrafiltration has a pore size of approximately 0.002 to 0.1 microns, an MWCO of approximately 10,000 to 100,000 daltons, and an operating pressure of approximately 200 to 700 kPa (30 to 100 psi). UF will remove all microbiological species removed by MF (partial removal of bacteria), as well as some viruses (but not an absolute barrier to viruses) and humic materials. Disinfection can provide a second barrier to contamination and is therefore recommended.

The primary advantages of low-pressure UF membrane processes are compared with conventional clarification and disinfection (post-chlorination) processes are:

- No need for chemicals (coagulants, flocculants, disinfectants, pH adjustment)
- Size-exclusion filtration as opposed to media depth filtration

- Constant quality of the treated water in terms of particle and microbial removal
- Process and plant compactness
- Simple automation

However, fouling can cause difficulties in membrane technology for water treatment.

NANOFILTRATION

Nanofiltration membranes have a nominal pore size of approximately 0.001 microns and an MWCO of 1,000 to 100,000 daltons. Pushing water through these smaller membrane pores requires a higher operation pressure than either MF or UF. Operating pressures are usually near 600 kPa (90psi) and can be as high as 1,000 kPa (150psi). These systems can remove virtually all cysts, bacteria, viruses, and humic materials. They provide excellent protection from DBP formation if the disinfectant residual is added after the membrane filtration step.

Because NF membranes also remove alkalinity, the product water can be corrosive, and measures, such as blending raw water and product water or adding alkalinity, may be needed to reduce corrosivity. NF also removes hardness from water, which accounts for NF membranes sometimes being called “softening membranes.” Hard water treated by NF will need pretreatment to avoid precipitation of hardness ions on the membrane. However, more energy is required for NF than MF or UF.

REVERSE OSMOSIS

Reverse osmosis can effectively remove nearly all inorganic contaminants from water. RO can also effectively remove radium, natural organic substances, pesticides, cysts, bacteria and viruses. RO is particularly effective when used in series with multiple units. Disinfection is also recommended to ensure the safety of water.

Some of the advantages of RO are:

- Removes nearly all contaminant ions and most dissolved non-ions,
- Relatively insensitive to flow and total dissolved solids (TDS level and suitable for small systems with a high degree of seasonal fluctuation in water demand,
- RO operates immediately, without any minimum break-in period,
- Low effluent concentration possible,
- Bacteria and particles are also removed, and
- Operational simplicity and automation allow for less operator attention and make RO suitable for small system applications.
- Some of the limitations of RO are:

- High capital and operating costs,
- Managing the wastewater (brine solution) is a potential problem,
- High level of pretreatment is required in some cases,
- Membranes are prone to fouling and
- Produces the most wastewater at between 25-50 percent of the feed.

MEMBRANE PROCESSES 13.3

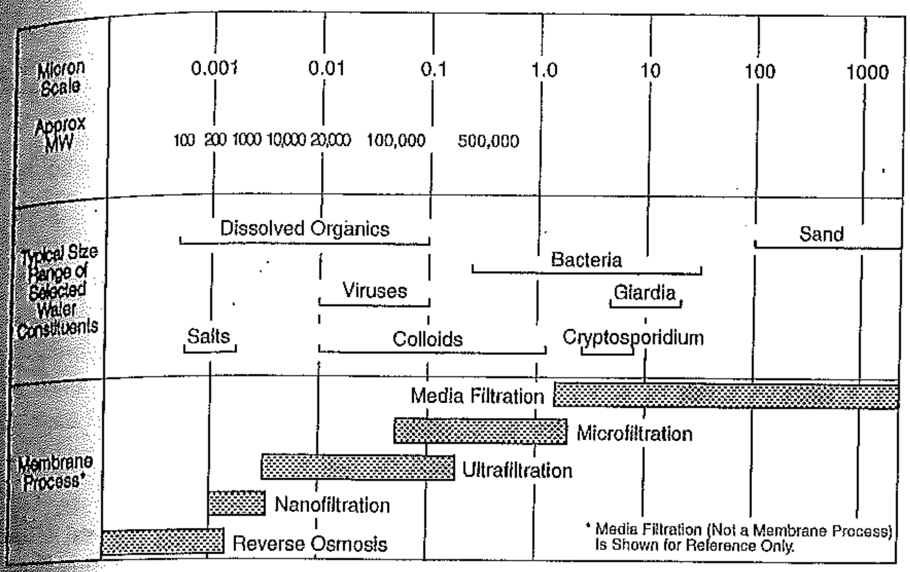


FIGURE 13.2 Pressure-driven membrane process application guide.

MEMBRANE MATERIALS

Normally, membrane material is manufactured from a synthetic polymer, although other forms, including ceramic and metallic "membranes," may be available. Almost all membranes manufactured for drinking water are made of polymeric material, since they are significantly less expensive than membranes constructed of other materials.

Membranes constructed of polymers that react with oxidants used in drinking water treatment should not be used with chlorinated feed water. Mechanical strength is another consideration, since a membrane with greater strength can withstand larger trans-membrane pressure (TMP) levels, allowing for greater operational flexibility and the use of higher pressures.

Membranes with bi-directional strength may allow cleaning operations or integrity testing to be performed from either feed or filtrate side of the membrane. Membranes with a particular surface charge may remove particulate or microbial contaminants of the opposite charge due to electrostatic attraction. Membranes can also be hydrophilic (water attracting) or hydrophobic (water repelling). These terms describe how easily membranes can be wetted, as well as its ability to resist fouling to some degree.

MF and UF membranes may be constructed from a wide variety of materials, including cellulose acetate, polyvinylidene fluoride, polyacrylonitrile, polypropylene, polysulfone, polyethersulfone, or other polymers. Each of these materials has different properties with respect to the surface charge, degree of hydrophobicity, pH and oxidant tolerance, strength and flexibility.

NF and RO membranes are generally manufactured from cellulose acetate or ployamide materials, and their various advantages and disadvantages. Cellulose membranes are susceptible to biodegradation and must be operated within a narrow, pH range of 4 to 8 but they do have some resistance to continuous low-level oxidants.

Chlorine doses of 0.5 mg/L or less may control biodegration and biological fouling without damaging the membrane. Polyamide membranes, by contrast, can be used under a wide range of pH conditions and are not subject to biodegradation. Although these membranes have very limited tolerance for strong oxidants, they are compatible with weaker oxidants such as cholramines. These membranes require significantly less pressure to operate and have become the predominate material used for NF or RO applications.

MEMBRANE MODULES

Membrane filters are usually manufactured as flat sheet stock or as hollow fibers and then formed into on of several different types of membrane modules. Module construction typically involves potting or sealing the membrane material into an assembly, such as with hollow-fiber module. These types of modules are designed for long-term use over the course of a number of years. Spiral-wound modules are also manufactured for long-term use, although these modules are encased in a separate pressure vessel that is independent of the module itself.

Hollow-Fiber Modules

Most hallow-fiber modules used in drinking water treatment applications are manufactured for MF or UF membranes to filter particulate matter. These modules are comprised of hollow-fiber membranes, which are long and very narrow tubes that may be constructed of membrane materials described previously. The fibers may be bundled in one of several different arrangements.

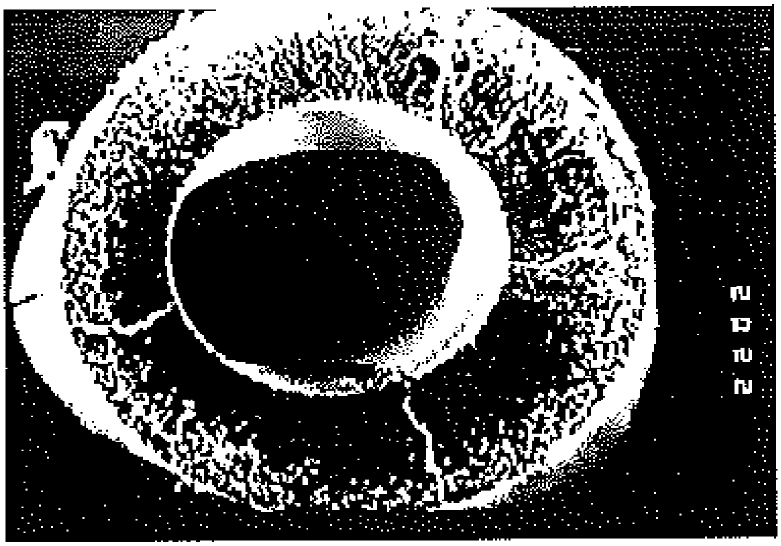
Fibers can be bundled together longitudinally, potted in a resin on both ends, and encased in a pressure vessel. These modules are typically mounted vertically, although horizontal mounting may be used. These fibers can be similar to spiral-wound modules and inserted into pressure vessels independent of the module itself. These modules (and the pressure vessels) are mounted horizontally. Bundled hollow fibers can also be vertically and submerged in a basin that does not need a pressure vessel.

A typical hollow-fiber module may consist of several hundred to over 10,000 fibers. Although dimensions vary by manufacturer, approximate ranges for hollow-fiber construction are:

Outside diameter	0.5 – 2.0 mm
Inside diameter	0.3-1.0 mm
Fiber wall thickness	0.1-0.6 mm
Fiber length	1-2 meters

Hollow-fiber membrane modules may operate in an "inside-out" or "outside-in" mode. In inside-out mode, feed water enters the center of the fiber (lumen) and is filtered radially through the fiber wall. Filtrate is then collected from outside the fiber. During outside-in operation, feed water passes from outside the fiber to the inside, where filtrate is collected in the center of the fiber.

Hollow Fiber Cross-Section Photomicrograph



When a hollow-fiber module is operated in an inside-out mode, pressurized feed water may enter the center of the fiber at either end of the module, while filtrate exits through a port located at the center or end of the module. In outside-in mode, feed water typically enters the module through an inlet port located in the center and is filtered into the center of the fiber, where the filtrate exits through a port at one end of the module. Most hollow-fiber systems operate in direct filtration mode and are periodically backwashed to remove the accumulated solids.

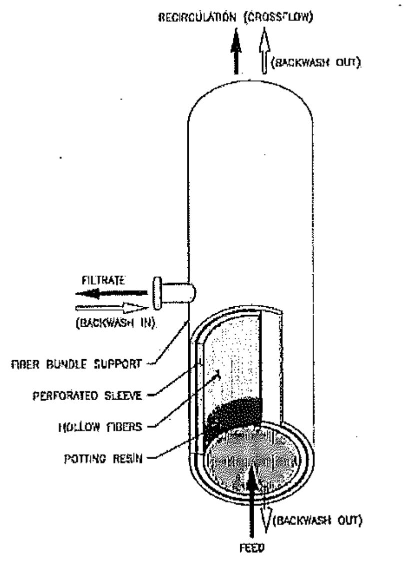
Spiral-Wound Modules

Spiral-wound modules were developed to remove dissolved solids, and are most often associated with NF/RO processes. The basic unit is a sandwich of flat membrane sheets called a “leaf” wound around a central perforated tube. One leaf consists of two membrane sheets placed back to back and separated by a spacer called permeate carrier. Layers of the leaf are glued along three edges, while the unglued edge is sealed around the perforated central tube.

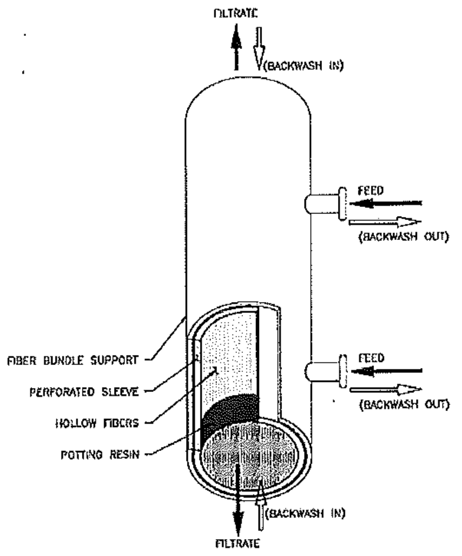
Feed water enters the spacer channels at the end of the spiral-wound element in a path parallel to the central tube. As feed water flows through the spacers, a portion permeates through either of the two surrounding membrane layers and into the permeate carrier, leaving behind any dissolved and particulate contaminates that are rejected by the membrane.

Filtered water in the permeate carrier travels spirally inward toward the central collector tube, while water in the feed spacer that does not permeate through the membrane continues to flow across the membrane surface, becoming increasingly concentrated with rejected contaminates. This concentrate stream exits the element parallel to the central tube through the opposite end from which the feed water entered.

Inside-Out and Outside-In Modes of Operation (Using Pressure Vessels)

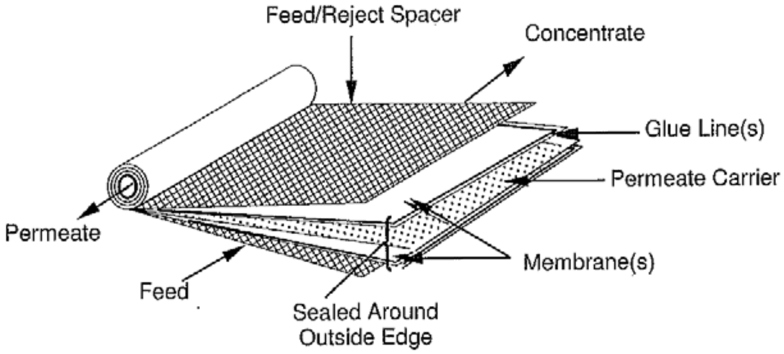


Inside-Out Hollow-Fiber Configuration



Outside-In Hollow-Fiber Configuration

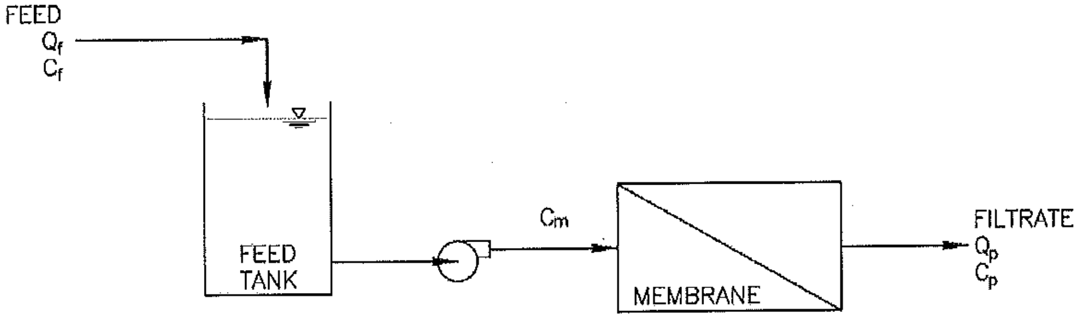
Spiral-Wound Membrane Module



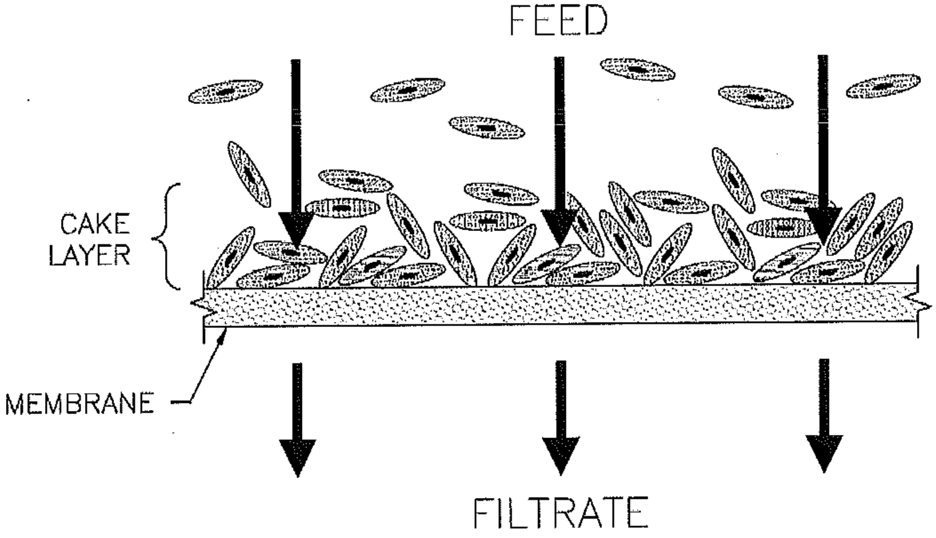
DEPOSITION MODE

Membrane filtration systems operating in deposition have one influent (feed) and one effluent (filtrate) stream. These systems are also commonly called "dead-end" or "direct" filtration systems and are similar to conventional granular media filters in terms of hydraulic configuration. In deposition mode, contaminates suspended in the feed stream accumulate on the membrane surface and are held in place by hydraulic forces acting perpendicular to the membrane, forming a cake layer.

Schematic of a System Operating in Deposition Mode



Deposition Mode



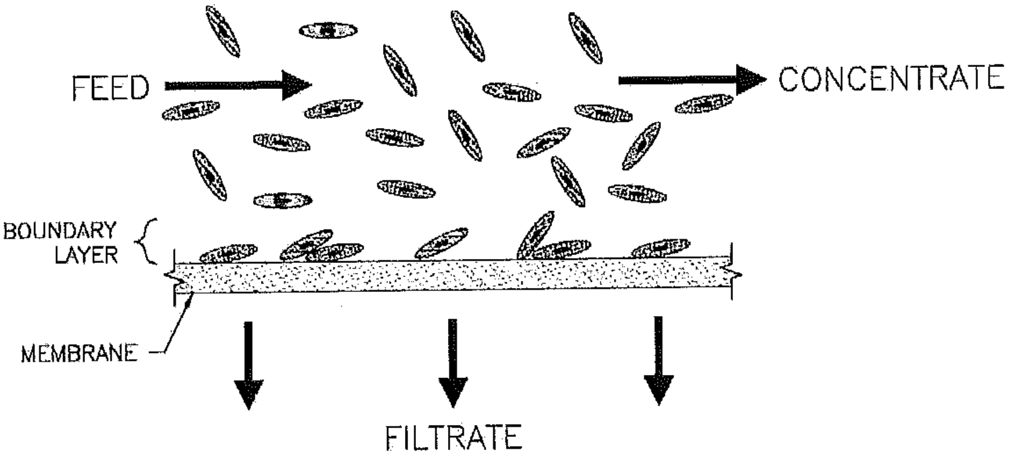
Most hollow-fiber MF and UF systems operate in deposition mode. Typically, accumulated solids are removed from MF/UF systems by backwashing. However, some systems operate until accumulated solids reduce the flow and/or TMP to an unacceptable level, at which point the membrane cartridge is replaced.

Some MF/UF systems utilize a periodic “backpulse” or a short interval of reverse flow (which may include air and/or addition of small doses of oxidants) designed to dislodge particles from the membrane surface without removing these solids from the system. This process re-suspends particles, effectively concentrating the suspended solids in the feed near the membrane surface and increasing the potential for pathogens or other particulate to pass through an integrity breach and contaminate the filtrate.

SUSPENSION MODE

In membrane filtration systems that operate in suspension mode, a scouring force using water and/or air is applied parallel to the membrane during production of the filtrate in a continuous or intermittent manner. The objective of operating in this mode is to minimize the accumulation of contaminants at the membrane surface or boundary layer, thus reducing fouling.

Suspension Mode



BACKWASHING

The backwash process is designed to remove contaminants accumulated on the membrane. Each membrane unit is backwashed separately and in a staggered pattern to minimize the number of units in simultaneous backwash at any given time. During backwash, the direction of flow is reverse for 30 seconds to 3 minutes. The force and direction of the flow dislodge the contaminants at the membrane surface and wash accumulated solids out through the discharge line. Membrane filtration systems are 15 to 60 minutes between backwash events. The backwash process reduces system productivity 5 to 10 percent due to the volume of filtrate used during backwash. Backwashing is almost exclusively associated with hollow-fiber MF and UF processes.

Backwashing is conducted according to manufacturer specifications and site-specific considerations. Although more frequent backwashing allows for higher fluxes, this is counterbalanced by the decrease in system productivity. In general, a backwash cycle is triggered when a performance-based benchmark is exceeded, such as operating time, volume, increase in TMP, and/or flux decline. Ideally, the backwash process restores the TMP to its clean level; however, most membranes exhibit a gradual increase in TMP after each backwash, indicating accumulation of foulants that cannot be removed by the backwash process alone. These foulants are addressed through chemical cleaning.

Some systems also utilize pressurized air and/or chlorine in combination with filtered water to remove solids, provide pathogen inactivation and biofouling control, and improve backwash effectiveness. A disinfectant such as chlorine may be added at every backwash to once per day.

Some MF/UF membranes use chemicals other than chlorine (such as acids, bases, surfactants, or other proprietary chemicals). These strategies are used to enhance membrane flux and extend intervals between chemical cleanings, thus lowering the cost of operation. State regulators may require enhanced cross-connection control measures for backwash piping and special provisions for rinsing the membranes after backwash be required.

Because spiral-wound membranes generally do not permit reverse flow, NF and RO membrane systems are not backwashed. For these systems, membrane fouling is controlled with chemical cleaning, flux control, and crossflow velocity. The inability of spiral-wound membranes to be backwashed is one reason NF and RO membranes are seldom applied to directly treat water with high turbidity and/or suspended solids.

CHEMICAL CLEANING

Chemical cleaning also controls membrane fouling, particularly inorganic scaling and organic and befouling that is not removed with backwash. Chemical cleaning is conducted for each membrane unit separately and is typically staggered to minimize the number of units undergoing cleaning at any time.

While chemical cleaning is conducted on both MF/UF and NF/RO systems chemical cleaning is the primary mean of removing foulants in NF/RO systems. Although cleaning intervals may vary on a system-by-system basis, gradual accumulation of foulants makes chemical cleaning necessary. Membrane cartridge filters are an exception, however, in that cartridge filters are usually designed to be disposable and are not subject to chemical cleaning.

The goal of chemical cleaning is to restore the TMP of the system to its clean level. Any foulant that is removed by either the backwash or chemical cleaning process is known as reversible fouling. Over time, membrane processes also experience some degree of irreversible fouling which cannot be removed through chemical cleaning or backwashing. Irreversible fouling occurs in all membrane systems, and eventually requires membrane replacement.

There are a variety of different chemicals that may be used for membrane cleaning, and each is targeted to remove a specific form of fouling. For example, citric acid is used to dissolve inorganic scaling. Strong bases such as caustic are typically used to dissolve organic material. Detergents and surfactants may also be used to remove organic and particulate foulants, particularly those that are difficult to dissolve. Chemical cleaning may also use a strong chlorine solution to control biofouling. Due to the variety of foulants present in source waters, it is often necessary to use a combination of different chemicals in series to address multiple types of fouling.

Chemical Cleaning Agents

Category	Chemicals Commonly Used	Typical Target Contaminant(s)
Acid	• Citric Acid ($C_6H_8O_7$) • Hydrochloric Acid (HCl)	Inorganic scale
Base	• Caustic (NaOH)	Organics
Oxidants / Disinfectants	• Sodium Hypochlorite (NaOCl) • Chlorine (Cl_2) Gas • Hydrogen Peroxide (H_2O_2)	Organics; Biofilms
Surfactants	• Various	Organics; Inert particles

Proprietary cleaning chemicals are available, and these specialty cleaning agents may be useful when more conventional chemicals are ineffective. For example, enzymatic cleaners have been effective at dissolving organic contaminants. Chemical cleaning options are limited for membranes that cannot tolerate oxidants and/or extreme pH levels. A chemical cleaning regimen may be specified by the manufacturer based on site-specific source water quality.

Clean-in-place (CIP) is often used to describe chemical cleaning since it is typically conducted while the membrane modules remain within the membrane unit (in-situ). The cleaning process re-circulates a cleaning solution through the membrane system at high velocities (to generate scouring action) and elevated temperature (to enhance the solubility of the foulants).

A soak cycle follows the recirculation phase. After the soak cycle, the membrane system is flushed to remove residual traces of the cleaning solution(s). The processes may be repeated using a different cleaning solution to target different types of foulants until the membranes have been successfully cleaned. Softened or de-mineralized water may be required for the cleaning solution, or as rinse water.

While backwashing may be conducted at more regular intervals, chemical cleaning is done only when necessary. Chemical cleaning is generally necessary for MF and UF systems when periodic backwashing to restore system productivity reaches a point of diminishing returns. For NF and RO systems, a 10 to 15 percent decline in flux or a 50 percent increase in differential pressure may indicate the need for chemical cleaning.

Delaying necessary chemical cleaning can accelerate irreversible fouling, reduce production capacity, and shorten membrane life. A benchmark of 30 days is commonly used as a minimum required interval between chemical cleanings for MF/UF systems, although a well-designed system may operate for much longer between cleanings. NF/RO systems are normally designed to operate for much longer periods between chemical cleanings, from 3 months to 1 year.

In addition to a CIP when a point of diminishing productivity is reached, some MF/UF membrane system manufacturers recommend a routine, short duration chemical cleaning to minimize the accumulation of foulants. These processes are referred to “chemical washes” or “maintenance cleans,” and are implemented on preset intervals ranging from several times pre day to once every several days, depending on the propensity of the water to cause membrane fouling.

Isolating cleaning chemicals from the treated (filtered) water is an important consideration. In addition, it is important to properly flush the membrane unit after the cleaning process and before restarting the filtration cycle. The flushed water should be diverted to waste until filtrate water quality parameters (turbidity for MF/UF systems and pH for NF/RO systems) return to normal levels. The volume of flushed water can be significant when surfactants are used.

For MF/US systems, it is common to recycle as much as 90 percent of the cleaning chemicals for reuse, thus reducing the volume of chemical waste as well as the cost associated with cleaning. Recycling cleaning solutions is less common with NF/RO systems, since used cleaning solutions accumulate dissolved constituents with repeated use, diminishing effectiveness of the cleaning agents.

WASTE STREAM DISPOSAL

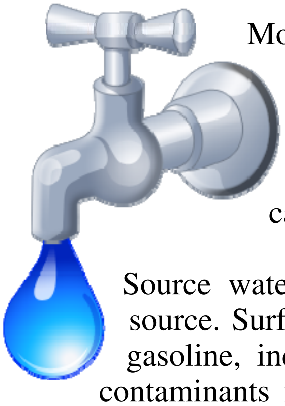
Waste stream disposal is a significant problem in many areas. Unlike conventional treatment processes, in which approximately 5 to 10 percent of the influent water is discharged as waste, membrane processes produce waste streams as much as 15 percent of the total treated water volume. Because little or no chemical treatment is used in a membrane system, the concentrate stream usually contains only the contaminates found in source water (although at much higher concentrations), and concentrate can sometimes be disposed of in the source water. Other alternatives include deep well injection, dilution and spray irrigation, or disposal in municipal sewer. These alternatives are usually necessary for NF wastes, which usually contain concentrated organic and inorganic compounds. Disposal must be carefully considered and applicable discharge regulations must be respected.

MEMBRANE INTEGRITY TESTING

One of the most critical aspects of employing membrane technology is ensuring that the membranes are intact and continuing to provide a barrier between the feedwater and the permanent or product water. There are several different methods that can be employed to monitor membrane integrity, including turbidity monitoring, particle counting or monitoring, air pressure testing, bubble point testing, sonic wave sensing, and biological monitoring.

Adapted from PA website, dated November 2005, and National Drinking Water Clearing House Web site, dated March 1999

Taste and Odor



Most customers judge the quality of drinking water by taste and odor. If the customer is satisfied with these qualities, it is assumed the water is safe to drink. Many harmful contaminants in water cannot be detected due to taste or smell and many of the contaminants found in drinking water that have a detectable taste or odor are not harmful. Sources of taste and odor problems can be found in surface water and groundwater.

Source water protection involves the prevention of contaminants from entering the source. Surface water or groundwater may become contaminated by pollutants such as gasoline, industrial solvents or a wide variety of volatile organics. The removal of contaminants from surface water or groundwater is costly and may involve the use of aeration, powdered activated carbon, or both.

If taste and odor must be controlled at the treatment plant, oxidation, aeration and adsorption can be effective in reducing taste and odor, and improved coagulation filtration.

ODOR MEASUREMENTS

One of the most common methods for measuring odor in water is the threshold odor test. It involves a series of flasks presented to an observer, who is told that some of the samples contain odors and that the series is arranged in order of increasing concentrations. The observer is also given a known odor-free blank for reference during the test.

The observer compares the flasks in ascending order with the blank and then notes whether an odor is detected in any sample flask. Individuals vary in their reactions to certain types of odors. An odor stimulus that is agreeable to one may be disagreeable to another. Such differences complicate the attempts to predict the odor intensity of the mixtures.

METHANE AND HYDROGEN SULFIDE IN GROUNDWATER

Methane gas from the decomposition of organic matter tastes like garlic and the biggest danger from the presence of methane is its explosiveness. It can be removed by aeration.

Hydrogen sulfide (H_2S) in water is a common problem that is therefore discussed separately from the other taste and odor problems. The most common method of removing hydrogen sulfide from water is by aeration. Carbon adsorption is also effective, but more expensive.

ALGAE AND MICROORGANISMS IN SURFACE WATER

Most taste and odors in surface water are organic and derived from algae blooms. Algae growths can be influenced by the pollution from domestic waste, run-off from fertilizer, and animal, domestic, and industrial waste.

Algae are simple forms of plant life that exist in relatively clean water, are widely distributed in nature, and usually present in lakes, ponds, and streams. Most are microscopic in size and vary from single cells to filaments, chains or groups of cells. Their presence normally does not constitute a health risk. There are thousands of types of algae species; however, the most common types that cause taste and odors are:

- Cyanophyceae - These types are responsible for most taste and odor complaints. They are blue-green in color and float at or near the surface of a surface source.
- Diatomaceae - These are one-celled plants reproduce by splitting. The cell walls contain green and brown coloring matter. Dead organisms produce a fishy or geranium odor in the spring and fall.
- Chlorophyceae - These are one-celled green algae that are mostly free floaters which produce a grassy or fishy odor or taste.

Since algae are aquatic plants, they require the same conditions (sunlight and nutrients) as land plants. Algae analysis has shown that as much as ten percent of the weight is nitrogen and that they contain significant amounts of phosphorus. Nitrogen and phosphorus are important components of fertilizers. The amount of run-off from farms and city lots may be the reason that some bodies of water support heavy algae growths while others do not. Other factors, such as a water surface's size, shape, and depth also influence the growth of different types of algae.

- Protozoa - These microorganisms belong to the simplest form of animal life and some forms have characteristics from both the animal and plant kingdoms. Odors and tastes caused by protozoa have been described as fishy, aromatic, cucumber-like, or muskmelon-like.
- Schizomycetes - These microorganisms, known as iron and sulfur bacteria, cause hydrogen sulfide to be found in water supplies. They include crenothrix and beggiatoa. Most often found in groundwater supplies, they produce an offensive odor of decaying matter.
- Actinomycetes - Closely allied with microscopic plants, actinomycetes are one-celled, filamentous microorganisms occupying a separate group between fungi and bacteria, but more closely associated with the latter. They account for a large part of the microbial population of soils and bottoms of lakes and rivers. Odors associated with this group have been described as earthy or musty.

INDUSTRIAL WASTE IN SURFACE WATER

Most compounds that pollute surface water are organic. These materials can, under certain conditions, cause persistent difficulties even when present in only trace amounts. Many compounds used in industrial operations can cause problems for the operator even at very low levels. Chemicals that can create taste and odor in water include, at these concentrations:

Formaldehyde	50,000 parts per billion (ppb)
Phenols	250 - 4,000 ppb
Xylene	300 - 1,000 ppb
Refinery hydrocarbons	25 - 50 ppb
Chlorinated phenols	1 - 100 ppb

Even small concentrations of these compounds can cause problems. In most cases, the consumer will not be able to identify the exact chemical that is causing the problem, but will instead report a specific type of taste, such as medicinal or metallic. Phenols and related compounds are often the source of the medicinal taste.

The taste of phenols is intensified by the addition of chlorine. Refinery waste from a paper mill can cause a distinctive odor. Hydrocarbons from this waste form an oily film on the water; the waste of a paper mill using the sulfite process will have that characteristic paper-mill smell.

Zinc, copper, and other metals produce characteristic taste in water. Wastes from a metal industry can cause taste, but not odor, problems.

Domestic wastewater contains a mixture of organic material. In wastewater treatment, some of these compounds may be partially oxidized and produce an odor. When wastewater effluent chlorinated to control bacteria, it may develop a chlorine odor from the formation of chlor-organic compounds.

Domestic wastewater may also contain a relatively high concentration of nitrogen compounds. During stabilization of nitrogen, ammonia is produced which will produce chloramines when combined with chlorine. These compounds have a very persistent swimming-pool odor.

TASTE AND ODOR REMOVAL

Oxidation

In most cases, oxidation is the best method for controlling taste and odor problems. Oxidation can be carried out with the following chemicals:

Potassium permanganate, most often used and is a very strong oxidant. According to the California Department of Health Services Water Treatment Plant Operation, a dosage range of 0.1 to 0.5 mg/l can control taste and odor problems.

Ozone is also effective oxidizing of taste and odor compounds. Ozone changes the characteristics of the taste and odor in addition to reducing the level of the odor-producing compound. Ozone dosages of 2 mg/l to 5 mg/1 have been used. Several pilot studies have shown that the combination of ozone and hydrogen peroxide may be superior to the use of ozone alone.

Chlorine dioxide or chorine are also effective methods of taste and odor control, but use as a control chemical must be evaluated carefully due to the formation of THMs and chlorophenol when organics are present.

Aeration

Aeration is a practical solution for taste and odor control when the problem is caused by volatile compounds, such as hydrogen sulfide. It is generally not the best method for controlling taste and odors that are caused by algae. (See Aeration Chapter)

Adsorption

Adding powdered activated carbon to water or using of granular activated carbon (GAC) in the water filter can remove taste and odor. Powdered activated carbon (PAC) is the preferred method when the taste and odor is moderate and infrequent.

Two basic types of PAC feed systems are dry storage and dry feeding. If the hourly feed rate is less than 150 pounds, the feed system should be use a solution tank. If the hourly feed rate exceeds 150 pounds, a slurry system should be considered.

The powdered activated carbon dosage will vary from 1 to 50 mg/l. A dosage of 25 mg/l is considered by many industry experts to be the maximum dosage.

Granular activated carbon filters should be considered when moderate-to-severe taste and odor problems exist frequently. GAC is similar to normal filters; however, the bed contact time is very important. The contact time should range from 3-to-10 minutes for purposes of taste and odor control and the filter rate will range from 3 to 6 gpm/ft^2. When the GAC is exhausted, the total volume of the bed must be replaced with new or regenerated GAC, which can be created by heating and re-burning used GAC to destroy the material it removed.

HYDROGEN SULFIDE REMOVAL

Aeration

Aeration is both practical and effective in removing hydrogen sulfide if the total level of sulfides is less than 3 to 4 mg/l. It is essential to adjust the pH of the water to a level below 7 prior to aeration. Air-to-water flow ratio should be in the range of 80-100: 1 and hydraulic loading for the tray-type aerator should be 7 - 15 gpm/ft^2.

Hydrogen Sulfide (H_2S) + ½ Oxygen in Air (0_2) <----> Water (H_20) + Sulfur (S)

Chlorination

Chlorine is often used to oxidize hydrogen sulfide in groundwater. The following is the reaction that takes place:

Hydrogen Sulfide (H_2S) + 4 Chlorine (Cl_2) + 4 Water (H_20)----> Sulfuric Acid (H_2S0_4) + 8 Hydrochloric (Muriatic) Acid (HCL)

Therefore, 8.3 parts of chlorine are required to oxidize one part of hydrogen sulfide. Factors that affect this reaction are temperature, pH, and reaction time.

Potassium Permanganate

Potassium permanganate is a common oxidant that is often used in water treatment processes. This reaction takes place to remove hydrogen sulfide:

4 Potassium Permanganate ($KMnO_4$) + 3 Hydrogen Sulfide (H_2S)
---> 2 Potassium Sulfate (K_2S0_4) + 3 Mangarous Oxide (MnO)
+ Mangarous Dioxide (MnO_2) + 3 Water (H_20)

As a result, 6.2 parts of potassium permanganate are required to oxidize one part of hydrogen sulfide. pH of the water plays an important role in the oxidation, with pH 6.5 to 7 being optimal.

TASTE AND ODOR REMOVAL FROM DISTRIBUTION

Taste and odors occurring in the distribution system are primarily the result of corrosion of pipe material and/or growth of iron bacteria, such as crenothrix and leptorix, the water main. If the water has high sulfates and is allowed to stand in dead ends, taste and odor problems may be compounded by sulfate-reducing bacteria.

These problems can be rectified only by proper design of the system, such as eliminating dead ends and providing adequate means of flushing the system. Maintenance crews must keep the water lines clean by regularly flushing out deposits and the microorganisms that accumulate within these deposits.

Water treatment plants can also minimize taste and odor problems by maintaining an adequate residual of chlorine to combat the growth of bacteria in the system and by using anti-corrosion measures, either by adjusting the pH of the water or by adding corrosion inhibitors to the finished water (See Corrosion Chapter).

Notes:

Distribution System Operation

The proper operation of the distribution system is equal in importance as the operation of a water treatment plant. The distribution system delivers the water from the source to the customer.

PIPING MATERIALS

Of the many types of pipe in use today, no one type fits all conditions of service. Knowledge of the different types of pipe will allow the operator to select the one that best fits the installation.

CAST IRON PIPE

In the United States today there are more miles of cast iron pipe in service than any other type of pipe. Cast iron enjoys this distinction because it has been used as a piping material for centuries and it provides long, useful life in underground piping service. It is available in diameters from two to 48 inches and in individual lengths from 18 to 20 feet.

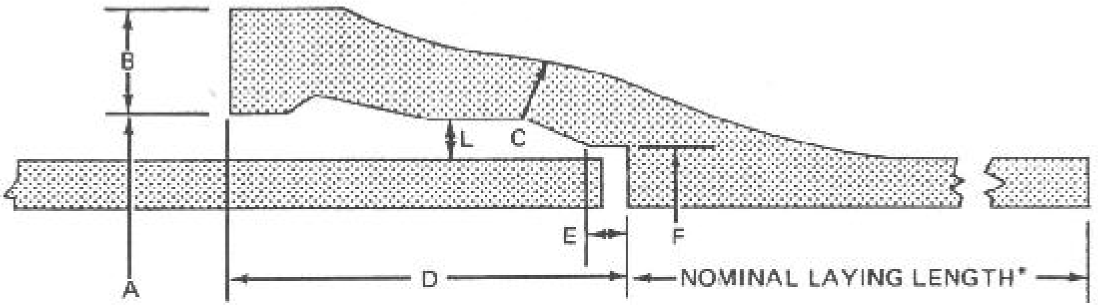
Interior corrosion and the formation of tubercles that reduce the carrying capacity of the pipe are major problems in iron (ferrous) piping materials. Most cast iron pipe used today has its interior lined with a thin coating of Portland cement, which greatly reduces the corrosion as well as friction losses.

Although many miles of the older type “pit cast” or “sand cast” iron pipe is still in service, centrifugal cast iron pipe is more common. The thickness of the pipe is dictated by the depth of bury and the pressure that will be applied. Class 50 to Class 54 is the most common pipe classes in Minnesota.

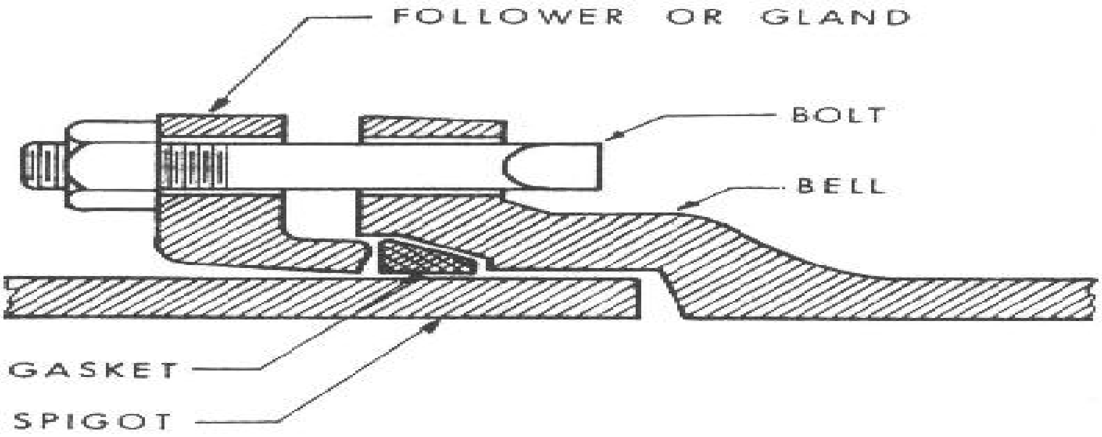
Cast iron pipe is adaptable to most service conditions. However, the pipe is subject to excessive outside corrosion in a highly acid soil, where the carbon dioxide content is high. Under these conditions, a pipe material other than cast iron may be a better choice.

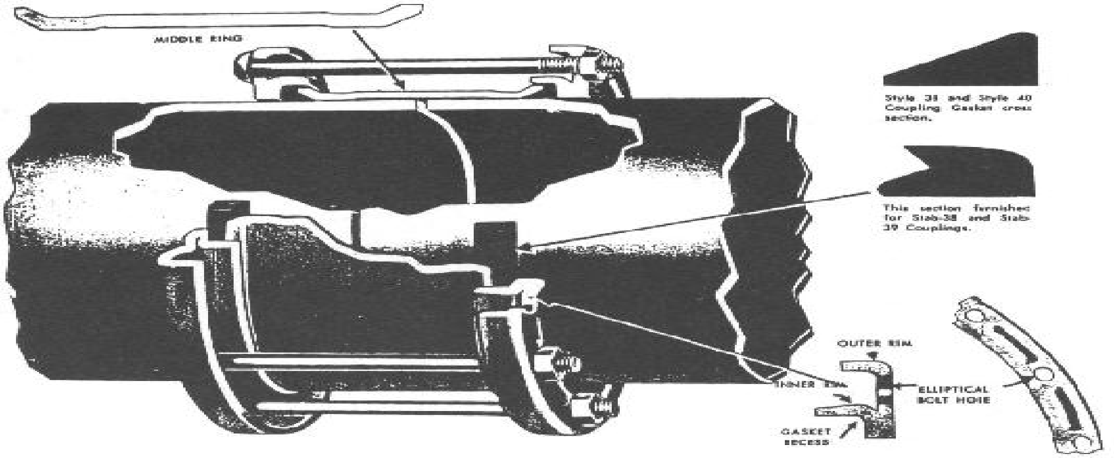
Pipe Joints

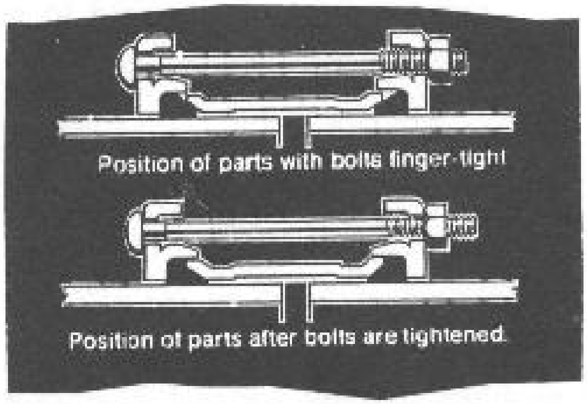
Until around 1950, a lead joint was commonly used on cast iron pipe. In this joint, the bell and spigot are put together with a yarning material which is chalked into the joint to prevent leakage. Molten lead is then poured into the joint to provide the strength needed to hold the pressure of the water. The lead will have to be chalked after it has cooled to make the joint watertight. In many utilities it was common practice to use a sulphur material which required no chalking in place of the lead. The use of lead joints is now prohibited.



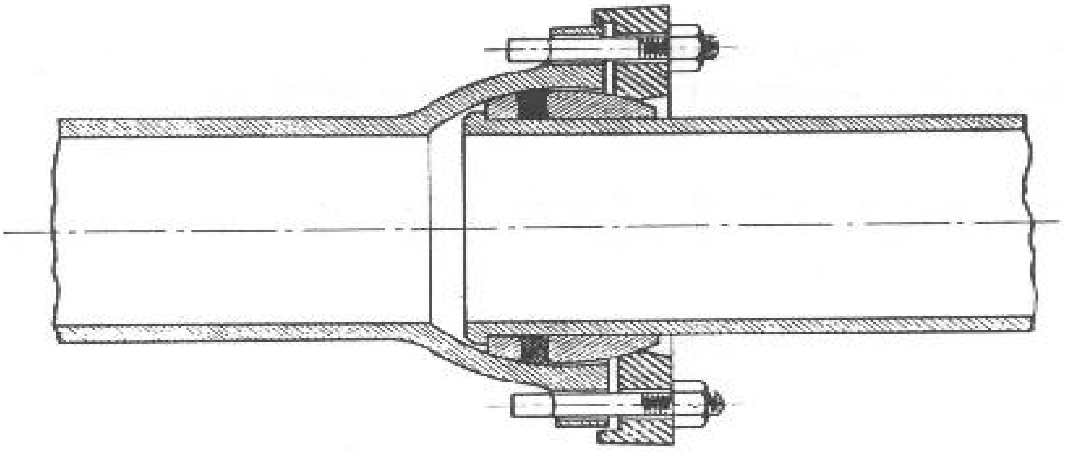
About 40 years ago the mechanical joint replaced the bell and spigot joint as the most popular method of joining cast iron pipe. The mechanical joint is made watertight by wedging a rubber gasket into a tapered groove formed by the bell of the previously laid pipe and the spigot of the pipe being laid. Wedging is accomplished by drawing bolts between the bell flange and the follower ring or gland. The mechanical joint is used on slip joint pipe and on hydrants that are joined to the pipe. A dresser coupling is a special type of mechanical joint.



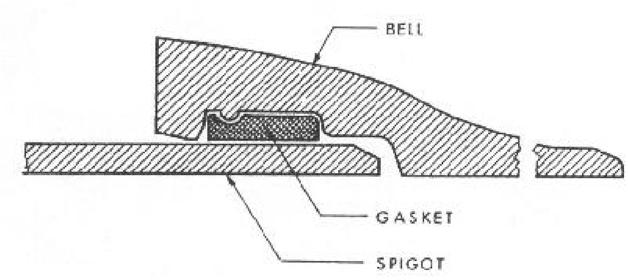


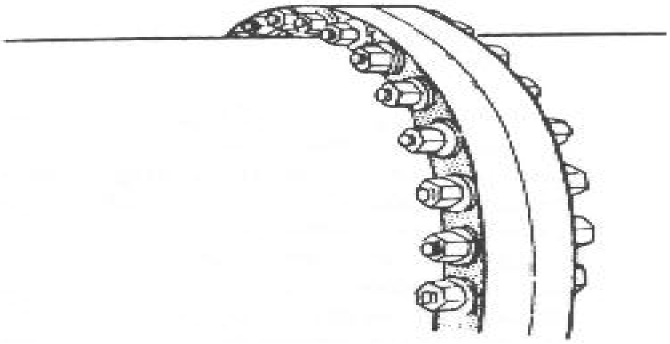


Ball joint pipe provides a simple, rugged type flexible joint for cast iron and ductile iron pipe and is ideally suited for underwater installation where the cost of equipment and labor require a speedy and reliable assembly. Pipes connected with ball joints may be pulled across streams with a cable as the joints are positively locked together. They may also be laid directly from a barge. The lengths of pipe and joints are sufficiently strong to support their own weight safely in the water. They may be laid without diver in deep water as long as they are filled with water, which displaces the air in the pipe.



A joint with a bell and spigot, similar to a lead joint, has become the standard joint for construction of pipelines that use cast iron or ductile iron pipe today. This joint is called a compression push on a slip joint. It uses rubber or composition gaskets which fit into the bell end of the pipe with the spigot end being shoved into the bell to compress the gasket. The rubber gaskets are sold under trade names, such as Tyton or Bell Tite.





Another common joint is the flanged joint. It is made by threading plain-end pipe and screwing it on flanges that are faced and drilled to permit being bolted together.

DUCTILE IRON PIPE

Ductile iron pipe was introduced in the mid-1950s as a replacement for cast iron pipes. It resembles cast iron pipe in appearance and has many of the characteristics of cast iron although it is less brittle, more flexible, and will not break as easily as the cast iron pipe.

Ductile iron is particularly suited to bridge crossings, installations supported on piers or piling, areas under deep fills, and in conditions where differential pressure may cause breakage of other pipe materials.

Joints used on ductile iron are the same as the ones described for cast iron pipe with the slip joint being the most common today. Fittings for ductile iron have the same outside diameter as cast iron; as a result, fittings are interchangeable between the two types of pipe.

The preferred method of cutting ductile pipe is sawing rather than snapping it, as is often done with cast iron pipe.

STEEL PIPE

Steel pipe, along with lead, was used extensively for service lines in the early part of the century. Some of this type of pipe is still in service.

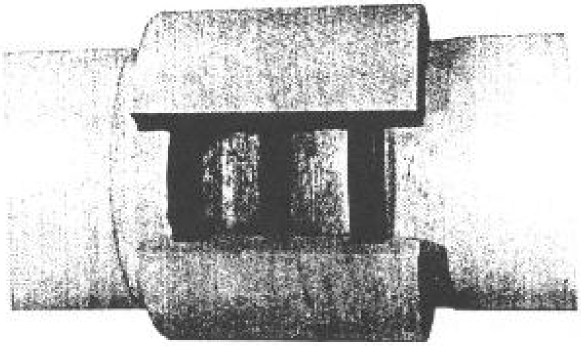
Standard steel pipe is used in large diameter pipe, primarily transmission pipe. This pipe needs to be wrapped in materials that will control the outside corrosion. The inside of the pipe is usually coated with Portland cement to prevent corrosion on the inside of the pipe.

Thin wall steel pipe is usually furnished in 40-foot lengths. Thickness ranges from 14 gage to 3/8 inch or larger, depending on the service conditions. Ten gage is generally the thinnest material used in waterworks service.

Standard steel pipe is designed to be joined by slip joints or dresser couplings. It is easily installed, reasonably flexible, and can be designed to withstand severe conditions. Service taps into thin wall steel pipe can only be done in relatively low pressure areas unless the pipe is reinforced in some way. Service saddles are usually used for service taps. Because it is more prone to corrosion, steel pipe can be expected to fail earlier than cast iron or ductile pipe. Large diameter steel pipe can be cheaper to install than the other types.

ASBESTOS CEMENT PIPE

Asbestos cement pipe is a highly corrosion-resistant formulation of asbestos, silica, and Portland cement. Under most service conditions, its smooth interior and resistance to interior corrosion sustain high water carrying capacities throughout its life. The major disadvantage of asbestos cement pipe is its limited beam strength and its low resistance to being bent. The pipe must be handled, installed, and bedded more carefully than some other types of pipe. Ends of the pipe are machined to allow joining in a type of slip joint in which the two ends of the pipe are inserted into an asbestos coupling. Rubber gaskets compressed in the coupling form a watertight seal. Cast iron fittings are normally used along with asbestos cement pipe. Recently there have been concerns of asbestos fibers separating from the pipe and entering the water being carried in the pipe.



PLASTIC PIPE

The use of plastic has increased dramatically as a water-supply pipe. It is resistant to corrosion yet remains flexible after construction. The joints on the pipe are generally of the slip joint construction and the fittings generally of the cast iron variety although fittings made of plastic are also available. Services may be tapped directly into the pipe, but most utilities use service saddles to make service connections.

Plastic pipe has good corrosion resistance, is easy to install, handle, and connect and has a good flow characteristic. It has now been used for several decades and has proven to provide good service. A disadvantage is that, being non-metallic, it cannot be thawed by electric resistance methods if frozen nor can it be located underground with electronic pipe locators unless a tracer wire is provided with the pipe installation. PVC pipe must be able to be located, such as with a copper tracer wire.

SERVICE PIPE

Pipe used in service connections is generally copper up to two inches in thickness or else ductile iron or cast iron above that width. Copper pipe is readily available in widths from one-half to two inches and in rolls up to 60 feet. For underground service, copper pipe is often flared and joined with threaded couplings.

Plastic pipe is gaining popularity for use in services because of copper's higher cost as well as lead and copper regulations. Plastic pipe comes in rolls usually 100 feet in length; the fittings are similar to the ones used on copper. The pipe may be flared, but the most common fitting is the wedge lock.

PIPE SIZE AND LOCATION FOR MAINS

Water mains should be placed in the public right of way or easements must be obtained if it becomes necessary to cross private property. The overall pattern of the system should provide for as many closed loops as possible. Long isolated lines terminating in dead ends without interconnections should be avoided.

The locations should be selected to:

- Provide a straight-line alignment where possible.
- Match a standard pattern applicable to the entire system, such as the water main being located on the north or east sides of the street and the sewers on the south or west sides.
- Be readily accessible for maintenance, repair, or replacement with minimum damage to existing streets and other underground utilities.

- Avoid conflict, contamination, and possible cross connection with the sanitary sewers. The water main must be ten feet from a sanitary sewer when they are running parallel. If they come closer than 18 inches when crossing, the sewer must meet water-main standards.
- Provide provide protection from physical damage due to freezing and other weather conditions. In Minnesota, the pipe should be buried seven feet below the ground surface to prevent it from freezing.

PIPE SIZE

The size of the water main will depend on what services it will supply and the flow expected. When determining the water demand, pressure losses have to be taken into consideration. If fire protection is required, the minimum size of a water main must be six inches in diameter. Some utilities have adopted an eight-inch minimum size for the main network.

Testing and Disinfecting

All new mains must be pressure tested and disinfected. Pressure testing will determine if the installation has been installed correctly and if the main is ready for service. Disinfection will ensure that the water delivered through the main is safe to use.

Pressure Testing

Pressure testing is done by filling the water lines under test pressure and noting the amount of leakage, if any, that takes place. Hydrostatic (water) testing is by far the most common and logical for water mains.

Pressures for testing are normally 2-1/2 times the normal operating pressure or at least 150 psi. This will disclose faulty pipes, bad joints, breaks, and other major defects. All pressures are to be measured at the lowest point in the system under test. The duration of the test should be no less than two hours and need not exceed 24 hours. If the utility is testing a fire service, the pressure is expected to be 200 psi for at least one hour.

All new mains are allowed some leakage, which is computed from the following formula (for mechanical joint pipe or slip joint pipe):

$$L = \frac{N \times D \times P}{3700}$$

where

L = Allowable leakage per hour in gallons
N = Number of joints in the test section
D = Nominal pipe diameter in inches
P = Average pressure during the test in psi

When the leakage test reveals an excessive loss of water, the source of the leakage must be found and corrected. Additional tests and repairs should be made until the leakage is brought to within the allowable limits.

The procedure for making a leakage test is quite simple. The test section is isolated in a suitable manner. All bends and dead ends shall be blocked against movement. Water is introduced into the low point through taps or fittings on the pipe. Hydrants, blowoffs, or air release valves along the pipe should be opened to allow the air in the pipe to be expelled. If suitable taps or connections are not available to expel the air, the main must be tapped at the high points to allow the air to escape. These taps will have to be removed and plugged after the test is complete.

After the air in the pipe has been expelled, the line is filled by pumping to sufficient pressure, as measured by a calibrated test gauge located at the low point. A hand-operated positive displacement pump is satisfactory for the purpose. At the end of the test, or hourly if the test is longer, the pump is again operated to restore the test pressure. Leakage is determined by the amount of makeup water required to restore the pressure. Most manufacturers of pipe provide a table of maximum leakage allowance per 100 couplings per hour at the selected test pressure.

Disinfecting

All new mains must be disinfected in accordance with AWWA Standard C651 before being placed into service. The problems encountered in disinfection will be lessened, and the likelihood of satisfactory results will be increased, if proper precautions are taken during pipe installation to prevent dirt, trench water, and other foreign material from entering the pipe. The disinfection procedure consists of three operations: preliminary flushing, chlorination, and final flushing and testing.

Preliminary flushing is done prior to chemical disinfection. Mains must be flushed by running a sufficient amount of water through them. A velocity of 2-1/2 feet per second is considered minimum for flushing. High velocities will do a better job. Even velocities of four to five feet per second may not remove the heavier material. However, if proper precautions are taken to prevent entry of the heavier material during construction, a flushing velocity of 2-1/2 feet per second will produce satisfactory results.

The only disinfecting agents in general use for water mains are chlorine compounds. They are fed directly into the line as a water solution of liquid or gas chlorine, placed in the pipe as tablets prior to the pipe being filled with water, or injected as chlorine gas.

A liquid or gas chlorine water mixture is fed with a solution feed chlorinator. Dry gas may be fed directly through proper devices that regulate the flow rate and provide effective diffusion of the gas into the water.

The following types of chlorine compounds are used:

- Calcium Hypochlorite--available as a commercial product under such trade names as HTH, Perchloron, and Pittchlor.
- Chlorinated lime--also called chloride of lime or bleaching powder.
- Sodium hypochlorite--also known as liquid bleach.

These compounds are prepared for feeding into the main as a one-percent water solution (10,000 ppm). The amount of the compounds required to make a one-percent solution depends on the chlorine content of the compound.

The disinfecting agent should be introduced into the main through a corporation stop at the top of the pipe at the beginning of the new line. Water from the existing system or another suitable source should flow into the new pipeline during the application of the chlorine. The flow of water and chlorine mixture should be proportioned so that the chlorine dosage will be no less than 50 ppm. The chlorinated water should be held in the main for at least 24 hours and must have 10 ppm free chlorine residual at the end of the 24 hour period.

Treated water should stand in the pipeline at least 24 hours. During this time, all newly installed valves should be operated. Circumstances may preclude a 24-hour retention period. In these cases, the chlorine concentration may be increased and the retention time reduced. For example, a 100 ppm chlorine concentration could be used for a period of 12 hours. Consult AWWA Standard C651 for the approved ways of disinfecting the water mains.

The final operation in the procedure is the removal of the chlorine compound from the pipe line by flushing. This flushing should continue until the water in the pipeline has the same chlorine residual as the water in the rest of the water system. Before the pipe can be put into service, total coliform samples should be taken at several points in the new system, usually with one sample taken per block, plus one from each dead end. These samples must be taken on two consecutive days and the test results must be negative.

SERVICE LINE DESIGN

The condition of the service lines is often an overlooked part of the water system. In most systems, the total length of service lines may nearly equal and sometimes even exceed the total length of the mains.

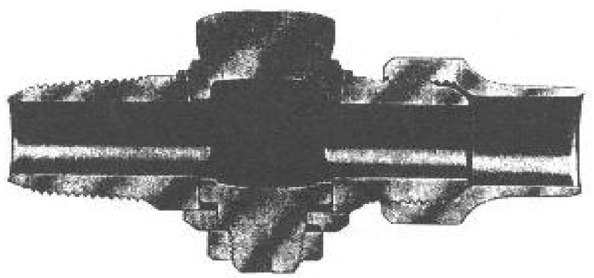
Service lines consist of two parts: the service connection that extends from the main in the street to the property line or curb stop; and the portion of the pipe that runs from the curb stop to the building. In most cities, the water operator needs to be concerned only with size, selection of pipe materials, and installation of the service connection.

Materials and installation practices apply equally to that portion of the service line located on the customer’s property. Every water utility should have regulations consistent with the Minnesota Plumbing Code requirements. These regulations shall cover such items as approved materials, depth of lines, installation procedures, inspections, responsibility for the work, responsibility for payment of costs, and other information necessary to provide an understanding of the requirements.

SERVICE LINE PARTS

Each service connection consists of:

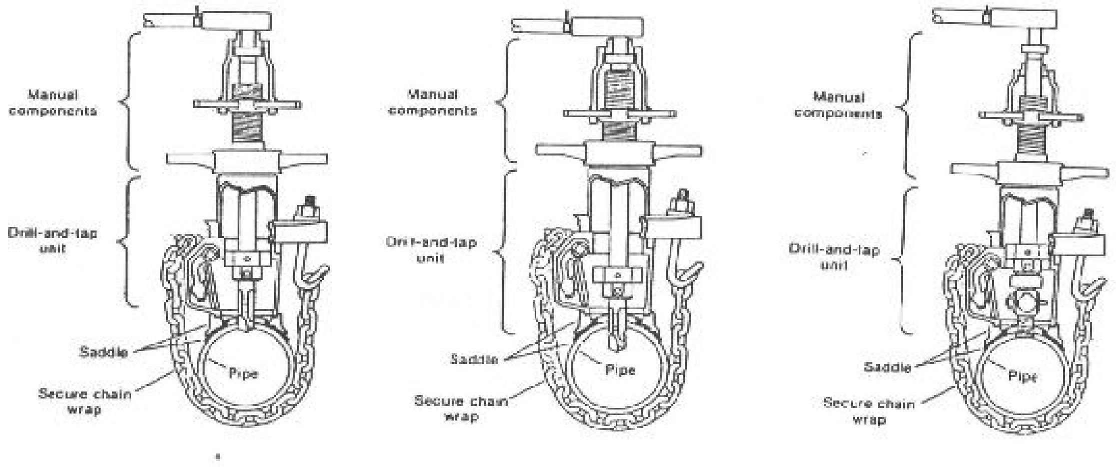
1) The connection at the main, which is made with the use of a corporation stop or valve to control the pressure during installation. This valve will generally be installed by a tapping machine and with the main pressurized.



2) A length of pipe long enough to reach from the water main to the property line, where another valve is installed to control the water service.

3) A shutoff valve at the property line to allow the water to be shutoff without having to dig in the street. In most cases, this valve remains the property of the utility. The shutoff valve can be operated only with a special wrench, preventing the property owner from operating the valve.

4) Meters installed to measure the amount of water supplied to the customer. In some cases, the meter is installed at the curb line, but in Minnesota the normal location of the meter is inside the customer's premises.

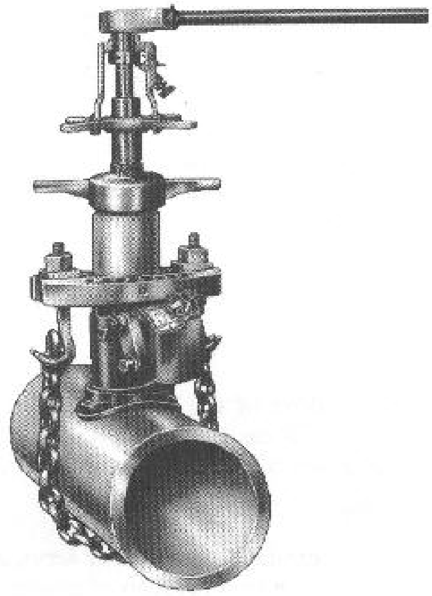


a. With the combined drill-and-tap unit, first drill a hole into the main.

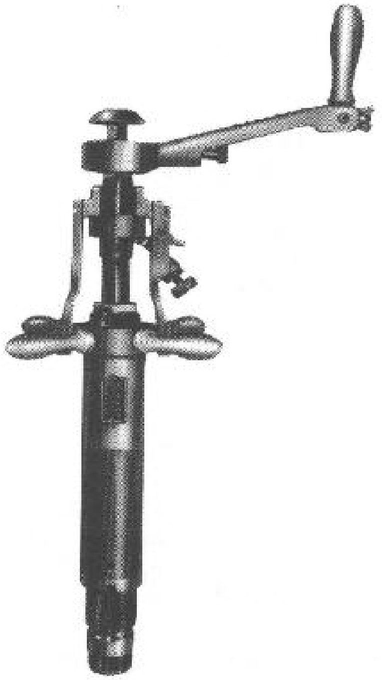
b. After the hole is drilled, insert the tap.

c. Again, with the drill-and-tap unit, insert the threaded inlet of a corporation cock. The service can then be activated.

Wet Tapping



Manual Tapping Machine



Manual Drilling Machine

SIZE OF SERVICE

Pressure losses in the service line can be substantial. If care is not taken in the sizing of the service parts, pressure losses can result in a operating pressure that is too low even though the main pressure is maintained at satisfactory levels. The size and length of pipe and the number of stops, valves, fittings, and meters, as well as the demand rate, influence the amount of pressure loss in the service line. Losses can be calculated by using a set of pressure loss charts.

In the small-size pipe usually found in service lines, these losses are not minor. In fact, they may be greater than the total losses in the remainder of the pipe. As previously noted, a typical service connection consists of a corporation stop, curb stop, meter valve, and meter. The common fittings, along with the service pipe, create the pressure losses between the water main and the point of the water use.

A normal household instantaneous demand is in the 6 to 15 gpm range. The demand comes from the simultaneous use of plumbing fixtures and appliances in the building.

Demand Rates for Household Fixtures

Fixture	*Demand Rate (GPM)*
Bathtub	4
Dishwasher	3 – 5
Disposal Unit	2 – 3
Laundry Tub	5
Lawn Sprinkler	5
Shower	3
Toilet	4
Washing Machine	3 – 7

VALVES

Valve Selection

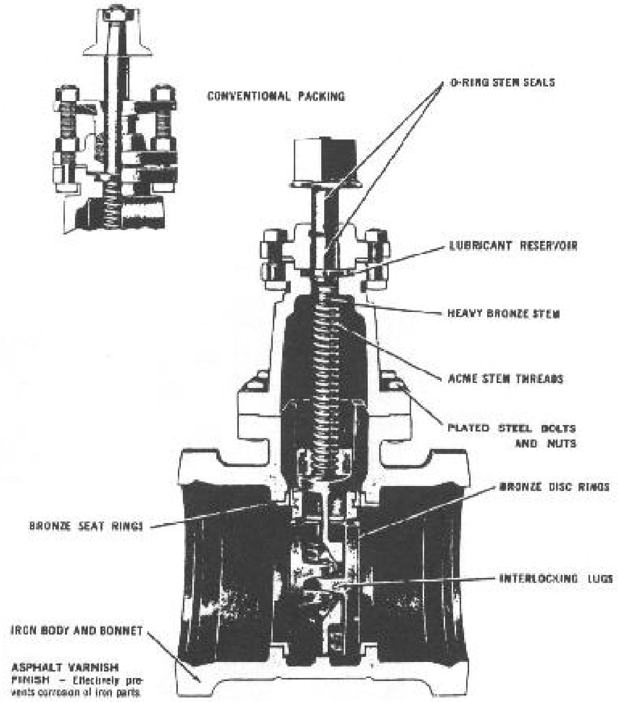
Valve placement depends on the layout of the system, location of the customers, location of points susceptible to damage, and cost factors. The Ten State Standards adopted by the Minnesota Department of Health call for valve spacing of every 500 feet in commercial districts and 800 to 1,000 feet in other sections.

Valves are installed at enough points on a water system to minimize loss of water service during repairs. It is common to place valves at street intersections or at the extension of property lines. Valves are supplied with valve boxes or pits for maintenance. Many types of valve are used in the water industry, but all have basically the same function--to control or to stop the flow in pipes.

Gate Valves

The most common type of valve used in a water distribution system is the gate valve. The main gate valve type is one with a non-rising stem, a valve in which the stem does not rise as the valve is opened. This valve is reasonably dependable, has an almost unobstructed waterway when open, is very economical in smaller sizes, and can be installed underground with a minimum cost. A photo of a valve riser is shown at right. It is important that the riser is installed correctly. Also, rods now are used so that the long shut off wrench isn't needed.

A gate valve is not well adapted for throttling flow or for frequent operation. Either will cause excessive wear on the seating edges of the discs and guides. Infrequent operation may cause the valve to freeze in one position or become difficult to operate. Where the water carries small amounts of sand or silt, the valve seats may fill with deposited material unless operated at regular intervals to keep the valve seat clear.



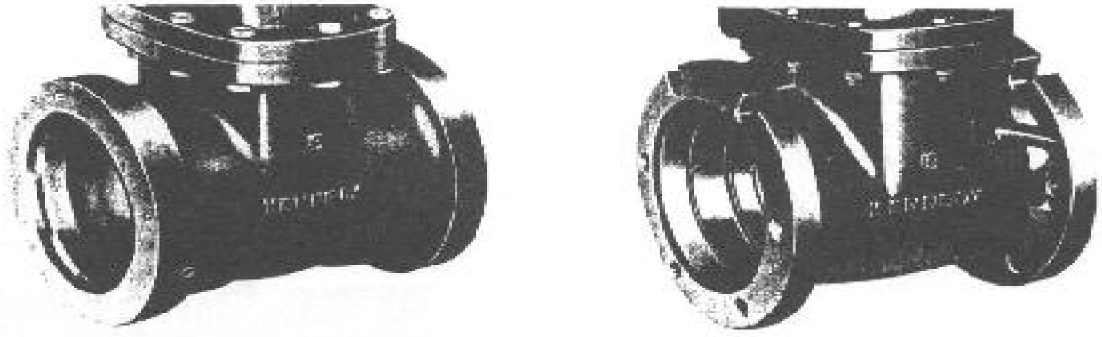
The gates or wedges that provide the means of closing the line are forced into the flow line by the stem until the wedges reach the bottom of the valve. At this point, additional pressure on the stem will force a wedge out between the discs and the side of the valve seats to seal the valve.

Another type is the resilient seat gate valve, which is basically the same as a gate valve with one important difference. It does not have a depression in the bottom of the valve to collect debris and prevent the valve from closing. The valve plug will push into the flow and seal on the sides of the valve seats without the wedges to force the seal.

For 12-inch and smaller lines, gate valves are the most common type of valve used in underground application. Large gate valves, 14 inches and above, are installed with a smaller by-pass valve to reduce the pressure differential when opening or closing the valve. It may be impractical to install larger gate valves in a vertical position due to height limitations. In such cases, gate valves are installed with their stems horizontal and the valves geared so the axis of the operating nut is vertical. A gate valve to be installed in a horizontal position should be equipped with rollers and tracks to carry the weight of the discs.

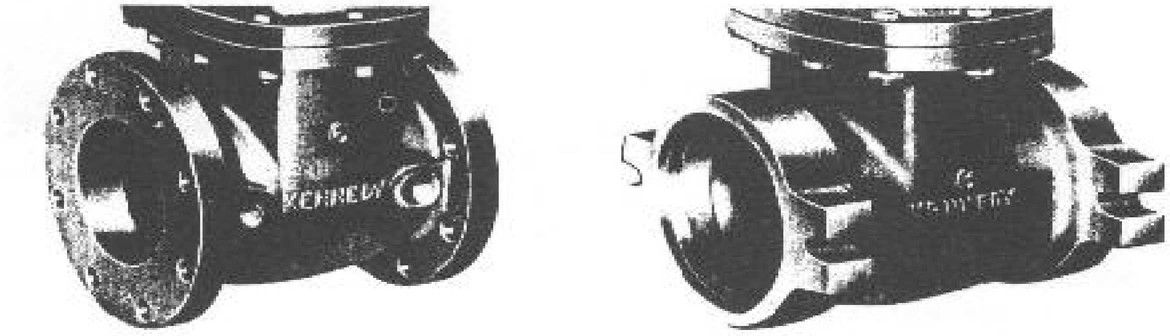
Until the introduction of the O-ring seal, the seal between the operating stem of the valve and the valve bonnet was accomplished with a packing held tight with a bolted connection. Leakage around the packing was common, particularly after the valve had been in service for several years. Tightening the packing nuts or replacing the packing was difficult and often costly, as excavation was normally necessary. The O-ring seal is a definite improvement.

Gate valves are available with bell and spigot, flanged, mechanical joint or slip-on ends and can, through special orders, be furnished with different types of connections on each end of the valve.



BELL ENDS

MECHANICAL JOINT

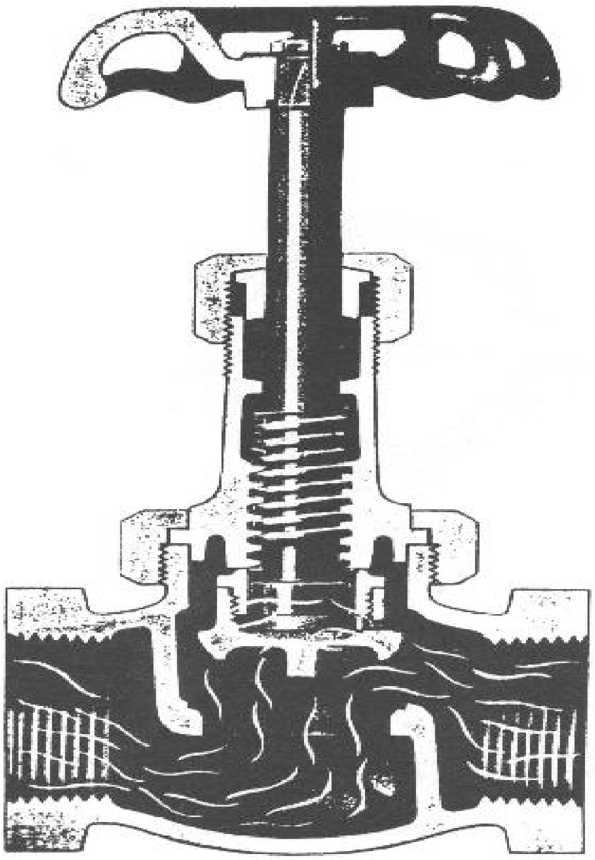


FLANGED JOINT

ASBESTOS-CEMENT JOINT

Joints Used to Install Valves

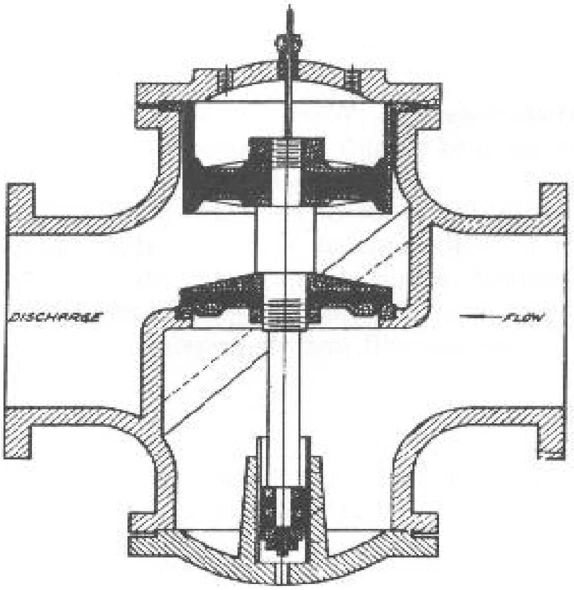
Globe Valves and Angle Valves



Except for some special service applications, the globe valves used in water systems are generally three inches or smaller. The high-pressure loss in this valve limits it to smaller sizes. The globe valve operates by forcing a tapered plug into the port through which the water flows.

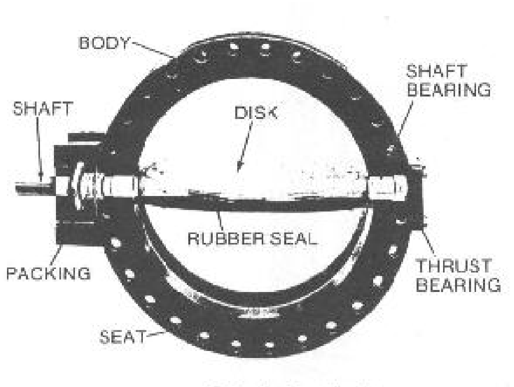
An angle valve is a globe valve in which the entrance and exit from the valve are at right angles from each other. This type of valve is frequently used before a meter installation at a residential service.

Large globe valves are used frequently for throttling and control applications such as pressure reducing, altitude valves, check valves, and other special purpose applications. The larger globe valves are normally joined by flanged connections.



Butterfly Valves

Rubber-seated butterfly valves are particularly adapted to certain service conditions in the water industry.



Parts of a Butterfly Valve

The butterfly valve consists of a shaft-mounted disc that rotates in a 90-degree arc from full open to full closed. When the disc is rotated into the closed position, it compresses the rubber seat, which is slightly smaller in diameter than the disc, and a tight seal is made. Since the valve shaft rotates only 90 degrees from the open to the closed position, some type of gear or lever is used to control the speed of operation and aid in maintaining a partially open or closed position. For buried service, the gear assembly must be enclosed.

Although butterfly valves are frequently used in place of gate valves to shut off services, the butterfly is also used in throttling or in automatic control of the flow of water. The valve will open, close, or throttle on command from a controller. Electric motors or hydraulic or pneumatic cylinders are the most common types of power sources for these automatic operations.

VALVE MAINTENANCE

Valves are one of the most important parts of a distribution system. When the utility has a break in a water main, its crews need to find the valve quickly and be able to operate it.

Therefore, the location of each valve should be recorded on a set of as-builds plans that are accessible to utility operators at all times. However, it is not unusual to find a valve that has been covered by street work or that has had its box damaged during construction to the point that the valve wrench can no longer be put on the operating nut of the valve. Pipe locators help in finding the valve boxes, but they do not insure that the valves will operate properly.

Inspection

A well-organized valve inspection program is essential for proper maintenance. Each valve in the system should be operated at least once a year to make sure that it can be located and that it works.

Valves in a distribution system allow small areas to be isolated for emergency maintenance. This means that most valves suffer from lack of operation, not wear. No definitive rules exist as to how often a valve should be operated, but an annual check is common. The type of water in the system, the location of valves, and their size all have a bearing on the frequency.

The following procedures should be followed in a proper valve inspection program:

1. The location of each valve should be checked along with measurements to record reference points.
2. Valves should be operated in both directions, fully closed and fully opened, and the number of turns should be recorded. Any valves that operated in the opposite direction from the normal should be noted. Valves should be left in a position one-half turn from the normal position for fully opened or fully closed.
3. Valves should normally be left in the open position, but valves that are normally left closed should be noted.
4. Badly corroded valves should be operated several times, and, if necessary, a flow should be introduced to clean the valve seat.
5. The condition of the valve packing, stem nut, and gears should be checked.
6. Valve boxes should be checked, cleaned out, and raised, lowered, or replaced as required.

Most water systems number the valves for quick identification; all systems must keep a record of the location, type, and time of installation.

MINNESOTA RURAL WATER ASSOCIATION
VALVE RECORD

No.______________ **Location**____

Type__________________________ **Make**__________________________________

Type of Jointing_____**Sizing**________ **Operating Nut**______________________

Opens Left______**Opens Right**______ **No. of Turns**________________________

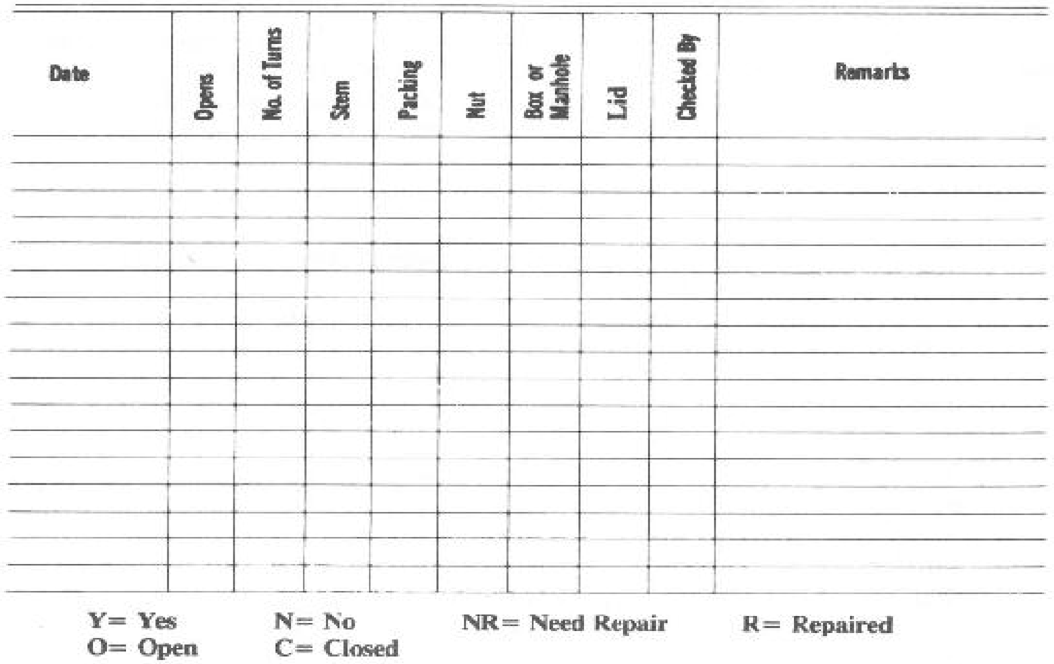
Valve In______________________________ **Route No.**________________________

Comments:

____

____

____



Date	Opens	No. of Turns	Stem	Packing	Nut	Box or Manhole	Lid	Checked By	Remarks

Y= Yes N= No NR= Need Repair R= Repaired
O= Open C= Closed

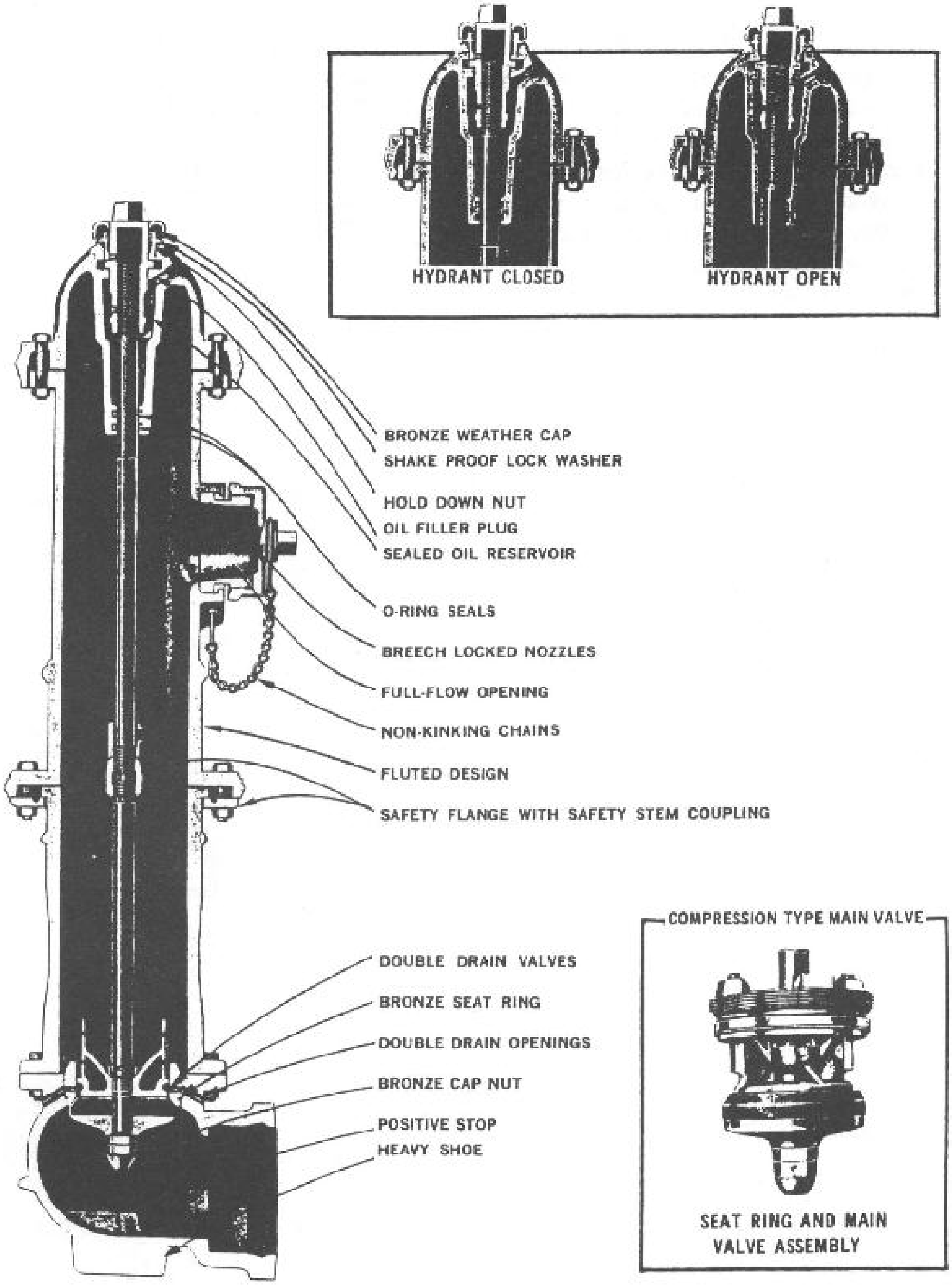
HYDRANTS

Hydrant Selection

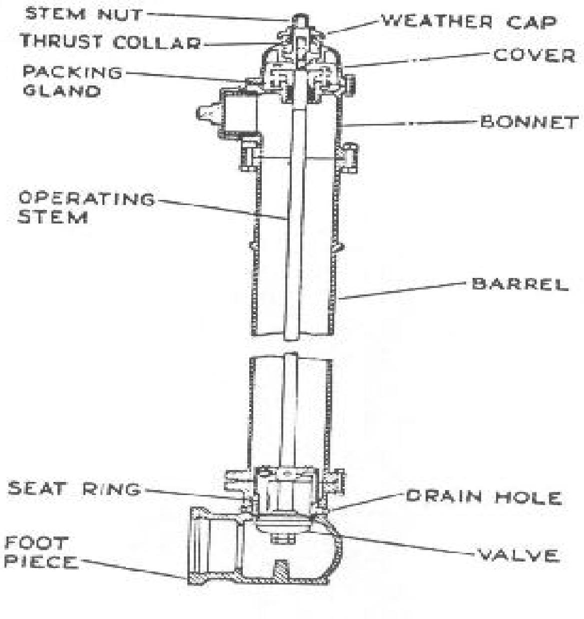
Hydrants are located throughout the water system to provide for fire protection but they also provide a means of assessing the condition of the water system. Spacing of hydrants varies slightly with the design of the water system, value of the surrounding property, and area served, but they are usually found at intersections in areas that are not subject to traffic damage. The outlets of the hydrant should face the street. In general, hydrants should be spaced at 500 to 600 foot intervals in average-value areas and at 300-foot intervals in high value areas.

The purpose of a hydrant is to provide a quick, simple, and dependable method of connecting a fire hose to a source of water under pressure. Hydrants used in Minnesota are of two different basic types: the compression type, which opens against the flow and the corey or toggle type, which opens with the flow. The pipe connection for the compression type is at the bottom of the hydrant; the connection for the corey type is about one foot from the bottom. The two can be distinguished by the operating-nut location. The compression hydrant has its operating-nut in the center of the bonnet; the corey hydrant operating-nut is offset to the back of the hydrant bonnet.

The size of the hydrant refers to the size of the opening in the valve. For example, a four-inch hydrant has a four-inch valve. Hydrants can be furnished with one to four 2.5-inch nozzles and one or two four-inch steamer nozzles. The most common combination is two 2.5-inch nozzles and one steamer nozzle. The length of the hydrant is referred to as the depth of bury and is the distance from the surface of the ground to the bottom of the inlet pipe.

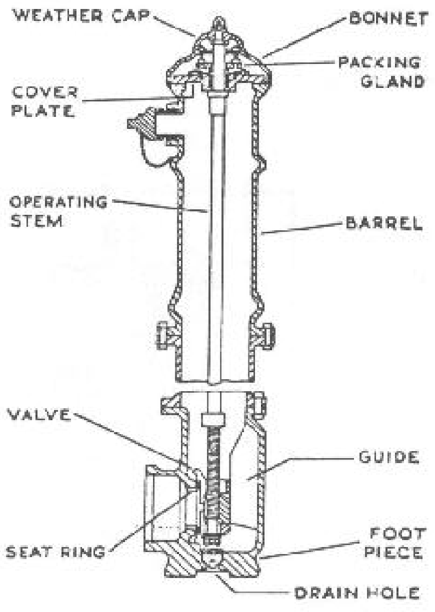

HYDRANT CLOSED
HYDRANT OPEN
BRONZE WEATHER CAP
SHAKE PROOF LOCK WASHER
HOLD DOWN NUT
OIL FILLER PLUG
SEALED OIL RESERVOIR
O-RING SEALS
BREECH LOCKED NOZZLES
FULL-FLOW OPENING
NON-KINKING CHAINS
FLUTED DESIGN
SAFETY FLANGE WITH SAFETY STEM COUPLING
COMPRESSION TYPE MAIN VALVE
DOUBLE DRAIN VALVES
BRONZE SEAT RING
DOUBLE DRAIN OPENINGS
BRONZE CAP NUT
POSITIVE STOP
HEAVY SHOE
SEAT RING AND MAIN VALVE ASSEMBLY

The hydrant barrel is cast iron and the wear points are bronze. Hydrants normally are manufactured so that the main valve remains closed if the hydrant barrel is broken off. Most hydrants today are provided with break-away parts at or near the surface so that a broken hydrant can be repaired without having to dig to the base of the hydrant.

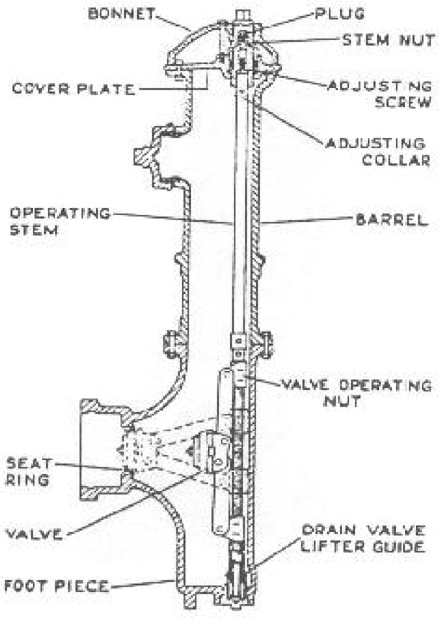


COMPRESSION

Hydrants are furnished with bell, mechanical joint, or flanged-bottom connections. The type of connection is dictated by the type of pipe that is used. If the hydrant is to be furnished with its own hydrant valve, the flanged connection would possibly be best. Nozzles provided should correspond to the type used by the fire department. The most common threads used in Minnesota are the National Standard threads.



GATE



CORY

HYDRANT MAINTENANCE

Fire hydrants are installed for emergency use and should be inspected at least once per year to ensure their correct operation. Their exposure to the elements makes them prone to damage and failure. Inspection is often performed in conjunction with a flushing program.

The correct inspection procedure is as follows:

1. The hydrant should be sounded for leaks.
2. It should be operated and flushed, its ease or difficulty of operation noted, and any worn parts fixed.
3. The condition of the drain valve, operating nut, nozzles, nozzles caps, chains, packing, and paint should be noted.
4. After operation and closure, the interior should be observed to see if the barrel drains properly.
5. The setting of the hydrant and the distance of the nozzles from the ground and the curb line should be noted and, if needed, fixed.
6. The hydrant should be lubricated if needed.
7. The accessibility of the hydrant, its ground clearance, and its interference from poles or other objects should be noted and corrected if necessary.

Frequent painting of hydrants is an excellent public-relations tool as hydrants are usually the only element of the distribution system seen by the general public.

Hydrants are designed for emergency use. Therefore, they are not suited to continuous use as a water supply. Hydrants should not be regularly used to fill tanks and should never be used with the valve partially opened for throttling. A hydrant should be opened slowly and fully and then closed fully. After the hydrant is closed, the operating nut should be turned back enough to free it from any tension (about 1/2 turn). When hydrants are used for filling tanks, proper backflow equipment should be used.

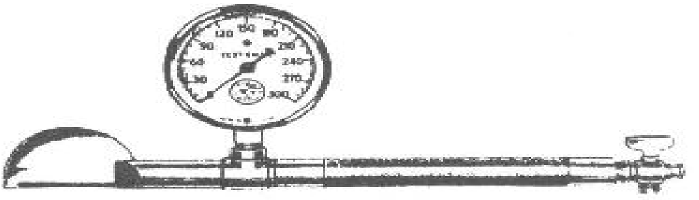
Flushing

Regular flushing of hydrants is important to ensure that it works and is in operational condition at all times. In addition, flushing can reveal information about the condition of the water system itself.

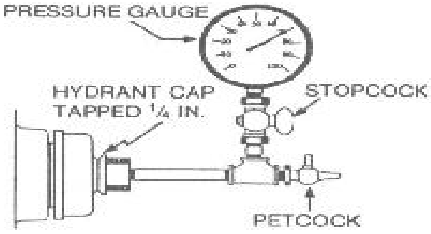
When a water system is flushed, the velocity has to be high enough--at least 2.5 feet per second--to sweep out any material accumulated in the system. If the necessary velocity cannot be obtained, the system should be valved to allow it to short circuit and induce the velocities needed. Flushing begins closest to the water source or treatment plant and working downstream in the distribution system.

Flow Tests

Flow tests from hydrants are important to determine the condition of the distribution system, particularly during peak-demand days. These tests also determine the amount of water available for firefighting. The tests are performed by opening one or more hydrants and measuring the flow, noting also a change in pressure at a nearby hydrant. A pitot gauge--an instrument with a tube having a small hole in one end, centered in the stream flowing from the hydrant nozzle-may be used to determine flows from the hydrant. The velocity of the water flow is transmitted as pressure to a pressure gauge attached to the tube.



Pitot Tube and Gauge



60-psi Pressure Gauge

From the pitot or pressure gauge reading, the flow can be calculated using a chart. The hydrant flow is expressed as gallons per minute. The standards used for hydrants express the flow as gpm at 20 psi.

MINNESOTA RURAL WATER ASSOCIATION
HYDRANT RECORD

No.____________ Location ____

Make ____________________________ Model ____

Type ____________________________ No.Outlets _______ 2 ½" ________ 4 ½"_____ Other

Size of Main_______________________ Date Installed_________________________________

Size of Riser_______________________ Size of Lead Line______________________________

Static Pressure_____________________ Flow Pressure_________________________________

Connected to a looped Systems?______ Discharge____________________________________
(gallons per minutes)

Provided with Street Gate Valve?_____Give Location Diagram

Remarks_________________________________

____

____

Date	Flushed	Lubricated	Painted	Repaired	Pentagon	Cap & Chain	Checked By	Remarks

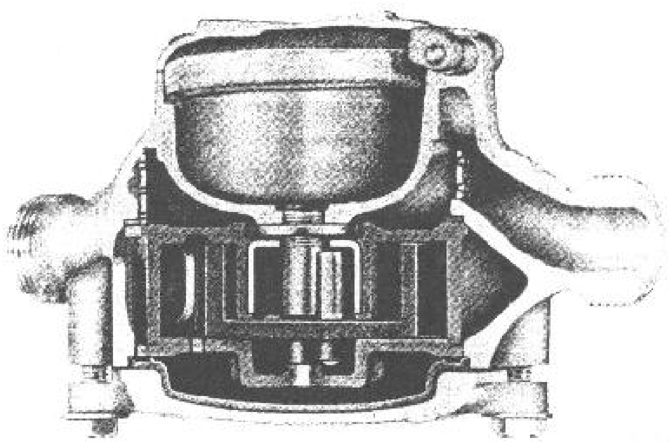
METERS

Service Meter Selection

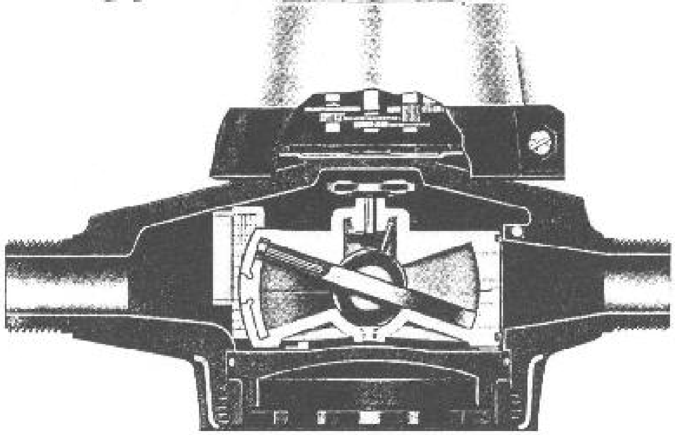
A water meter measures the amount of water passing through it and determines the amount a customer is charged. Two basic types of meters are used in the water industry: the displacement meter and the velocity meter.

Displacement Meters

The common small diameter service meter is of the displacement type. Displacement meters are capable of measuring small flows with relatively high accuracy. Water flowing through the meter is measured by counting the number of times the chamber is filled and emptied.



Piston Meter



Nutating-Disc Meter

A displacement meter has either a nutating disc or a piston meter as its measuring device. Water flowing into the chamber causes the disc or piston to pivot, transferring the pulses to a gear train and, from there, to the dials on the register.

The displacement meter is limited to use with comparatively low flow rates associated with normal domestic service. Excessive wear and inaccurate registration occur when displacement meters are operated in excess of their capacities.

RECOMMENDED CAPACITIES OF DISPLACEMENT METERS

Size	*Minimum Capacity gpm*	*Average Capacity gpm*	*Maximum Capacity gpm*
5/8 by 3/4	1/4	4	20
3/4	1/2	6	30
1	3/4	10	50
2	2	32	160
3	4-1/2	60	300
4	8	100	500
6	14	200	1,000

Velocity or Current Meters

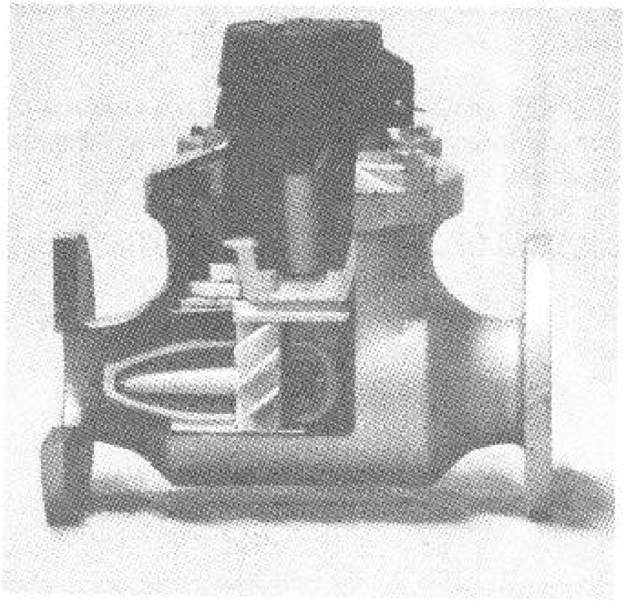
A velocity meter, or current meter as it is more commonly called, registers the volume of water passing through it by measuring the velocity of the flow within a known cross-section area. The two basic current-meter types in use are the turbine and the propeller meters.

The basic operating principle of a turbine meter is the same as that of the hydraulic turbine. A bladed rotor is mounted in a special passage, through which the stream of water is directed. The reaction of the water against the blades of the rotor causes it to rotate at a speed proportional to the velocity of the flow. The rotating movement is transferred through a gear train to the meter register.

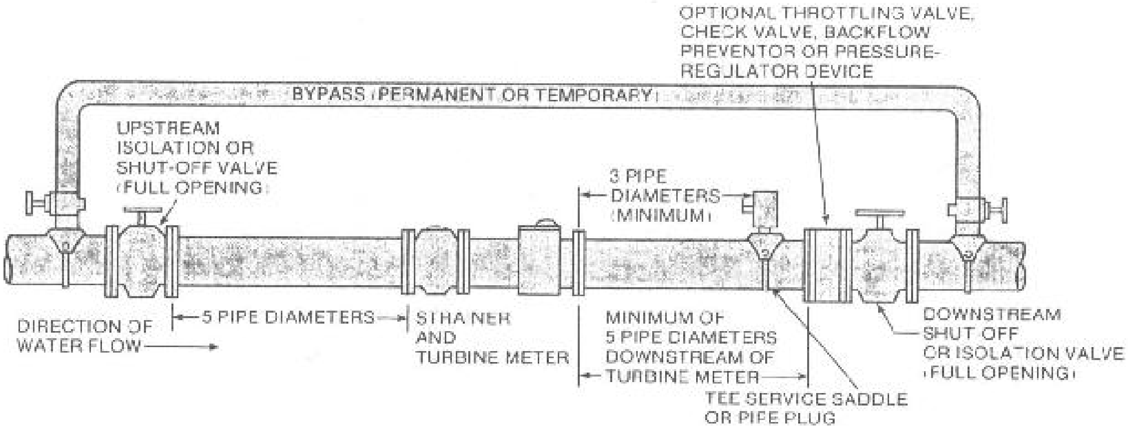
There are three general designs of turbine rotors. In the first, the water flows through the rotor blades at a right angle to the blades. The term "turbine meter" was formerly applied to this design. In the second design, called helical or axial flow type, the flow is parallel to the rotor axis. In the third type, called a mixed-flow turbine meter, the flow is part axial and part radial.

Turbine meters are used to measure relatively high flows and where there is sufficient head to overcome the friction loss through the meter.

The location of the meter in relationship to elbows or fittings is very important. The meter should be located five straight pipe diameters, upstream and downstream, from the nearest valve or fitting.



Turbine Meter



Optimum Turbine Meter Installation

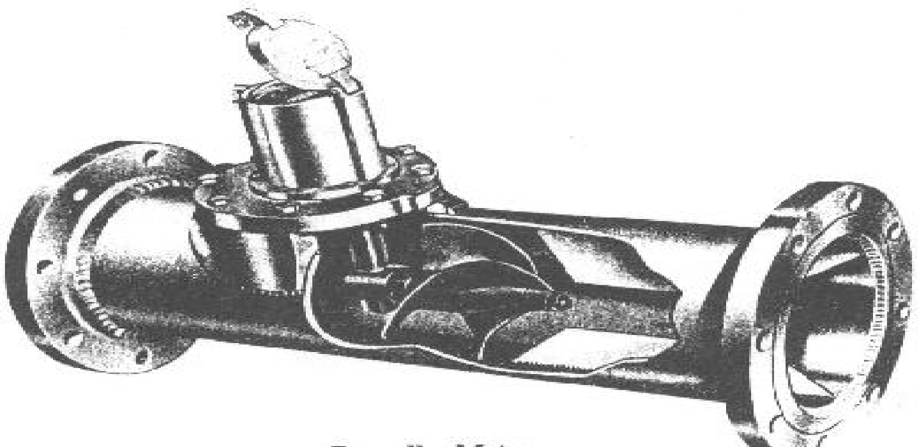
The following table provides a suggested volume comparison to use in selecting a turbine meter:

RECOMMENDED CAPACITIES FOR TURBINE METERS

Size	*Minimum Capacity gpm*	*Average Capacity gpm*	*Maximum Capacity gpm*
1 – ½	5	25	75
2	10	53	160
3	15	133	400
4	20	233	700
8	30	533	1,600
10	75	1,267	3,800
12	100	1,933	5,800
16	200	3,833	11,500

A turbine meter has a much larger range of flow than a displacement meter. During the selection of a meter, the average flow should be used to size the meter. Flow in the low range should be infrequent, and it is expected that some water loss would result if the flow remains in that range.

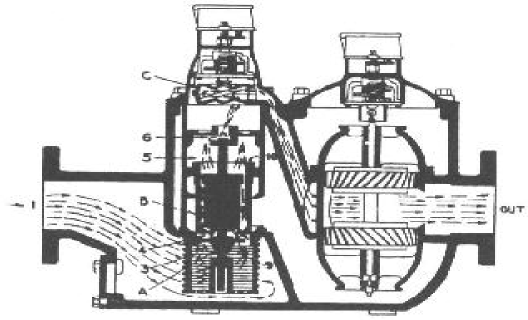
The propeller meter is a special type of axial flow turbine meter. In contrast to the turbine, where the direction of water flow changes while passing through the meter, the water flows straight through the propeller meter. The friction losses in a propeller meter are lower than in the same size turbine meter at the same flow. Propeller meters are generally less accurate than turbine meters at the lower rates of flow. Propeller meters are particularly adaptable to metering in mains where it is desirable to keep the friction loss at a minimum, where a high degree of accuracy is not needed, and where the flow range is relatively limited. A propeller meter is generally less expensive than a turbine meter of the same size.



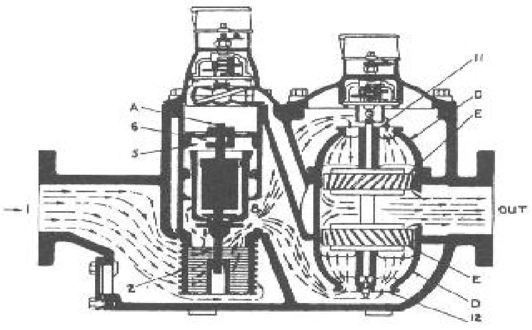
Propeller Meter

Compound Meters

In situations in which a customer's water use fluctuates regularly over a wide range, compound meters are used to accurately measure the water consumption. A compound meter is a combination meter with a turbine section for high flows and a displacement section for low flows. In normal operation, the low flows pass through the displacement section until the friction loss is so great that the valve opens, allowing the water to flow through the turbine section of the meter. A compound meter in good repair is capable of measuring flow with 98 percent accuracy over a wide range of flow conditions. There are other ways to read meters such as AMR (Automatic Meter Reading), telephone radio read, etc.



Compound Meter with Verticle Lift Check
at Low Flow Rates



Compound Meter with Verticle Lift Check
at High Flow Rates

METER MAINTENANCE

Having meters installed at the customers' locations provides the only fair and equitable method of charging for water. This is one of the most economical means of reducing water waste. They usually pay for themselves through a reduction in plant size. Meters are the "cash registers" of the water system and should be maintained in proper working order.

The accuracy of customers' meters should be checked regularly. The benefits of a scheduled meter maintenance program include increased revenue and a uniform work load. Large losses of revenue result from the practice of removing a meter only when a service is disconnected or when the meter has stopped. The cost of meter removal and repair is minor when compared with revenue lost by low or no registration. A metered system allows for the equitable distribution of the cost of water service. Serious inequities and injustices can result unless the meters are maintained at a high, uniform level of efficiency and unless every reasonable effort is made to see that inequities do not occur.

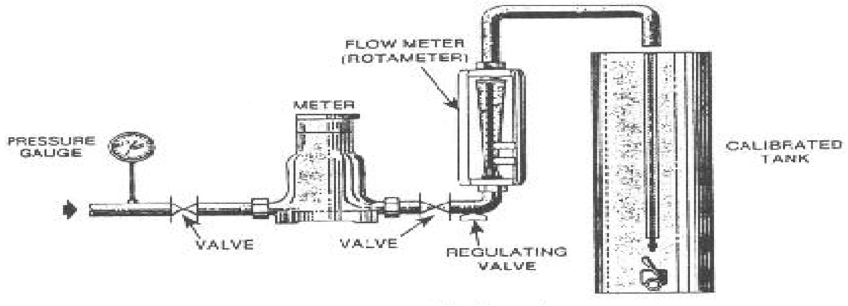
Basic Maintenance and Repair

The maintenance of positive displacement meters consists of temporarily removing them from the customer's service, taking them apart, and thoroughly cleaning and inspecting all parts. After the meter is dismantled, the measuring chamber should be carefully inspected for pitting. The moving parts, such as the disc, thrust rollers, and slots should be checked for excessive wear and corrosion. The disc should be checked with a straight edge and examined for swelling and distortion caused by freezing, heat, or hot water.

After defective and badly worn parts have been replaced, the disc should be reassembled in the chamber. Proper clearances should be provided and shims should be inserted if required.

Some important steps to follow in meter maintenance:

1. Clean all meter parts thoroughly
2. Check the action of the disc in the chamber before and after assembly in the main casing.
3. Remember that friction is just as detrimental as slippage to correct registration.
4. Store meters away from heat sources.
5. Use a new meter as a standard of comparison for tolerances and clearances.
6. Retest the meter for accuracy after repair. Special test benches are available for that purpose.
7. If necessary, call upon the manufacturer for advice and help.

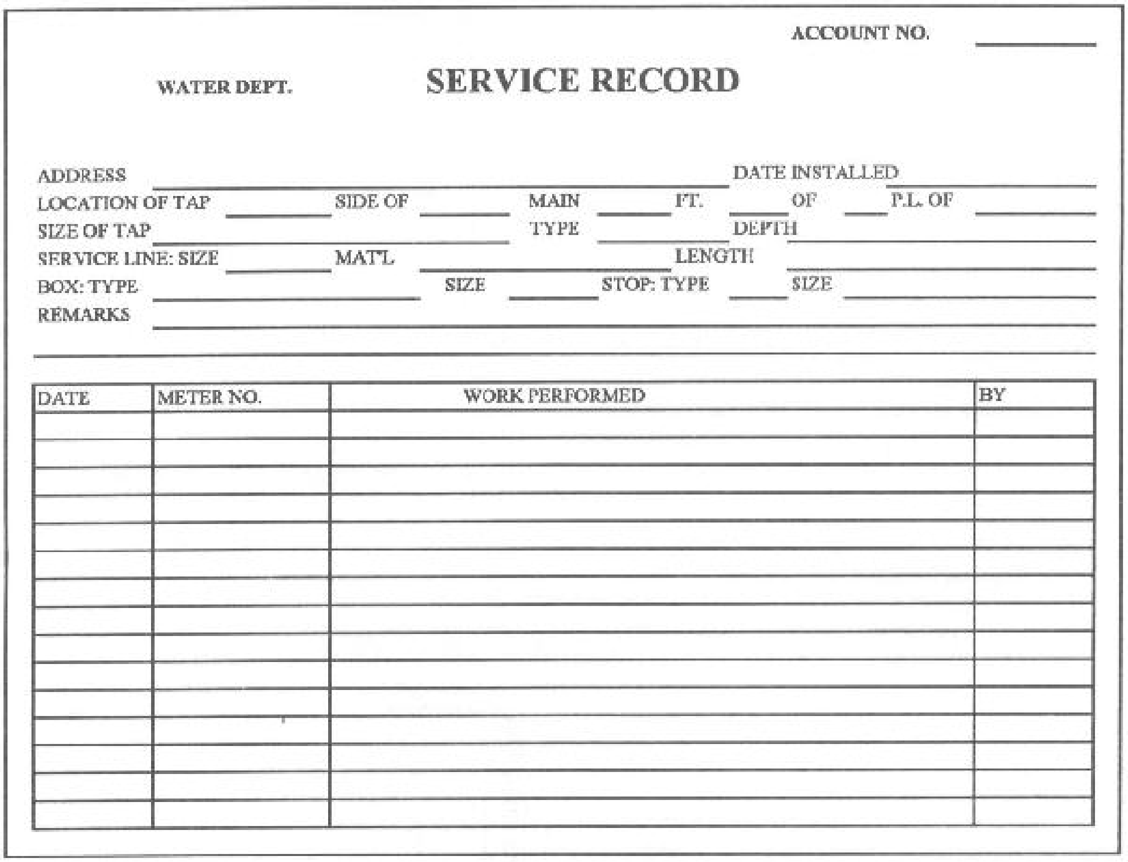


Meter Testing Equipment

All meter repairs follow essentially the same procedures.

METER RECORDS

A suitable meter record provides full and complete information about the installation repair and testing of each meter. The time devoted to maintaining complete records is considerable because of the number of units involved and the probability that they will not remain at one location during their lifetime. Any record system should provide such basic data as the date of purchase, size, make, type, location of meter, and the data on all tests and repairs. A meter history card can be used for maintaining such records.



ACCOUNT NO. ______

WATER DEPT. **SERVICE RECORD**

ADDRESS ______ DATE INSTALLED ______
LOCATION OF TAP ______ SIDE OF ______ MAIN ______ FT. ______ OF ______ P.L. OF ______
SIZE OF TAP ______ TYPE ______ DEPTH ______
SERVICE LINE: SIZE ______ MAT'L ______ LENGTH ______
BOX: TYPE ______ SIZE ______ STOP: TYPE ______ SIZE ______
REMARKS ______

DATE	METER NO.	WORK PERFORMED	BY

22

Storage

Vessels or tanks for storing potable water are critical to the efficient operation of any water distribution system. Storage tanks serve two major purposes. One is to provide storage volume and the other is to provide pressure to the distribution system. A particular tank can serve one or both purposes depending on its location within the system and its type of configuration.

There are a variety of tank types or configurations. The major types are ground storage, elevated, and hydropneumatic tanks. Construction materials for the various types of tanks are generally concrete and steel although some tanks for small storage volumes and special uses could be constructed of fiberglass. The operation of storage tanks is critical to maintaining a continued flow of water to a distribution system for domestic, commercial, or industrial use and for fire protection. The sizing of a water storage tank is dependent upon the function it is intended to provide. Each water distribution system is unique in its need for storage. Other factors, such as cost, also play an important role in determining the size of a potable water storage tank. The maintenance of storage tanks is critical to public health and safety. A water storage tank should be inspected, cleaned, and repaired regularly to be considered reliable.

TANK PURPOSES

The two primary purposes for the use of storage tanks within a water distribution system are to provide for volume and pressure. Many water storage tanks provide both.

Providing sufficient storage volume is generally the function of a water storage tank. A typical operating day in any public water system involves varying demands for the water. The demand volumes that a system may use for planning design purposes are:

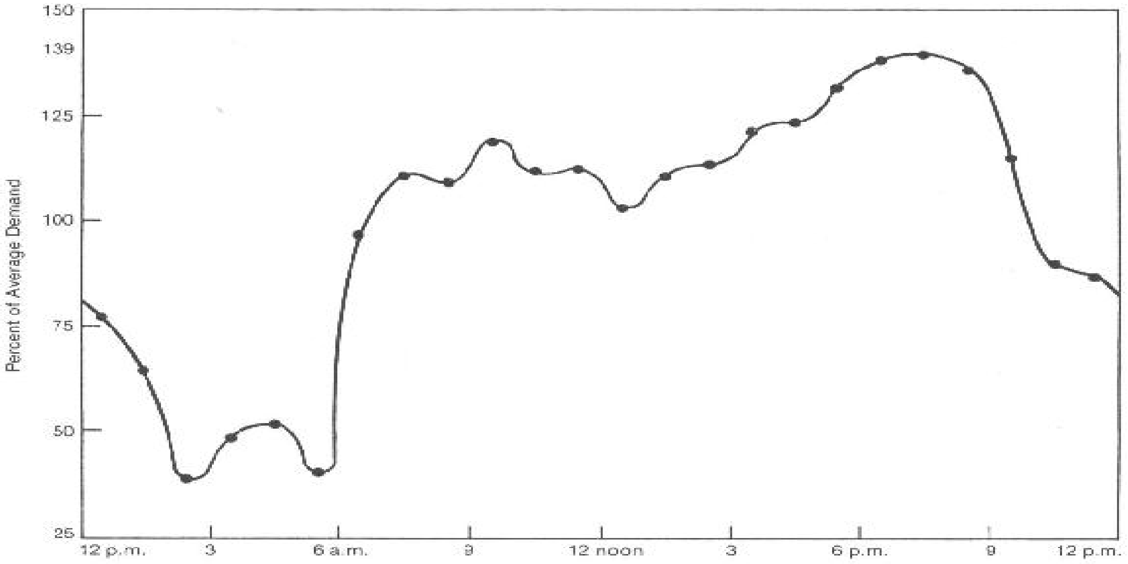
AVERAGE DAY DEMAND in million gallons per day (MGD):
The total amount of water use for a system for a year divided by 365 days.

AVERAGE WINTER DAY DEMAND in MGD:
The total amount of water use for a system during the months of December, January, and February, divided by the number of days in the period (either 90 or 91 depending on whether February has 28 or 29 days).

AVERAGE SUMMER DAY DEMAND in MGD:
The total amount of water use for a system during the months of July and August, divided by the number of days (62).

PEAK DAY DEMAND in MGD:
The highest daily water use for a system in one 24-hour period. It is generally best to take the average of the peak-day demand over a period of several years. This smoothes out averages that could be abnormally high because of a situation that could have caused excessive demand on one of the days.

It is not necessary to have pumps capable of supplying a system with water to accommodate all of the varied demand conditions. The reason is illustrated by showing the hourly variations of water demands during a 24-hour period for a typical system.



Typical system diurnal-demand curve.

A storage tank allows the use of constant flow in the distribution system. Pumps that fill the storage tanks are operated by controls which start and stop them as the water level in the storage tanks rises and falls during the day. When demands are high, the pumps cannot keep up with the requirements for the water and the storage volume is reduced. When demands are low, the pumps have excess capacity and are able to refill the storage tank to full for the next high-demand period.

The other function of storage tanks is to provide pressure. All water distribution systems must have a means of pressurizing the system. The most common method of creating system pressure is through the use of an elevated water storage tank to develop the necessary feet of head to force water through the system.

If the land around the distribution systems allows, a ground-storage tank can be constructed on a high hill to serve as an elevated storage tank.

Another method of pressurizing water distribution systems is through the use of hydropneumatic tanks although they usually provide very small amount of reserve storage and are not adequate for fire-protection purposes.

TYPES OF WATER STORAGE TANKS

There are three basic types of potable water-storage tanks: ground storage tanks, elevated storage tanks, and hydropneumatic tanks.

Ground storage tanks can be installed either below or above ground. They are fabricated of concrete or steel. They generally have the function of providing large volumes of storage for peak-day demand when the capacity of the source of supply is less than the maximum daily volume the specific system may need. An example of a situation in which the peak-day demand is larger than what the system can deliver daily is a system served by a well that can deliver only enough water to satisfy the distribution system for a short time of high-volume need. Having a large ground storage tank allows the operator to set the pumps to operate mainly during off-peak hours, usually overnight when power rates are lower, to fill the tank for the daytime peak period demand.

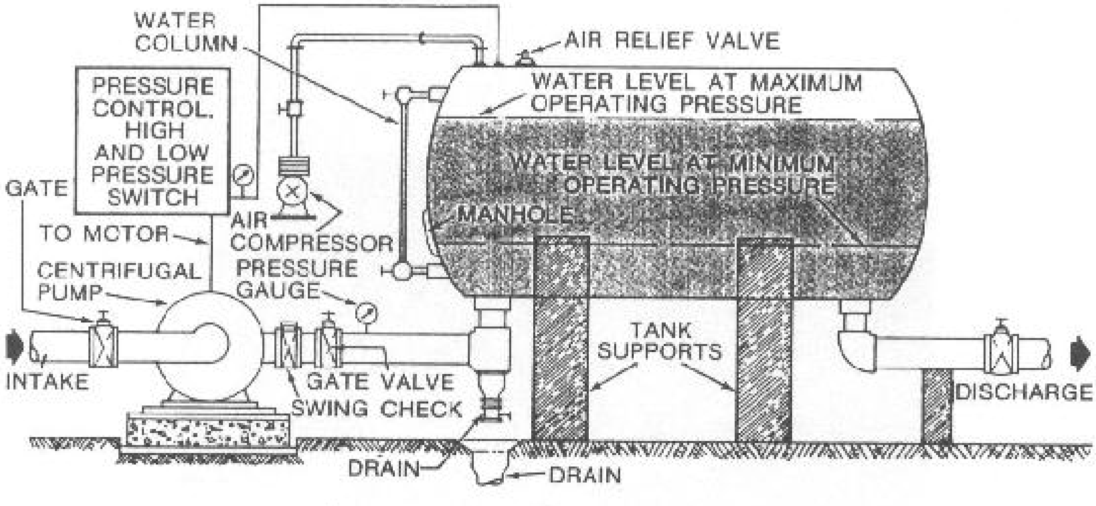
It is usually necessary to pump water from a ground storage tank to an elevated storage tank to provide uniform pressure to a distribution system. Ground storage tanks can provide system pressure if they are located on hills within or near the distribution system area. Such situations are ideal since ground storage tanks are usually less expensive to construct than elevated storage tanks.

A Ground Storage Tank

Ground storage tanks constructed of concrete can be built either below or above ground. Concrete is used more often for below-ground construction because it is not affected by corrosion and has the strength to support the pressure of the earth around it even when empty. Older below-ground tanks made of concrete were constructed with a covering of earth over the top to protect the tank and provide insulation. This is no longer acceptable because of concerns of leaks in the roof or hatches which could allow rain or groundwater to enter the tank with chemical or biological contaminations such as fertilizer, herbicides, pesticides, and pathogenic bacteria or viruses. Current standards require that the top or roof of a below-ground potable water storage tank be constructed at a height of not less than two feet above the surrounding grade. Concrete used for above ground-storage tanks is usually pre-cast and assembled at the site, in a circular shape to provide strength.

Because of the relatively low construction cost, above-ground tanks constructed at ground level are usually made of either welded or bolted steel. Following construction, welded steel tanks must be coated both inside and out to protect against corrosion and electrolytic reactions which eventually could cause leaks or structural damage. Bolted steel tanks are usually lined with a factory-applied glass coating, and seams are caulked during construction to prevent leaks.

Hydropneumatic tanks are used to provide pressure to very small public water systems such as resorts, mobile home parks and very small communities. They are not a good storage vessel for fire protection purposes due to the small volume of water within the vessel.



Pneumatic Steel Pressure Tank

Hydropneumatic tanks operate on the same principle as a home water system in that the pressure-rated tank contains approximately two-thirds water and one-third air at full capacity. An air compressor is required to maintain a proper volume of air within the tank at the necessary pressure. At low operating level the tank will contain about one-third water and two-thirds air.

The air is pressurized to provide a system head and operates at about a 20-pound-per-square-inch pressure difference between high and low water levels. A system using a hydropneumatic tank with a need for an average operating pressure of 40 psi would then have a 50 psi pressure at high levels and a 30 psi pressure at low levels.

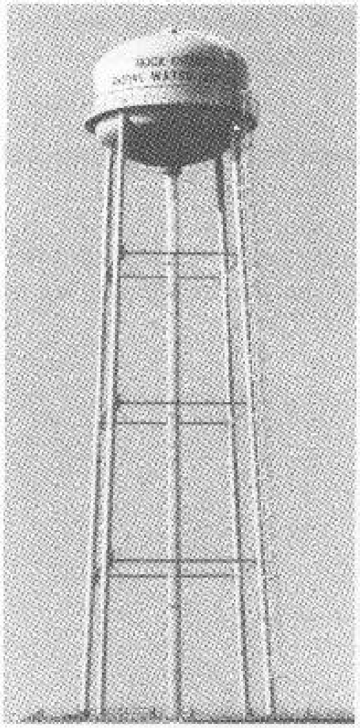
Hydropneumatic tanks are generally constructed of steel and must meet the standards of the American Society of Mechanical Engineers (ASME) for pressure-rated tanks. The tanks are usually long and cylindrical, positioned horizontally on concrete support piers. They look similar to a propane storage tank.

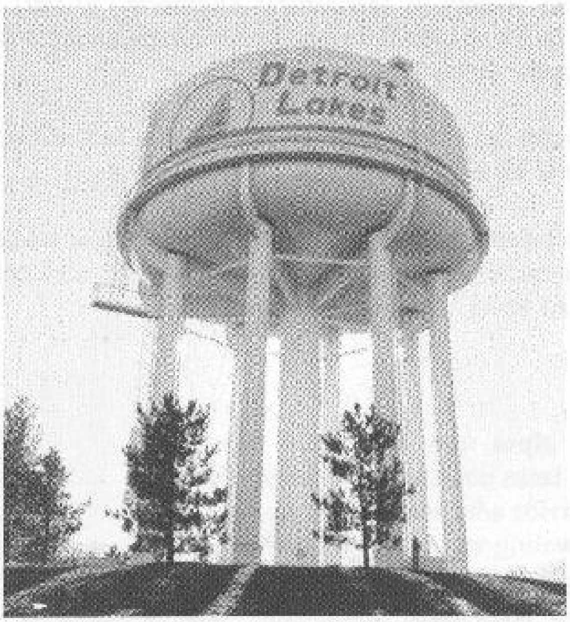
Hydropneumatic tanks must be housed in a heated building to prevent freezing of the tank and associated piping, air compressor, and controls.

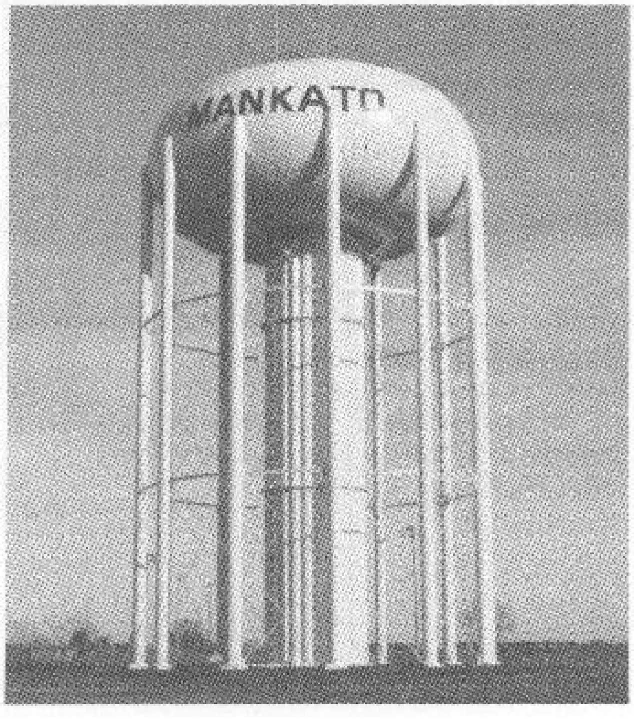
Elevated storage tanks are usually constructed of welded, bolted, or riveted steel, although a few wooden tanks still exist. Configurations for elevated steel tanks include standpipes, leg or supported tanks, and single pedestal tanks.

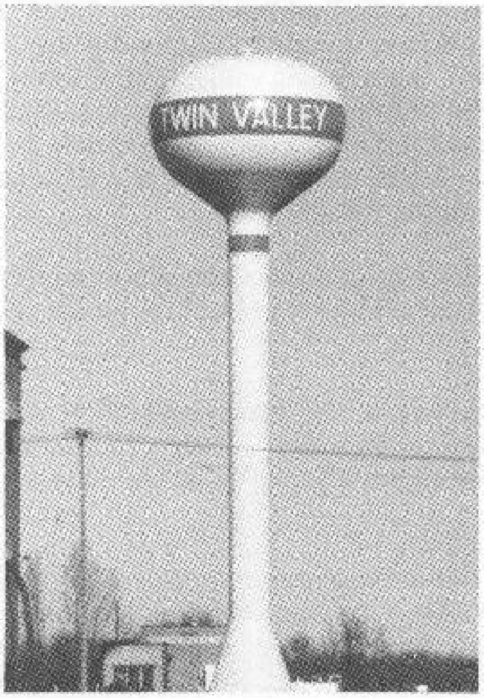
Stand pipes are essentially ground storage tanks constructed to a height that will provide adequate system pressure in the operating range. Their diameter is constant from the ground to the top, and they are completely filled with water. While a standpipe contains a large volume of water, only the upper volumes would be available for use if pressure demands throughout the system are to be maintained. There is a tendency for lower-level standpipes to freeze unless they are operated very carefully or equipped with circulation or air bubblers to prevent or reduce ice build-up in the winter. Stand pipes are generally constructed of welded or bolted steel. Access to the top of the tank is usually by an exterior ladder. The inlet pipe generally only extends one to two feet above the floor at the base.

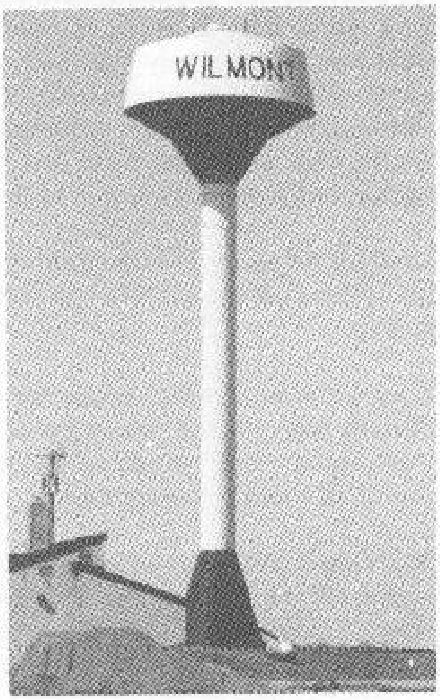
Leg supported tanks are the most common type of elevated tank seen in our area. A large volume tank is supported by a structural system of legs and crosses or wind bracing. Water enters and leaves the tank through an insulated riser pipe usually located in the center of the support structure for the tank. This type of elevated tank is less prone to freezing than a standpipe because the water tends to circulate better throughout the stored volume. Leg supported tanks still require careful operation to minimize ice sheet build up during the winter months.











Single pedestal tanks have a single support structure in the center of the tank with a large volume tank at the top. A pedestal tank is easier and less expensive to maintain, but more costly to construct. The riser pipe and access ladder are contained within the pedestal tube and, since the pedestal and base are not normally heated, the riser pipe is insulated to reduce the potential for freezing.

There are many variations of each of these three types of elevated water storage tanks. In all cases, however, the system pressure is provided by the height of the water above the ground. This type of water storage tank is generally the most cost-effective method of maintaining a relatively uniform operating pressure within a water distribution system.

OPERATION OF STORAGE TANKS

The proper operation of a water storage tank is critical to both the overall system operation and the life of the water storage vessel. Improper operation can result in large repair and maintenance costs in addition to shortening the storage tank's useful life. It is important to reduce ice build-up within non-heated tanks and to periodically clean the interior of the tanks for health and maintenance reasons.

The operating principles of all the pressure-creating tank types are the same.

All gases, liquids, and solids have weight as a result of the Earth's gravitational forces. In order for a liquid, such as water, to create a downward force it must be contained within a vessel. Otherwise, it will simply flatten out on the surface. When dealing with liquids, the force exerted by the weight of a contained liquid is expressed in terms of the weight of the liquid over a certain area of flat surface, expressed in pounds per square inch (psi). For example, freshwater weighs 62.4 pounds per cubic foot. In other words, the pressure exerted on a one-square-foot surface that is one feet deep is 62.4 pounds per square foot (psf).

Dividing the psf by 144 (the number of square inches in one square foot) tells us that the weight per square inch exerted by a one-foot depth of water is 0.43333 (about 7/16) pounds per square inch (psi).

A cube of water one inch square and one foot high weighs 0.4333 pounds. If 100 of these pieces of water were stacked one on top of the other, the weight would be 43.33. This stack of water would exert 43.33 pounds of weight on the one-square-inch surface on the bottom or 43.33 pounds of pressure per square inch.

Water contained in a vessel or pipe 100 feet high will exert a pressure of 43.33 pounds per square inch at the bottom of the pipe. The pressure is constant no matter the diameter of the pipe. It could be one inch or ten feet in diameter, but the pressure at the bottom of this vessel will still be 43.33 pounds per square inch.

With this in mind, it becomes easier to understand that an elevated tank will create a pressure equal to its height in feet to the water line times 0.433 pounds. Pressure can also be expressed as feet of head. One foot of head equals 0.433 psi. One psi equals 2.31 feet of head.

For further practice calculating head and pressure, study the Mathematics chapter in this manual.

WINTER OPERATION

Ground storage tanks are the easiest to operate as they are readily accessible for observation. The most important concerns are ice build-up and damage to coatings and the structure. Below-ground tanks are less prone to ice build-up than above-ground tanks. During warm-weather months, coating life can be extended by operating at fuller levels. This reduces the temperature changes and subsequent expansions and contractions of the tank which can damage the coating materials.

Ground storage tanks with the single purpose of providing reserve storage should be kept full to avoid stagnant water and ensure minimal ice formation.

The major concern during a severe winter is for damage to the interior of a ground storage tank by abrasion to the coating. As a floating sheet of ice moves up and down with the water level, the sides of the tank are rubbed and the life of the coating is shortened. The second concern is for damage to the tank itself. Ice creates tremendous pressure as it freezes and thaws. If allowed to occur, these pressures can bend or break the tank. The third concern is the fact that storage volume of the tank is reduced by the volume of the ice in the tank. Overflow systems on ground storage tanks should be checked frequently for ice build-up. The bug screens on the overflow vent should be checked often. Hatches to water storage tanks should be locked at all times to ensure security of the tanks from vandalism.

Elevated tanks are very prone to ice formation because they are entirely exposed to the elements. Wind and cold quickly dissipate or remove the heat from the water in the tank. If possible, an elevated tank should be operated with at least one volume change per day. This will reduce the formation of stagnant water as well as ice. Overflow systems should be checked frequently. Any ice formation from an accidental overflow should be removed to prevent structural damage. Ice on the tank adds weight to the structure. This additional weight, which was not considered in the design of the tank, can cause severe damage. Under extreme conditions, the tank could even collapse. Elevated tanks should also be locked to prevent vandalism. This reduces the liability of the owner.

Hydropneumatic tanks are not prone to freezing and ice formation as they are usually housed in heated buildings. These tanks should never be operated above the pressure rating of the tank shown on the manufacturer's plate. The pressure blow-off valve should be checked frequently for proper operation. This tank, like any of the others, requires regular cleaning and inspection of the interior.

ROUTINE MAINTENANCE

The routine maintenance includes mowing the area around the tank foundation, sweeping debris from the foundations, checking the locks on hatches, observing the pressure gauges within the system, and, during the winter months, periodically comparing pumping records. Sweeping the foundation tops on a regular basis will reduce coating, base-plate, and concrete failure at the tank foundation. Utility staff should inspect the tank surface regularly, checking especially for any peeling of the coatings. This inspection should include the inside of the tank as well as the outer surface. Because of the specialized inspection-rigging equipment required, it is best to have the inside surfaces inspected by a consultant.

The comparison of pumping records and tank-water levels during winter months can help indicate if there is ice build-up. If the ice is floating, the problem will not be evident. A careful comparison can, however, warn an observant operator of ice formation clinging to the tank walls. If, for the same operating range, less water is required to fill a tank during the winter than during the summer, ice is probably attached to the tank walls. Because the ice displaces an equal volume of water at both high and low levels, floating ice can only be observed visually when a tank is operating.

VOLUME SIZING OF POTABLE WATER STORAGE TANKS

The design and sizing of a water storage tank is best performed by a consulting professional engineer. The process is quite complex and involves many considerations. The operators need to have a basic knowledge of the recommendations for storage volume within a system. The current recommendations are that the storage volume should be equal to the average daily demand for the system, not including fire protection requirements. These recommendations are sound from the standpoint of being able to provide for public water supply and fire protection for a day without having to pump water into the tank; however, because of the climate, they are often not practical in Minnesota. In most cases, because the water cannot be changed frequently, a stored volume of water for both fire protection and public use will be so large that freezing will occur. Each water system must be analyzed individually to provide for the best combination of storage volume, fire protection needs and the water use patterns of the customers to provide a storage volume which is adequate, but also manageable and affordable for the system.

Cross Connections

A cross connection is a direct connection of a non-potable water source with a potable source. Cross connections can result in serious illness and even death. Backflow can be the result of a cross connection which can affect water quality and create health problems.

One of the most notorious incidents of cross connection was the “Holy Cross Episode,” when many members of the Holy Cross football team developed infectious hepatitis as a result of contact with contaminated water pooled around a sprinkler head. The water supply became contaminated when a partial vacuum in the water distribution system was created due to a nearby fire which drew contaminated water back into the potable water supply.

Another backflow contamination case occurred in Minnesota in 1978 after an herbicide was backsiphoned from a farmer’s tank truck into a city’s water system. The farmer filled his water tank from a hose by the city’s water plant. The water pressure suddenly dropped and the pesticide in the truck was siphoned into the city’s water system. Fortunately, no illness from the contamination occurred, but the city had to limit its water use until the entire system could be flushed and refilled with clean water.

BACKFLOW

Backflow is defined as undesired, reversed flow of liquid in a piping system. Backflow can be caused by back siphonage, back pressure, or a combination of the two.

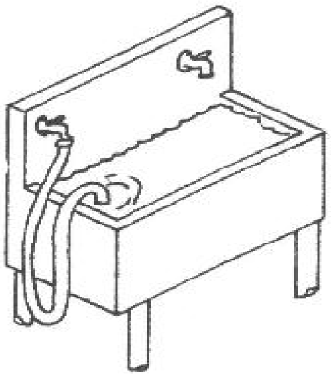
1. Back-siphonage backflow occurs when there is a partial vacuum (negative pressures) in a water-supply system, drawing the water from a contaminated source into a potable water supply. The effect is similar to sipping a soda by inhaling through a straw. For example, during a large fire, a pumper is connected to a hydrant; high flows pumped out of the distribution system can result in significantly reduced water pressure around the withdrawal point. A partial vacuum has been created in the system, causing suction of contaminated water into the potable water system. During such conditions, it is possible for water to be withdrawn from non-potable sources such as air-conditioning systems, water tanks, boilers, fertilizer tanks and washing machines into buildings located near a fire. The same conditions can be caused by a water-main break.

2. Back-pressure backflow occurs when the pressure of the non-potable system exceeds the positive pressure in the water distribution lines. For example, there is a potable water connection to a hot water boiler system that is not protected by an approved backflow preventer. If pressure in the boiler system increases to a point that it exceeds the pressure in the potable water distribution system, a backflow from the boiler to the potable water system may occur.

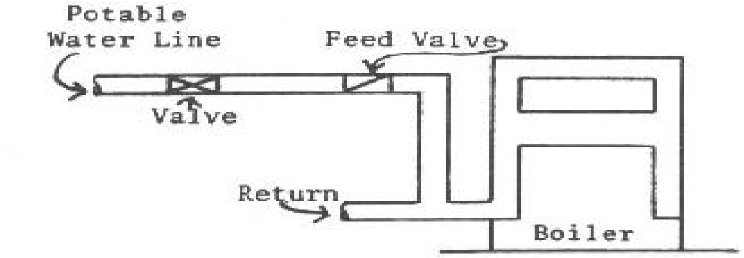
CROSS CONNECTIONS

Cross connections can occur in a variety of locations, including commercial buildings, hospitals, farms, houses, and apartment complexes. The following examples illustrate cross connections:

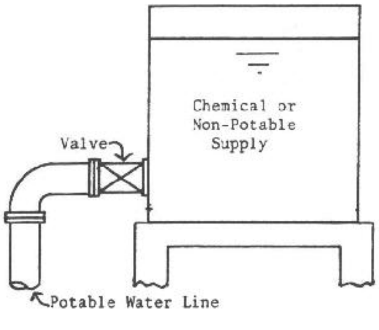
1. A prevalent type of cross connection is illustrated by a hose connected to a sillcock with the other end of the hose lying in a pool or sink full of polluted or contaminated water. In this case backflow occurs by back siphonage. If a partial vacuum is set up in the water distribution system, water can be drawn from the tank by suction when the faucet is opened.



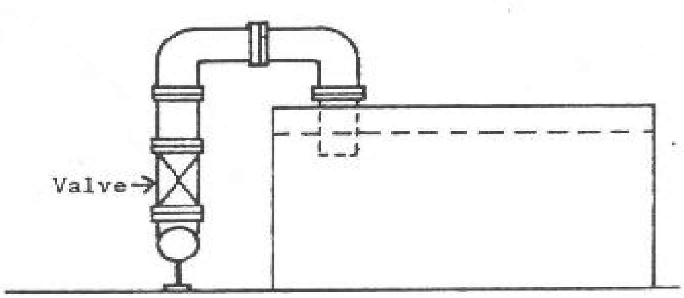
2. Cross connection to pressurized systems, such as a hot water boiler, is not uncommon. In this case backflow can occur by back pressure and by back siphonage. Back pressure backflow can occur when the water pressure in the boiler or pressurized tank exceeds the positive pressure in the water distribution lines.



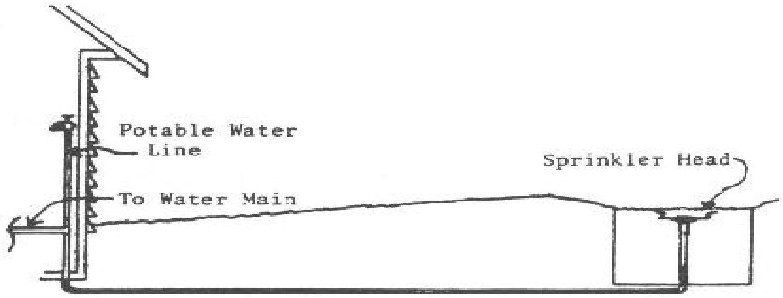
3. A cross connection to an elevated tank containing a non-potable substance can cause backflow by back pressure. Backflow can occur if the valve is left open and the pressure caused by the water elevation in the tank exceeds the line pressure.



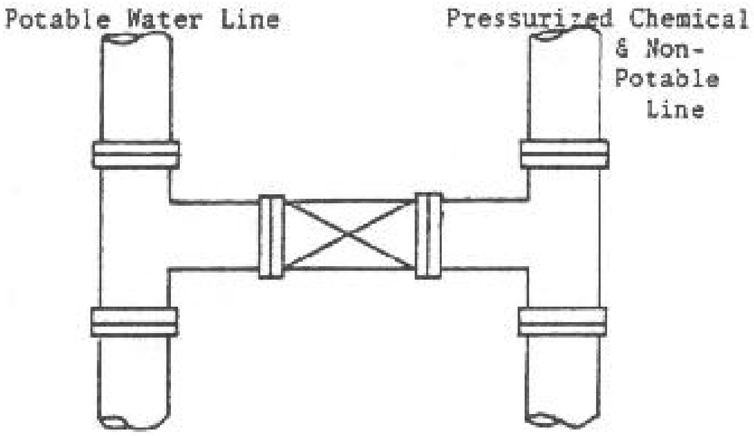
4. A cross connection is created when an open tank is connected to a water line with no air gap. When the valve is opened, back siphonage can occur if a partial vacuum develops in the water system that draws water from the tank into the water system.



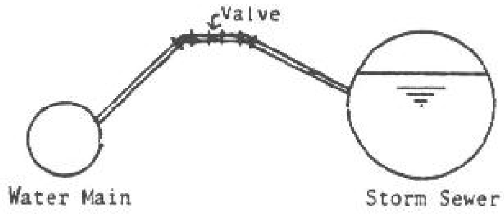
5. A cross connection to a sprinkler system can cause back siphonage when a partial vacuum in the water system draws water from pooled water near a sprinkler head. This type of cross connection led to the "Holy Cross Episode" that was mentioned earlier. Backflow caused by back pressure can occur when the sprinkler head is at a higher elevation than the connection to the potable water system.



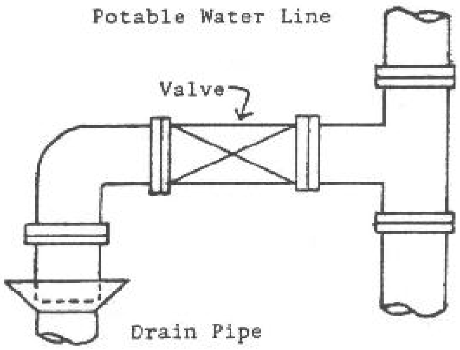
6. A cross connection to a pressurized pipe carrying contaminated water can cause backflow. When the valve is opened, backflow by back pressure can occur if the pressure in the non-potable lines is higher than the positive pressure in the potable system.



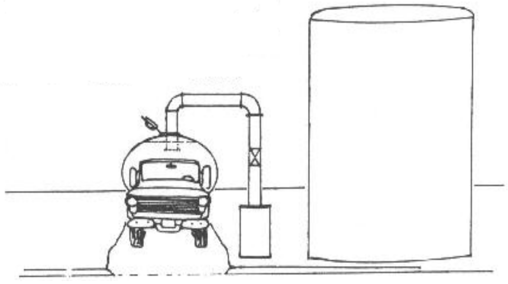
7. A cross connection to a gravity sewer can be created when a water main is connected to the sewer either to drain water from the water line or to keep water flowing in the water main to prevent it from freezing. Backflow can occur by back siphonage when the valve is left open.



8. When a cross connection to a drain pipe exists, backflow can occur by back siphonage if the valve is left open and there is not enough air gap between the outlet of the cross connection and the drain pipe. A partial vacuum in the potable water line can draw contaminated water from the drain pipe. An example of this would be the drain line from a home water softener.



9. A cross connection can be created when a hose connection from a water line is used to fill a tanker truck. Backflow can occur by back siphonage if a partial vacuum is developed in the water system. This is what happened in the Minnesota case mentioned earlier.



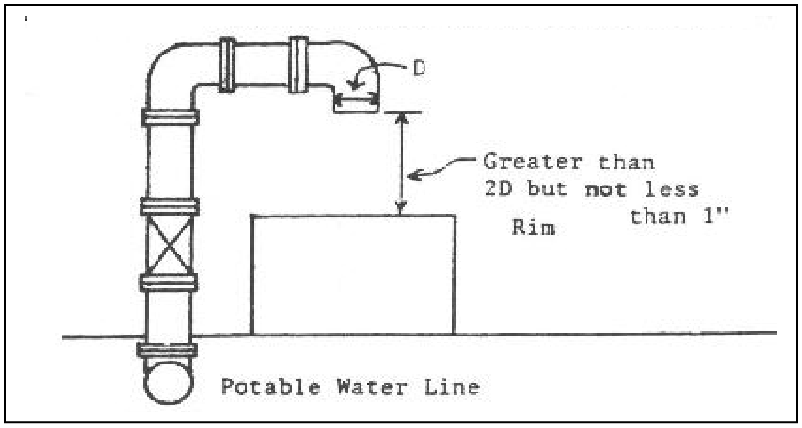
These are a few of the possible types of cross connections that can occur. The variety of possible cross connections is almost infinite, making them difficult to control.

MEANS USED TO PROTECT AGAINST CROSS CONNECTIONS

There are five basic means which are used to prevent or reduce the possibility of backflow in cross connections: air gaps, atmospheric vacuum breakers, pressure-type vacuum breaker assemblies, double check valve assemblies, and reduced-pressure backflow prevention assemblies. The latter assembly must be certified by an approved testing laboratory before being acceptable to the Minnesota Department of Health.

Air gap

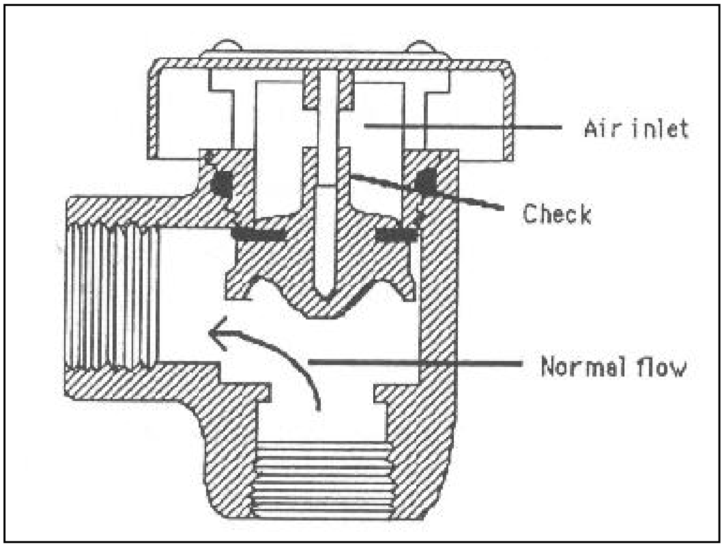
Of the five means listed, the air gap--physical separation of the potable and non potable systems by an air space--is the most reliable backflow prevention measure. The vertical distance between the supply pipe and the flood-level rim should be two times the diameter of the supply pipe, but never less than one inch. This type of backflow prevention technique can be used in situations in which potable water runs into a tank or a source which is under atmospheric pressure. Obviously, this type of backflow prevention method cannot be used for a direct connection to a pressurized system.



Atmospheric vacuum breakers

These devices do not prevent backflow due to back pressure. They must be installed on the discharge side of the last control valve. They must be installed six inches above the rim of the fixture they serve. In addition, they cannot be used under continuous pressure for a period of eight hours or more. Atmospheric vacuum breakers are usually used with hose bibs or sillcocks in situations in which a hose is attached to a sprinkler system or is draining into a tank. Once installed, atmospheric vacuum breakers cannot be tested.

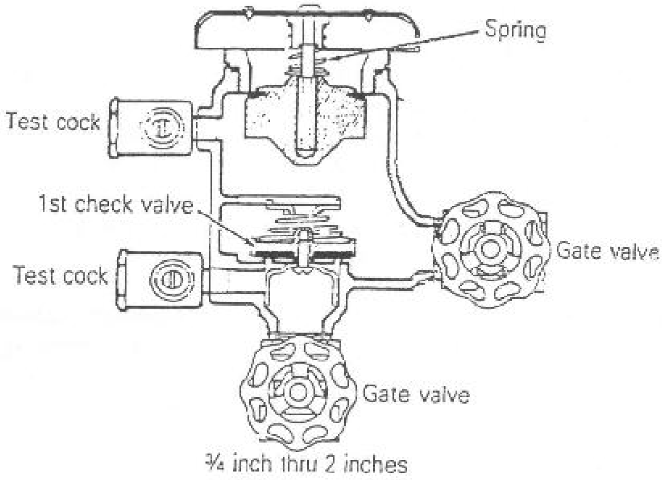
The next picture shows the operation of one type of atmospheric vacuum breaker. Under normal conditions, the gate is forced to the side, preventing air from entering. When the water system is under a partial vacuum, atmospheric pressure forces open the gate, allowing the formation of an air gap that prevents back siphonage.



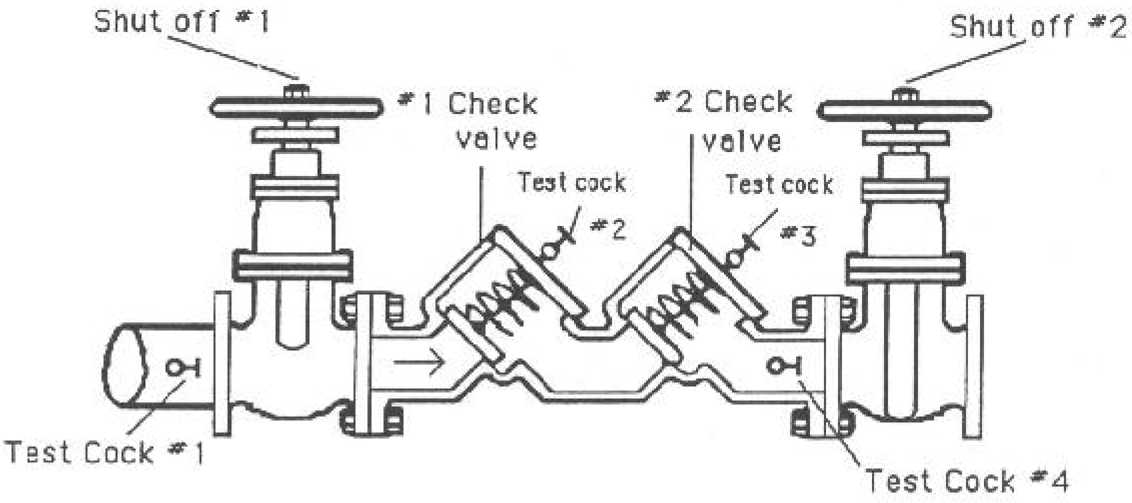
Pressure-type vacuum breaker assembly

Pressure-type vacuum breaker assemblies are similar to atmospheric vacuum breakers except that these devices can be used under continuous pressure. They cannot prevent backflow due to back pressure and must be installed above the usage point to prevent back siphonage. They must be installed at least 12 inches above the rim of the device that they are protecting.

The schematic of this assembly is shown below. It is spring loaded to allow air to enter the device. Under normal conditions, water pressure compresses the spring, closing the air opening with the plunger. If a partial vacuum in the assembly is obtained, air is allowed to enter the assembly, forming an air gap. These assemblies, once installed, can still be tested.



Double checks valve assemblies
These assemblies are used for a direct connection between two potable water systems. Under continuous pressure they cannot be used to connect a potable water supply to a contaminated or high-hazard water system. The assembly, as shown, consists of two ordinary spring-loaded or internally loaded swing check valves mounted in series, two shut off valves and four test cocks. They offer only a partial degree of protection because particles can prevent proper seating of the valves causing them to leak. Double-check valve assemblies protect against back pressure and back siphonage conditions. Once installed, they can be tested.



Reduced-pressure principal backflow prevention assembly (RPZ)
This assembly provides the greatest protection against back pressure and back siphonage. The RPZ can be used under continuous pressure and in high-hazard conditions. The RPZ is designed so it will operate even if both the check valves become fouled. A reduced-pressure backflow preventer, as shown, consists of two internally loaded check valves with a zone of reduced pressure between the check valves, two shut off valves and four test cocks. The reduced-pressure chamber also has a spring-differential pressure relief valve.

Such a backflow preventer can be installed on water lines that are used to fill tank trucks. Many private facilities in communities allow farmers or others needing water to fill their tank trucks. These facilities must be inspected for approved backflow prevention devices. In addition, a city must not allow tank trucks to fill from hydrants which are not protected by backflow prevention equipment.

Normal operation of the RPZ

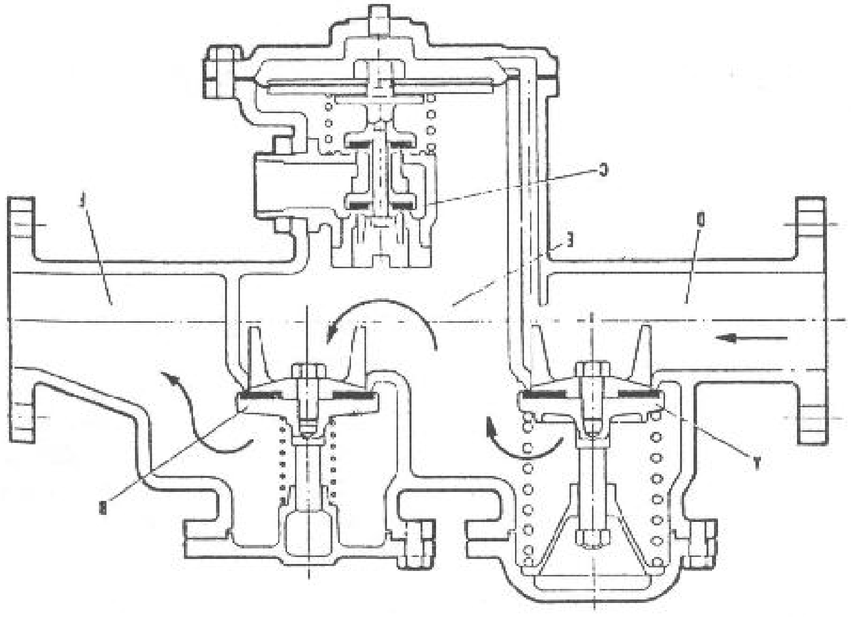
As water flows through the first check valve (A), a pressure reduction is created in the reduced-pressure chamber. The relief valve is held closed because of the reduced pressure between (D) and (E). The second check valve (B) is lightly spring-loaded to allow passage of water into (F).

During back siphonage the following occurs:

When inlet pressure in (D) drops below atmospheric pressure, the relief valve (C) is forced open by the diaphragm creating an air gap in (E). If check valve (B) is leaking, water will drain continuously from the relief valve, indicating a malfunctioning of that check valve.

During a back pressure situation the following occurs:

In the event that check valve (B) leaks, check valve (B) is closed when downstream pressure increases above influent pressure, the increased pressure in zone (E) will cause the relief valve to open and water to drain from the chamber. The relief valve does not keep the pressure in zone (E) below the pressure in zone (D) so that backflow cannot occur. If the check valve (B) does not leak, backflow will not enter the center chamber. See the attached schematics on page 320 (from Watts) on the operation of an RPZ.



NOTE: The RPZ above must be accompanied by a valve on both ends to be an approved and testable RPZ assembly.

EXCERPT FROM MINNESOTA PLUMBING CODE: 4715.2100 BACKFLOW PREVENTERS

A. Atmospheric vacuum breaker (AVB):
   1. must be installed at least six inches above spill line (see special requirements in part 4715.2150);
   2. no possibility of back pressure permitted;
   3. only permitted on discharge side of last control valve; and
   4. no more than eight hours of continuous line pressure permitted.

B. Pressure vacuum breaker (PVB):
   1. must be installed at least 12 inches above spill line;
   2. no possibility of back pressure permitted; and
   3. continuous line pressure permitted.

C. Spill-proof vacuum breaker (SVB):
   1. must be installed at least six inches above spill line;
   2. no possibility of back pressure permitted;
   3. continuous line pressure permitted; and
   4. field testable.

D. Hose connection vacuum breaker (Hose VB):
   1. required for threaded hose connections;
   2. back pressure not permitted;
   3. continuous line pressure not permitted; and
   4. any new device must be field testable.

E Double-check valve with intermediate atmospheric vent (DCVIAV):
   1. permitted for low or moderate hazard with small pipe sizes;
   2. back pressure permitted; and
   3. continuous line pressure permitted.

F. Reduced pressure zone backflow preventer assembly (RPZ):
   1. any degree of hazard permitted;
   2. back pressure permitted; and
   3. continuous line pressure permitted.

G. Double-check valve assembly (DCVA):
   1. permitted only for nontoxic, low hazard installations with nuisance or aesthetic concern;
   2. back pressure permitted; and
   3. continuous line pressure permitted.

STAT AUTH: MS s 16B.61; 326.37 to 326.45 HIST: 15 SR 76

Installation of RPZs

The following should be considered when installing a reduced-pressure principal backflow preventer:

a. In new installations it is important that the piping be thoroughly flushed.

b. Install strainers in front of the check valves to prevent foreign material from disrupting the operation of the check valves.

c. If continuous water supply is required, then two backflow preventers can be installed in parallel. Resilient seated gate valves or ball valves should be installed on both sides of each backflow preventer so that the water supply can be maintained while the other backflow preventer can be serviced. Gate valves or ball valves are necessary for the testing of these assemblies.

d. The backflow-prevention assemblies should be installed at least 12 inches above the floor or grade and a maximum height of 72 inches. They should also be at least 12 inches out from walls or other obstacles which may interfere with testing procedures; never in a pit or manhole.

e. Because RPZs will discharge water when back pressure or back siphonage conditions occur, a drain must be provided. The RPZ also drains when the check valve is fouled.

f. The relief valve must drain through an air gap and any discharge should be clearly visible.

g. The relief valve port shall remain open.

h. The installation of reduced pressure zone backflow preventers is permitted only when periodic testing is done by a trained backflow preventer tester acceptable to the administrative authority. Inspection intervals shall not exceed one year, and records must be kept. All devices must be tested after initial installation to assure that debris from the piping installation has not interfered with the functioning of the assembly.

i. A person certified/licensed by the Minnesota Department of Health shall perform all testing and maintenance work.

Maintenance of RPZs

Backflow preventers should be inspected and tested annually and overhauled every five years. In Minnesota, this must be done by a person certified and/or licensed by the Minnesota Department of Health (MDH) to perform such work. The installation of a reduced-pressure backflow preventer shall be permitted only when there is an approved backflow testing and inspection program provided by the local administrative authority. In addition, they shall be inspected frequently after initial installation to assure that they have been properly installed and that debris resulting from the piping installation has not interfered with the functioning of the assembly.

<u>Inspection records</u>

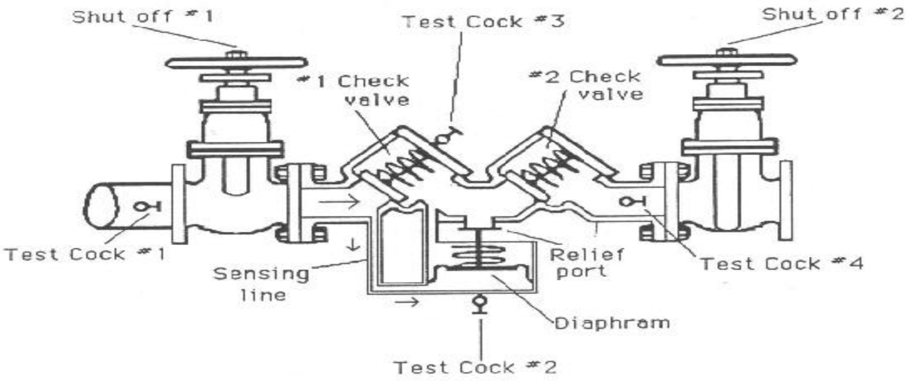
A test and inspection tag must be affixed to the assembly. The tester shall date and sign the tag and include his or her backflow preventer tester identification number. Written records of testing and maintenance must be maintained and submitted to the administrative authority. Any backflow preventer that is testable and in service should be placed on a service-maintenance schedule.

The testing and maintenance of the assembly shall be preformed by a certified tester. Backflow-tester identification numbers are issued by the MDH after qualified schooling. In a municipality with a population over 5000, the tester also has to be a licensed plumber. A chart comparing the different types of backflow-preventers is attached.

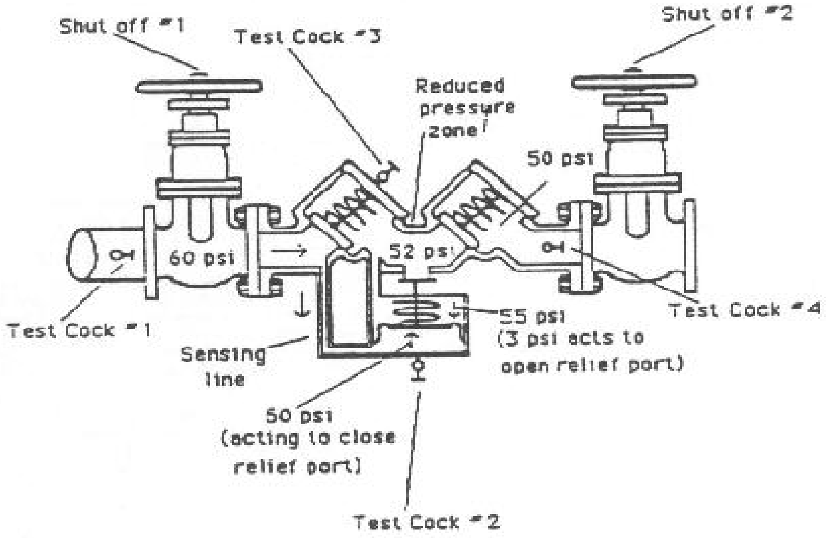
Four basic types of backflow preventers and their uses

Type & Purpose	Description	Installed At	Examples of Installations
1. REDUCED PRESSURE PRINCIPLE BACKFLOW PREVENTER For high hazard cross connections.	Two independent check valves with intermediate relief valve. Supplied with shut-off valves and ball type test cocks.	All cross connections subject to backpressure or backsiphonage where there is a high potential health hazard from contamination. Continuous pressure.	Main Supply Lines: Commercial Boilers; Cooling Towers; Hospital Equipment; Processing Tanks; Laboratory Equipment; Waste Digesters; Car Wash; Sewage Treatment
2. DOUBLE CHECK VALVE ASSEMBLY For low hazard cross connections.	Two independent check valves. Supplied with shut-off valves and ball type test cocks.	All cross connections subject to backpressure where there is low potential health hazard or nuisance. Continuous pressure.	Main Supply Lines: Food Cookers; Tanks & Vats; Lawn Sprinklers; Fire Sprinkler Lines; Commercial Pools (Nontoxic)
DOUBLE DETECTOR CHECK VALVE ASSEMBLY For low hazard applications.	Double check valve assembly with a water meter and double check in by-pass line.	Fire protection system supply main. Detects leaks and unauthorized use of water.	Fire Sprinkler Lines (Nontoxic)
DUAL CHECK VALVE BACKFLOW PREVENTER For low hazard applications.	Two independent check valves. Checks are removable for testing.	Cross connections where there is a low potential health hazard & moderate flow requirements.	Residential Supply Lines (at the meter) (Nontoxic)
3. BACKFLOW PREVENTER WITH INTERMEDIATE ATMOSPHERIC VENT For moderate hazard cross connections in small pipe sizes.	Two independent check valves with intermediate vacuum breaker and relief valve.	Cross connections subject to backpressure or back-siphonage where there is a moderate health hazard. Continuous pressure.	Boiler (Small); Cooling Towers (Small); Dairy Equipment; Residential
		Pump outlet to prevent backflow of carbon dioxide gas and carbonated water into the water supply system to beverage machines.	Post-Mix Carbonated Beverage Machine
LABORATORY FAUCET and DOUBLE CHECK VALVE with INTER-MEDIATE VACUUM BREAKERS In small pipe sizes For moderate to low hazard.	Two independent check valves with intermediate vacuum breaker and relief valve.	Cross-connections subject to backpressure or back-siphonage where there is a moderate to low health hazard.	Laboratory Faucets and Pipe Lines; Barber Shop and Beauty Parlor Sinks
4. ATMOSPHERIC VACUUM BREAKERS For moderate to high hazard cross connections.	Single float and disc with large atmospheric port.	Cross connections not subject to backpressure or continuous pressure. Install at least 6" above fixture rim. Protection against backsiphonage only.	Process Tanks; Dishwashers; Soap Dispensers; Washing Machines; Lawn Sprinklers.
PRESSURE TYPE VACUUM BREAKERS For moderate to high hazard cross connections.	Spring loaded single float and disc with independent 1st check. Supplied with shut-off valves & ball type test cocks.	This valve is designed for installation in a continuous pressure potable water supply system 12" above the over-flow level of the system being supplied. Protection against backsiphonage only.	Laboratory Equipment; Cooling Towers; Comm. Laundry Machines; Swimming Pools; Chemical Plating Tanks; Lg. Toilet & Urinal Facilities; Degreasers; Photo Tanks; Live Stock Water Systems; Lawn Sprinklers
HOSE CONNECTION VACUUM BREAKERS For residential & industrial hose supply outlets.	Single check with atmospheric vacuum breaker vent.	Install directly on hose bibbs, service sinks & wall hydrants. Not for continuous pressure.	Hose Bibbs; Service Sinks; Hydrants.

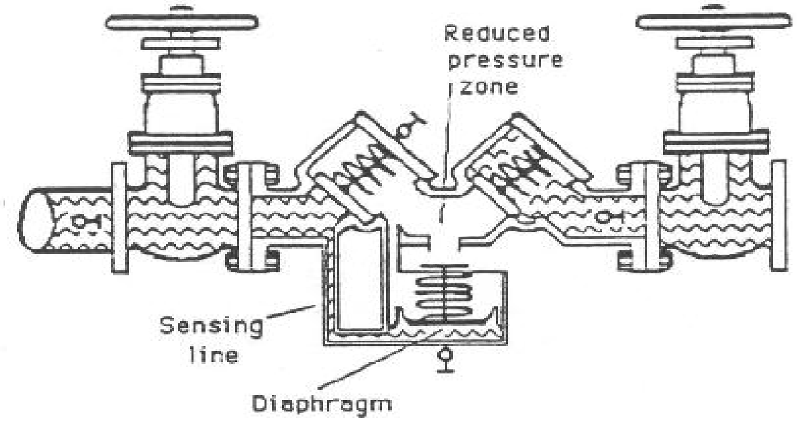
Watts Regulator - Schematics on the operation of RPZ



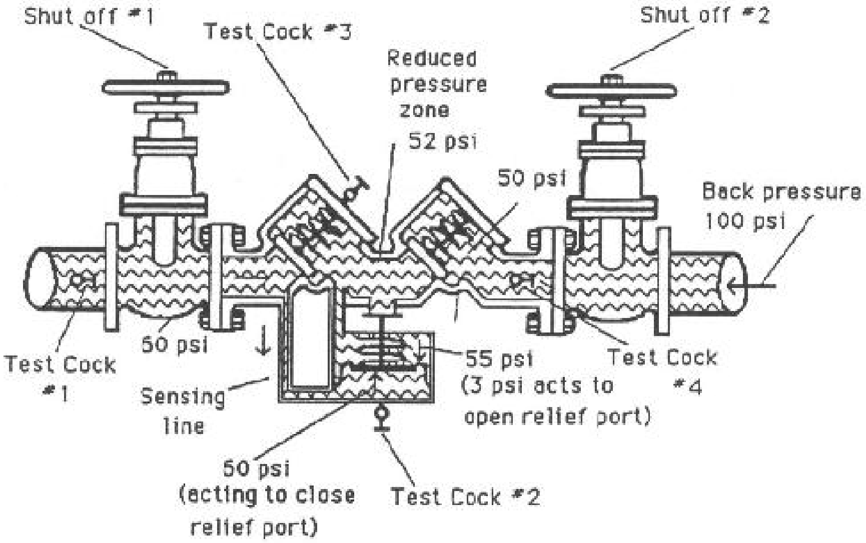
Reduced Pressure Principle Assemby. This backflow preventer is also frequently called a Reduced Pressure Zone Assembly. (RPZ)



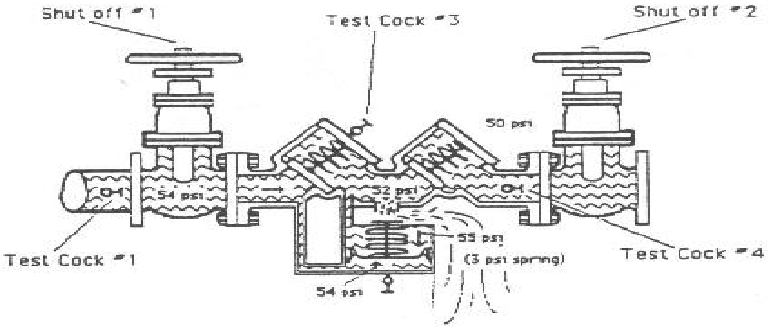
RPZ Under Normal Flow. Assume a supply pressure of 60 psi and a pressure reduction by the first check valve of 8 psi, creating a pressure of 52 psi in the reduced pressure zone. If the relief valve has a 3 psi spring, the pressure working to open the port would be 55 psi (52 psi + 3 psi) and the pressure working to keep the port closed is 60 psi. Thus under normal flow conditions, the relief valve remains open.



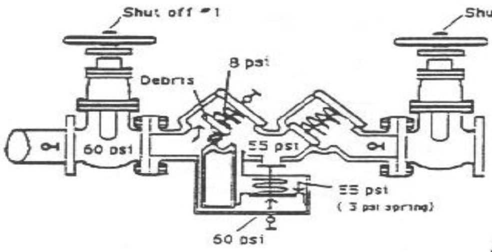
Leaking RPZ. Under special condition during backsiphonage, the relief valve will open, all the water in the reduced pressure zone “dumps”, creating an air gap between check valve #1 and check valve #2.

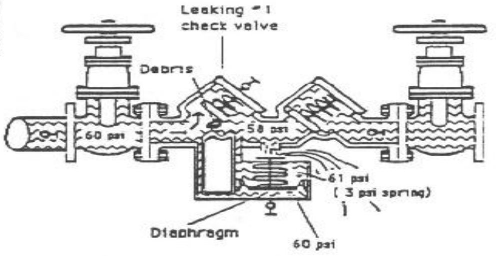


RPZ during Back Pressure Conditions. Assume a supply pressure of 60 psi, a relief valve spring pressure of 3 psi, a spring pressure of 8 psi for the first check valve and back pressure from the downstream side of 100 psi. If the second check valve is working properly the pressure in the reduced pressure zone will not increase.

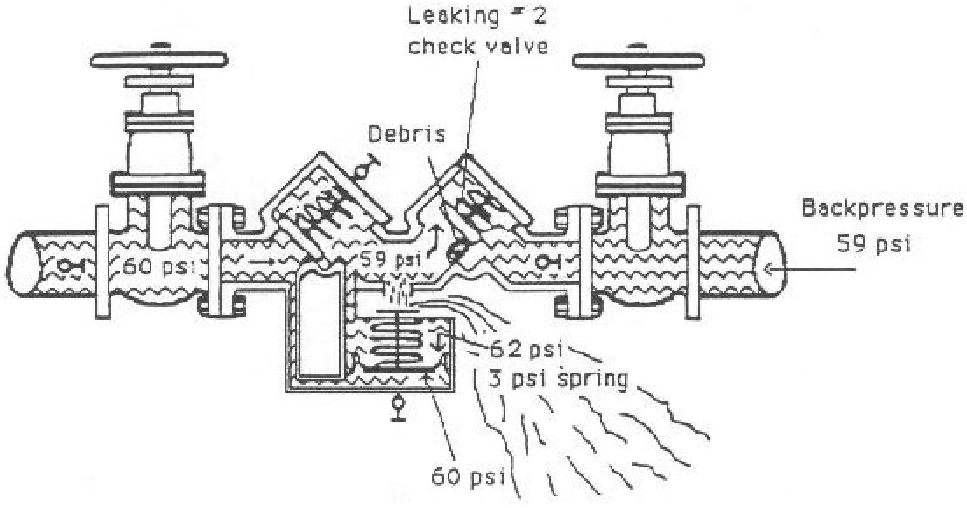


RPZ during Backsiphonage Conditions. The supply pressure falls to 54 psi (perhaps because the lines are being flushed). Because the assembly is under static conditions, the pressure in the zone will remain at 52 psi (since the first check prevents backflow or water out of the zone and the second check will not allow water in the zone to move downstream until there is a demand for water from the customer). The pressure of 52 psi within the zone combined with the pressure exerted by the spring, 3 psi, will cause the relief valve to open and dump the water in the zone.

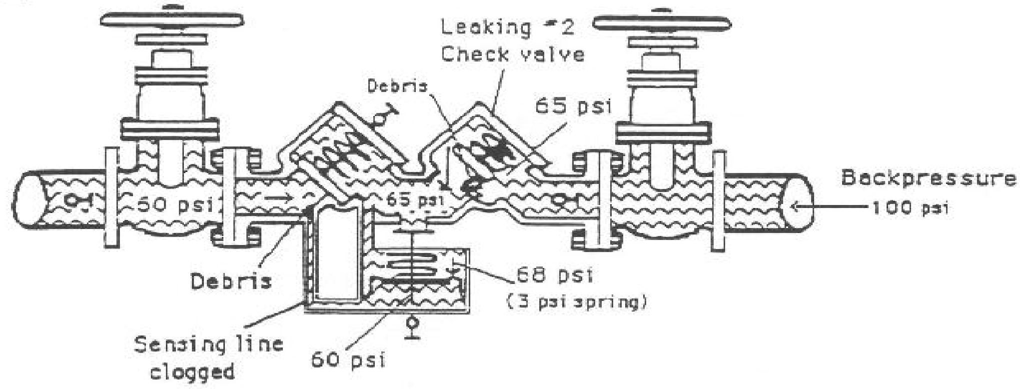




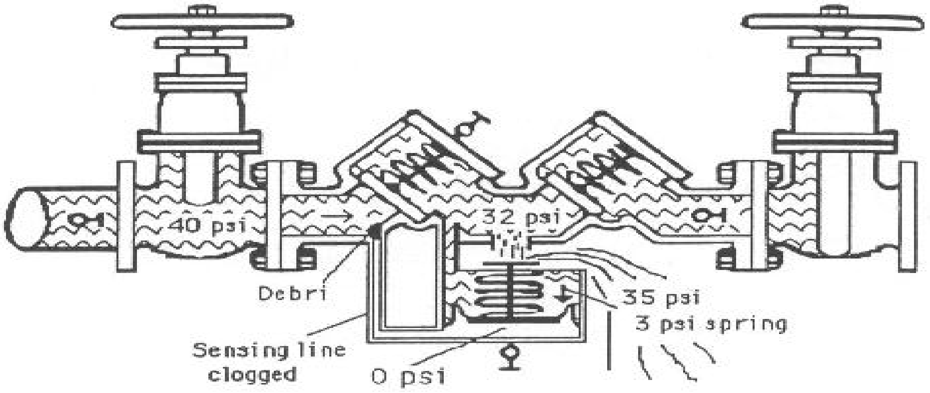
RPZ Failing First Check Valve. Under normal flow conditions, the pressure inside the zone is 52 psi and the pressure acting to open the relief valve is 55 psi. If the first check fails, the pressure inside the zone will increase toward 60 psi. When the pressure inside the zone reaches 58 psi, the total pressure acting to open the diaphragm is 61 psi. This is sufficient pressure to open the relief valve and continuously dump water from the zone.



RPZ Failing Second Check Valve During Back Pressure Conditions. If a pump connected to the consumer's potable water line creates a pressure of 59 psi and the second check valve is leaking, the pressure acting to open the relief valve is 62 psi (59 psi + 3 psi), while the pressure acting to keep it closed is only 60 psi. Therefore, the relief valve will open.



RPZ with Clogged Sensing Line Under Back Pressure Conditions. Assume a static condition, a first check spring pressure of 8 psi, a relief valve spring pressure of 3 psi, a supply pressure of 60 psi, and a pressure of 60 psi trapped in the sensing line. If the second check valve leaked during back pressure conditions and the pressure in the zone increased to 100 psi, the relief valve will not open even though the pressure working to open the relief valve (65 psi) is greater than the pressure supplied by the sensing line (60 psi), because water inside the sensing line cannot be compressed. The diaphragm cannot move to allow the relief valve to open.



RPZ with Clogged Sensing Line with 0 psi in the Sensing Line. The pressure inside the zone is 32 psi, and the pressure acting to open the relief valve is 35 psi. If the sensing line is clogged and the pressure acting to keep the relief valve closed is 0 psi, the relief valve will open and continue to dump water from the zone until the sensing line is cleared allowing water pressure to the upstream side of the diaphragm.

CROSS CONNECTION CONTROL PROGRAMS

The protection of a potable water supply from becoming contaminated from cross connections is the duty of the city's public health staff, water works managers, maintenance personnel, building managers, and plumbing inspectors and installers. The duties include the design, evaluation, installation, and maintenance of the piping systems. Those responsible for inspecting plumbing should insist on protection against backflow. Plumbers and maintenance personnel should follow codes and ordinances to eliminate, or reduce the chances of backflow. Any defects found should be reported in writing to those in charge and those defects corrected as soon as possible.

WHAT SHOULD BE DONE TO CONTROL CROSS CONNECTIONS

Water works operators and superintendents should be knowledgeable of any cross connections in their own and their customers' distribution systems. They should develop a sound program that eliminates health hazards caused by cross connections. Often, hazards can be prevented by a simple air gap or backflow prevention device. Air gaps are, of course, the best measure to use when there is potential for a cross connection to an extreme hazard.

Some general programs for a city's water distributions system are:

1. Elimination or protection of direct connections between potable and non-potable systems.
2. Elimination of private well connections to public water supplies.
3. Design of piping systems in the potable water distribution systems so that enough water at the desired pressure is always available.

4. Staying alert during a large fire for possible problems with low-pressure areas when water pressure may be reduced in the distribution system.
5. Repair water main breaks immediately. A large pressure drop in the entire system can occur when a water main breaks.

Priority

A plan of action should first concentrate on the complete removal of cross connections, based on the degree of the hazard involved. All cross connections between a potable water supply and a piping system conveying or containing sewage, toxic or hazardous chemicals, or non-potable sources should be eliminated.

Second, plumbing defects and cross connections should be eliminated by an on-going instructional program in plumbing repair. The city needs to oversee plumbing operations.

Third, unused or obsolete fixtures having inlets ending below the overflow level should be eliminated. Although lower in priority, fixtures with inlets below the flood level rim should be equipped with vacuum breakers. If a vacuum preventer is not provided, low amounts of low hazardous water may be siphoned into the potable water supply. The priority depends on the degree of hazard, volume of water, and number of people affected. A careful study of actions is needed to rate the priorities.

4715.2110 TYPES OF DEVICES REQUIRED WHERE AN AIR GAP CANNOT BE PROVIDED.[1]

					Only allowed where no back pressure is possible		
		RPZ	DCV IAV	DCVA	SVB or PVB	AVB	Hose VB
A.	Boiler, other than one- or two-family residential	X					
B.	Boiler, one- or two-family residential	X	X				
C.	Car wash	X			X	X	
D.	Carbonated beverage machine (postmix) (see part 4715.2163)		X				
E.	Chemical line	X					
F.	Chemical tank	X			X	X	
G.	Chiller	X					
H.	Cooling tower	X	X		X	X	
I.	Dental units (separate assembly required for each unit)	X					
J.	Dishwasher, commercial				X	X	
K.	Fire sprinkler system[2]	X	X	X			
L.	Flush tank (water closet, urinal, similar) (see part 4715.2150)	X			X	X	
M.	Flush valve (water closet, urinal, similar) (see part 4715.2150)	X			X	X	
N.	Food and beverage equipment or system	X	X	X	X	X	
O.	Garbage can washer	X			X	X	
P.	Glycol or other antifreeze system	X					
Q.	Lab equipment	X			X	X	
R.	Lab faucet					X	
S.	Laundry machine, commercial	X	X		X	X	

T.	Lawn, garden or greenhouse sprinkler system	X			X	X	
U.	Operating, dissection, embalming or mortuary table (see part 4715.1950)	X			X	X	
V.	Private potable water supply (where permitted by administrative authority)	X	X	X			
W.	Private nonpotable water supply (where permitted by administrative authority)	X					
X.	Process line	X	X				
Y.	Process tank	X			X	X	
Z.	RV dump station	X	X		X	X	
AA.	Sewage treatment	X			X	X	
BB.	Soap dispenser	X	X		X	X	
CC.	Swimming pool, fountain, pond, baptistry, aquarium or similar	X	X		X	X	
DD.	Threaded hose connections, including: hose bibbs, hydrants, service sinks, laundry trays					X[3]	X
EE.	Truck fill	X			X	X	
FF.	Vacuum systems or aspirators	X			X	X	

1. For installations not listed in this part, review with the Administrative Authority.

2. Installations must comply with AWWA-M14, chapter 6 (1990) except that the following statement is deleted from section 6.3: At any time where the fire sprinkler piping is not an acceptable potable water system material, there shall be a backflow-prevention assembly isolating the fire sprinkler system from the potable water system.

3. A vacuum breaker installed as an integral part of a product approved to a standard does not require additional backflow prevention on the hose threads; the product must be constructed so that if the integral backflow preventer is removed, the remaining threads will not be hose thread type. An unprotected threaded hose connection must be protected against backflow by addition of a backflow preventer complying with ASSE 1052.

Statutory Authority: *MS s 16B.59 to 16B.75; 326.37 to 326.45; 326B.101 to 326B.194; 326B.43 to 326B.49*

History: *15 SR 76; 19 SR 590; 23 SR 686; 28 SR 146; L 2007 c 140 art 4 s 61; art 6 s 15; art 13 s 4; L 2008 c 337 s 64*

Posted: *February 19, 2009*

Microbiology

Acute waterborne diseases such as cholera and typhoid fever were major epidemics in the late-1800s and early-1900s. Methods to detect and remove these organisms were developed, and water operators are responsible to ensure the water supply is safe.

Diseases caused by pathogenic bacteria, viruses, and protozoa can be transmitted through fecal contamination to humans; and drinking water is just one of several carriers of these agents. Pathogens are disease-producing organisms and the presence of these is often related to poor sanitation practices. Microorganisms associated with recent waterborne outbreaks include the protozoa, bacteria, and virus. The following lists some of the most common waterborne diseases and their possible causes:

Waterborne Disease	Pathogen	Source of Pathogen	Symptoms
Gastroenteritis	Virus	Animal or Human Feces	Diarrhea, Vomiting
Typhoid Fever	Salmonella Typhosa	Human Feces	Inflamed Intestine, Enlarged Spleen, High Temperature
Dysentery	Shigella species	Human Feces	Diarrhea
Cholera	Vibrio Cholera	Human Feces	Vomiting, Severe Diarrhea, Dehydration
Infectious Hepatitis	Virus	Human Feces, Shell Fish	Yellowed Skin, Abdominal Pain
Amebic Dysentery	Entamoeba Histolitca	Human Feces	Mild Diarrhea
Giardiasis	Giardia Lamblia (a protozoa, one-celled animal)	Animal or Human Feces	Diarrhea, Cramps, Nausea, Weakness
Cryptosporidious	Cryptosporiduim parrum	Animal or Human Feces	Diarrhea, Cramps, Nausea, Weakness

It is difficult, expensive and potentially hazardous to test for the presence of all types of pathogens. Instead, the technician or operator tests for the presence of indicators, organisms that, when present, indicate that pathogens may be present.

Coliforms have been chosen to be the bacterial group routinely tested to assess the bacteriological safety of water. Presence of any of the coliform group of bacteria, i.e. total coliforms, indicates general contamination, while the presence of fecal coliforms indicates contamination of human or animal origin. An ideal indicator organism would have the following characteristics:

- Indicator should always be absent in clean, uncontaminated water and present when pathogens are present.
- Indicator should be present in large numbers in fecal matter.
- Indicator and pathogen should respond similarly to treatment processes.
- Indicator should be easy to isolate, identify, and count.
- Ratio of indicator to pathogen should be high.
- Indicator and pathogen should come from the same source.

While total coliform do not meet all the criteria in all cases, they are the best indicators available.

TOTAL COLIFORM

The total coliform group of bacteria has been used as indicators in water treatment since the early 1900s. This group of organisms is found both in soil and in the waste of warm-blooded animals. It includes the Eschericia coli (E. coli), which is a common bacterium in the feces of warm-blooded animals. USEPA has set microbiological standards for drinking water, and public water suppliers that collect fewer than 40 samples per month are allowed one total coliform positive per month. Systems that collect 40 or more samples per month are allowed 5 percent total coliform positive results per month.

Fecal coliform provide stronger evidence of the possible presence of pathogens than do total coliform. This group indicates the presence of fecal matter, which could be of human or animal origin. One positive test does not prove that fecal contamination exists; and more tests must be taken. Samples can be contaminated from external sources or there may have been other problems such as unsterile bottles and laboratory error. The most common problem, however, involve errors in sampling. The current regulations require that if a sample is positive (shows the presence of coliforms), the water supplier must take four more samples, one at the same location as the sample that was positive, one within five service connections on each side of the positive location, and one from a representative site on the distribution system.

HETEROTROPHIC PLATE COUNT

The total or heterotrophic plate count (HPC) test measures the numbers present of a large group of bacteria, including both nonpathogens and pathogens. Because it does not isolate a specific organism, the HPC cannot be correlated with the likelihood of waterborne-disease outbreak. Water with a high HPC can contain many, few or no pathogens. The significance of using the HPC test is that it indicates a generally poor biological water quality for PWSs using surface water sources. Five-hundred colonies per milliliter have been suggested as an upper level, above which corrective action should be taken. This is applicable only to surface water supplies.

The microbiological contaminant section of the Public Water Supply Regulations chapter shows the frequency required.

SAMPLING AND SITE SELECTION

The number of samples required for the system is based on the size and number of people served by the system. Routine sampling sites should be representative of the water system. The sites should include some dead ends as well as areas where the flow is high. Sampling points may be scattered across the system and can include such sites as park buildings and fire stations. It is important that service lines are used and that the water being sampled comes directly from the water system rather than from the indoor plumbing.

Sampling taps should be selected carefully, and taps that should be avoided, if possible, include:

- Outdoor faucets with a likelihood of contamination from the ground surface. Frost-free hydrants should also be avoided since they can be contaminated by dust and snow.
- Mixing faucets where water from the hot side may not be representative of water from the system.
- Faucets supplying dishwater in cafes, drug stores, or other sites that may contain higher than normal bacterial contamination.
- Swing spouts because bacteria can grow where the faucet pivots.
- Leaky faucets or faucets that allow water to seep around the packing nut. A fixture in poor condition can introduce contamination into the sample.

SAMPLE CONTAINER

Proper use of the sample container is important and the sample can be positive for total coliform if the container becomes contaminated. Most laboratories supply sterilized sample bottles or bags to be used when taking the samples in addition to approved mailing cartons and appropriate forms. Sample containers may be made of glass or plastic.

- Bottles should have a wide mouth and a capacity of at least 125 milliliters. Only containers that are sterile and contain sodium thiosulfate to neutralize the chlorine in the water sample should be used. Most laboratories supply bottles that are ready for testing.

- Caps used on the sample must be sterile. Sample bottles should be examined for possible contamination. If the cap is loose, the bottle should not be used.
- Bottles that have been in storage for a long period of time have an increased likelihood of contamination and should not be used.
- Bottles without a label may get misplaced at the laboratory.

SAMPLE COLLECTION

Technique used in taking the sample is important. The following steps should be followed:

- Remove the aerator, if there is one, from the faucet. Some utilities will allow the tap to run for a short time and then flame the faucet with a torch. Flaming is not required but will assure that the outside of the tap is sterile. Caution is required as plastic faucets may melt if flamed. (The collector may also sterilize the tap with an alcohol pad.)
- Turn on the faucet and allow it to run for five to six minutes so that the sample drawn is from the distribution system, not the interior plumbing of the building. If the service is large, the tap should be run longer. The hot-water tap should not be used for sampling.
- After the lines have been flushed, open the container and hang on to the bottle cap, taking care to not touch the inside of the cap. Do not rinse the container and do not overfill.
- Place the sample container in the flow from the faucet without contacting the tap. Fill the bottle to the fill line, if provided. Leave space at the top of the container so that the laboratory can mix the sample before testing it. If the bottle is overfilled, take a new sample with a new container. The minimum sample required at the laboratory is 100 ml, and it is important not to flush out the preservative in the bottle.
- Seal the container as soon as it is filled and removed from the flow. If a sample bag is used, be sure it is sealed properly; these bags can leak easily.

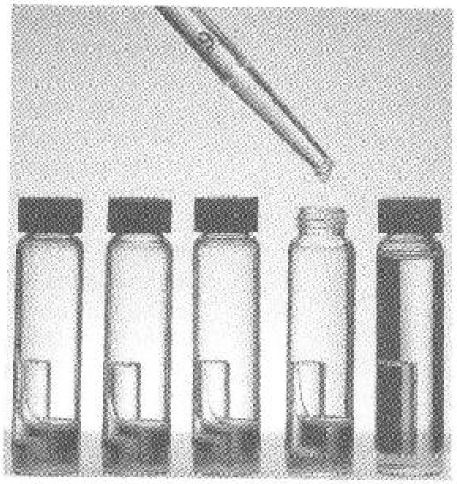
Do the necessary paperwork, which includes filling in the PWS identification number, time, date, collector name, and location taken on the sample's label and on the reporting forms. The forms may require other information, such as pH, chlorine residual, and iron concentration.

If additional tests are required, don't use the same bottle used for total coliforms. Instead take a different sample from the same water faucet. Different types of tests require different types of bottles. Consult with laboratory prior to taking other types of samples to ensure that you use the correct sample bottle.

TEST METHODS

All coliform tests done for compliance with the Safe Drinking Water Act must be performed by a laboratory approved for such testing by the Minnesota Department of Health. Three basic test methods are used to establish the presence of coliform bacteria. Selection of the test method is the responsibility of the laboratory and MDH. The laboratory must be certified by the state to perform the method used. The technicians doing the tests must also be certified.

MULTIPLE TUBE FERMENTATION



Multiple tube fermentation is very rarely used. The multiple tube fermentation or most probable number (MPN) test progresses through two steps, the presumptive and confirmed test. A final check may be done by use of the completed test. The presumptive test is not exclusive for coliform bacteria; some other bacteria present in soil or water may also produce a presumptive test, but the confirmed test is specific for coliform bacteria. The completed test, used for quality-control purposes, definitely establishes the presence of coliform bacteria. Bacteriological testing of most public water supplies stops after the confirmed test. This is the minimum test required of the positive samples.

The presumptive test is the first step of the MPN test. Samples are poured into each of five tubes containing a culture media and an inverted vial. The samples are incubated at 37° C (98.6° F) for 24 hours, checked and then incubated for another 24 hours, then checked again. If coliform bacteria are present, gas will be forming in the inverted vial within the 48-hour period. This indicates a presumptive positive sample. If no gas forms, the sample is considered negative.

The confirmed test is more selective for coliform bacteria. Cultures from the positive samples in the presumptive test are transferred to brilliant green lactose bile broth tubes, also containing inverted vials, and incubated. If no gas is produced after 48 hours, the test is negative, meaning no coliform bacteria are present. If gas is produced, the test is positive, indicating the presence of coliform bacteria. From the number of positive samples found, the technician uses statistical (MPN) tables to determine the number of coliforms present in the original sample.

If further confirmation is needed, positive samples may be transferred to the completed test where the selection for coliform bacteria is even closer than for the confirmed test. The positive sample is transferred to a plate containing a special growth media and incubated for up to 24 hours. A second portion is placed in a lauryl tryptose broth and incubated for the same 18 to 24 hours. The completed test is positive if gas is formed in the lauryl tryptose broth and coliform bacteria are found on the plate. If no gas is formed, the test is considered negative.

MEMBRANE FILTER METHOD

Many private laboratories still use the membrane filter technique, but it is becoming less common. The membrane technique was, until recently, the most common method used to isolate coliform bacteria. A given size sample, generally 100 milliliters, is filtered through a membrane, small-pore filter, which is then incubated in contact with a selective culture agar at 37° C (98.6° F). A coliform bacteria colony will develop at each point on the membrane where a viable coliform was left on the membrane during filtration. After the incubation period of 24 hours, the number of colonies per plate is counted. They represent the actual number of coliforms that were present in the volume of samples filtered.

A typical coliform bacteria colony is pink to dark red with a distinctive green metallic sheen on the surface. All organisms that produce such colonies within 24 hours are considered members of the coliform group.

Fig. I

1. Center membrane filter on filter holder. Handle membrane only on outer $^{3}/_{16}$ inch with forceps sterilized before use in ethyl or methyl alcohol and passed lightly through a flame.

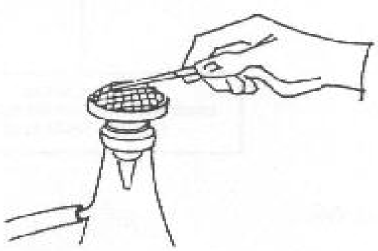
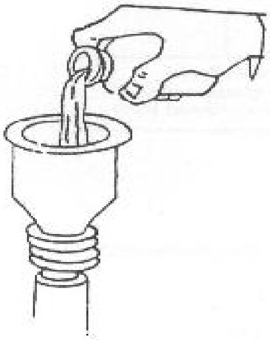


Fig. II

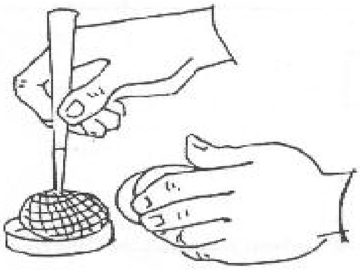
2. Place funnel onto filter holder.

Fig. III



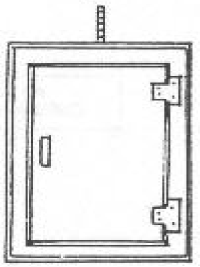
3. Pour or pipet sample aliquot into funnel. Avoid spattering. After suction is applied rinse four times with sterile buffered distilled water.

Fig. IV



4. Remove membrane filter from filter holder with sterile forceps. Place membrane on pad. Cover with petri top.

Fig. V



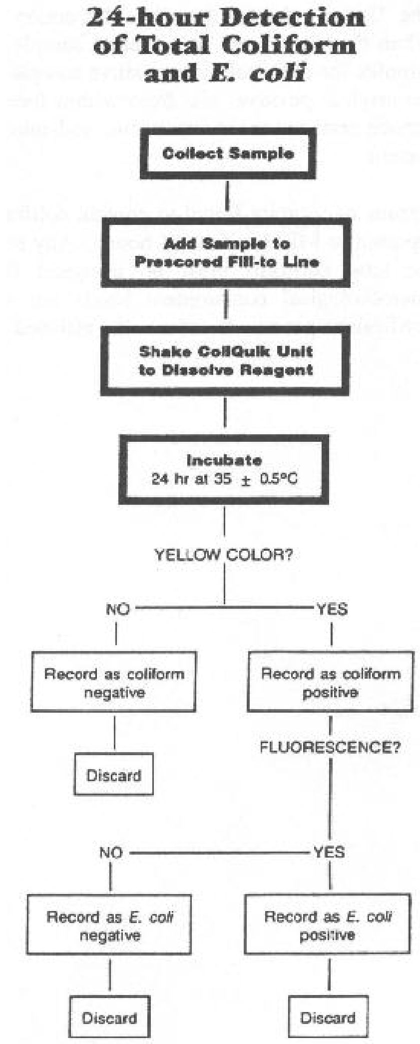
5. Incubate in inverted position for 22 ± 2 hours.

6. Count coliform appearing colonies on membrane.

COLILERT TEST

The colilert test is probably the most widely used coliform detection method at this time and is a method accepted by the U. S. EPA for coliform testing. The colilert test is used for simultaneous detection and confirmation of both total coliforms and Eschericia coli (E. coli) fecal coliforms. As the colilert test is a presence/absence test, it does not indicate the extent of contamination.

The colilert test method is just as accurate as the membrane filtration method and many believe it is more sensitive than the other methods.


24-hour Detection of Total Coliform and *E. coli*

The colilert reagent contains a formulation of salts, nitrogen, and carbon sources that are specific to total coliform. It contains specific indicator nutrients that create a yellow color when total coliforms are present and fluorescence when E. coil is present. The reagent is added to a 100-milliliter water sample in a sterile, non-fluorescent borosilicate glass container. The vessel is capped and shaken vigorously by repeated inversion to aid in mixing of the reagent. It is then incubated at 35° C for 24 hours. (An 18-hour preliminary test may be requested if there is reason to need test results more quickly.) After 24 hours, the technician compares the reaction vessels to the color in a comparator supplied with the test kit. If the inoculated reagent has a yellow color equal to or greater than the comparator, the presence of total coliform bacteria is confirmed.

The technician tests each reaction vessel for fluorescence by placing it five inches from an ultraviolet light in a dark environment. If the

POSITIVE TOTAL COLIFORM RESULT

When total coliform are found in a routine sample, the water supplier must collect at least four repeat samples for each coliform positive sample found. One repeat sample shall be from the site of the original positive, one from within five service connections upstream, one from within five service connections downstream, and one from another representative site on distribution system.

Results of samples found to contain coliform bacteria and results of all repeat samples must be reported to MDH within 24 hours. Any routine or repeat samples that are found to be positive for total coliform must be analyzed for fecal coliform or E. coli. When maximum microbiological contaminant levels are exceeded, the water supplier must use the proper notification process to inform the affected consumers.

Notes:

Appendix A

GENERAL SAMPLING REQUIREMENTS

This is a review of sampling techniques to be used when you collect samples for the Safe Drinking Water Act, required by the Minnesota Department of Health.

These instructions apply to all contaminants:

►Do not rinse or empty bottles. Several bottles contain a preservative that must remain in the bottle.

►Assume that any liquid present when a bottle arrives from the laboratory is caustic. If it comes in contact with skin or eyes, use first aid procedures for acid burns.

►If there is an overflow while filling a sample bottle, restart the procedure using a new sample bottle.

►Samples should be mailed the same day they are collected. Be aware of "holding times." The holding time is the maximum amount of time a sample has to be analyzed. The holding time starts at the time of collection and ends when the sample is received by the lab. Once the holding time has been exceeded the sample may need to be recollected. Holding times vary for contaminants.

►A lab form must <u>always</u> be returned with samples.

BACTI	Bacteriological (Positive/Absent Total Coliform) (30 Hour Holding Time)
ARSENIC	Arsenic (14 Day Holding Time)
FLUORIDE	Fluoride (28 Day Holding Time)
NITRATE (NO_3)	Nitrate + Nitrite Nitrogen, Total (14 Day Holding Time)
DBP	Disinfection By-products (THM & HAA5s) (14 Day Holding Time)
THM	Trihalomethane (consists of 4 contaminants) Bromodichloromethane Bromoform Chlorodibromomethane Chloroform
HAA5	Haloacetic Acids (consists of 5 contaminants) Dibromoacetic Acid Dichloroacetic Acid Monobromoacetic Acid Monochloroacetic Acid Trichloroacetic Acid
RADCHEM	Radiochemical (consists of 2 contaminants) (5 Day Holding Time) Radium 226+Radium 228 Gross Alpha
PBCU	Lead and Copper (14 Day Holding Time)

PROCEDURES

BACTI

SAMPLE BOTTLE: One (1) - 100 ml clear "round" bottle. ***WARNING:*** DO NOT flush out any powder that is in the bottle, this is a dechlorinating agent.

SAMPLING LOCATION: The bacteriological sample must be taken at a representative location on the distribution system. Do not take the sample at the pumphouse.

Important Note: The sample must be received by the designated lab within 30 hours of being collected or the sample may be rejected. Collect the sample on a MONDAY, TUESDAY or WEDNESDAY and immediately deliver to the post office for shipment, by FIRST CLASS mail.

Collecting the Sample:

1. Before sampling, remove any point-of-use devices or faucet attachments such as screens, aerators, washers, or hoses.
2. Turn on the faucet and let the water run in a steady stream approximately 5 minutes or until the water temperature is stabilized. If sampling from a single lever faucet, be sure the handle is pushed over to the cold side completely.

   RECOMMENDATION: You may sterilize the faucet prior to collecting the sample. The sterilization is done after removing any attachments and before turning the faucet on. The sterilization can be done by flaming the edge of the faucet with a torch or cigarette lighter for at least 15 seconds, or wiping the edge with an alcohol wipe. IF FLAMING IS ATTEMPTED, DO SO WITH CAUTION. DO NOT FLAME PLASTIC FAUCETS.

3. Reduce the water flow to a steady stream that allows for filling without spilling. DO NOT change the flow rate once you have started sampling (changing the flow rate while sampling could dislodge microbial growth and unwanted contaminants).
4. Remove the cap from the bottle and hold the cap in hand. DO NOT touch the underside of the cap or inside the bottle.
5. Quickly position the bottle under the water flow. DO NOT allow the bottle to touch the faucet or water to splash up onto the faucet.
6. Fill the bottle up to the fill line, indicated by the line on the bottle that reads "100 ml." DO NOT overfill the bottle. Quickly remove the sampling bottle from the water flow, replace the cap and tighten.
7. Turn the faucet off and replace point-of-use devices or faucet attachments, if necessary.
8. Wipe the outside of the bottle dry. Write the date and the sampling location (name or address of business/residence of where the sample was taken from) on the label provided by MDH and put the label on the bottle.
9. Complete the front of the labform provided by MDH by filling in the date the sample was collected, time collected, the name of the person who collected the sample, and sampling point (name or address of where the sample was taken).

ARSENIC

SAMPLE BOTTLE: One (1) 250-ml rectangular plastic bottle (provided by MDH)

SAMPLING LOCATION: Arsenic sample(s) must be taken at the designated well or entry point listed in the "sampling point" area(s) on the front of the labform provided by MDH. There should be a tap in the well house or treatment plant from which to take the sample(s). **Samples are to be taken after any treatment. For systems that use filtration, the sample should be collected after the filter.**

Collecting the Sample:

1. Before sampling, remove any point-of-use devices or faucet attachments such as aerators, screens or hoses.
2. If sampling from a well, allow the well pump to run for at least one hour (or until the well drawdown level is reached and stabilized) before sampling.
3. Turn on the tap and let the water run in a steady stream for approximately 5 minutes or until the water temperature is stabilized. DO NOT change the flow rate once you have started sampling (changing the flow rate while sampling could dislodge unwanted contaminants). If sampling from a single lever faucet, be sure the handle is pushed over to the cold side completely.
4. Remove the cap from the bottle and hold the cap in hand. DO NOT touch the underside of the cap or the inside of the bottle.
5. Quickly position the bottle under the water flow. DO NOT allow the sampling bottle to touch the faucet or water to splash up onto the faucet.
6. Fill the bottle, replace the cap and tighten.
7. Turn off the tap and replace the point-of-use device or faucet attachments, if necessary.
8. Wipe the outside of the bottle dry. Write the date the sample was collected on the label provided by MDH and put the label on the bottle. If you have more than one sample to collect, be sure that the description of the sampling site on the label you are attaching to the bottle corresponds with the location where you have taken the sample from.
9. Complete the labform provided by MDH by filling in the date the sample was collected, and the name of the person who collected the sample(s) and the time the sample was collected.

FLUORIDE

SAMPLE BOTTLE: One (1) 100-ml cylindrical plastic bottle (provided by MDH)

SAMPLING LOCATION: Samples must be taken at a representative location on the distribution system. Do not take the sample on or near the wellhouse or treatment plant. Provide specific location where sample was collected from in the Sampling Point area on the front of the labform provided by MDH.

Collecting the Sample:

1. Before sampling, remove any point-of-use devices or faucet attachments such as screens, aerators, washers, or hoses.
2. Turn on the faucet and let the water run in a steady stream approximately 5 minutes or until the water temperature is stabilized. If sampling from a single lever faucet, be sure the handle is pushed over to the cold side completely.
3. Reduce the water flow to a steady stream that allows for filling without spilling. DO NOT change the flow rate once you have started sampling (changing the flow rate while sampling could dislodge microbial growth and unwanted contaminants).
4. Remove the cap from the bottle and hold the cap in hand. DO NOT touch the underside of the cap or inside the bottle.
5. Quickly position the bottle under the water flow. DO NOT allow the bottle to touch the faucet or water to splash up onto the faucet.

6. Fill the bottle and quickly remove the sampling bottle from the water flow, replace the cap and tighten.
7. Turn the faucet off and replace point-of-use devices or faucet attachments, if necessary.
8. Wipe the outside of the bottle dry. Write the date and the sampling location (name or address of business/residence of where the sample was taken from) on the label provided by MDH and put the label on the bottle.
9. Complete the front of the labform provided by MDH by filling in the date the sample was collected, time collected, the name of the person who collected the sample, and sampling point (name or address of where the sample was taken).

NO_3 (Nitrate)

SAMPLE BOTTLE: One (1) - 120 ml cylindrical bottle with a yellow sticker on the cap (provided by MDH)
WARNING:
KEEP BOTTLE(S) OUT OF THE REACH OF CHILDREN and DO NOT INGEST. The sampling bottle contains a sulfuric acid solution (H2S04) and will burn skin and clothing upon contact.

SAMPLING LOCATION: The nitrate sample(s) must be taken at the designated well or entry point requested on the MDH labform. If water is treated, collect the sample after any treatment has taken place. There should be a tap in the well house or treatment plant from which to take the sample(s). Emergency back-up wells are also required to be sampled for nitrate.

Collecting the Sample:

1. Before sampling, remove any point-of-use devices or faucet attachments such as screens, aerators or hoses.
2. Turn on the tap and let the water run in a steady stream for approximately 5 minutes or until the water temperature is stabilized. If sampling from a single lever faucet, be sure the handle is pushed over to the cold side completely.
3. Reduce the water flow to a steady stream that allows for filling without spilling. DO NOT change the flow rate once you have started sampling (changing the flow rate while sampling could dislodge microbial growth and unwanted contaminants).
4. Remove the cap from the bottle and hold the cap in hand. DO NOT touch the underside of the cap or the inside of the bottle.
5. Quickly position the bottle under the water flow. DO NOT allow the sampling bottle to touch the faucet or water to splash up onto the faucet.
6. Fill the bottle to the shoulder. DO NOT overfill the bottle. Quickly remove the sampling bottle from the water flow, replace the cap and tighten.
7. Turn the tap off and replace the point-of-use device or faucet attachments, if necessary.
8. Wipe the outside of the bottle dry. Write the date on the label provided by MDH and put the label on the bottle. IF you have more than one sample to collect, be sure that the description of the sampling site on the label you are attaching to the bottle corresponds with the location where you have taken the sample from.
9. Complete the front of the labform provided by MDH by filling in the date and time the sample was collected, and the name of the person who collected the sample(s).

DBPs (Trihalomethane and Haloacetic Acids – THM/HAA5)

SAMPLING LOCATION:

- A set of 3 THM vials and a HAA5 amber bottle must be filled at the same tap.
- Sample taps must not be downstream of any point-of-entry (POE) or point-of-use (POU) on-site treatment system.
- Samples must be collected from the distribution system. Do not collect the samples from a hydrant or private residence.
- The location must represent your system's maximum residence time (MRT) water. MRT water is the oldest water in your system. It is usually the longest distance from wells, treatment plants and/or storage tank(s).

Collecting the Samples:

1. Take the samples at the Sample Point(s) listed on the labform provided by MDH.
2. Write the date and the sampling point location (if it is not already shown) on the bottle labels (provided). There are 4 bottle labels per sampling site.
3. Complete the following on the labform provided by MDH: Date Collected, Time Collected, Collector Name and the Sampling Point (address/location where sample is taken - must match the bottle labels)
4. Choose a cold water tap that is clean, free of attachments (aerator, strainer, hoses, etc.), in good repair, and not attached to a carbon (charcoal) treatment device. Avoid faucets with swivel necks, and drinking fountains.
5. Run a full flow of cold water for 2 to 3 minutes. When sampling from a single-lever faucet, be sure the handle is pushed all the way over to the cold water side. The time required to flush the system will vary depending on location. In most cases, the water temperature will drop after the interior plumbing has been flushed.
6. Reduce the water flow to a constant steady stream that allows filling without spilling. Do not change the water flow once you have started collecting the samples (changing the flow rate could dislodge microbial growth and unwanted contaminants).

HAA5s: One (1) 250-ml with a Teflon lined cap (pre-preserved). Do not rinse or overfill the bottle.

7. Remove the cap from the bottle and hold the cap in your hand or place it on a clean surface. DO NOT touch the underside of the cap or the inside of the bottle.
8. Fill the bottle to the shoulder, cap the bottle, and agitate for one minute. Do not over-tighten.
9. Set sample aside and continue with filling the THM vials.

THM: Three (3) 40-ml vials per site. Each vial contains a powder preservative, and each vial requires an additional preservative (provided) to be added during the collection process. DO NOT RINSE OR CONTINUOUSLY OVERFLOW THE VIALS

10. Remove the cap from the vial and hold the cap in your hand or place it on a clean surface. DO NOT touch the underside of the cap or the inside of the vial.
11. Begin the filling process by quickly positioning the vial under the water flow (6 to 8 inches below the faucet) with the vial held at a slight angle. The objective is to collect the water with as little agitation as possible. Do not allow the sampling container to touch the faucet, or water to splash up onto the faucet. Add water until the vial is half full. Remove the vial from the water flow. Do not turn off the water.
12. Add 3 to 4 drops (1:1 Hydrochloric Acid) preservative using the dropper that is provided in the sampling kit. Use caution when adding preservatives. They are corrosive and can be damaging to skin, eyes, and clothes. Proper eye and skin protection precautions should be used.

13. Continue to fill the vial with water from the water flow or use the vial cap to top off the vial to form a meniscus (the curved surface at the top of a column of liquid).
14. Carefully replace the cap on the vial so that the milky white side of the septum is in contact with the water. Do not touch the septum. Do not over-tighten.
15. Check for air bubbles by turning the vial upside down and tapping it lightly against your other hand. If bubbles are present, add additional water and form a new meniscus. Recheck for air bubbles and repeat this step until no air bubbles are present. Do not empty the sample and start over. The presence of air bubbles will result in rejection of the sample.
16. Shake sample container vigorously for one minute.
17. Wipe the outside of the vials and amber bottle dry.
18. Turn the tap off and replace the aerator, strainer, or hose if necessary
19. Put the bottle labels on the vials and bottle. Confirm the sampling site on the labels and Sample Point on the labform to be sure they correspond with the location from which you are collecting the samples.
20. Avoid light exposure and **chill the samples to 4 degrees C**.

RADCHEMS (Radiochemicals)

SAMPLE BOTTLE: 1 gallon collapsible plastic container

SAMPLING LOCATION: Radiochemical sample(s) must be taken at the designated well, treatment plant or combined discharge (after any treatment has taken place), listed in the "sampling point" area(s) on the front of labform provided by MDH. There should be a tap in the well house or treatment plant from which to take the sample(s).

Collecting the Sample:

1. Before sampling, remove any point-of-use devices or faucet attachments such as aerators, screens or hoses.
2. Let the water run for at least 20 minutes before sampling. DO NOT change the flow rate once you have started sampling (changing the flow rate while sampling could dislodge unwanted contaminants).
3. Remove the cap from the bottle and open up (pull apart) the expandable container completely.
4. Position the bottle under the water flow. DO NOT allow the sampling bottle to touch the faucet or water to splash up onto the faucet.
5. Once the expanded container is as **completely full of water as possible,** replace the cap and tighten.
6. Turn off the tap and replace the point-of-use device or faucet attachments, if necessary.
7. Wipe the outside of the container dry. Write the date the sample was collected on the label provided and put the label on the bottle. IF you have more than one sample to collect, be sure that the description of the sampling site on the label you are attaching to the bottle corresponds with the location where you have taken the sample from.
9. Complete the labform provided by MDH by filling in the date the sample(s) was collected, the name of the person who collected the sample(s) and what time the sample(s) were collected.

PB/CU (Lead/Copper)

SAMPLE BOTTLE: 1 L plastic

SAMPLING LOCATION:
Lead and copper sampling is required by the U.S. Environmental Protection Agency's (EPA) Lead and Copper Rule to determine the contribution of faucet fixtures and household plumbing to the lead and copper levels in tap water.

- Samples must be collected at occupied private residences that meet the EPA Tier requirements. Sampling locations will be listed on the Laboratory Analysis Request Form which will be enclosed in your sampling kit.
- Instructions for the Public Water Supply (PWS), and lead/copper sampling instructions for the resident/sample collector will be enclosed with the sample bottles.
- The sampling kit will be sent from a contract laboratory approximately one month prior to when samples are to be collected.
- Samples must be collected during your designated sampling month.
- The number of samples you are required to collect is based on the population of your system. No system will collect less then 5 samples. If you receive 10 bottles, you must collect 10 samples.

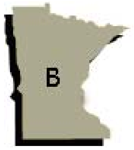
<u>Collecting the Samples (PWS Responsibility)</u>:

1. Contact each resident/sample collector to arrange a date/time to drop off a sample bottle and a copy of the lead/copper sampling instructions.
2. Using the site numbers that are listed on the Laboratory Analysis Request Form write a site number on the sample bottle label using water-proof ink. When dropping the sample bottle off with the resident/sample collector, be sure the site number/address on the bottle matches the resident's address.
3. Make copies of the lead/copper sampling instructions document. A copy is to be given to each resident/sample collector.
4. Discuss sampling procedures with the resident/sample collector, and arrange a pickup date/time and location (i.e. front door step) of the sample.
5. When picking up the sample, ensure the bottle cap is on securely and the bottle does not leak. Verify the collection date is written on the bottle, and enter the collection date for each sample collected on the Laboratory Analysis Request Form. Provide a complete street address for each site if none is listed,
6. Remove the Tap Water Sample Form from the sample bottle. Verify the home owner completed the form. If the resident/sample collector has indicated that plumbing repairs/replacement has been done or a whole-house water softener has been installed in the home since the previous sampling event, report those to MDH. The PWS keeps the Tap Water Sample Form, do not send it to the laboratory.
7. Place the Laboratory Analysis Request Form in a waterproof zip lock bag, and place it in the shipping container with the lead/copper samples.
8. Mail the samples and the completed Laboratory Analysis Request Form to the contract lab. The samples must be received by the laboratory within 14 days of collection. The Minnesota Department of Health is responsible for the cost of lead and copper analysis; however, the postage/cost for shipping the samples to the designated lab is your system's responsibility.

Collecting the Samples (Resident/Sample Collector Responsibility):

PWS must review the following instructions with each resident/sample collector.

1. Use extreme care to keep the bottle clean. Do not remove the sample bottle cap until you are ready to sample.
2. Water within the household plumbing should not be used for at least 6 hours, but do not go past 12 hours before the sample is collected.
3. Prior to the 6-hour hold on water use, run cold water through the faucet for about 1 minute.
4. Samples are collected by the resident/sample collector upon waking or after returning from work and before any water in the house has been used.
5. Samples are to be taken from a non-softened kitchen or bathroom cold-water faucet. Do not sample at an outside spigot or faucet, faucets that are seldom used, or from a water faucet that has a point-of-use or point-of-entry treatment device designed to remove inorganic contaminants (e.g., filter unit, etc.).
6. Position the faucet to sample from the cold water line only. Do not remove the faucet's aerator.
7. Uncap the sample bottle and place it under the faucet.
8. Open the faucet slowly and allow the sample bottle to fill at about the same flow that you would normally fill a drinking glass. As the water level in the sample bottle approaches the shoulder, close the faucet slowly. Leave about 1 inch of air space in the bottle.
9. Tightly cap the sample bottle. After the sample is collected, the bottle should be set upside down for 1 or 2 minutes to ensure the cap will not leak. If the bottle cap is leaking, re-tighten the cap or use tape around the cap to seal. Wipe the bottle dry.
10. Write the date the sample was collected on the bottle label, in water-proof ink.
11. Complete the Tap Water Sample Form and fasten it to the sample bottle with tape or a rubber band.
12. Place the sample bottle and Tap Water Sample Form at the predetermined pick-up location, on the date/time decided on with your PWS.



Appendix B

WATER OPERATOR CERTIFICATION SUMMARY
Chapter 9400

Minnesota Rules, Chapter 9400 covers Water Treatment Certification; the full text of this chapter is provided on the following pages.

NOTES:

CHAPTER 9400

POLLUTION CONTROL AGENCY AND DEPARTMENT OF HEALTH

WATER TREATMENT CERTIFICATION

9400.0100 DEFINITIONS.

Subpart 1. **Scope.** Terms used in this chapter that are defined in Minnesota Statutes, chapters 115 and 116, have the meanings given in statute. For purposes of this chapter, the terms defined in this part have the meanings given them.

Subp. 2. **Agency.** "Agency" means the Minnesota Pollution Control Agency.

Subp. 2a. **Contact hour.** "Contact hour" means 50 to 60 minutes of lecture, demonstration, workshop, or continuing education or training, excluding coffee breaks, registration, meals, and social activities.

Subp. 3. **Department.** "Department" means the Minnesota Department of Health.

Subp. 3a. **Direct responsibility.** "Direct responsibility" means the water or wastewater operator having full and active responsibility for the operation of a portion of, or all of, a system, facility, or wastewater collection system.

Subp. 4. **Facility.** "Facility" means wastewater treatment facility as defined in Minnesota Statutes, section 115.71.

Subp. 4a. **Management.** "Management" means persons who direct or supervise the operation of a system or facility. Management also refers to shift operators who make operational decisions or operate systems or facilities without supervision from a supervisor.

Subp. 4b. **Operation.** "Operation" means the routine performance of duties at a system or facility to achieve results that meet existing state laws and rules pertaining to water and wastewater.

Subp. 5. [Repealed, 21 SR 1165]

Subp. 5a. **Point-of-entry treatment device.** "Point-of-entry treatment device" means a treatment device applied to the drinking water entering a house or building for the purpose of reducing contaminants in the drinking water distributed throughout the house or building.

Subp. 5b. **Point-of-use treatment device.** "Point-of-use treatment device" means a treatment device applied to a single tap used for the purpose of reducing contaminants in drinking water at that one tap.

Subp. 6. [Repealed, 21 SR 1165]

Subp. 7. **System.** "System" means a water supply system as defined in Minnesota Statutes, section 115.71.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.0200 SCOPE.

This chapter establishes the requirements for:

A. individuals to be certified as water or wastewater treatment operators; and

B. the classification of systems and facilities.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165*

Posted: *October 2, 2007*

9400.0300 [Repealed, 21 SR 1165]

Posted: *October 2, 2007*

9400.0350 CERTIFICATION.

A. A water operator certificate to operate a community or nontransient noncommunity water system must be issued by the commissioner of health.

B. A wastewater operator certificate to operate a wastewater treatment facility must be issued by the commissioner of the Pollution Control Agency.

C. A city manager, superintendent of public works, or other administrative official is not eligible to be certified as an operator unless that person's duties include the operation of the system or facility.

Statutory Authority: *MS s 115.72*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.0400 CLASSIFICATION OF SYSTEMS.

Subpart 1. **Basis.** The classification of all systems must be based on the degree of hazard to the public health, together with the type and capacity of the system and the population affected.

Subp. 1a. **Operator availability.** All systems must have a certified water supply system operator as specified in Minnesota Statutes, sections 115.71, subdivision 10, and 115.73. This person, or an operator certified at the same level or above, must be available on site or able to be contacted as needed to initiate an appropriate action in a timely manner.

Subp. 2. **Rating values.** The classification of a system must be based on the following rating values:

A. water supply source:

(1) groundwater, five points;

(2) surface water, 15 points;

B. treatment processes:

(1) groundwater source:

(a) aeration, two points;

(b) chemical precipitation (softening including filtration), 16 points;

(c) filtration other than after softening process, ten points;

(d) ion exchange, five points;

(e) chlorination, five points;

(f) chemical oxidation, two points;

(g) stabilization, two points;

(h) air stripping, five points;

(i) carbon contactors, five points;

(j) fluoridation, five points;

(k) ammonia addition, five points;

(l) taste and odor control, two points;

(m) ozonation, eight points;

(n) membrane filtration, ten points;

(o) chlorine dioxide, eight points;

(p) unlisted new technologies, three to ten points (based on relative complexity);

(2) surface water source:

(a) ozonation, eight points;

(b) coagulation, ten points;

(c) sedimentation, five points;

(d) filtration, ten points;

(e) chlorination, five points;

(f) ion exchange, five points;

(g) chemical oxidation, two points;

(h) carbon contactors, five points;

(i) stabilization, two points;

(j) membrane filtration, ten points;

(k) fluoridation, five points;

(l) ammonia addition, five points;

(m) taste and odor control, two points;

(n) chlorine dioxide, eight points;

(o) unlisted new technologies, three to ten points (based on relative complexity);

C. distribution storage capacity:

(1) 0 to 5,000 gallons, one point;

(2) 5,001 to 50,000 gallons, two points;

(3) 50,001 to 500,000 gallons, three points;

(4) 500,001 to 5,000,000 gallons, four points;

(5) over 5,000,000 gallons, five points;

D. number of wells:

(1) one to three, two points;

(2) four to seven, four points;

(3) eight to 15, six points;

(4) over 15, eight points;

E. population affected:

(1) 0 to 1,000 persons, two points;

(2) 1,001 to 5,000 persons, five points;

(3) 5,001 to 10,000 persons, 11 points;

(4) 10,001 to 20,000 persons, 20 points;

(5) 20,001 to 50,000 persons, 32 points;

(6) 50,001 to 100,000 persons, 47 points;

(7) 100,001 persons and over, 70 points.

Subp. 3. **Accumulated value.** The accumulated point values for systems are as follows:

A. Class A, 76 or more points;

B. Class B, 56 to 75 points;

C. Class C, 31 to 55 points;

D. Class D, 30 or less points; and

E. Class E, regardless of point values, any system comprised of a groundwater source with no treatment other than point-of-entry or point-of-use treatment devices not used for compliance with the federal Safe Drinking Water Act, United States Code, title 42, sections 300f to 300j-26 (1996 and as subsequently amended), serving a maximum of 500 persons.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.0500 CLASSIFICATION OF FACILITIES.

Subpart 1. **Basis.** The classification of all wastewater treatment facilities actually used or intended for use by the public and required to have permits under part 7080.0030, subpart 1a, for individual sewage treatment systems or chapter 7001, must be based on the degree of hazard to the public health, together with the type and loading of the facilities and the population served or the average population equivalent of the wastewater handled.

Subp. 2. **Rating values.** Facility classification must be based on the following rating values:

A. size:

(1) maximum population equivalent (P.E.) served, one point per 10,000 P.E. or part thereof;

(2) average wet weather design flow, one point per million gallons per day or part of a million gallons per day;

B. permit final effluent limitations:

(1) surface water discharge:

(a) carbonaceous biochemical oxygen demand (CBOD) limit. The loading must be based on the most restrictive of the effluent concentration loading or mass loading. The mass loading equivalent concentration must be calculated using the facility average wet weather design flow. CBOD loading of:

i. 14 milligrams per liter or less, five points;

ii. more than 14 milligrams per liter to 24 milligrams per liter, four points;

iii. more than 24 milligrams per liter to 39 milligrams per liter, three points;

iv. more than 39 milligrams per liter, two points;

(b) nutrient limits:

i. nitrogen limit, six points;

ii. phosphorus limit, eight points;

(2) land discharge, two points;

(3) subsurface discharge, four points;

C. variation in raw wastes based upon maximum month design values:

(1) one percent to five percent industrial flow or carbonaceous biochemical oxygen demand (CBOD) loading, whichever is greater, contributed to facility, one point;

(2) more than five percent to ten percent industrial flow or CBOD loading, whichever is greater, contributed to facility, two points;

(3) more than ten percent to 25 percent industrial flow or CBOD loading, whichever is greater, contributed to facility, three points;

(4) more than 25 percent to 50 percent industrial flow or CBOD loading, whichever is greater, contributed to facility, four points;

(5) more than 50 percent industrial flow or CBOD loading, whichever is greater, contributed to facility, five points;

D. liquids handling:

(1) screening, comminution, three points;

(2) grit removal, three points;

(3) pumping of raw wastewater flow, three points;

(4) preaeration, postaeration, or both, with less than two hours' detention time, three points;

(5) influent static or rotating screen, three points;

(6) flow equalization basin, primary clarifier, or both, five points;

(7) septic tank, three points;

(8) combined sedimentation and digestion, five points;

(9) trickling filter, seven points;

(10) activated sludge, including pure oxygen activated sludge and sequencing batch reactor, 13 points;

(11) trickling filter solids contact (TFSC) and activated biofilter, ten points;

(12) stabilization pond, designed for more than 180 days' detention time, five points;

(13) aerated pond designed for more than two hours' detention time, five points;

(14) anaerobic contactor process, ten points;

(15) anaerobic pond, four points;

(16) rotating biological surface including submerged biological surface, seven points;

(17) secondary clarifier, five points;

(18) on-site generation of oxygen, five points;

(19) aerated polishing pond designed for less than 180 days' detention time, five points;

(20) polishing pond without aeration, two points;

(21) chemical addition for solids removal or pH adjustment, two points;

(22) subsurface soil treatment system constructed in accordance with chapter 7080, three points;

(23) rapid infiltration basin, three points;

(24) biological sand filter without backwash, three points;

(25) effluent irrigation, five points;

(26) effluent polishing filter with backwash, eight points;

(27) ion exchange, ten points;

(28) reverse osmosis, electrodialysis, 15 points;

(29) chemical recovery, carbon regeneration, four points;

(30) effluent microscreening, three points;

(31) disinfection:

(a) chlorination with or without dechlorination, five points;

(b) ultraviolet light, five points;

(c) ozonation, five points;

(32) unlisted new technologies, three to ten points (based on relative complexity);

E. solids handling:

(1) gravity thickening with or without chemical treatment, five points;

(2) anaerobic digestion, ten points;

(3) aerobic digestion, six points;

(4) sludge drying bed, two points;

(5) mechanical thickening or dewatering, eight points;

(6) solids reduction, such as incineration, wet oxidation, 12 points;

(7) on-land disposal, five points;

(8) lime stabilization of sludge, five points;

(9) sludge or septage storage, if the facility has neither anaerobic nor aerobic digestion, three points;

(10) composting, five points;

(11) unlisted new technologies, three to ten points (based on relative complexity);

F. laboratory monitoring:

(1) minimum required tests (pH, Cl_2 residual, dissolved oxygen, settleable solids, carbonaceous biochemical oxygen demand, and total suspended solids), two points;

(2) bacteriology (fecal coliform, total coliform, fecal streptococcal, etc.), three points;

(3) nutrients, one point;

(4) groundwater monitoring, one point.

Subp. 3. **Accumulated values.**

A. The accumulated point values for wastewater treatment facilities are as follows:

(1) Class A, 76 or more points;

(2) Class B, 56 to 75 points;

(3) Class C, 31 to 55 points;

(4) Class D, 30 and less points.

B. Notwithstanding item A, a facility that is given points for processes in subpart 2, item D, subitem (9), (10), (11), or (16), must be classified as a Class C facility or higher.

Subp. 4. **Type S facility.** A type S treatment facility means a system of collection, pumping, and conveyance facilities distinctly separate in operation from a facility which treats, stabilizes, or disposes of the wastewater collected, pumped, or conveyed.

A. Where a type S facility is not distinctly separate, it is considered to be part of the treatment facility for which the designated operator is responsible.

B. A type S treatment facility must be subclassified as follows:

(1) Class S-A, serving a population of 50,000 or more;

(2) Class S-B, serving a population of 15,000 or more but less than 50,000;

(3) Class S-C, serving a population of 1,500 or more but less than 15,000;

(4) Class S-D, serving a population of less than 1,500.

C. A type S treatment facility must be subclassified as follows:

(1) Class S-A, serving a population of 50,000 or more;

(2) Class S-B, serving a population of 15,000 or more but less than 50,000;

(3) Class S-C, serving a population of 1,500 or more but less than 15,000;

(4) Class S-D, serving a population of less than 1,500.

Statutory Authority: *MS s 115.03; 115.55; 115.56; 115.72; 115.79*

History: *21 SR 1165; 24 SR 426; 25 SR 1633*

Posted: *October 2, 2007*

9400.0600 RECLASSIFYING SYSTEMS OR FACILITIES.

Subpart 1. **Reclassification.** When the accumulated point value necessitates a change in the classification of a system or facility, the commissioner of health shall modify the classification of a system or the commissioner of the pollution control agency shall modify the classification of a facility according to parts 9400.0400 and 9400.0500.

Subp. 2. **Implementation.** Reclassification must be made:

A. after completion of a system sanitary survey by the commissioner of health; or

B. at the time of issuance or reissuance of a facility permit by the commissioner of the pollution control agency.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.0700 CERTIFICATION OF SYSTEM AND FACILITY OPERATORS.

Subpart 1. [Repealed, 21 SR 1165]

Subp. 2. **Certification in particular class.** An applicant who seeks certification must:

A. meet the qualifications for one of the classes specified in this part and take and pass an exam; or

B. meet the requirements for reciprocity under part 9400.1350.

Subp. 3. **Class A certificate.** An applicant for a Class A certificate must:

A. have been certified as a Class B operator for at least two years; and

B. have:

(1) a high school diploma or equivalent with at least eight years experience in the operation, including at least two years as a part of the management, of a Class A or B system or facility, or a similar industrial facility; or

(2) a bachelor's degree from an accredited institution in chemical, civil, environmental, mechanical, or sanitary engineering or in a physical or biological science, and submit satisfactory evidence of at least four years experience in the operation, including at least two years as a part of the management, of a Class A or B system or facility or a similar industrial facility.

Subp. 4. **Class B certificate.** An applicant for a Class B certificate must:

A. have been certified as a Class C operator for at least one year; and

B. have:

(1) a high school diploma or equivalent with at least six years experience in the operation of a Class A, B, or C system or facility, or a similar industrial facility; or

(2) a bachelor's degree from an accredited institution in chemical, civil, environmental, mechanical, or sanitary engineering or in a physical or biological science, and submit satisfactory evidence of at least two years experience in the operation of a Class A, B, or C system or facility, or similar industrial facility.

Subp. 5. **Class C certificate.** An applicant for a Class C certificate must have:

A. a high school diploma or equivalent, with at least three years experience in the operation of a Class A, B, C, or D system or facility, or similar industrial facility; or

B. a bachelor's degree from an accredited institution in chemical, civil, environmental, mechanical, or sanitary engineering or in a physical or biological science, and submit satisfactory evidence of at least one year experience in the operation of a Class A, B, C, or D system or facility, or similar industrial facility.

Subp. 6. **Class D certificate.** An applicant for a Class D certificate must:

A. have a high school diploma or equivalent; and

B. have:

(1) at least one year experience in the operation of a Class A, B, C, or D system or facility, or in a related field; or

(2) satisfactorily completed a postsecondary program of courses in water or wastewater technology approved by the respective agency or department at an accredited institution.

Subp. 6a. **Class E certificate.** An applicant for a Class E certificate must:

A. have a high school diploma or equivalent; and

B. have:

(1) at least three months experience in the operation of a Class A, B, C, D, or E system or facility, or in a related field; or

(2) satisfactorily completed a postsecondary program of courses in water or wastewater technology approved by the respective agency or department at an accredited institution.

Subp. 7. **Type S certificate.** An applicant for a type S wastewater treatment certificate must possess the same education and experience required for a regular wastewater certificate in the same class, except experience must have been gained in a facility or type S facility and:

A. an applicant for an S-A type certificate must have been certified as an S-B or B facility operator for at least two years; or

B. an applicant for a type S-B certificate must have been certified as an S-C or C facility operator for at least one year.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.0800 SUBSTITUTIONS FOR QUALIFICATIONS.

Subpart 1. **Experience in a system or type S facility substituted for experience in a facility.** When a person applies for a certificate to operate a facility, at least 50 percent of the experience required in part 9400.0700 for the class of certificate requested must have been obtained in a facility. The other 50 percent may be obtained in a type S facility or a system. The classification of the type S facility or system the applicant operated must not be more than one class below the class of certificate requested.

Subp. 1a. **Experience in a facility substituted for experience in a system.** When a person applies for a certificate to operate a system, at least 50 percent of the experience required in part 9400.0700 for the class of certificate requested must have been obtained in a system. The other 50 percent may be obtained in a facility, but not in a type S facility. The classification of the facility the applicant operated must not be more than one class below the class of certificate requested.

Subp. 2. **Education substituted for experience.** A person who applies for a Class A, S-A, B, S-B, C, or S-C certificate may substitute education for experience according to the formula in this subpart.

A. Except as noted in item B, the experience required in part 9400.0700, subparts 2 to 7, will be reduced by one month for the successful completion of 40 contact hours of correspondence courses or other courses relating to water supply or wastewater treatment from an accredited institution in chemical, civil, environmental, mechanical, or sanitary engineering or in the physical or biological sciences.

B. In no event shall such education be substituted for experience so as to reduce the experience requirement to:

(1) less than one year for Class A, S-A, B, S-B, C, S-C, D, S-D; or

(2) less than three months for Class E.

Subp. 3. **Experience substituted for education.** One year of experience in the operation of a system or facility may be considered as equivalent to one year of high school. Experience which is substituted for education cannot also be used to satisfy the experience requirements.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.0900 APPLICATION FOR EXAMINATION.

Subpart 1. **Form and time.** Application for examination must be made in writing to the commissioner of health for certification to operate a system or to the commissioner of the Pollution Control Agency for certification to operate a facility on a prescribed form issued by the department or agency administering the examination. The application for examination must be submitted at least 15 days before the date on which the examination will be given.

Subp. 2. **Proof of attendance.** The applicant may be required to submit a copy of the school or college diploma, equivalency certificate, or other proof of school or college attendance or graduation if the applicant is substituting educational experience for operating experience.

Subp. 3. **Examination fee.** A nonrefundable examination fee must accompany the application.

Subp. 4. **Application for examination.** An applicant who applies for examination but fails to satisfy all the conditions prescribed in parts 9400.0100 to 9400.1500 may reapply for examination as described in subparts 1 to 3 when all conditions are satisfied.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165*

Posted: *October 2, 2007*

9400.1000 EXAMINATIONS.

Subpart 1. **Preparation.** The respective commissioner shall prepare the examinations to be used in determining the knowledge, ability, and skills of operators.

Subp. 2. **Examination.** Separate examinations must be prepared for each designated system and facility class to cover basic differences in the duties and responsibilities of operators, types of water and wastewater treatment, variations in water and wastewater characteristics, water distribution systems, and wastewater collection systems. The examination must test the applicant's knowledge in any one or more of the following areas, as they relate to either water or wastewater treatment: basic science, mathematics, operating procedures, treatment processes, equipment, equipment maintenance, management, and state law and rules relating to water and wastewater. The applicant is prohibited from using any resource materials during an examination.

Subp. 3. [Repealed, 21 SR 1165]

Subp. 4. [Repealed, 21 SR 1165]

Subp. 5. **Passing.** A grade of 70 percent is considered a passing grade.

Subp. 6. **Results; review.** The respective commissioner shall notify the applicant of the exam results. Examinations will not be returned to the applicant, but upon request within 60 days' notification of the results, the applicant may be allowed to review the examination.

Subp. 7. **Reexamination.** An applicant who fails to pass the examination may not retake the same examination for a period of three months.

Subp. 8. **Certificate fee.** The applicant must submit the certification fee within 90 days after written notification of positive results of the examination. If an applicant fails to submit the certification fee within 90 days, the applicant must apply for reexamination as in part 9400.0900.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.1100 ISSUANCE OF CERTIFICATES.

Certificates shall be issued by the commissioner of health for water operator certificates, or the commissioner of the Pollution Control Agency for wastewater operator certificates, when all the conditions prescribed in parts 9400.0100 to 9400.1500 have been satisfied.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165*

Posted: *October 2, 2007*

9400.1200 RENEWAL OF CERTIFICATES.

Subpart 1. **Minimum requirements.** A certificate in any given classification must be renewed within 30 days after its expiration date. A renewal certificate will be issued upon receipt of the application, renewal fee, and evidence of the fact that the operator has, during the preceding three years, obtained credit as described in subpart 4 or 5, for the number of hours specified in the following schedule:

A. Class A and S-A, 32 contact hours;

B. Class B and S-B, 24 contact hours;

C. Class C and S-C, 16 contact hours;

D. Class D and S-D, 8 contact hours; and

E. Class E, 4 contact hours.

Subp. 2. [Repealed, 21 SR 1165]

Subp. 3. **Accredited courses and activities.** The respective commissioner shall prepare and make available a list of accredited training courses and approved educational activities for which credit may be obtained.

Subp. 4. **Water operator certificate renewal.** When a person applies to renew a water operator certificate, at least 50 percent of the contact hours required for renewal in subpart 1 must be from water-related courses approved by the commissioner of the department. The other 50 percent may be from wastewater or other related courses approved by the commissioner of the department, provided that the course or portion of the course has been approved by the commissioner of health.

Subp. 5. **Wastewater operator certificate renewal.** When a person applies to renew a wastewater operator certificate, at least 50 percent of the contact hours required for renewal in subpart 1 must be from wastewater-related courses approved by the commissioner of the agency. The other 50 percent may be from water or other related courses approved by the commissioner of the agency, provided that the course or portion of the course has been approved by the commissioner of the Pollution Control Agency.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.1300 REINSTATEMENT AND RECERTIFICATION.

Subpart 1. **Application.** A person whose certificate has expired may apply to the commissioner of health, for reinstatement of a water operator certificate, or to the commissioner of the Pollution Control Agency for reinstatement of a wastewater operator certificate. An applicant's certificate may only be reinstated to the class of the certificate which had expired. Before a certificate will be issued, such person must submit the following: the application for reinstatement; the nonrefundable fee for a reinstatement certificate; and evidence of the fact that the person has complied with the continuing education requirements imposed in part 9400.1200, subpart 1, during the entire time since the expired certificate was last issued or renewed.

Subp. 2. **Denial.** A person who is denied reinstatement who wants to be recertified must follow the procedures for a new applicant specified in parts 9400.0900 and 9400.1000. The nonrefundable reinstatement fee shall be considered the fee for application of examination.

Subp. 3. **Time.** A person may apply for reinstatement up to one year after expiration of the previous certificate. If more than one year has elapsed from the expiration of the certificate, a person must apply for the certificate as specified in parts 9400.0900 and 9400.1000.

Subp. 4. **Reinstatement after suspension.** The commissioner of health or the commissioner of the Pollution Control Agency respectively will reinstate a suspended certificate if the individual whose certificate has been suspended fulfills the terms of the suspension order and meets all applicable requirements of the rules for obtaining a certificate.

Subp. 5. **Revocation.** An individual whose certificate has been revoked according to Minnesota Statutes, section 144.99, subdivisions 8 to 10, may not apply for certification before the expiration date of the revocation order or for at least one year following the written notice of revocation.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

9400.1350 RECIPROCITY.

According to Minnesota Statutes, section 115.76, when a person who has a certificate in another state applies for certification as a water or wastewater operator, a determination will be made by the respective commissioner as to whether the applicant is eligible for certification and for what class of facility or system. The certification requirements of the other state must not be in conflict with Minnesota Statutes, sections 115.71 to 115.77, and must be of a standard not lower than those in this chapter.

A. If the certification requirements of the other state are not in conflict with Minnesota Statutes, sections 115.71 to 115.77, and are of a standard not lower than those in this chapter, the applicant must be granted a certificate.

B. If the certification requirements of the other state are in conflict with Minnesota Statutes, sections 115.71 to 115.77, and are of a standard lower than those in this chapter, the applicant must be notified in writing by the respective commissioner of those areas which were not equivalent and what, additionally, the applicant must do to meet the standards in this chapter.

C. The nonrefundable reciprocity fee shall be considered the fee for application of examination if the applicant is denied a certificate through reciprocity.

Statutory Authority: *MS s 115.72*

History: *21 SR 1165*

Posted: *October 2, 2007*

9400.1400 [Repealed, 21 SR 1165]

Posted: *October 2, 2007*

9400.1500 CONDITIONAL CERTIFICATE.

Subpart 1. **Conditions and renewal.** The operator of a system or facility which is reclassified to a higher class pursuant to part 9400.0600 may be issued a conditional certificate in the higher class. A conditional certificate must be issued upon application, without examination, and shall be effective for three years from the date of issue. A conditional certificate must be renewed as specified in part 9400.1200. A conditional certificate must specify that the operator named therein is certified to operate only the system or facility for which the conditional certificate is issued.

Subp. 2. **Certification limits.** No conditional certificate will be granted if reclassification was the result of an alteration to the system or facility.

Subp. 3. [Repealed, 25 SR 1633]

Subp. 4. **Nontransient noncommunity systems.**

A. An operator who has exercised direct responsibility for a nontransient noncommunity water system before October 1, 2001, is eligible to receive a conditional certificate for that system. The application for the conditional certificate must be submitted by the owner of the nontransient noncommunity system at which the operator exercises direct responsibility.

B. An application for a conditional certificate under item A must be submitted by the owner of a nontransient noncommunity water system before October 1, 2003.

C. A person assuming direct responsibility for a nontransient noncommunity system on or after October 1, 2001, is not eligible for a conditional certificate and must apply for a certificate according to part 9400.0700.

Statutory Authority: *MS s 115.72; 115.79*

History: *21 SR 1165; 25 SR 1633*

Posted: *October 2, 2007*

Appendix C

MINNESOTA DEPARTMENT OF NATURAL RESOURCES DIVISION OF WATERS MINNESOTA RULES RELATED TO WATER APPROPRIATION PERMITS

6115.0610 PURPOSE AND STATUTORY AUTHORITY.

These parts set forth minimum standards and criteria pertaining to the regulation, conservation, and allocation of the water resources of the state, including the review, issuance, and denial of water appropriation applications and the modification, suspension, or termination of existing permits.

6115.0660 APPLICATION FOR PERMIT.

Subpart 3. Information required.

E. Statement of justification supporting the reasonableness and practicality of use with respect to adequacy of the water source, amounts of use, and purposes, including available facts on:

(1) hydrology and hydraulics of the water sources involved, including for surface waters the applicant's analysis of the effect of proposed withdrawals on levels and flows and anticipated impacts, if any, on instream flow or lake level conditions to the extent that such facts are not already available to the commissioner;
(2) proposed pumping schedule including rates, times, and duration;
(3) amounts of water to be appropriated on a maximum daily, monthly, and annual basis;
(4) means, methods, and techniques of appropriation;
(5) alternative sources of water or methods which were considered, to attain the appropriation objective and why the particular alternative proposed in the application was selected.

F. Information on any water storage facilities and capabilities and any proposed reuse and conservation practices.

6115.0670 COMMISSIONER'S ACTIONS ON PERMIT APPLICATIONS.

Subpart 2. Review and analysis of data. Review and analysis of data:

A. The commissioner shall consider the following factors, as applicable;

(1) the location and nature of the area involved and the type of appropriation and its impact on the availability, distribution, and condition of water and related land resources in the area involved;
(2) the hydrology and hydraulics of the water resources involved and the capability of the resources, to sustain the proposed appropriation based on existing and probable future use;

- (3) the probable effects on the environment including anticipated changes in the resources, unavoidable detrimental effects and alternatives to the proposed appropriation;
- (4) the relationship, consistency, and compliance with existing federal, state, and local laws, rules, legal requirements, and water management plans;
- (5) the public health, safety, and welfare served or impacted by the proposed appropriation;
- (6) the quantity, quality, and timing of any waters returned after use and the impact on the receiving waters involved;
- (7) the efficiency of use and intended application of water conservation practices;
- (8) the comments of local and regional units of government, federal and state agencies, private persons, and other affected or interested parties;
- (9) the adequacy of state water resources availability when diversions of any waters of the state to any place outside of the state are proposed;
- (10) the economic benefits of the proposed appropriation based on supporting data when supplied by the applicant.

Subpart 3. Decision on applications.

A. No permit shall be granted if:

- (4) the appropriation is not consistent with approved state, regional, and local water and related land resources management plans, provided that regional and local plans are consistent with statewide plans;

6115.0690 ADDITIONAL REQUIREMENTS AND CONDITIONS FOR PUBLIC WATER SUPPLIES.

Subpart 1. Additional application information. The applicant shall be required to submit to the commissioner all or portions of the following data in addition to the requirements of part 6115.0660:

- A. the number of domestic users;
- B. reasonable projection of population growth;
- C. the number and type of industrial and commercial users of the public water supply system;
- D. the amount of water to be supplied to domestic, industrial, and commercial users respectively;
- E. other users by type of use and amount to be used from the public water supply system such as golf courses, recreational lake level maintenance, water transferred to other supply systems;
- F. information regarding the quantity of the appropriated water to be used in distribution and waste water treatment facilities, not including volume of actual waste water; and
- G. details on emergency plans for water shortage periods outlining public information programs, priorities for limitations of discretionary water use, and alternate sources of public water supplies.

Subpart 2. Commissioner's actions. The commissioner shall allow the appropriation of water for public water supply systems based on evaluation and analysis of the data submitted by the applicant under provisions of parts 6115.0660 and subpart 1 of this part and the procedures outlined in part 6115.0670 and subject to subpart 3.

Subpart 3. Other requirements. Appropriation permits issued to public water supply authorities shall be subject to requirements of Minnesota Statutes, section 103G.291, relating to critical water deficiency periods and restriction of nonessential uses.

6115.0770 WATER CONSERVATION.

In order to maintain water conservation practices in the water appropriation and use regulatory program it is necessary that existing and proposed appropriators and users of waters of the state employ the best available means and practices based on economic considerations for assuring wise use and development of the waters of the state in the most practical and feasible manner possible to promote the efficient use of waters.

Based on the data submitted by applicants and permittees and current information on best available water conservation technology and practice the commissioner, in cooperation with the owners of water supply systems may analyze the water use practices and procedures and may require a more efficient use of water to be employed by the permittee or applicant, subject to notice and opportunity for hearing.

6115.0810 WATER APPROPRIATION AND USE MANAGEMENT PLANS.

Subpart 1. In general. In order to address the provisions of Minnesota Statutes, sections 103B.155, 103G.261, and 103G.271, subdivision 2, the commissioner, in cooperation with other state and federal agencies, regional commissions and authorities, local governments and citizens, establishes the following process for the preparation and implementation of the elements of any state, regional, and local plan relating to water appropriation and use.

Subp. 2. Criteria and procedures. Since the availability, distribution, and utilization of waters of the state and the character and use of related land resources vary considerably throughout the state, a comprehensive water appropriation management planning process must be based on these considerations and according to the following principles and procedures:

A. Water appropriation management plans should be prepared for specific definable areas of the state on consideration of:

(1) The hydrologic and physical characteristics of the water and related land resources for which a management plan is necessary. The area must be of sufficient size and area extent so that the interrelationship of geohydrologic and climatic factors can be adequately defined and managed.

(2) The determination by the commissioner of the need for establishment of a water appropriation management plan for the waters of the state within a specific definable area based on:

(a) areas where development of the waters of the state is, or is likely to, increase considerably within the next five to ten years;
(b) areas where severe water availability problems exist or are soon likely to exist;
(c) areas where there are adequate facts and available geohydrologic data relating to the availability, distribution, and use of the waters of the state and where there is local interest in establishing water appropriation management plans.

B. Upon establishment of the need for a water appropriation management plan pursuant to item A, the commissioner shall establish a management planning process including procedures, a public participation process, and development of a planning team consisting of representatives of the department, permittee, any other interested, concerned, and involved government or citizen group listed in subpart 1 to review and cooperate in preparation of the plan.

Subp. 3. General requirements and contents of plan. Every water appropriation plan should, at a minimum, include:

A. An evaluation of the amount and dependability of information on the hydrologic systems of the area and the adequacy of the information to provide necessary facts on the amounts of water which can be reasonably withdrawn from the waters of the state in the area without creating major environmental problems or diminishing the long-term seasonal supply of water for various purposes. This will provide essential background information for establishing protected flows and protection elevations, part 6115.0670, subpart 3, item B, subitem (6).

B. An evaluation of data on stream quality and flows, lake water quality and levels, groundwater quality and levels, and climatic factors. This will provide essential data useful to the applicant and the commissioner in permit application considerations, parts 6115.0660 to 6115.0720.

C. An evaluation of present and anticipated future use of water and lands and the amounts and distribution of use within the area. This will facilitate the determinations necessary under part 6115.0670, subpart 2, item A, subitem (2).

D. An evaluation of the problems and concerns relating to use of the waters within the area.

E. Water conservation alternatives and methods and procedures for dealing with water shortages or excesses during periods of deficient or excess water. See parts 6115.0660, subpart 3, item F; 6115.0690, subpart 1, item G; and subpart 2 of this part.

F. Considerations of the relationship of the water appropriation and use management plan to other water resources programs of the state, such as floodplain management, shoreland management, water surface use management, water quality management, soil and water conservation management, and agricultural land management.

DEPARTMENT OF NATURAL RESOURCES - DIVISION OF WATER
RATE SCHEDULE FOR ANNUAL REPORT OF WATER USE FEES

Minnesota Statutes 103G.271 requires fees and annual water use reports for each active water appropriation permit. Fees are based on the amount of water use. The following rate schedule can be used to determine water use fees. Please be sure to note any minimum or maximum fee limits that may apply.

VOLUME APPROPRIATED		FEE
0 to 50 million gallons	-	$140.00 minimum fee
50 to 100 million gallons	-	$3.50 for each million
100 to 150 million gallons	-	$4.00 for each million
150 to 200 million gallons	-	$4.50 for each million
200 to 250 million gallons	-	$5.00 for each million
250 to 300 million gallons	-	$5.50 for each million
300 to 350 million gallons	-	$6.00 for each million
350 to 400 million gallons	-	$6.50 for each million
400 to 450 million gallons	-	$7.00 for each million
450 to 500 million gallons	-	$7.50 for each million
Above 500 million gallons	-	$8.00 for each million

MINIMUM ANNUAL WATER USE FEE FOR AGRICULTURAL IRRIGATION

Agricultural irrigation permittees that did not appropriate any water during the year or had their permit suspended for more than seven days pay a minimum fee of $20 per permit.

MAXIMUM ANNUAL WATER USE FEES

$750 for any single agricultural irrigation permit
$60,000 total for an entity with 3 or less permits
$90,000 total for an entity with 4 to 5 permits
$300,000 total for an entity with more than 5 permits
$250,000 total for a city of the first class
$10,000 for a municipality that furnishes electric service and cogenerates steam for home heating.

ONCE-THROUGH HEATING AND COOLING SYSTEMS ONLY

A separate annual water use fee schedule exists for once-through heating and cooling (HVAC) systems. Non-profit corporations and school districts pay $200 per million gallons and all other entities with once-through heating and cooling systems pay $420 per million gallons. There is no maximum fee for once-through systems.

SUMMER SURCHARGE

A surcharge of $30 per million gallons will be applied to the volume of water used in each of the months of June, July, and August that exceeds the volume of water used in January of each year. The summer surcharge applies to municipal water use, irrigation of golf courses and landscape irrigation. This is a surcharge in addition to the regular fee rate based on the yearly total volume used.

PROCESSING FEE EXEMPTIONS

State and federal agencies are exempt from annual water use fees.

Water Use Report Directions

Enclosed are the 2008 Water Use Report forms for your
Minnesota Department of Natural Resources water appropriation permits

Please complete these forms with all requested information and return with the appropriate fee by February 15, 2009, even if no water was used during 2008.

Fee Rate Changes

Please pay close attention to the fee rates as most fee rates and minimums have changed from past years.

A condition of each water appropriation permit is the monthly measurement and yearly reporting of water use with an approved measuring device to an accuracy of 10%. A monthly water use reporting ***Installation Worksheet*** is printed for each active installation (well/pump station) for each permit. Fill in the monthly water used in units of whole gallons for each installation. A flow meter, flow rate meter, or timing device is required to measure water use. Only pre-approved alternate methods can be substituted. See the metering brochure for details at: http://files.dnr.state.mn.us/waters/watermgmt_section/appropriations/flowmeter.pdf

The **Fee Calculation Worksheet** is used to determine your processing fee based on the amount of water used. Add the individual installation totals to make a grand total for each permit. Use the fee rate table to determine the fee and follow the instructions to calculate the amount due.

The **Permit Data Verification Form** is used to check compliance with the permitted water use volume and to request amendment, transfer, or termination of permits. Note the fee exemptions for amendments and transfers.

Please note the following items related to water use reporting:

To calculate monthly water use from:
A Flow Meter: Subtract the beginning of the month readings from end of the month readings. Convert the result into gallons for each month. If meter readings are in cubic-feet, multiply by **7.4805** to convert to gallons.

A Timing Device: To convert to gallons: multiply the hours pumped times the pump rate (in gallons per minute) times 60 (minutes). [Example: 150 hrs x 800 gpm x 60 min/hr = 7,200,000 gallons]

For irrigators:
Gallons of water per acre = Total Annual Gallons ÷ number of irrigated acres
Inches of water per acre = Gallons of water per acre ÷ 27,154

Calculate the inches per acre for each crop type by installation. The total of each individual crop acres times the inches per acre, when converted into gallons, should equal the total water use for each installation.

Pay by check or money order. We are unable to accept payment by cash or credit card.
Make your check or money order payable to **MN DNR Waters.**
All money received goes to the State of Minnesota General Fund. Return all completed forms with payment to the address on the Fee Calculation Worksheet. You may pay for all permits using one check.

Questions? Please call (651)259-5678 (answered during the day, voice mail at night) or send email to **wateruse@dnr.state.mn.us**. Please include your name, permit number, telephone number, and specific questions when leaving a message. We will return your call or send you the information/forms requested.

Non-Reporting: Permits for which reports and fees are not received by **February 15, 2009** are subject to termination. All active permits require reports and fees, except as noted. Permittees that do not submit the required fee will be referred to the Minnesota Department of Revenue for collection and additional collection, enforcement and interest fees will apply.

To suggest changes that you feel would make water use reporting easier or more effective, please send your comments on a separate sheet of paper. We welcome your ideas.

Turn over for general information on Minnesota water use

Minnesota Water Use

DNR water appropriation permits are required for all users withdrawing more than ten thousand gallons of water per day or one million gallons per year. Uses less than this, such as rural domestic use do not require a permit and are not included in these figures.

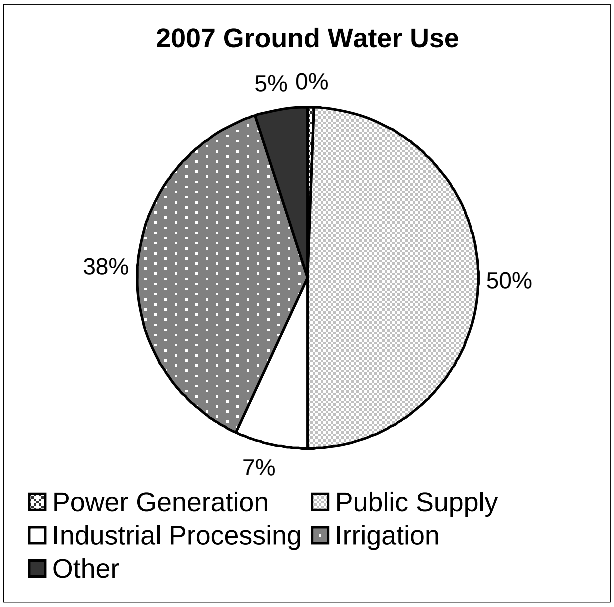
Water use data are used for many purposes, such as documenting permitted water use, identifying water use trends, understanding the hydrology of aquifers from which water is withdrawn, evaluating well interferences and impacts from water appropriations.

The majority of water withdrawn for power generation is from surface water sources and is used for cooling purposes and then returned to the original source.

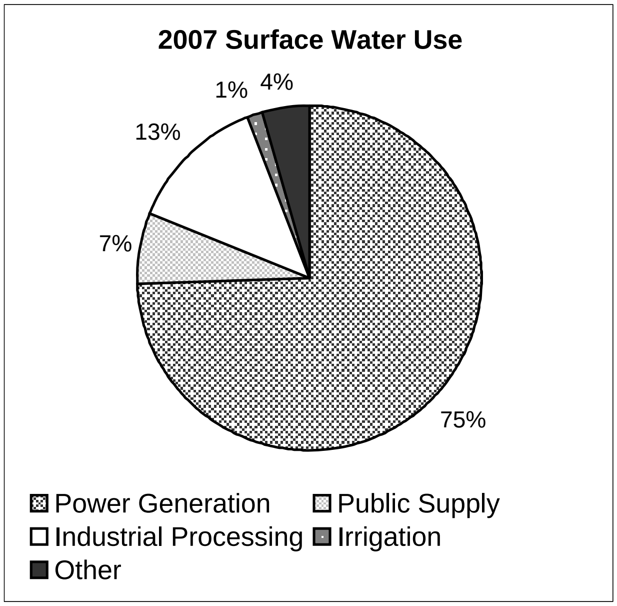
The "Other" category includes uses such as air conditioning, construction dewatering, water level maintenance of lakes, pollution containment, pipeline testing, aquaculture and livestock watering.

Irrigation includes golf courses, landscaping, nurseries, major crops and wild rice.

See the MN DNR web site for the latest water use information: **www.dnr.state.mn.us/waters**



2007 Ground Water Use



2007 Surface Water Use

2007 Water Use in Billions of Gallons

Power Generation	**838.7**
Public Supply	**226.7**
Industrial Processing	**167.5**
Irrigation	**131.9**
Other	**64.3**
Totals	**1429.1**

Appendix D

CONVERSIONS AND FORUMULAS

1 Cubic foot (ft^3)	=	7.5 gallons
1 cubic foot of water	=	62.4 pounds
1 gallon of water	=	8.34 pounds
1 pound per square inch (psi)	=	2.31 feet of water (head)
1 foot of water (head)	=	.434 pounds per square inch (psi)
1 grain per gallon	=	17.1 parts per million (ppm)
1 part per million (ppm)	=	1 milligram per liter (mg/l)
1 pound (1 lb.)	=	454 grams
1 foot	=	12 inches
1 yard	=	3 feet
1 meter	=	3.281 feet
1 liter	=	0.264 gallons
1 gallon	=	3.785 liters

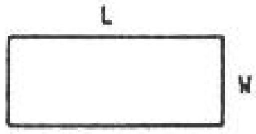
Continuity Equation $Q=A \times V$ where
Q = rate of flow (ft^3/sec)
A = cross-sectional area (ft^2)
V = velocity (ft/sec)

Detention Time $T=V/Q$ where
T = detention time (sec)
V = volume (ft^3)
Q = rate of flow (ft^3/sec)

$$\text{Pounds of pure chemical} = \text{ppm} \times \frac{\text{(gallons treated)}}{1{,}000{,}000} \times 8.34$$

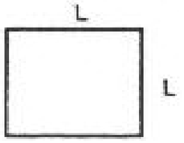
CIRCUMFERENCE AND AREA

Rectangle



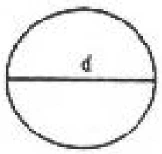
Circumference = (2 x L) + (2 x W)
Area = L x W

Square



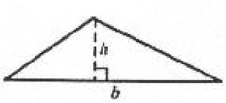
Circumference = 4 x L
Area = L x L

Circle



Circumference = $\pi \times d$
Area = $\pi \times r^2$ or $0.785 \times d^2$
π = 3.14
r = d/2

Triangle

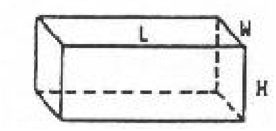


$$A = \frac{B \text{ x } H}{2}$$

B = length of base
H = height of base to tip of angle

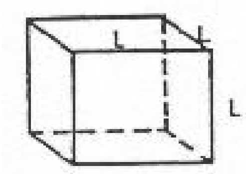
VOLUMES AND SURFACE AREA

Rectangular Solid



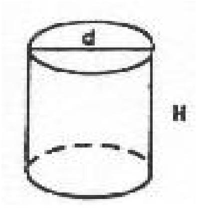
Volume = H x L x W
Surface Area = 2 x (L x H) +
2 x (H x W) +
2 x (L x W)

Cube



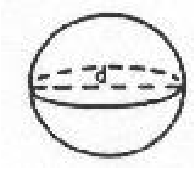
Volume = L x L x L
Surface Area = 6 x L x L

Cylinder



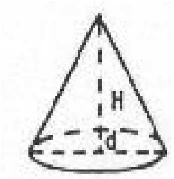
Volume = Area x height or
π x r^2 x H or
0.785 x d^2 x H
Surface Area = top + bottom + side =
2 x (π x r^2)
+ π x d x H
π = 3.14
r = d/2

Sphere



Volume = 4/3 x π x r^3
Surface Area = 4 x π x r^2
π = 3.14
r = d/2

Cone



Volume = π/3 x r^2 x H
π = 3.14
r = d/2

Appendix E

PERIODIC TABLE OF THE ELEMENTS

Atomic weights conform to the 1961 values of the Commission on Atomic Weights.

KEY

Atomic Mass (Weight) — 12.01115

Symbol — C

Atomic Number — 6

Transition Elements

GROUPS

Period	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1	1.00797 H 1																1.00797 H 1	4.0026 He 2
2	6.939 Li 3	9.0122 Be 4											10.811 B 5	12.01115 C 6	14.0067 N 7	15.9994 O 8	18.9984 F 9	20.183 Ne 10
3	22.9898 Na 11	24.312 Mg 12											26.9815 Al 13	28.086 Si 14	30.9738 P 15	32.064 S 16	35.453 Cl 17	39.948 Ar 18
4	39.102 K 19	40.08 Ca 20	44.956 Sc 21	47.90 Ti 22	50.942 V 23	51.996 Cr 24	54.9380 Mn 25	55.847 Fe 26	58.9332 Co 27	58.71 Ni 28	63.54 Cu 29	65.37 Zn 30	69.72 Ga 31	72.59 Ge 32	74.9216 As 33	78.96 Se 34	79.909 Br 35	83.80 Kr 36
5	85.47 Rb 37	87.62 Sr 38	88.905 Y 39	91.22 Zr 40	92.906 Nb 41	95.94 Mo 42	(99) Tc 43	101.07 Ru 44	102.905 Rh 45	106.4 Pd 46	107.870 Ag 47	112.40 Cd 48	114.82 In 49	118.69 Sn 50	121.75 Sb 51	127.60 Te 52	126.9044 I 53	131.30 Xe 54
6	132.905 Cs 55	137.34 Ba 56	138.91 La 57	178.49 Hf 72	180.948 Ta 73	183.85 W 74	186.2 Re 75	190.2 Os 76	192.2 Ir 77	195.09 Pt 78	196.967 Au 79	200.59 Hg 80	204.37 Tl 81	207.19 Pb 82	208.980 Bi 83	(210) Po 84	(210) At 85	(222) Rn 86
7	(223) Fr 87	(226) Ra 88	(227) Ac 89															

Numbers in parentheses are mass numbers of most tables or most common isotope.

Lanthanide Series

140.12 Ce 58	140.907 Pr 59	144.24 Nd 60	(147) Pm 61	150.35 Sm 62	151.96 Eu 63	157.25 Gd 64	158.924 Tb 65	162.50 Dy 66	164.930 Ho 67	167.26 Er 68	168.934 Tm 69	173.04 Yb 70	174.97 Lu 71

Actinide Series

232.038 Th 90	(231) Pa 91	238.03 U 92	(237) Np 93	(242) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(249) Cf 98	(254) Es 99	(253) Fm 100	(256) Md 101	(254) No 102	(257) Lw 103

TABLE OF ATOMIC WEIGHTS OF COMMONLY USED ELEMENTS IN THE WATER INDUSTRY

Name	Symbol	Atomic Weight
aluminum	Al	27.0
calcium	Ca	40.1
carbon	C	12.0
chlorine	Cl	35.4
fluoride	F	19.0
hydrogen	H	1.0
iron	Fe	55.8
magnesium	Mg	24.3
manganese	Mn	54.9
nitrogen	N	14.0
oxygen	O	16.0
potassium	K	39.1
sodium	Na	23.0
sulfur	S	32.1

Appendix F

Consumer Confidence Reports

Most Frequently Asked CCR Questions:

What's the deadline for distribution of my CCR?
The deadline for distribution to customers is July 1st. A copy of the completed and signed certification form and a copy of the report are also due to MDH by July 1st.

Can our system have an exception to the July 1, 2008 distribution date?
A decision is based on the circumstances. Pass these calls on to Kathy Russell at 651/201-4678.

Can I get an electronic version of the report?
Yes.

I'm new and this is my first time through the CCR process.
Direct them to Kathy Russell at 651/201-4678.

Can I reformat my report?
Yes, but it must include all the information contained in the report you received from MDH; particularly the two paragraphs on the last page of the report must be printed word-for-word.

Can I add contaminants that were sampled for but not detected to my report?
Yes, as long as they are listed in a separate table from the list of detected contaminants.

Questions about distribution requirements.
Distribution requirements depend on the population of the system. Pass these questions on to Kathy Russell.

I'm missing my report, certification form, etc.
E-mail, fax or mail them what they're missing.

My address is changed and I never received my packet of CCR information.
Pass these calls on to Kathy Russell so the database can be updated with the correct information.

The information/results contained in the CCR are incorrect.
Pass these calls on to Kathy Russell or Cindy Swanson.

Consumer Confidence Reports

In 1996, Congress amended the federal Safe Drinking Water Act, adding a provision requiring that all community water systems deliver an annual water quality report to their customers. No additional monitoring is necessary as a result of this rule; the report requires information only on monitoring already being done.

The goal of the Consumer Confidence Report (CCR) Rule is to provide information to customers about their drinking water without confusing or alarming them and to:

- advance consumers' understanding of drinking water,
- heighten awareness of the need to protect water resources, and
- enhance the image of the professionals in the drinking water community.

The reports must be completed and distributed by July 1 of each year and will cover monitoring activities through the end of the previous calendar year.

Even though a great deal of information is required for the report, ***don't worry!*** All community water systems will receive a ready-to-go report each year from the Minnesota Department of Health (MDH). You will have to insert a phone number where your customers can call if they have questions or would like to learn more about the water you supply them. It's also possible that you might have to fill in some more data. However, the report you receive from the Minnesota Department of Health is substantially complete. More information about this is available on page 3.

This booklet contains information on the CCR Rule and how Minnesota is working with its community water systems to help them comply with the rule. Keep this book handy and use it both as a resource when it is time to complete your report as well as a reference guide for questions that may come up anytime during the year.

To receive additional copies of this booklet, call the Minnesota Department of Health Drinking Water Message Center:

Twin Cities Metro Area—651/215-1324
Toll-free from Greater Minnesota—1/800/818-9318

MINNESOTA MDH DEPARTMENT OF HEALTH
625 ROBERT ST N
PO BOX 64975
ST PAUL MN 55164-0975

To request this document in another format, call 651/215-0700; TDD 651/215-0707 or toll-free through the Minnesota Relay Service, 1/800-627-3529 (ask for 651/215-0700).

March 2002
IC 141-0191

Printed on Recycled Paper

Table of Contents

Minimum Content Requirements

The report you issue must contain certain information to comply with the rule. MDH will provide this information to you. The required information includes:

Source of Water
You must identify the source of your water by type (surface water source, groundwater source) and by the specific body of water (name of river, lake, stream, watershed, or aquifer).

Source Water Assessment
If your system has completed a source water assessment, you must note the availability of the plan and how residents can get a copy of it as well as summarize your system's susceptibility to contamination.

Definition of Terms
Your report must contain brief and plainly worded definitions of the terms used in the report. The terms may include Maximum Contaminant Level (MCL), Maximum Contaminant Level Goal (MCLG), Action Level (AL), Parts per Billion (ppb), Parts per Million (ppm), and No Detection (nd).

Regulated Contaminants Detected
If a regulated contaminant is detected but not at a level that exceeds the maximum contaminant level (MCL), you must list it in a table along with the level of the contaminant detected, the maximum contaminant level, and maximum contaminant level goal for that contaminant, such as in the table below. You also have to note the source of the contaminant; this could be either the specific source, if it is known, or the typical source of the particular contaminant.

Contaminant (units)	MCLG	MCL	Level Detected		Typical Source of Contaminant
			Range	Average/ Result*	
Barium (ppm)	2.0	2.0	—	0.12	Natural Deposits; Drilling Wastes.
Arsenic (ppb)	0	50.0	—	2.7	Erosion of natural deposits; Runoff from orchards.
Tetrachloroethylene (ppm)	0	5.0	nd-2.2	1.1	Leaching from PVC pipes; Discharge from factories and dry cleaners.

*This is the value used to determine compliance with federal standards. It sometimes is the highest value detected and sometimes is an average of all the detected results.

Unregulated Contaminants
Your report must contain information on the levels of unregulated contaminants for which monitoring is required.

Unregulated contaminants are those that water systems must test for but do not have Maximum Contaminant Levels. The health risk posed by unregulated contaminants is determined by comparing the levels found with health advisory values known as Health Risk Limits. Unregulated contaminants include chloroform, bromodichloromethane, sulfate, and sodium. (Sodium has special monitoring requirements in Minnesota and, as a result, falls into the category of unregulated contaminants.)

Minimum Content Requirements—Continued on page 2

Health Effects Listed for Violations

If the level of detection of a contaminant is above the MCL, resulting in a violation, this contaminant must be highlighted in some way (such as an asterisk) within the table of detected contaminants. At the end of the table, it must be noted as a violation with the following information included: an explanation of the violation(s), including the duration of the violation, the potential adverse health effects, and actions taken by the system to address the violation.

Compliance

You must include information on compliance with national primary drinking water regulations; this mainly covers violations that took place in the previous calendar year. The violations can be for exceeding a maximum contaminant level; they can also be for missing a sample or not reporting information on time.

Environmental Protection Agency (EPA) Hotline and Standard Language

Three sections of standard language, which include the EPA toll-free hotline number, have to be in the report. Two of the sections must be printed word-for-word, with one of these sections displayed in a prominent manner (which may be achieved by using boldfaced or italicized type). For the other section, you have the option of using comparable language. For a complete description of the standard language, including which section can be reworded, see pages 12 and 13.

Special Language for Arsenic, Nitrate, Fluoride, Lead, and Total Trihalomethanes

If levels detected are 50 percent or more of the MCL (but not above the MCL) for nitrate, fluoride, or lead; if the compliance level for arsenic is above 5 parts per billion; or if the compliance level for total trihalomethanes is above 80 parts per billion (but not above the MCL), additional information must be included. The language for this information is on page 14.

Other Information

Your report must contain a phone number of a contact person for people to call if they have questions **as well as** where they can obtain information about opportunities for public participation in decisions that may affect the quality of the water.

Systems serving a large non-English speaking population must include a statement in the appropriate language(s) regarding the importance of the report.

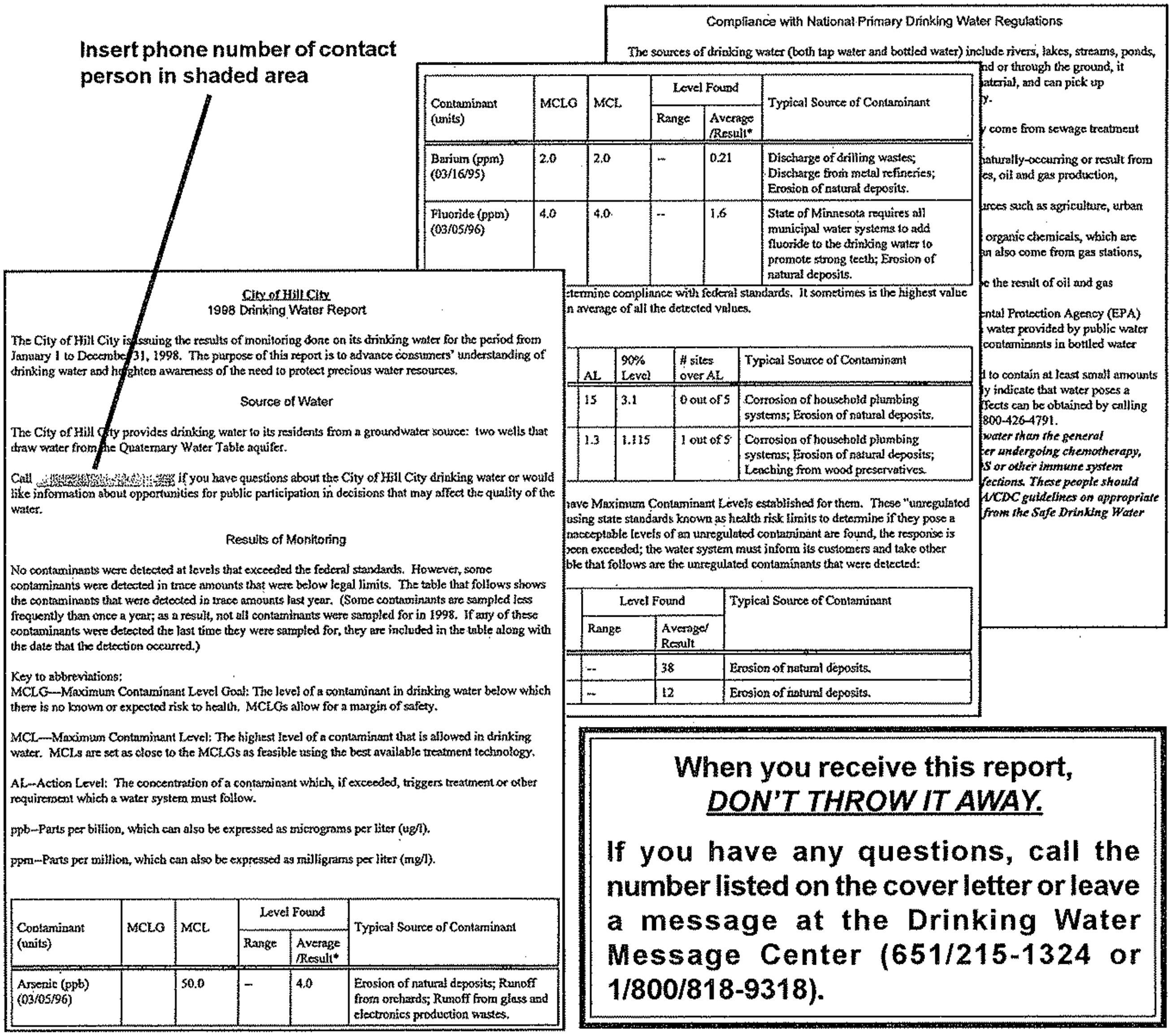
Don't Worry!!!!

You need not fret about the difficulty in assembling all the information required for your report. In Minnesota, we will do this for you (see the section, *What Is Minnesota Doing to Help Its Systems Comply with the Rule?* on the next page).

However, your water system will be responsible for doing the proper distribution of the report. (See page 6 for information on distribution requirements.)

What Is Minnesota Doing to Help Its Systems Comply with the Rule?

Each year, in early April, the Minnesota Department of Health (MDH) will provide you with a ready-made report that contains almost all of the required information. This will include your source of water, necessary definitions, a table of detected contaminants, and all the required standard language.



Insert phone number of contact person in shaded area

City of Hill City
1998 Drinking Water Report

The City of Hill City is issuing the results of monitoring done on its drinking water for the period from January 1 to December 31, 1998. The purpose of this report is to advance consumers' understanding of drinking water and heighten awareness of the need to protect precious water resources.

Source of Water

The City of Hill City provides drinking water to its residents from a groundwater source: two wells that draw water from the Quaternary Water Table aquifer.

Call if you have questions about the City of Hill City drinking water or would like information about opportunities for public participation in decisions that may affect the quality of the water.

Results of Monitoring

No contaminants were detected at levels that exceeded the federal standards. However, some contaminants were detected in trace amounts that were below legal limits. The table that follows shows the contaminants that were detected in trace amounts last year. (Some contaminants are sampled less frequently than once a year; as a result, not all contaminants were sampled for in 1998. If any of these contaminants were detected the last time they were sampled for, they are included in the table along with the date that the detection occurred.)

Key to abbreviations:
MCLG—Maximum Contaminant Level Goal: The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.

MCL—Maximum Contaminant Level: The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.

AL--Action Level: The concentration of a contaminant which, if exceeded, triggers treatment or other requirement which a water system must follow.

ppb--Parts per billion, which can also be expressed as micrograms per liter (ug/l).

ppm--Parts per million, which can also be expressed as milligrams per liter (mg/l).

Contaminant (units)	MCLG	MCL	Level Found		Typical Source of Contaminant
			Range	Average /Result*	
Arsenic (ppb) (03/05/96)		50.0	--	4.0	Erosion of natural deposits; Runoff from orchards; Runoff from glass and electronics production wastes.

Contaminant (units)	MCLG	MCL	Level Found		Typical Source of Contaminant
			Range	Average /Result*	
Barium (ppm) (03/16/95)	2.0	2.0	--	0.21	Discharge of drilling wastes; Discharge from metal refineries; Erosion of natural deposits.
Fluoride (ppm) (03/05/96)	4.0	4.0	--	1.6	State of Minnesota requires all municipal water systems to add fluoride to the drinking water to promote strong teeth; Erosion of natural deposits.

etermine compliance with federal standards. It sometimes is the highest value
n average of all the detected values.

AL	90% Level	# sites over AL	Typical Source of Contaminant
15	3.1	0 out of 5	Corrosion of household plumbing systems; Erosion of natural deposits.
1.3	1.115	1 out of 5	Corrosion of household plumbing systems; Erosion of natural deposits; Leaching from wood preservatives.

ave Maximum Contaminant Levels established for them. These "unregulated
using state standards known as health risk limits to determine if they pose a
nacceptable levels of an unregulated contaminant are found, the response is
een exceeded; the water system must inform its customers and take other
ble that follows are the unregulated contaminants that were detected:

Level Found		Typical Source of Contaminant
Range	Average/ Result	
--	38	Erosion of natural deposits.
--	12	Erosion of natural deposits.

Compliance with National Primary Drinking Water Regulations

The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds,
nd or through the ground, it
aterial, and can pick up
y.

y come from sewage treatment

naturally-occurring or result from
es, oil and gas production,

urces such as agriculture, urban

organic chemicals, which are
an also come from gas stations,

e the result of oil and gas

ental Protection Agency (EPA)
water provided by public water
contaminants in bottled water

d to contain at least small amounts
y indicate that water poses a
ffects can be obtained by calling
800-426-4791.
water than the general
er undergoing chemotherapy,
S or other immune system
fections. These people should
A/CDC guidelines on appropriate
from the Safe Drinking Water

When you receive this report,
DON'T THROW IT AWAY.

If you have any questions, call the number listed on the cover letter or leave a message at the Drinking Water Message Center (651/215-1324 or 1/800/818-9318).

The report that MDH provides to each water system has shaded areas to indicate where information needs to be added. At a minimum, you will have to fill in the phone number of a contact person. You will also have to add information about actions you took if you had any kind of a violation (either for exceeding an MCL or for not submitting a sample on time) during the year.

If you use surface water (or buy any of your water from a surface supplier), you will also have to fill in the relevant numbers for turbidity. When this information is filled in, the report is complete. You can then use this as your official report.

If your system purchases its water from another system, be sure and read this next part.

What about Systems that Purchase the Water They Distribute to Their Customers?

Even systems that purchase all their water from another system must produce and distribute a report. Systems that purchase only a portion of their water from another system must include the monitoring information for that system in their report. The report you receive from MDH will contain information about the water system that you purchase your water from.

The Consumer Confidence Rule requires wholesalers (systems that sell their water to other systems) to provide the purchasing systems with the necessary information by April 1 of each year. However, in Minnesota, this probably isn't necessary since MDH will send a ready-made report to each system. For purchasing systems, the report will contain the required monitoring information for the wholesaler. ***Exception:*** Purchasing systems that purchase any water from a surface-water system will need to obtain the turbidity information from that system.

What Else Will Accompany the Report from MDH?

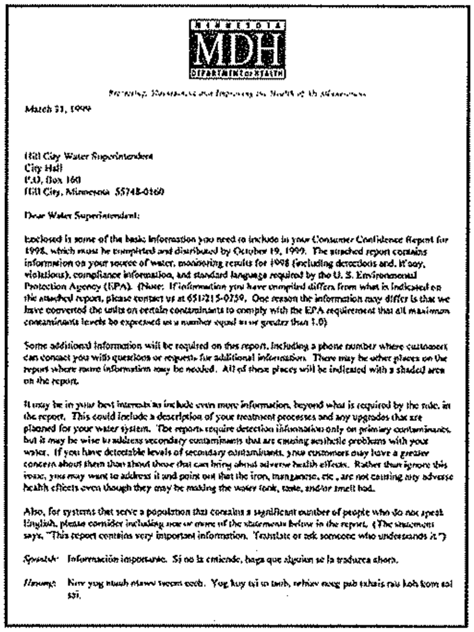
The ready-made report will be sent to the owner or superintendent of each community water system. It will be accompanied by a cover letter and a certification form. The cover letter contains instructions; it also has the population served noted for the individual system and a list of the distribution options (if any) available to the system.

The certification form contains the name and Public Water Supply identification number for your system. It also lists the distribution options available to you. When the distribution of your report is complete, the superintendent must check the type of distribution that was performed and then complete the information at the bottom (which includes a place for the date the distribution was completed, signature and printed name of the person certifying the information, and the phone number of this person).

The certification form must be sent to MDH along with a copy of the report. **(Even if you use the ready-made report provided by MDH and do nothing more than insert a phone number, you must still send a copy of this report back to MDH.)** If you used the distribution option of publishing the report in its entirety in one or more local newspapers, be sure and include a clipping of the published report from one of the papers.

The owner of the system (which may be the city clerk for a municipal water system) will receive a separate letter, informing him or her that the complete report and instructions have been sent to the system's superintendent.

Copies of the letter and certification form are on the next page.



MINNESOTA MDH DEPARTMENT of HEALTH

Protecting, Maintaining and Improving the Health of All Minnesotans

March 31, 1999

Hill City Water Superintendent
City Hall
P.O. Box 160
Hill City, Minnesota 55748-0160

Dear Water Superintendent:

Enclosed is some of the basic information you need to include in your Consumer Confidence Report for 1998, which must be completed and distributed by October 19, 1999. The attached report contains information on your source of water, monitoring results for 1998 (including detections and, if any, violations), compliance information, and standard language required by the U. S. Environmental Protection Agency (EPA). (Note: If information you have compiled differs from what is indicated on the attached report, please contact us at 651/215-0759. One reason the information may differ is that we have converted the units on certain contaminants to comply with the EPA requirement that all maximum contaminants levels be expressed as a number equal to or greater than 1.0)

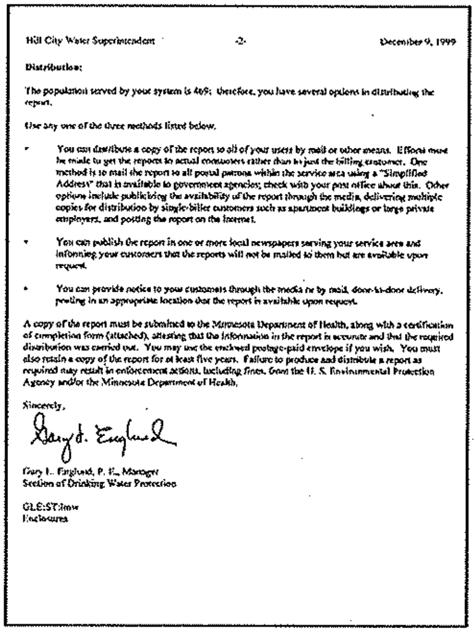
Some additional information will be required on this report, including a phone number where customers can contact you with questions or requests for additional information. There may be other places on the report where more information may be needed. All of these places will be indicated with a shaded area on the report.

It may be in your best interests to include even more information, beyond what is required by the rule, in the report. This could include a description of your treatment processes and any upgrades that are planned for your water system. The reports require detection information only on primary contaminants, but it may be wise to address secondary contaminants that are causing aesthetic problems with your water. If you have detectable levels of secondary contaminants, your customers may have a greater concern about them than about those that can bring about adverse health effects. Rather than ignore this issue, you may want to address it and point out that the iron, manganese, etc., are not causing any adverse health effects even though they may be making the water look, taste, and/or smell bad.

Also, for systems that serve a population that contains a significant number of people who do not speak English, please consider including one or more of the statements below in the report. (The statement says, "This report contains very important information. Translate or ask someone who understands it.")

Spanish: Información importante. Si no la entiende, haga que alguien se la traduzca ahora.

Hmong: Nov yog ntaub ntawv tseem ceeb. Yog koj tsi to taub, nrhiav neeg pab txhais rau koj kom sai sai.



Hill City Water Superintendent -2- December 9, 1999

Distribution:

The population served by your system is 469; therefore, you have several options in distributing the report.

Use any one of the three methods listed below.

- You can distribute a copy of the report to all of your users by mail or other means. Efforts must be made to get the reports to actual consumers rather than to just the billing customer. One method is to mail the report to all postal patrons within the service area using a "Simplified Address" that is available to government agencies; check with your post office about this. Other options include publicizing the availability of the report through the media, delivering multiple copies for distribution by single-biller customers such as apartment buildings or large private employers, and posting the report on the Internet.
- You can publish the report in one or more local newspapers serving your service area and informing your customers that the reports will not be mailed to them but are available upon request.
- You can provide notice to your customers through the media or by mail, door-to-door delivery, posting in an appropriate location that the report is available upon request.

A copy of the report must be submitted to the Minnesota Department of Health, along with a certification of completion form (attached), attesting that the information in the report is accurate and that the required distribution was carried out. You may use the enclosed postage-paid envelope if you wish. You must also retain a copy of the report for at least five years. Failure to produce and distribute a report as required may result in enforcement actions, including fines, from the U. S. Environmental Protection Agency and/or the Minnesota Department of Health.

Sincerely,

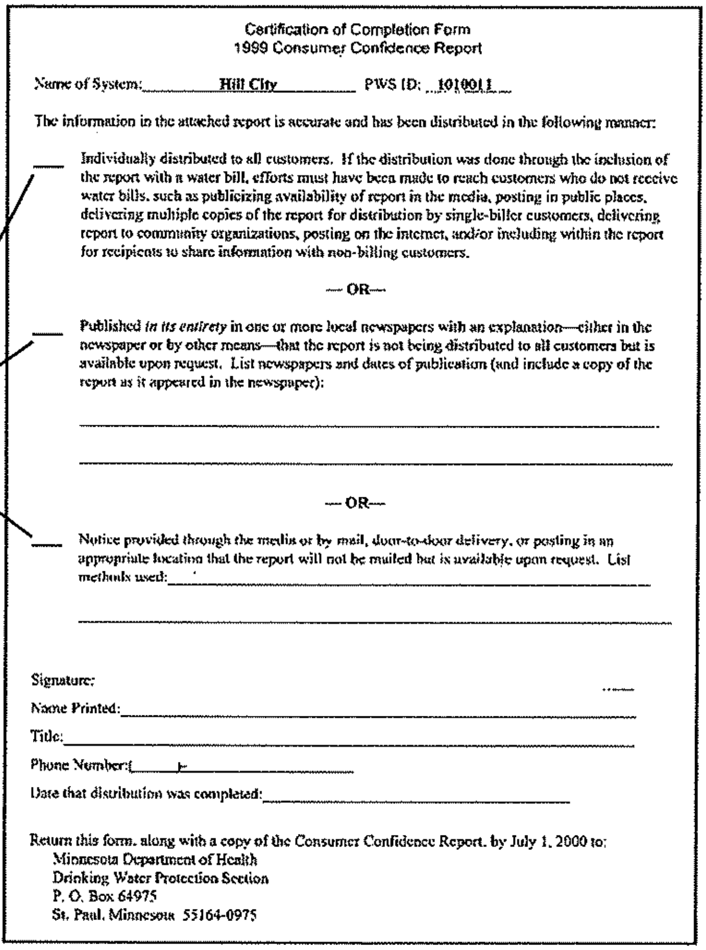
Gary L. Englund

Gary L. Englund, P. E., Manager
Section of Drinking Water Protection

GLE:ST:mw
Enclosures

A cover letter with instructions will accompany the report sent by MDH to the superintendent (above). The owner or city clerk will also receive a cover letter.

Below is the certification form, which must be completed and returned to MDH with a copy of the report by the July 1 deadline. Systems that use the newspaper publishing option must include a copy of the report from the newspaper. Note: The certification form shown below is for a system serving fewer than 500 people. Larger systems will not have the same distribution options.



Certification of Completion Form
1999 Consumer Confidence Report

Name of System: Hill City PWS ID: 1010011

The information in the attached report is accurate and has been distributed in the following manner:

___ Individually distributed to all customers. If the distribution was done through the inclusion of the report with a water bill, efforts must have been made to reach customers who do not receive water bills, such as publicizing availability of report in the media, posting in public places, delivering multiple copies of the report for distribution by single-biller customers, delivering report to community organizations, posting on the internet, and/or including within the report for recipients to share information with non-billing customers.

—OR—

___ Published *in its entirety* in one or more local newspapers with an explanation—either in the newspaper or by other means—that the report is not being distributed to all customers but is available upon request. List newspapers and dates of publication (and include a copy of the report as it appeared in the newspaper):

____

____

—OR—

___ Notice provided through the media or by mail, door-to-door delivery, or posting in an appropriate location that the report will not be mailed but is available upon request. List methods used: ______________________________

____

Signature:

Name Printed: ______________________________

Title: ______________________________

Phone Number: (____) ____-________

Date that distribution was completed: ______________________________

Return this form, along with a copy of the Consumer Confidence Report, by July 1, 2000 to:
Minnesota Department of Health
Drinking Water Protection Section
P. O. Box 64975
St. Paul, Minnesota 55164-0975

Check the distribution method that you used

Distribution Requirements

The size of the population served by your system will determine the options (if any) you have in distributing the report to your customers. Systems serving a population of greater than 10,000 will have to individually distribute the report (with systems serving populations of greater than 100,000 also having to post the report on an internet site). Smaller systems may use other methods of distributing the report,listed below.

After you've completed the distribution, you will have to send a copy of the report, along with a completed and signed certification form (shown on page 5), to MDH.

Systems serving populations of 10,000 or greater
These systems must "mail or otherwise deliver one copy of the report to each customer."

If the report is sent out with a water bill, the system must make "good faith efforts" to get the report to actual consumers rather than to just the billing customer. These efforts could include publicizing the availability of the report through the media, delivering multiple copies for distribution by single-biller customers such as apartment buildings or large private employers, and posting the report on the internet.

Rather than including the report with the water bill, a system may distribute the report in a separate mailing to all postal patrons within the service area using a "Simplified Address" that is available to government agencies. It is also permissible to print the report in its entirety in a city newsletter that goes to all residents served by the system.

Note: Systems serving a population of 100,000 or greater must post the report on an internet site in addition to performing the individual distribution described above.

Systems serving populations of greater than 500 but fewer than 10,000
These systems have the option of performing individual distribution or of publishing the report *in its entirety* in one or more local newspapers serving their service area.

To satisfy distribution requirements with this option, it is not permitted to have only a summary printed nor a mere notice of the availability of the report.

Systems using this option must also inform their customers that the reports will not be mailed to them (this can be done in the newspaper or newspapers in which the report appears) and that the reports are available to the public upon request.

Systems serving populations of 500 or fewer
These systems have the option of performing individual distribution; publishing the report in its entirety in one or more local newspapers serving their service area and informing customers that the report will not be mailed to them; or by providing notice at least once per year to their customers by mail, by door-to-door delivery, or by posting in an appropriate location that the report is available upon request.

In all cases, the system must still be ready to provide a report to any resident who requests it.

Record Keeping

You should maintain a copy of the report for three years and be ready to provide a copy to anyone who requests it during that time. You must also mail a copy of the report, along with the completed and signed certification form, to the Minnesota Department of Health by July 1 of each year.

Small Systems

It's Not that Expensive

To Small Systems (serving a population of 500 or fewer):

Please note that your water system can produce and distribute the report for little cost. Since you have the option of merely providing notice to your customers of the availability of the report, you don't have to distribute a copy to all customers nor do you have to purchase advertising space to publish it in a newspaper. Rather, you can satisfy the distribution requirement by posting notices that the report is available and/or notifying any radio stations or newspapers serving your area and asking them to let citizens know they can acquire a copy of the report by contacting the water system. Make as many copies of the report as you think might be needed (and be ready to copy more if you receive more requests than you originally anticipated). If you use the report we have sent, make sure a phone number for a contact person is included as well as any other information that may need to be added (shaded areas on the report indicate where information needs to be filled in).

You certainly may spend more money to reformat the information into a new document or to hire a consultant to produce the report for you, **but this is not required.** Using the report that we have provided will satisfy the content requirements.

Cautions, Enhancements, and Tips

As long as you fill in the necessary information such as a phone number, you can use the report provided by MDH and be assured that your report complies with all the requirements of the Consumer Confidence Rule.

If you reformat the required information into a new document, you have to make sure it is done correctly. This doesn't mean it is a bad thing to create a new document; to the contrary, systems are encouraged to do this and to add additional information that isn't required but that will enhance their customers' understanding about the system and about drinking water in general.

Cautions

Systems that reformat the required information into a new document should take care to avoid some of the mistakes that other systems have made. Here are a few of the cautions:

In addition to the contaminants that were detected, some systems are choosing to list contaminants that were sampled for but not detected. This is fine *as long as* it is in a separate table from the list of detected contaminants. The detected and undetected contaminants <u>cannot</u> be listed together.

For most of the regulated contaminants, the system will have to list the compliance value (which could be either the highest value or the average value of all the samples taken) and the range detected (if more than one sample was taken). However, for lead and copper as well as for turbidity, different information is required. For lead and copper it is the 90th percentile level and the number of sampling sites that were over the action level.

Contaminant (units)	MCLG	MCL	90% Level	# sites over AL	Typical Source of Contaminant
Lead (ppb)	0	15	6.3	0 of 20	Corrosion of household plumbing systems.
Copper (ppm)	1.3	1.3	0.073	0 of 20	Corrosion of household plumbing systems.

For turbidity, it is the highest single measurement and the lowest monthly percentage of samples meeting the turbidity limits. As a result, different column headings will be needed for lead and copper and for turbidity. It is therefore a good idea to have separate tables for turbidity, for lead and copper, and for the other regulated contaminants. If turbidity has to be included (which will be the case for surface-water systems or those who purchase water from surface systems), the report must contain a brief explanation of the reason for measuring turbidity. The Minnesota Department of Health has included such a statement in the ready-made report it sends out, and the affected systems should make sure that this statement is included in their reports.

Contaminant (units)	MCLG	MCL	**	***	Typical Source of Contaminant
Turbidity (NTU)	n/a	TT	▨	▨	Soil runoff

**Lowest Monthly Percentage of Samples Meeting the Turbidity Limits ***Highest Single Measurement Turbidity is a measure of the clarity of the water. We monitor it because it is a good indicator of the effectiveness of our filtration system.

Surface water systems, or those who purchase any portion of their water from a surface water system, will have to include a table for turbidity with an explanation of the reasons for monitoring for it. Systems will have to fill in the turbidity results in the shaded area indicated on the report provided by MDH.

Enhancements and Tips

Many water systems have included additional information and graphics, which help to promote understanding about drinking water to their customers.

Some have inserted a checkmark by the listing of each detected contaminant to indicate that it met the standard. An example:

Contaminant (units)	MCLG	MCL	Level Detected		Typical Source of Contaminant	Meets Regulatory Requirement
			Range	Average/ Result		
Mercury (ppb)	2.0	2.0	—	0.01	Erosion of natural deposits; Discharge from refineries and factories.	✓
Nitrate (as Nitrogen) (ppm)	10.0	10.0	nd-0.37	0.37	Runoff from fertilizer use; Leaching from septic tanks. Erosion of natural deposits.	✓

Note: Some systems using checkmarks labeled the column with the term, "Met or exceeded the standard." Be careful when using the word "exceeded." Although in these cases, the water systems intended for it to mean "bettered," there can be confusion about its meaning. Normally, to exceed a standard means to go above it or to violate the standard.

Don't use the word exceed if you mean that the contaminant level was below, and in compliance with, the standard.

More Tips:

Other systems inserted a list of contaminants with secondary standards (those that don't affect health but can cause the water to look, taste, or smell bad). Detections of contaminants such as iron and manganese are not required to be listed in the reports. However, it can be a good idea to address this issue, particularly for systems that have elevated levels of these types of contaminants. Customers of these systems may have greater concerns about contaminants that are causing their water to be discolored than they do about contaminants that can bring about adverse health effects.

Other useful information that may be added includes:

- A description of the treatment process used by the water system.
- Any upgrades the system is planning.
- Information on the amount of training that the system's operators receive each year; this is a good way to emphasize the professionalism of the people treating and distributing the water.

Even systems that use the ready-made report provided by MDH may attach an additional sheet (or sheets) that contains more information on their systems, such as what has been described in the above paragraphs.

The CCR as a Communication Tool

Consumer Confidence reports should be the starting point, not the end point, in communication. It may be a good idea to share the information in the report with newspapers and/or radio stations. They may be interested in doing a story on the report and may contact you for more information. This is a chance to deliver certain messages about their system—that it is staffed by dedicated professionals who work hard to make the water safe, that the water from your system and other public water systems is more thoroughly tested and regulated than water from any other source, including bottled water, etc. In addition to getting more positive messages out about your system's water, it will alert your residents to the coming of the report.

Note: Such a story in a newspaper probably will not satisfy the distribution requirement for systems who have the option of using newspaper publication. The only way the requirement can be satisfied in this way is for the report to be published in its entirety, which probably will not happen in an article done by the paper. However, this is still an excellent means of communicating with customers and is useful to do in addition to whatever other means are used to satisfy distribution requirements.

Standard Language

The reports require three separate sections of standard language. All the required language will be included in the ready-made reports that MDH provides to each system.

If a system reformats the information from MDH in a new report, it must include the language; however, one of the sections may be reworded and tailored to the situation of the individual system. The other two sections must be printed word-for-word (and one of those sections must be prominently displayed).

Below are the three sections of the standard language required for the reports.

Systems may use comparable language for this section. This means they can reword the information below and/or tailor it to their system; it does not mean that the inclusion of this information is optional. Even if it is reworded and/or tailored, the information in this section must be substantially included:

- The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and, in some cases, radio active material, and can pick up substances resulting from the presence of animals or from human activity.

  Contaminants that may be present in source water include:

  Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.

  Inorganic contaminants, such as salts and metals, which can be naturally-occurring or result from urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming.

  Pesticides and herbicides, which may come from a variety of sources such as agriculture, urban stormwater runoff, and residential uses.

  Organic chemical contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban stormwater runoff, and septic systems.

  Radioactive contaminants, which can be naturally-occurring or be the result of oil and gas production and mining activities.

  In order to ensure that tap water is safe to drink, the U. S. Environmental Protection Agency (EPA) prescribes regulations which limit the amount of certain contaminants in water provided by public water systems. Food and Drug Administration regulations establish limits for contaminants in bottled water which must provide the same protection for public health.

Standard Language—Continued on next page

- **This information must be included word for word:**

  Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the Environmental Protection Agency's Safe Drinking Water Hotline at 800-426-4791.

- **This information must be included word for word and must be prominently displayed (which could be done by using a boldfaced, italicized, or underlined type style):**

  Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. Environmental Protection Agency/Centers for Disease Control guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline at 800-426-4791.

Special Language for Nitrate, Fluoride, Lead, Total Trihalomethanes, and Arsenic

If levels detected are 50 percent or more of the MCL (but below the MCL) for nitrate or fluoride (for nitrate, above 5 ppm; for fluoride, above 2 ppm), additional information must be included. Special language must be included for lead if more than 5 percent (but fewer than 10 percent) of the samples were above the action level of 15 ppb by systems that take 20 or more samples. Systems that collect fewer than 20 lead samples do not have to include the special language for lead. If the compliance level (the average, not the high end of the range) for Total Trihalomethanes is above 80 ppb (but below the MCL) or if the compliance level for arsenic is above 5 ppb, additional information must be included. The language is noted below for each of the contaminants.

Nitrate (above 5 ppm but below the MCL):
Nitrate in drinking water at levels above 10 parts per million is a health risk for infants of less than six months of age. High nitrate levels in drinking water can cause blue baby syndrome. Nitrate levels may rise quickly for short periods of time because of rainfall or agricultural activity. If you are caring for an infant, you should ask advice from your health care provider.

Fluoride (above 2 ppm but below the MCL):
Some people who drink water containing fluoride in excess of the MCL over many years could get bone disease, including pain and tenderness of the bones. Fluoride in drinking water at half the MCL or more may cause mottling of children's teeth, usually in children less than nine years old. Mottling, also known as dental fluorosis, may include brown staining and/or pitting of the teeth, and occurs only in developing teeth before they erupt from the gums.

Lead (more than 5 percent but fewer than 10 percent of samples above the action level for systems that collect 20 or more lead samples):
Infants and young children are typically more vulnerable to lead in drinking water than the general population. The lead levels in your water system were found to be in compliance with drinking water standards; however, it is possible that lead levels at your home may be higher than at other homes in the community as a result of materials used in your home's plumbing. If you are concerned about elevated lead levels in your home's water, you may wish to have your water tested and flush your tap for 30 seconds to two minutes before using tap water. Additional information is available from the Safe Drinking Water Hotline at 800-426-4791.

Total Trihalomethanes (above 80 ppm but below the MCL):
Some people who drink water containing trihalomethanes in excess of the MCL over many years may experience problems with their liver, kidneys, or central nervous systems, and may have an increased risk of getting cancer.

Special Language—Continued on next page

Arsenic (above 5 ppb and up to and including 10 ppb):
While your drinking water meets EPA's standard for arsenic, it does contain low levels of arsenic. EPA's standard balances the current understanding of arsenic's possible health effects against the costs of removing arsenic from drinking water. EPA continues to research the health effects of low levels of arsenic, which is a mineral known to cause cancer in humans at high concentrations and is linked to other health effects such as skin damage and circulatory problems.

Arsenic (above 10 ppb and up to and including 50 ppb):
Some people who drink water containing arsenic in excess of the MCL over many years could experience skin damage or problems with their circulatory system, and may have an increased risk of getting cancer.

Plan ahead!

The ready-made report will not be available from MDH until early April and the reports are due July 1. This means that you should be thinking about the reports and the distribution of them well before you receive the ready-made report from MDH; otherwise, you may find that you don't have enough time to get the report printed and distributed before the deadline. This is especially true if your systems serves a population of greater than 10,000, since you will be required to perform individual distribution of all reports.

For example, if a system plans to reformat the MDH report for inclusion in a quarterly city newsletter that goes out in May, it needs to have a plan of action in place before it receives its report from MDH. If the city isn't able to get the report into the May newsletter and the next newsletter isn't scheduled for distribution until August, it will have to do something else, since waiting for the next newsletter will cause the system to miss the July 1 distribution deadline. The same is true if a system plans to handle distribution through a quarterly water bill.

Exceptions to the deadline will not be made because of a system's failure to plan ahead (or any other reason, for that matter). The deadline is locked in by rule, and MDH has no legal flexibility to change it.

Failure to produce and distribute a report by the deadline is a major violation of the federal Safe Drinking Water Act.

Appendix G

Advisory Council on Water Supply Systems and Wastewater Treatment Facilities - Members

Water Supply System Operator Representative, Metro
Term end: January 1, 2018
Jim Sadler, Chair
Utilities Supervisor, City of Maple Grove
Phone: 763-494-6377
Fax: 763-494-6424
jsadler@ci.maple-grove.mn.us

Collection System Operator Representative
Term end: January 1, 2018
Howard Jacobson
520 Garfield Avenue
Duluth, MN 55802
Phone: 218-730-4061
Fax: 218-730-4176
hjacobson@duluthmn.gov

Water Supply System Operator Representative, Rural System
Term end: January 1, 2018
Herb Watry
Public Works Supervisor
126 N. Marshall Avenue
Litchfield, Minnesota 55355
Phone: 320-693-7201 (Office)
Fax: 320-693-9134
herb.watry@ci.litchfield.mn.us

Minnesota Pollution Control Agency Representative
Term end: January 1, 2018
Charles Thompson
Supervisor, Certification and Training Unit
Prevention and Assistance Division
Minnesota Pollution Control Agency
520 Lafayette Road N.
St. Paul, MN 55155-4194
Phone: 651-757-2777
Fax: 651-297-8676
charles.thompson@state.mn.us

Metropolitan Council Environmental Services Representative
Term end: January 1, 2018
Ruth Estes
Metropolitan Council Environmental Services
2400 Childs Road
St. Paul, MN 55106
Phone: 651-602-4913
Fax: 651-602-8394
ruth.estes@metc.state.mn.us

Water Supply System Operator Representative. Non-Municipal
Term end: January 1, 2018
Vacant

Member of the Public Representative
Term end: January 1, 2018
John Baerg
33360 630th Avenue
Butterfield, MN 56120
Phone: 507-956-2315
jbaerg38@gmail.com

Wastewater Operator Representative, Rural Facility
Term end: January 1, 2018
Scott Gilbertson
1025 Roosevelt Avenue
Detroit Lakes, Minnesota 56502
Phone: 218-234-8118
sgilbertson@lakesnet.net

Department of Health Representative
Term end: January 1, 2018
Robert Smude
Minnesota Department of Health
Drinking Water Protection Section
625 North Robert Street
P.O. Box 64975
St. Paul, MN 55164-0975
Phone: 651-201-4677
Fax: 612-201-4701
robert.smude@state.mn.us

Municipalities Representative
Term end: January 1, 2018
Brian Mehr
24183 268th Avenue
Paynesville, Minnesota 56362
Phone: 320-234-4231
bmehr@ci.hutchinson.mn.us

Member of the Public Representative, Academia
Term end: January 1, 2018
William Spain
Water Environment Technologies
St. Cloud Technical and Community College
1540 Northway Drive
St. Cloud, MN 56301
Phone: 320-308-5952
Fax: 320-308-5905
bspain@sctcc.edu

Other Water-Wastewater Contacts
Dianne Navratil
Wastewater Certification Officer
Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155
Phone: 651-296-9269
Fax: 651-297-8676
dianne.navratil@state.mn.us

Mark Sloan
Water Certification Officer
Minnesota Department of Health
Drinking Water Protection Section
625 North Robert Street
P.O. Box 64975
St. Paul, MN 55164-0975
Phone: 651-201-4652
Fax: 651-201-4701
mark.sloan@state.mn.us

NOTES:

Appendix H

Water and Wastewater Related Training Performed by

State Agencies

Minnesota Department of Health
Minnesota Pollution Control Agency
Minnesota Board of Water and Soil Resources
Minnesota Department of Natural Resources
Minnesota Department of Agriculture

Universities

University of Minnesota
Bemidji State University
St. Cloud State University
Mankato State University
Winona State University
Moorhead State University

Community and Technical Colleges

St. Cloud Technical College
Vermilion Community College

Professional Associations and others

Minnesota Rural Water Association
Minnesota Section AWWA
Minnesota Wastewater Operators Association
Central States Water Environmental Association
Minnesota Water Well Association
Minnesota Groundwater Association
Minnesota Environmental Health Association
Midwest Assistance Program
Minnesota Water and Wastewater Operators Certification Council
League of Minnesota Cities
Consultants and Distributors

Notes:

Minnesota Department of Health
Protecting, maintaining and improving the health of all Minnesotans

Frequently Called Phone Numbers by Subject

This page lists frequently called phone numbers by subject in alphabetical order.

Last revision: Tuesday, June 30, 2015 at 10:14AM

Subject	**MDH Division or other MN State Agency**	**Phone Number**
Abandoned Dumps	EH	651-201-4899
Abandoned Wells	EH	651-201-4600
Abortion Reporting Statistics	Center for Health Statistics	651-201-5945
Abstinence Education	CFH	651-201-3752
Accidents (Deaths)	Center for Health Statistics	651-201-3504
Acid Rain	MPCA	651-296-7754
Acupuncture	Med. Prac. Bd.	612-617-2130
Adolescent Health	CFH	651-201-3627
Adoption	DHS	651-431-2000
Advisory Council Alcohol/Drug Abuse	HPCD	651-201-5496
Advisory Council Hearing Instrument Dispenser	HOP	651-201-3724
Advisory Council Maternal and Child Health	CFH	651-201-3874
Advisory Council Plumbing/Exam	Dept. of Labor & Industry	651-284-5889
Advisory Council Wells and Boring	EH	651-201-4600
Agriculture, MN Dept. (general)	Agriculture	651-201-6000
Food Inspection	Agriculture	651-201-6027
Consumer Info.	Agriculture	1-800-535-4555
Agriculture, Plant/Poison Ivy Info.	U of M	612-625-1915
Aging, MN Board	Board	651-431-2500 or 1-800-882-6262

AIDS Case Reports/Sci. Info.	IDEPC	651-201-5414 or 1-877-676-5414
AIDS Hotline	AIDSLINE	612-373-2437 or 1-800-248-2437
AIDS Prevention Programs	IDEPC	651-201-5414 or 1-877-676-5414
Air Cleaners	EH	651-201-4601
Air Contaminants Complaints	MPCA	651-266-8989 (St. Paul) 651-296-7300 (Minneapolis)
Air Pollution (Asbestos)	MPCA	651-296-6300
Complaints	MPCA	651-296-7300
Formaldehyde	EH	651-201-4601
Clean Indoor Air Act	EH	651-201-4601
Indoor Air	EH	651-201-4601
Minn Complaints - Industrial	MPCA	651-296-7300
MN - Private Homes	EH	651-201-4620
Alcohol/Drug Abuse Counselors/Licensing		612-617-2178
Alcohol and Drug Abuse Division of DHS	DHS	651-431-2460
Alcohol/Drug Abuse Prevention	HPCD	651-201-5496
Alcohol/Drug Testing in Workplace	Labor Standards	651-284-5005
Alcohol Exposed Pregnancy	CFH	651-201-3753
Alternative Health Care Practice	Health Policy	651-201-3728
Alternative Medicine	Health Policy	651-201-3728
Alzheimer Association		952-830-0512 or 1-800-232-0851
Ambulance	EMS Board	651-201-2801
Amebiasis	IDEPC	651-201-5414 or 1-877-676-5414
Animal Bites	IDEPC	651-201-5414 or 1-877-676-5414
Animal Board of Health	Department of Agriculture	651-296-2942
Animal Control, St. Paul Only (others, refer to your city)	City	651-645-3953
Annex, Metro Square	DLC	651-215-0460

Anthrax	IDEPC	651-201-5414 or 1-877-676-5414
Apartment Complaints/Inspections	City Hall	City Inspector
Apartment/Landlord Complaints	Tenants Union	651-221-0501 (St. Paul) 612-673-3003 (Minneapolis)
Arsenic (private well water)	Well Management	651-201-4600
Arsenic (public water supply)	Drinking Water Protection	651-201-4700
Arthritis	HPCD	651-201-5659
Asbestos Abatement	EH	651-201-4620
Asbestos Contractor	EH	651-201-4620
Asbestos Health Questions	EH	651-201-4620
Asbestos in the Home	EH	651-201-4620
Asbestos in the Workplace	MNOSHA	651-284-5054
Assistance Paying for Medical Treatment	MCS	651-201-5100
Assisted Living	Health Regulation	651-201-4101
Asthma	HPCD	651-201-5909
Athletic Trainer	Med. Prac. Bd.	612-617-2130
Attorney General, Office of	AG's Office	651-296-3353
Audiologists	HOP	651-201-3726
Babesiosis	IDEPC	651-201-5414 or 1-877-676-5414
Background Checks (nursing homes)	Health Regulation	651-201-4101
Bacteria (general nonspecific bacteria)	IDEPC	651-201-5414 or 1-877-676-5414
Beaches	EH	651-201-4500
Behavioral Risk Factor Surveillance Survey	Center for Health Statistics	651-201-5996
Bicycle Helmet Evaluation	HPCD	651-201-5484 or 651-201-5440
Bioterrorism	IDEPC	651-201-5414 or 1-877-676-5414
Bird Droppings	IDEPC	651-201-5414 or 1-877-676-5414
Birth Certificates	Office of Vital Records--from	651-201-5980

	1900 to present can be made at all local registrar offices in Minn. Birth certificates before 1900 can be obtained from the local registrar office in the county where the birth occurred.	
Born in Ramsey County	Ramsey County	651-266-1333
Birth Control	CFH	651-201-3743
Birth / Death Statistics	CHD	651-201-3504
Birth Defects Information Systems	EH	651-201-4899
Blastomycosis (lung or skin lesions)	IDEPC	651-201-5414 or 1-877-676-5414
Blind, Services for the	Economic Security	651-642-0500
Bloodborne Pathogens (work place)	OSHA	651-296-2116
Blood banks, complaints	FDA/Minneapolis	612-334-4100 Extension 184
Blood banks, regulation	FDA/Minneapolis	612-334-4100 Extension 239
Blood Pressure Control	HPCD	651-201-5411
Blood Testing, Premarital	PHL	651-201-5200
Blue-Green Algae Toxicity	EH	651-201-4906
Boat Toilets	DNR	651-296-6157
Body Art Establishment	HOP	651-201-3770
Boiler Operators License	Labor and Industry	651-284-5080
Bone Density Scanning (Sliding Fee Scale)	Neighborhood Health Care Network (Ramsey & Hennepin Counties	651-489-2273
Bone Marrow Donor Education Program		Refer people to Red Cross 651-291-6789
Botulism	IDEPC	651-201-5414 or 1-877-676-

		5414
Borrelia burgdorferi (Lyme disease)	IDEPC	651-201-5414 or 1-877-676-5414
Breast/Cervical Cancer	HPCD	651-201-5600
Breastfeeding Coordinator	CFH	651-201-4406
Brucellosis	IDEPC	651-201-5414 or 1-877-676-5414
Bugs	IDEPC	651-201-5414 or 1-877-676-5414
Business Licensing Office, Small	Trade and Economic Development	651-296-5023
CMV (Cytomegalovirus)	IDEPC	651-201-5414 or 1-877-676-5414
Campgrounds	EH	651-201-4500
Campylobacter	IDEPC	651-201-5414 or 1-877-676-5414
Cancer Control	HPCD	651-201-5600 or 1-888-643-2584
Cancer Statistics, Deaths	Cntr Hlth Statistics	651-201-3504
Cancer Surveillance, Reported Cases	MCSS	651-201-5900
Carbon Dioxide Detectors	EH	651-201-4601
Carbon Monoxide, Cars/traffic	MPCA	651-296-6300
Carbon Monoxide, Poisoning-Indoors	EH	651-201-4601
Case Mix Review	Health Regulation	651-201-4301
Cat-scratch disease (*Bartonella*)	IDEPC	651-201-5414 or 1-877-676-5414
Catch Three Program (kids/teens)	DHS	651-296-1723
Center for Health Promotion	HPCD	651-201-5400
Certificates of Free Sale	Agriculture	651-201-6630
Certificate of Need	HEP	651-201-3576
Chemical Abuse	DHS	651-582-1832
Chemical Dependency Counselor, Licensing		612-617-2178
Chemical Exposure-Non-workplace	EH	651-201-4899

Chemical, Physical, Infections Employee Hazardous Materials Hotline	International Poison Center	1-800-222-1222
Chancroid (*Hemophilus parvum)*	IDEPC	651-201-5414 or 1-877-676-5414
Chickenpox	IDEPC	651-201-5414 or 1-877-676-5414
Chiggers	IDEPC	651-201-5414 or 1-877-676-5414
Child Abuse Prevention	DHS	651-296-2217
Child Care/School Health	CFH	651-201-3631
Child Health	CFH	651-201-3767
Child Health Screening	CFH	651-201-3734
Child Protection	DHS	651-431-2000
Child Safety Seat	Public Safety	651-215-9093
Child/Teen Checkup Training	CFH	651-201-3734
Children's Camps	EH	651-201-4500
Children's Health	CFH	651-201-3631
Children with Special Health Needs	CFH	651-201-3650 or 1-800-728-5420
Chiropractic Examiners Licensing	Board	651-201-2850
Chlamydia (*Chlamydia trachomatis*)	IDEPC	651-201-5414 or 1-877-676-5414
Chlamydia psittaci	IDEPC	651-201-5414 or 1-877-676-5414
Cholera (*Vibrio cholerae*)	IDEPC	651-201-5414 or 1-877-676-5414
Chronic Fatigue Syndrome	IDEPC	651-201-5414 or 1-877-676-5414
Clean Indoor Air Act	EH	651-201-4601
Clearinghouse	MCS	651-201-5178 or 1-800-657-3793
C.L.I.A., Clinical Lab Improvement Act	Health Regulation	651-201-4120
Clinic, Public Health	Ramsey County	651-292-7707
Rm 111 (AIDS/STD testing)	Ramsey County	651-266-1352
Clinic Referral, Services provided on sliding fee scale	Neighborhood Health Care Network	651-489-2273

Clinical Specimen Receiving	PHL	651-201-4953
CNA License (Copies of)		1-800-274-3444
Cobra	MCS	651-201-5178
Coccidioides (aka Cocci - lives in the sand in southern states, like Arizona)	IDEPC	651-201-5414 or 1-877-676-5414
Commodity Supplemental Food Program (CSFP)	CFH	651-201-4422
Compensated Care Reports	HEP	651-201-3550
Complementary & Alternative Health Care Practice	HPSC	651-201-3728
Comprehensive Health Care, MN	Blue Cross/Blue Shield	651-662-5290
Communications Office	CO	651-201-4989
Community and Family Health	CFH	651-201-3589
Congenital Rubella	IDEPC	651-201-5414 or 1-877-676-5414
Consumer Product Complaints & Information	Product Safety Commission	1-800-638-2772
Consumer Information	Attorney General's Office - Consumer Div.	651-296-3353
Contaminants, (Environmental) in air water, soil affecting health - First contact for the public with questions		651-201-4899
Convenience Store Licensing & Complaints	Agriculture	651-201-6027
Coordinated School Health	HPCD	651-201-5438
Cosmetology, Minn. Board of	Commerce	651-296-6319 or 1-800-657-3978
County Health Profiles	Library	651-201-5090
Cover Your Cough posters	IDEPC	available online only: Cover Your Cough
Coxsackie Virus	IDEPC	651-201-5414 or 1-877-676-5414
Crab Lice	IDEPC	651-201-5414 or 1-877-676-5414

Crematoriums, Licensing	Mortuary Science	651-201-3829
Creutzfeldt Jakob Disease	IDEPC	651-201-5414 or 1-877-676-5414
Cryptosporidium	IDEPC	651-201-5414 or 1-877-676-5414
Day Care	DHS	651-296-3971
Dakota County (day care, child support)	County	651-891-7400
Dakota County (food stamps, welfare)	County	651-554-5611
Dead Birds Reporting (West Nile)	IDEPC	651-201-5414/1-877-676-5414
Deaf and Hard of Hearing Services	DHS	651-431-5940 1-888-206-6513 TTY
Death Certificates	Office of Vital Records-Death Certificates- From 1997 to present also are available at all local registrar offices in the state. For deaths that occurred before 1997, records are available from MDH and the local registrar in the county where the death occurred.	651-201-5980
Death Statistics	Cntr Hlth Statistics	651-201-3504
Deaths (unexplained)	IDEPC	651-201-5414 or 1-877-676-5414
Dengue	IDEPC	651-201-5414 or 1-877-676-5414
Dental Assoc of MN	Dental Assoc	651-646-7454
Dentist, Hygienist & Assistant	Dentistry Board	612-617-2250
Diabetes - American Diabetes Assoc - International Diabetes Center	HPCD	651-201-5409 612-593-5333, or 1-800-342-2383 (MN only) 612-993-3393
Diarrhea	IDEPC	651-201-5414 or 1-877-676-5414

Dietitians Info.	HPCD MN Dietetics Assc	651-201-5493, or 651-628-9250
Dietitians Licensing	MN Dietetics Board	612-617-2175
Diphyllobothrium (intestinal tapeworm infections of long duration)	IDEPC	651-201-5414 or 1-877-676-5414
Diphtheria	IDEPC	651-201-5414 or 1-877-676-5414
Diseases, Illnesses, Viruses - Communicable	IDEPC	651-201-5414 or 1-877-676-5414
Disposing of Needles	MPCA	651-296-6300
Disqualified Workers Calls	OHFC	651-201-4208
DNA testing (Paternity)	Memorial Blood Center	612-871-3300
Divorce Decree Certificate	County Offices	Contact county office where divorce was granted
Doctors, Physicians Assistants	Med. Prac. Bd.	612-617-2130
Domestic Abuse	MN Center for Crime Victims Services	651-201-7300
Donor Cards	Red Cross	651-291-4654
Doula Registry	Health Regulation	651-201-3728
Drinking Water Supply, Public	EH	651-201-4700
Drug Prevention Education	HPCD	651-201-5496
Drug Program for Seniors (Senior Linkage Line)	DHS	1-800-333-2433
Ebola	IDEPC	651-201-5414 or 1-877-676-5414
Education, Department of		651-582-8200
Ehrlichiosis	IDEPC	651-201-5414 or 1-877-676-5414
Electrology Specialists	Cosmetology Bd.	651-296-6319
Emergency Medical Services	EMS Board	612-627-6000
Emergency Operations phone number	OEP	click here for emergency phone number
Emergency Preparedness		651-201-5700
Employee Relations, Dept. of	DOER	651-297-1184
Job Line	DOER	651-296-2616

Employment Verification	HR	651-201-5770
EMT Training Programs	EMS Board	651-201-2801 or 1-800-747-2011
Encephalitis	IDEPC	651-201-5414 or 1-877-676-5414
Enterococcus	IDEPC	651-201-5414 or 1-877-676-5414
Environmental Health	EH	651-201-4570
Environmental Health Specialists/Sanitarians	EH	651-201-4500
Environmental Sample Receiving	PHL	651-201-4952
Epidemiology	IDEPC	651-201-5414 or 1-877-676-5414
Epiglottitis	IDEPC	651-201-5414 or 1-877-676-5414
Epstein-Bar Virus (mononucleosis)	IDEPC	651-201-5414 or 1-877-676-5414
Escherichia coli O157:H7 (E.coli)	IDEPC	651-201-5414 or 1-877-676-5414
Essential Community Providers	HPSC	651-282-5601 or 1-800-657-3916
Family Health	CFH	651-201-3589
Family Health Epidemiology	CFH	651-201-3629
Family Home Visiting Program	CFH	651-201-3741
Family Medical Leave Act(FMLA)	DOER Insurance Program	651-296-2457
Family Planning	CFH	651-201-3743
Father's Adoption Registry	Office of Vital Records	651-201-5994 or 1-888-345-1726
Fifth Disease	IDEPC	651-201-5414 or 1-877-676-5414
Financial Aid	Higher Ed. Bd.	651-642-0538
Payment Questions	Financial Mgmt.	651-201-5224
Prof./Tech./Contractural Grant Serv.	Financial Mgmt.	651-201-5238
Teletype for Deaf & Hearing Impaired	OLF Reception Area	651-201-5897
First Aid Training/Certification	Red Cross	651-291-6704

First Call For Help, for Ramsey, Washington, Dakota Information/Referrals	United Way	651-224-1133
First Call For Help, for Anoka, Hennepin, Carver, Scott Information/ Referrals	United Way	612-335-5000
First Responder	EMS Board	612-627-6000 or 1-800-747-2011
Fish - Environment Contamination	EH	651-201-4899
Fishing Advisories	EH	651-201-4899
Fleas, Lice, etc.	IDEPC	651-201-5414 or 1-877-676-5414
Flu	IDEPC	651-201-5414 or 1-877-676-5414
Flu Shots	IDEPC	651-201-5504
Fluoridation	EH	651-201-4678
Follow Along Program (MN Children with Special Health Needs)	CFH	651-201-3644
Food Complaints, bought in grocery stores	Agriculture	651-201-6027 Call if store resides in Hopkins, Edina, Richfield, Golden Valley, Maplewood; otherwise contact city or county health dept. Moorhead and St. Cloud contact city health dept.
Food Compliance Division (questions on what gets tested where and how often)	Agriculture	651-201-6027
Food, Beverage and Lodging (Food Stands/Concession) Establishments Licensing and Complaints	EH	651-201-4500
Food and Drug Admin.	FDA	612-334-4100
Food Equipment	EH	651-201-4500
Food Irradiation, Food Safety Center	EH	651-201-4500 651-201-8980 TTY
Food Managers	EH	651-201-4500 651-201-0843
Food Poisoning	IDEPC	651-201-5414 or 1-877-676-5414

Food Sanitation (Inspection)	EH	651-201-4500
Food Stamps	County Social Service	County Social Service Office in county they live in
Food Testing - Lab	Agriculture	651-201-6010
Foodborne Illness Hotline	IDEPC	1-877-FOOD-ILL (1-877-366-3455), when calling from Minnesota
Foreign Travel Immunization Info.	IDEPC	612-676-5588 Touch Tone 612-676-5237 Rotary
Formaldehyde	EH	651-201-4601
"Freedom to Breathe" Act	EH	651-201-4601
Funeral Homes/Morticians	Mortuary Science	651-201-3829
Garbage Complaints - Twin Cities metro		Contact local government office.
Garbage Complaints - outside Twin Cities metro	MPCA	507-344-5243
Garbage, Licensed Establishments, Restaurants	EH	651-201-4500
Genetic/Hereditary Disease	HPCD	612-676-5268
Giardiasis	IDEPC	651-201-5414 or 1-877-676-5414
Gonorrhea	IDEPC	651-201-5414 or 1-877-676-5414
Grocery Stores, Bakeries, Meat	Agriculture	651-201-6027
Groundwater	EH	651-201-4600
Haemophilus influenzae (Hib)	IDEPC	651-201-5414 or 1-877-676-5414
Hand, foot and mouth disease (Coxsackie virus)	IDEPC	651-201-5414 or 1-877-676-5414
Hand Washing Signs, Requests/Complaints	EH	651-201-4500
Handicapped Access Bathrooms in Homes	Building Codes	651-296-4633
Handicapped, Council for the	Council	651-296-6785
Handicapped Parking Permits	MN DPS	651-296-6911
Hansen's Disease (leprosy)	IDEPC	651-201-5414 or 1-877-676-5414
Hantavirus	IDEPC	651-201-5414 or 1-877-676-

		5414
Hardship Waiver	DHS	651-582-1936
Hazardous Waster Community Relations	EH	651-201-4897
Hazardous Waste Disposal, Home, Twin Cities metro		Contact local government office.
Hazardous Waste Disposal, Home, outside Twin Cities metro	MPCA	651-344-2801
Hazardous Waste Disposal, Business, Twin Cities metro		Contact local government office.
Hazardous Waste Disposal, Business, outside Twin Cities metro	MPCA	507-344-5243
Hazardous Waste Sites	EH	651-201-4899
Head lice	IDEPC	651-201-5414 or 1-877-676-5414
Health Alert Network	IDEPC	651-201-5735
Health Care Directive Forms	Board on Aging	651-431-2500 or 1-800-882-6262
Health Care Facilities Complaints	Health Regulation	651-201-4201 or 1-800-369-7994
Health Care Facilities Licensing & Regulations	Health Regulation	651-201-4101
Health Care & Health Practices (Alternative Care)	Health Policy	651-282-5601
Health Economics	HEP	651-201-3550
Health Insurance Consumer Information	MCS	651-201-5178
Health Occupations Program	HOP	651-201-3731
Health Professional Shortage Area (HPSA)	CFH	651-201-3860
Health, Ethnic and Racial Disparities	OMMH	651-201-5813
Healthy People 2000	CFH	651-201-3873
Hearing (newborns)	CFH	651-201-3750
Hearing & Vision Screening	CFH	651-201-3762
Hearing Instrument Dispenser	HOP	651-201-3724
Helicobacter pylori	IDEPC	651-201-5414 or 1-877-676-5414

Hemolytic uremic syndrome (HUS)	IDEPC	651-201-5414 or 1-877-676-5414
Hemophilia	IDEPC	651-201-5414 or 1-877-676-5414
Hepatitis	IDEPC	651-201-5414 or 1-877-676-5414
Hennepin County Public Health		612-348-3000
Herpes (oral, genital)	IDEPC	651-201-5414 or 1-877-676-5414
Herpes zoster	IDEPC	651-201-5414 or 1-877-676-5414
High Blood Pressure	HPCD	651-201-5411
Higher Education Board	Board	651-642-0538
HIPPA (Health Insurance Portability and Accountability Act)	HPSI	651-201-3573
Histoplasmosis (bird/bat droppings)	IDEPC	651-201-5414 or 1-877-676-5414
HMO Complaints	MCS	651-201-5100 1-800-657-3916
Home Care Complaints	Health Regulation	651-201-4201 or 1-800-369-7994
Home Care Licensing	Health Regulation	651-201-5273
Home Schooling	Education	651-582-8200
Hospital Complaints	Health Regulation	651-201-4201 or 1-800-369-7994
Hospital Rate Review	DHS	651-431-2531
Hospital/Surgical Center/Diagnostic Imaging Financial and Services Info.	DAP	651-201-3575
Hotels/Motels	EH	651-201-4500
Housing Complaints	City Hall	
Housing With Services	Health Regulation	651-201-4101
HPSA (Health Professional Shortage Area)	CFH	201-201-3860
Human Resources, MDH	HR	651-201-5770
Human Services, MN Dept. of	DHS	651-431-2000
HUS (hemolytic uremic syndrome)	IDEPC	651-201-5414 or 1-877-676-

		5414
Immigration Information	Info Line	612-854-7754
Immunizations/Vaccines - Immunization Hotline (clinic vaccine orders for children) - Travel, International	IDEPC	651-201-5414 or 1-877-676-5414 651-201-5414 or 651-201-5513
Impetigo	IDEPC	651-201-5414 or 1-877-676-5414
Indoor Air Quality Business Homes & Schools	OSHA- Labor & Industry EH	651-284-5000 651-201-4601 1-800-798-9050
Industrial Hygienist, Licensing	OSHA	651-296-9799
Infant and Child Health	CFH	651-201-3734
Infant Mortality	CFH	651-201-3740
Infectious Diseases	IDEPC	651-201-5414 or 1-877-676-5414
Information Assistance	CFH	651-201-3650 1-800-728-5420
"Follow Along Program"	CFH	651-201-3644
"Medical Home Project"	CFH	651-201-3653
"Part C Early Intervention / Identification"	CFH	651-201-3641
Influenza	IDEPC	651-201-5414 or 1-877-676-5414
INH	IDEPC	651-201-5414 or 1-877-676-5414
Injury & Violence Prevention	HPCD	651-201-5484, or 651-201-5440
Inorganic Chemistry	PHL	651-201-5300
International Travel Information		1-877-394-8747
Insurance Companies, Regulation of	Commerce	651-296-2488 or 1-800-657-3602
Insurance Complaints (self-insured)	U.S. Dept of Labor	866-444-3272
Insurance Complaints (fully insured HMOs)	HPSC - Managed Care	651-201-5100
Irradiation of Food - Information	EH	651-201-4500

J1 Visa	CFH	651-201-3851
Kawasaki syndrome	IDEPC	651-201-5414 or 1-877-676-5414
Labor and Industry, Minn. Dept. of	Labor & Industry	651-284-5000
Labor Standards, Policy Questions	Labor & Industry	651-284-5005
Fee Employment Agencies	Labor & Industry	651-284-5050
Hotline	Labor & Industry	1-800-342-5354
Investigative Services	Labor & Industry	651-297-5797
Minimum Wage	Labor & Industry	651-284-5075
Occupation Safety Health	Labor & Industry	651-284-5050
Worker's Compensation	Labor & Industry	651-284-5005
Laboratories, Environmental Accreditation	PHL	651-201-5200
Asbestos	PHL	651-201-5302
Inorganic Chemistry	PHL	651-201-5300
Metals	PHL	651-201-5353
Organic Chemistry	PHL	651-201-5300
Water Microbiology	PHL	651-201-5300
Radiation	PHL	651-201-5353
Laboratories, Clinical	PHL	651-201-5200
Microbiology	PHL	651-201-5073
Enteric	PHL	651-201-5048
Tuberculosis	PHL	651-201-5053
Rabies	PHL	651-201-5254
Virus/ Immunology	PHL	651-201-5248
Landfills	MPCA	651-296-6300
Lead Abatement	EH	651-201-4620
Lead in People	EH	651-201-4620
Lead in water	EH	651-201-4700
Lead Testing, Home Visits	EH	651-201-4620
Legionellosis (Legionnaire's Disease)	IDEPC	651-201-5414 or 1-877-676-5414
Leishmaniasis	IDEPC	651-201-5414 or 1-877-676-5414
Leprosy (Hansen's disease)	IDEPC	651-201-5414 or 1-877-676-

		5414
Leptospirosis	IDEPC	651-201-5414 or 1-877-676-5414
Library	MDH Library	651-201-5090 Fax 651-201-3980
Lice, Fleas, Ticks Etc.	IDEPC	651-201-5414
Listeria	IDEPC	651-201-5414 or 1-877-676-5414
Living Will	Board on Aging	651-431-2500 or 1-800-882-6262
Loan Forgiveness	CFH	651-201-3870
Local Public Health	CFH	651-201-3880
Local Water Plans	EH	651-201-4700
Lyme Disease	IDEPC	651-201-5414 or 1-877-676-5414
Mad Cow Disease (BSE,CJD)	IDEPC	651-201-5414 or 1-877-676-5414
Malpractice	Med. Prac. Board	612-617-2130
Malaria	IDEPC	651-201-5414 or 1-877-676-5414
Mammograms, Information	HPCD	1-888-643-2584
Mammograms, Free	American Cancer Society	1-800-227-2345
Managed Care Brochures	MCS	651-201-5178
Managed Care Systems	MCS	651-201-5100
Mantoux Testing	IDEPC	651-201-5414 or 1-877-676-5414
Mantoux Testing (home health care requirements)	Health Regulation	651-201-5273
Manufactured Home Parks	EH	651-201-4500
Marriage, Board of	Board	612-617-2220
Marriage and Family Therapy Licensing	Board on Marriage	612-617-2220
Marriage Licenses	County Courthouse	County Courthouse
Marriage License Information - Searches	County Courthouse	County Courthouse
Massage Therapists	City/County	City/County

Maternal and Child Health	CFH	651-201-3760
Maternal and Child Health Advisory Force	CFH	651-201-3874
Mattress Resale	Attorney General's/Consumer Div.	651-296-3353
Measles, Mumps	IDEPC	651-201-5414 or 1-877-676-5414
Metals	PHL	651-201-5364
Media Inquiries, relating to health	Communications	651-201-4989
Medicaid/Medicare	DHS	651-431-2000
Medical Assistance	DHS	651-431-2000
Medical Home (MN Children with Special Health Needs)	CFH	651-201-3653
Medical Practice Licensing	Med. Prac. Board	612-617-2130
Medical Records	MCS	651-201-5178
Medical Administration in Schools	CFH	651-201-3631
Medication Aids	FPC	651-201-4127
Meningitis	IDEPC	651-201-5414 or 1-877-676-5414
Meningococcemia	IDEPC	651-201-5414 or 1-877-676-5414
Mental Health Practitioner, Unlicensed & Complaints	HOP	612-617-2100 or 1-800-657-3959
MERC	HPSC	651-201-3566
Meth Labs	EH	651-201-4899
Midwives, Certified Nurse	Board of Nursing	612-317-3000
MN Adverse Health Care Events Reporting Act (Bill 1019)	HPSI	651-201-3564
Minneapolis City Health Dept	Dept of Hlth & Family Support	612-673-2301
Minor Consent (Health care)	CFH	651-201-3627
Minority & Multicultural Health, Office of	MDH	651-201-5813
Minority Statistics	Center Health Statistics	651-201-5954

MN Board on Aging		651-431-2500 or 1-800-882-6262
MN Bookstore		651-297-3000 or 1-800-657-3757
MN Care	DHS	651-297-3862 or 1-800-657-3672
MN Department of Health, General Information	MDH	651-201-5000 or 1-888-345-0823
MN ENABL	CFH	651-201-3752
MN Family Independent Program (MFIP) Welfare Reform	Center Health Statistics	651-296-5831
MN Pregnancy Risk Assessment Provider Help Desk (Providers)	DHS	651-431-2700 or 1-800-366-5411 - For order forms that doctors fill out for Medical Assistance, call 651-296-9116
MN Pregnancy Assessment Form (Recipients)	DHS	651-296-7615 or 1-800-657-3739
MN Student Survey	Department of Education	651-582-8403
MN Psychological Assoc	Psychological Assoc	651-697-0440
MN Tobacco Help Line		1-877-270-7867
Mobile Home Parks	EH	651-201-4500
Mold/Moisture	EH	651-201-4601
Monkey bites	IDEPC	651-201-5414 or 1-877-676-5414
Mononucleosis	IDEPC	651-201-5414 or 1-877-676-5414
Mother's and Children (MAC)	CFH	651-484-8241 or 1-800-365-0270
Mortuary Science	HPSC	651-201-3829
MRSA (methicillin-resistant *Staphylococcus aureus*)	IDEPC	651-201-5414 or 1-877-676-5414
Mumps	IDEPC	651-201-5414 or 1-877-676-5414
Mycobacteria	IDEPC	651-201-5414 or 1-877-676-

		5414
Necrotizing fasciitis (flesh-eating disease)	IDEPC	651-201-5414 or 1-877-676-5414
Needle Disposal	MPCA	651-296-6300
Net Study (Background Checks)	DHS	651-296-3971
Newborn Screening	PHL	651-201-5466
No Smoking Law	EH	651-201-4601
Norwalk virus	IDEPC	651-201-5414 or 1-877-676-5414
Nursing Assistant Registry	Health Regulation	651-215-8705 or 1-800-397-6124
Nursing Home Administration License	Administration	651-201-2731
Nursing Home Facilities Complaints	Health Regulation	651-201-4201 or 1-800-369-7994
Nursing Home Facilities Licensing	Health Regulation	651-201-4101
Nursing, RN/LPN, Licensing	Board of Nursing	612-317-3000
Nutrition	HPCD	651-201-5440
Nutrition Assistance Program for Seniors (NAPS)	HPCD	651-201-4422
Nutritionist Licensing	Dietetics	612-617-2175
Oasis Project/Help Desk	Health Regulation	651-201-3818 or 1-800-657-3879
Occupational Therapists Licensing	HOP	651-201-3725
Office of Ombudsman for Older Minnesotans		651-431-2555 or 1-800-657-3591 Fax: 651-431-7452
Ophthalmologist	Med. Prac. Board	612-617-2130
Optometry Licensing	Board	612-617-2173
Organic Chemistry	PHL	651-201-5300
OSHA (St. Paul)		651-284-5050
Osteopath	Med. Prac. Board	612-617-2156
Paramedics	EMS Board	612-627-6000 or 1-800-747-2011
Parasites/parasitology	IDEPC	651-201-5414 or 1-877-676-5414
Parvovirus (Fifth Disease)	IDEPC	651-201-5414 or 1-877-676-

		5414
Part C Early Intervention/Identification (MN Children with Special Health Needs)	CFH	651-201-3641
Passports	Ramsey County	651-266-1333
Patient's Bill of Rights	Health Regulation	651-201-4101 (Web site)
Payments Questions	Financial Management	651-201-5224
Personal Care Assistant	DHS	651-431-2700
Pertussis (Whopping Cough)	IDEPC	651-201-5414 or 1-877-676-5414
Pesticides-spills, groundwater, fire	MPCA	651-296-6121
Pharmacy Licensing	Pharm. Board	651-201-2825
Physical Therapists	Med. Prac. Board	612-627-5406
Physician Assistants	Med. Prac. Board	612-617-2146
Pinkeye	IDEPC	651-201-5414 or 1-877-676-5414
Pinworms	IDEPC	651-201-5414 or 1-877-676-5414
PKU Testing/Results	PHL	651-201-5466
Plumbers/Plumbing, Exams/Licensing	Dept. of Labor & Industry	651-284-5067
Pneumonia	IDEPC	651-201-5414 or 1-877-676-5414
Podiatric Medicine Licensing	Board	612-617-2200
Poison Control	Minnesota Poison Control System	1-800-222-1222
Poliomyelitis	IDEPC	651-201-5414 or 1-877-676-5414
Positive Alternatives	CFH	651-201-3581
Power of Attorney for Health Form	U of M	612-625-4270
PPD	IDEPC	651-201-5414 or 1-877-676-5414
PRAMS	CFH	651-201-5941
Prescription Drugs	HEP	651-201-5178
Prison, Health Inspections	EH	651-201-4500
Prof./Tech./Contractural Grant Serv.	Financial	651-201-5238

	Management	
Psittacosis (from bird droppings)	IDEPC	651-201-5414 or 1-877-676-5414
Psychology Licensing	Board of Psych.	612-617-2230
Public Health Laboratory	PHL	651-201-5200
Purchasing - Solicitation/Bid, Responding to	Financial Mgmt.	651-201-4640
Q Fever	IDEPC	651-201-5414 or 1-877-676-5414
Rabies	IDEPC	651-201-5414 or 1-877-676-5414
Rabies Laboratory	PHL	651-201-5414 or 1-877-676-5414
Radiation, general questions	EH	651-201-4545
Radiation, transportation	EH	651-201-4545
(Irradiation of Food)	EH	651-201-4545
Radon	EH	651-201-4601
Radiologic Technologists	EH	651-201-4545
Ramsey County (child support)	County	651-266-3344
Ramsey County (daycare, food stamps)	County	651-266-4444
Ramsey County Public Health	50 W Kellogg (Can pick b/d cert. from 1935 to present at front desk.) 555 Cedar St	651-266-1333 651-266-1200
Rash illness	IDEPC	651-201-5414 or 1-877-676-5414
Recognition of Parentage	Health Policy	651-201-5961
Refugee Health	IDEPC	651-201-5414 or 1-877-676-5414
Reporting, by doctors of disease	IDEPC	651-201-5414 or 1-877-676-5414
Respiratory Care Practitioner	Med. Prac. Board	612-617-2146
Reye's Syndrome	IDEPC	651-201-5414 or 1-877-676-5414

Rheumatic fever	IDEPC	651-201-5414 or 1-877-676-5414
Ring worm	IDEPC	651-201-5414 or 1-877-676-5414
Rocky Mountain Spotted Fever	IDEPC	651-201-5414 or 1-877-676-5414
Rotavirus	IDEPC	651-201-5414 or 1-877-676-5414
Round worm	IDEPC	651-201-5414 or 1-877-676-5414
Room 111	Clinic	651-266-1352
RSV (respiratory virus)	IDEPC	651-201-5414 or 1-877-676-5414
Rubella	IDEPC	651-201-5414 or 1-877-676-5414
Rural Health	CFH	651-201-3838
(RHAC) Rural Health Advisory Committee	CFH	651-201-3853
Rural Health Grants	CFH	651-201-3842
STDs (sexually transmitted diseases)	IDEPC	651-201-5414 or 1-877-676-5414
Sage Screening	HPCD	1-888-643-2584
Salmonellosis (Salmonella)	IDEPC	651-201-5414 or 1-877-676-5414
Satellite Conference Info.	DLC	651-296-9006
Scabies	IDEPC	651-201-5414 or 1-877-676-5414
Scarlet fever	IDEPC	651-201-5414 or 1-877-676-5414
School Cafeteria, Complaints/Plan Review	EH	651-201-4500
School Readiness Update Program	CFH	651-201-3767
School Health Services	CFH	651-201-3631
Scoliosis	CFH	651-201-3734
Senior Linkage Line (Drug Program for Seniors)	DHS	1-800-333-2433
Septic System Disclosure	MPCA	651-296-6300

Septic Tanks Plan Review	MPCA	651-296-6300
Sewage Disposal Plans	MPCA	651-296-6300
Sexual Violence Prevention	HPCD	651-201-5483
Sexually Transmitted Disease (STD)	IDEPC	651-201-5414 or 1-877-676-5414
Report Cards	IDEPC	651-201-5414 or 1-877-676-5414
STD/Family Planning Hotline		1-800-783-2287
Shaken Baby Syndrome	CFH	651-201-3740
Shigellosis	IDEPC	651-201-5414 or 1-877-676-5414
Shingles (Chickenpox, Herpes Zoster)	IDEPC	651-201-5414
SHIP (Statewide Health Improvement Program)	OSHII	651-201-5443
Sick Building Syndrome	EH	651-201-4601
SIDS (Sudden Infant Death Syndrome)	CFH	651-201-3740
Smallpox	IDEPC	651-201-5414 or 1-877-676-5414
Smoke Detectors (Radiation Hazards)	EH	651-201-4545
Smoking (Nonsmoking) Programs	Tobacco Prevention & Control	651-201-3535
Social Security	Administration	1-800-772-1213
Social Worker	Board ,Social Work	612-617-2100
Speech Language Pathologist	HOP	651-201-3726
Spider bites	IDEPC	651-201-5414 or 1-877-676-5414
Stachybotrys (mold)	IDEPC	651-201-5414 or 1-877-676-5414
Staphylococcal aureus (staph-skin lesions, boils, infected lacerations	IDEPC	651-201-5414 or 1-877-676-5414
Strep Group A, B	IDEPC	651-201-5414 or 1-877-676-5414
Substance Abuse Prevention	HPCD	651-201-5496
Swimming Pool Complaints/Licensed	EH	651-201-4500
Swimming Pool Reg/Construction (Hot Tubs/Whirlpools)	EH	651-201-4500

Sterilization, of equipment	OSHA	651-296-2116
Suicide Prevention and Information	Crisis Connection	612-379-6363
Supplemental Nutrition Programs (WIC & CSFP)	CFH	651-201-4444
Swimmer's itch	IDEPC	651-201-5414 or 1-877-676-5414
Syphilis	IDEPC	651-201-5414 or 1-877-676-5414
Syringe Disposal	MPCA	651-296-6300
Tanning	Minneapolis St. Paul	612-676-2170 651-266-9090
Tanning Beds	City/County or FDA	
Tapeworm	IDEPC	651-201-5414 or 1-877-676-5414
Tattoo Technician and Piercer Technician	HOP	651-201-3770
TEFRA	DHS	651-296-2527
Teletype for Deaf & Hearing Impaired	OLF Reception Area	651-201-5897
Tenants Union	Union	651-221-0501 St. Paul 612-673-3003 Minneapolis
Tetanus	IDEPC	651-201-5414 or 1-877-676-5414
Ticks	IDEPC	651-201-5414 or 1-877-676-5414
Tobacco Use Prevention	Tobacco Prevention & Control	651-201-3535
Toxic Shock Syndrome	IDEPC	651-201-5414 or 1-877-676-5414
Toxoplasmosis	IDEPC	651-201-5414 or 1-877-676-5414
Trained Medication Aides	Health Regulation	651-201-4127
Training Video (Provider Enrollment)		651-285-5545
Travel Immunizations	IDEPC & CDC	651-201-5513 1-877-394-8747
Trauma Systems	CFH	651-201-3868

Trichinosis	IDEPC	651-201-5414 or 1-877-676-5414
Tuberculosis (TB)	IDEPC	651-201-5414 or 1-877-676-5414
Tularemia	IDEPC	651-201-5414 or 1-877-676-5414
Typhoid fever	IDEPC	651-201-5414 or 1-877-676-5414
Typhus	IDEPC	651-201-5414 or 1-877-676-5414
UCare		612-676-6500
Unemployment Benefits	Economic Security	651-296-3644
Uncompensated Care Reports	HOP	651-201-3550
U.S. Health & Human Serv.(Wash. D.C.)		202-619-0257 or 1-877-696-6775
VAERS (vaccine adverse events reporting)	IDEPC	651-201-5414 or 1-877-676-5414
Vaccinations/International Travel	IDEPC	651-201-5414 or 1-877-676-5414
Vancomycin-resistant enterococci (VRE)	IDEPC	651-201-5414 or 1-877-676-5414
Venereal Diseases	IDEPC	651-201-5414 or 1-877-676-5414
Veterinarian	Vet Board	612-617-2170
Video Conferencing Info.	DLC	651-215-0460
Video Tapes, Requesting	Library	651-201-5090
Violence, Youth		1-866-723-3968
Virus/Immunology	PHL	651-201-5248
Vision and Hearing	CFH	651-201-3762
Vulnerable adults	DHS	651-297-3984
Warts, genital	IDEPC	651-201-5414 or 1-877-676-5414
Washington County	County	651-439-3220
Water Microbiology	PHL	651-201-5300
Water Softeners	Dept. of Labor & Industry	651-284-5889
Water Testing, for wells along river	EH	651-201-4700

drinking water	EH	651-201-4700
Water Testing for Lead & Copper	EH	651-201-4700
Water Testing for Municipal Water Supplies	EH	651-201-4700
Water Testing for Near Landfills	EH	651-201-4899
Water Testing for New Wells	EH	651-201-4600
Water Well/Drinking Water Testing	EH	651-201-4600
Wells	EH	651-201-4600
Wellhead Protection	EH	651-201-4700
West Nile	IDEPC	651-201-5414/1-877-676-5414
Whooping cough (pertussis)	IDEPC	651-201-5414 or 1-877-676-5414
WIC, Participants	CFH	651-201-4444
WIC, Vendor Licensing	CFH	651-215-9694
Women's Health	CFH	651-201-3760
Women's Right to Know	CFH	651-201-3580 or 1-888-234-1137
Workforce Data	CFH	651-201-3846
X-ray machines, certification	EH	651-201-4545
Yellow Fever	IDEPC	651-201-5414 or 1-877-676-5414
Yersiniosis	IDEPC	651-201-5414 or 1-877-676-5414

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Appendix J

Minnesota Department of Health Exam Application

MDH web site address to download exam:
http://www.health.state.mn.us/divs/eh/water/wateroperator/forms/opexamapp.pdf

Contact Information

Minnesota Department of Health (MDH)
Section of Drinking Water Protection
Certification Office
625 North Robert Street
P.O. Box 64975
St. Paul, MN 55164-0975

Mark Sloan – 651/201-4652
E-mail address: mark.sloan@health.state.mn.us

Noel Hansen –651/201-4690
E-mail address: noel.hansen@health.state.mn.us

Notes:

Section of Drinking Water Protection
P.O. Box 64975
St. Paul, Minnesota 55164-0975

Water Supply System Operator Exam Application

Receptionist: 651-201-4700
Certification Office: 651-201-4696 or 651-201-4652 Fax: 651-201-4701
TDD: 651-201-5797 ; Minnesota Relay Service (Greater MN): 1-800-627-3529

(Applicant Do Not Write in This Space)

Application Fee ____________________
Approved __________ Rejected __________
Deposit Date ____________________
Deposit Number ____________________
Examination Date ____________________
Examination Results P F
Certification Fee ____________________
Deposit Date ____________________
Deposit Number ____________________
Certificate Issued ____________________
Certificate Expires ____________________
Certificate Number ____________________

Read Instructions Carefully Before Completing Application

1. Application must be typewritten or printed in ink.
2. Answer all questions in full. Incomplete applications will not be processed, they will be returned to the submitter.
3. The application fee must accompany application. This fee does not include certificate issuance fee.
4. Check and money orders shall be made payable to **(Minnesota Department of Health)(MDH)**. Checks returned for nonpayment will be charged a $20 fee (M.S. 332.50, Subd.2).
5. All application fees are **non-refundable**.
6. Submit the application and correct fee in the enclosed envelope.
7. **Applications must be postmarked no later than 15 days prior to the exam date.**
8. Please read the enclosed Tennessen Warning about your rights regarding the information you provide in this application.

Indicate your choice of location and date.

Exam Location: ______________________________ **Exam Date:** ____________________

To be eligible to take a certification exam, you must have hands-on operation experience (See certification qualification rules on back page). Exam application fees are **nonrefundable** even if you are found to be ineligible. If you have any questions about your eligibility, contact the certification office.

PLEASE CHECK (T)THE TYPE OF EXAM YOU ARE APPLYING FOR.

☐	$32	Water Supply System Operator Class A (You must submit a copy of your current position description).	☐	$40	Reciprocity (You must submit a copy of your current certificate).
☐	$32	Water Supply System Operator Class B	☐	$32	Water Supply System Operator Class D
☐	$32	Water Supply System Operator Class C	☐	$32	Water Supply System Operator Class E

Last Name (print clearly or type)	First Name (print clearly or type)	Middle Initial
Home Mailing Address	City	State and Zip
Home Phone (include area code)	Work Phone (include area code)	Social Security Number
Your Current Employer		

Complete Other Side →

TENNESSEN WARNING

Under Minnesota Statutes, section 13.41, information you provide on this application is private data until the time you are licensed. Once you are licensed, the information becomes public data and will be part of the agency's permanent file.

You are not legally required to provide any of the requested information. Failure to provide the information, however, will result in the denial of your application. Submitting false information is grounds for denying your application or suspending, revoking, or taking other disciplinary action against your credential after it is issued.

While your application is pending, the information you submitted, except your name and address, will not be shared outside of the MDH except as authorized or required by law. In such cases, it may then be shared with other, including the Office of the Attorney General, the Minnesota Department of Revenue and persons contacted for purposes of verification or investigation. If the matter of your credentials becomes contested, the information you submitted in this application may become public. When you become credentialed all information in this application becomes public, except your social security number, which remains private.

EDUCATION

Circle last grade completed

1 2 3 4 5 6 7 8 9 10 11 Graduated or GED (High School Equivalency)

College or University (list separately)	Dates Attended	Major	Certificate or Degree Received (AA, BS, etc.)

Complete Other Side ➡

EXPERIENCE

List your Water and Wastewater operation experience. Give nature of duties and responsibilities.
(List Most Recent First)

1)

Employer: ____________________

System or Organization Name: ____________________

Position: ____________________

Supervisor Name: ____________________

Supervisor Phone #: (   ) ____________________

Describe Job Duties: ____________________

Length of Experience:

Hours Per Week ________

From: ____/________
Month Year

To: ____/________
Month Year

2)

Employer: ____________________

System or Organization Name: ____________________

Position: ____________________

Supervisor Name: ____________________

Supervisor Phone #: (   ) ____________________

Describe Job Duties: ____________________

Length of Experience:

Hours Per Week ________

From: ____/________
Month Year

To: ____/________
Month Year

3)

Employer: ____________________

System or Organization Name: ____________________

Position: ____________________

Supervisor Name: ____________________

Supervisor Phone #: (   ) ____________________

Describe Job Duties: ____________________

Length of Experience:

Hours Per Week ________

From: ____/________
Month Year

To: ____/________
Month Year

Do you need special testing accommodations such as a reader or sign language interpreter? YES NO

If yes, please specify. ____________________

I declare that all information provided is true and complete. I hereby acknowledge that I have read and understand the information above.

Date ____________________ Signature (Do not print) ____________________

Qualification Rules

9400.0700 CERTIFICATION OF SYSTEM AND FACILITY OPERATORS. ➡

This is only a short summary of the Water Supply System Operator qualifications. The complete Minnesota Water and Wastewater Treatment Operator Certification Rule is available on http://www.revisor.leg.state.mn.us/arule/9400 , or by calling the certification office.

Subp. 2. **Certification in particular class.** An applicant who seeks certification must:

A. meet the qualifications for one of the classes specified in this part and take and pass an exam; or

B. meet the requirements for reciprocity under part 9400.1350.

Class A certificate. An applicant for a Class A certificate must:

A. have been certified as a Class B operator for at least two years; and

B. have:

(1) a high school diploma or equivalent with at least eight years experience in the operation, including at least two years as a part of the management, of a Class A or B system or facility, or a similar industrial facility; or

(2) a bachelor's degree from an accredited institution in chemical, civil, environmental, mechanical, or sanitary engineering or in a physical or biological science, and submit satisfactory evidence of at least four years experience in the operation, including at least two years as a part of the management, of a Class A or B system or facility or a similar industrial facility.

Class B certificate. An applicant for a Class B certificate must:

A. have been certified as a Class C operator for at least one year; and

B. have:

(1) a high school diploma or equivalent with at least six years experience in the operation of a Class A, B, or C system or facility, or a similar industrial facility; or

(2) a bachelor's degree from an accredited institution in chemical, civil, environmental, mechanical, or sanitary engineering or in a physical or biological science, and submit satisfactory evidence of at least two years experience in the operation of a Class A, B, or C system or facility, or similar industrial facility.

Class C certificate. An applicant for a Class C certificate must have:

A. a high school diploma or equivalent, with at least three years experience in the operation of a Class A, B, C, or D system or facility, or similar industrial facility; or

B. a bachelor's degree from an accredited institution in chemical, civil, environmental, mechanical, or sanitary engineering or in a physical or biological science, and submit satisfactory evidence of at least one year experience in the operation of a Class A, B, C, or D system or facility, or similar industrial facility.

Class D certificate. An applicant for a Class D certificate must have a high school diploma or equivalent; and

B. have:

(1) at least one year experience in the operation of a Class A, B, C, or D system or facility, or in a related field; or

(2) satisfactorily completed a postsecondary program of courses in water or wastewater technology approved by the respective agency or department at an accredited institution.

Class E certificate. An applicant for a Class E certificate must have a high school diploma or equivalent; and

B. have:

(1) at least three months experience in the operation of a Class A, B, C, or D, or E system or facility, or in a related field; or

(2) satisfactorily completed a postsecondary program of courses in water or wastewater technology approved by the respective agency or department at an accredited institution.

Appendix K

Additional References

Hach Water Analysis Handbook, Hach Company, 1989

Ground Water Quality in Southeastern Minnesota, R.D. Singer, M.T. Osterholm, C.P. Straub, 1982

Design and Construction of Water Wells, National Water Well Association, 1988

Ground Water Manual, U.S. Department of the Interior, 1985

Manual of Small Public Water Supply Systems, United States Environmental Agency, 1991

Water Distribution Systems Operation and Maintenance, MDH, 1979

Water Treatment Plant Operation, Volume I & II, California Department of Health Services, Sanitary Engineering Branch and United States Environmental Protection Agency, 1983

Manual of Individual and Non-Public Water Supply Systems, United States Environmental Protection Agency

Handbook of Public Water Systems, Culp, Wesner, Culp, 1986

Introduction to Water Treatment, Principles and Practices of Water Supply Operations, AWWA, 1984

Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health

Distribution Network Analysis for Water Utilities, AWWA, 1989

Basic Math Concepts for Water and Wastewater Plant Operators, Joanne Kirkpatrick Price, 1991

Pump Handbook, Karassik, Krutzsch, Fraser, Messina, 1986

Groundwater and Wells, Fletcher G. Driscoll, 1986

…and various AWWA and NRWA training manuals.

Notes: