PDHonline Course C198 (3 PDH)

All About Watermains - An Insider's View

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ALL ABOUT WATERMAINS – AN INSIDERS VIEW

Mark E. Hughes, P.E.

Course Content

A BRIEF HISTORY ON WATER DISTRIBUTION

While it has been noted that ancient civilizations over four thousand years ago in India, Egypt and Greece developed water supply and sewage systems. The romans over 2000 years ago were one of the first cultures to realize water delivery systems that were similar to what we take for granted today. They utilized systems like aquaducts which were basically stone lined channels that fed water from surface sources via gravity to their urbanized areas. To this day, evidence of their technology still exists in the form of large bridge like structures that span valleys across Europe. The romans even fabricated lead and wood pipes to deliver water to homes, baths and fountains. Last year a section of wooden watermain that was still delivering water was found in an excavation in England.

In this country, one of the earliest materials used for watermains was wood. Several methods of fabricating watermains during this era were utilized. One type of construction was to fabricate mains out of tapered wood staves like a barrel. These pieces were put together to form round pipes and bound with banding or wire. Other methods used short sections of tree limbs or tree trunks. These were either cut lengthwise and hollowed out and then banded back together, or in a more sophisticated process, the center of the limb was drilled out creating a wooden pipe.

These pipes had tapered ends that fit into each other and the joints were reinforced with wire or metal banding. During the construction of a sewer in an older Chicago suburb we came across a piece of old wooden watermain that was out of service, but still in good condition. The bell and spiggot ends of the pipes were evident and the wire banding holding the pieces together gave us a good idea of how this system was constructed.

One of the slang terms for a fire hydrant that still exists today came from the era of wooden watermains. The term “fireplug” came into use when the fire department needed to tap into a watermain to put out a fire. In those days there were no fire hydrants and the firemen would dig down to the watermain then drill a hole into the wooden watermain. Their hose was then screwed into the main and the fire was put out. When the hose was removed a wooded plug was pounded back into the main resulting in the term “fireplug”.

THE NEED FOR A WATERMAIN

Water water everywhere, but how does one get a drink? In the case of urbanized areas watermains are constructed for various reasons by different entities. In cases where new development is being experienced, watermains are constructed to extend the existing

water supply system to the newly developed area and may be built by the developers constructing housing or industrial facilities in an area where no urbanized facilities existed previously. In most cases however, a municipality or other government entity is responsible for construction of new facilities.
In older urban areas, watermains may be made of older materials like cast iron. While cast iron was a great material for it's time, it can tend to be brittle and affected by corrosion and movement in the ground. It is not uncommon to find municipalities with watermains that are over 100 years old. While working for a contractor during the construction of a new watermain in an older Chicago suburb, we discovered a fitting that had the date 1906 stamped on it. These mains are in need of replacement because of concerns over the integrity of the existing system and the need for annual repairs because of main breaks.

Main breaks are most commonly experienced in colder climates in response to the ground freezing and thawing. As the frost enters the ground in the fall or leaves the ground in the spring, there are shifts in the earth due to the expansion or contraction of moisture in the ground that exerts pressure on the watermains causing them to rupture. The water finds the path of least resistance and percolates up to the surface resulting in rivers of inconvenience on the streets.

In some cases the diameter of the existing older watermains may be under-sized and insufficient to meet new fire safety or water usage demands of the community. Many of these mains were built to serve smaller houses or a fewer number of houses in an area. In these cases new mains are constructed to replace the existing older under-designed systems.

Watermains are also constructed to address water quality issues where the circulation of water in an area is poor and it is necessary to connect an existing watermain to other adjacent mains to eliminate stagnant water that exists. This process also known as "looping" is also used to provide better connectivity for water systems in order to provide a network that can allow the supply of water to reach more areas and minimize the loss of water service during shutdowns for repairs for a main break or servicing.

DESIGNING A WATERMAIN

For new watermains that are serving a previously unserved area, the maximum possible demand of that area needs to be realized. If the watermain is needed to serve an industrialized area, a maximum usage must be determined based on the types of industry that could potentially be moving into an area. During my experience as a City engineer, there was a vegetable washing facility that was moving into a new industrial park that required an exceptional amount of water usage. As a result the new watermains built to serve that area were designed to handle maximum flows for a number of similar types of facilities that could potentially exist in that area.

In cases where older urban systems were being upgraded, the local fire department in the municipality I worked for was partially responsible for determining what the actual anticipated water usage needs would be in an area. Their estimates were based on the needs of their equipment to put out a fire. In one case we were replacing a larger transmission main that was serving an area consisting of older undersized mains. The concern from the fire department was that during the construction of the new transmission main, there was a period where the existing mains were cut off from the old transmission main and they would only be supplied from one direction.

The Fire Department's pumper truck equipment had the capabilities of "sucking" the older mains dry and possibly causing them to collapse if they were only fed from one direction. Ultimately it was realized that these older undersized mains needed to be replaced. However, connections to the existing feeder main were left in place before it was taken out of service in order to maintain maximum flow capabilities to the area until these undersized mains could be replaced or reconnected to the new feeder main after it was completed and placed in service.

There are numerous computer modeling programs available that can assist the design engineer in determining what size mains are needed in various areas. These programs typically require the design engineer to input the sizes of the existing mains in the area as well as ambient water pressure and the location of water supply sources. In addition, daily peak hour flow rates for consumers are established whether they are residential or commercial. Usually these are based on the number of residential consumers in an area or the potential ultimate capacity that is needed for a commercial area.

The typical size of a watermain serving a residential area is 8 to 10 inches in diameter, while larger mains serving commercial areas are 12 inches in diameter or greater. Larger transmission mains that convey water from the treatment plant to new subdivisions or areas away from the plant may be 16 to 24 inches in diameter. In the Chicago area Lake Michigan water is distributed to adjacent suburbs in 54 to 90 inch diameter mains.

HOW THE EPA AFFECTS DESIGN OF WATER SYSTEMS

The U.S. Environmental Protection Agency (EPA) is responsible for protecting public health and safety. Over time they have established rules and regulations regarding the construction of watermains, storm sewers and sanitary sewers. In many cases there are State EPA's or similar agencies that enforce the U.S. EPA's regulations. In Illinois there is the Illinois EPA (IEPA) and they have worked closely with a committee of Contractors, Engineers and other State agencies to develop specific design and construction criteria in order to establish Standard Specifications for water and sewer main construction.

These specifications address many issues including preventing contamination of the public water supply. One of the main ways this is accomplished is through sewer and water separation. Typically a sewer system and watermain must have a 10 foot separation horizontally and an 18" separation vertically. Figures 1 through 4 give examples of how this separation must be achieved. In cases where separation cannot be achieved, either the storm or sanitary sewer must be constructed of watermain quality materials, or the watermain or sewers must be encased in a sealed casing pipe that extends beyond the limits required by the EPA.

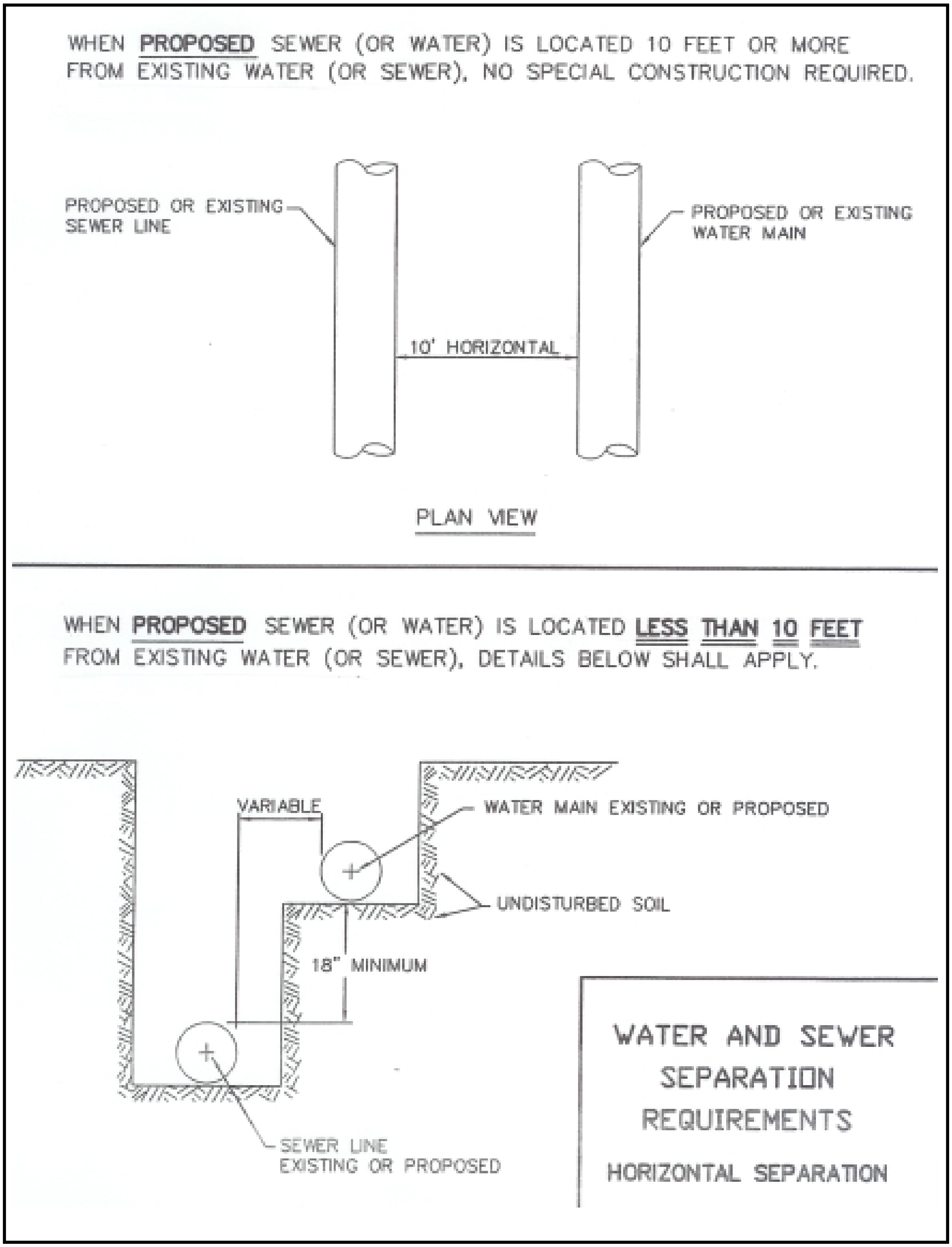


FIGURE 1

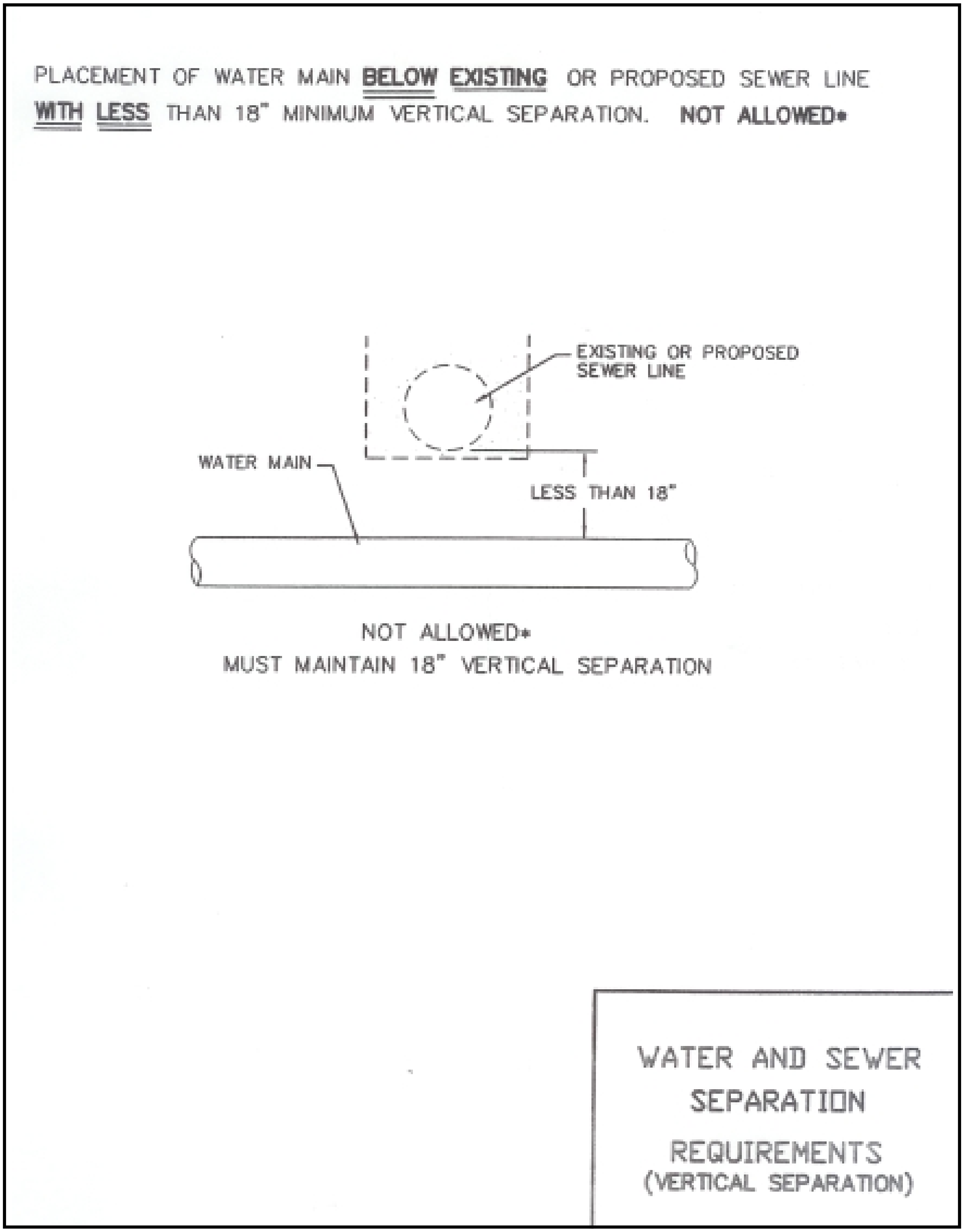
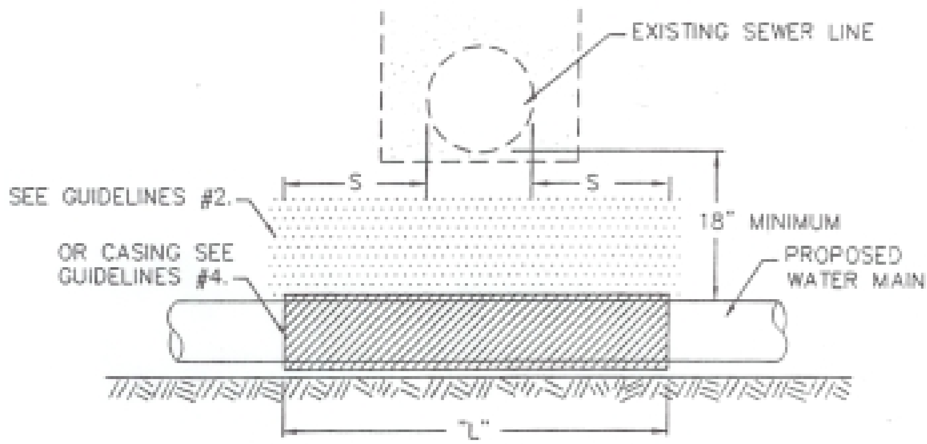

PLACEMENT OF WATER MAIN BELOW EXISTING OR PROPOSED SEWER LINE WITH LESS THAN 18" MINIMUM VERTICAL SEPARATION. NOT ALLOWED*
EXISTING OR PROPOSED SEWER LINE
WATER MAIN
LESS THAN 18"
NOT ALLOWED*
MUST MAINTAIN 18" VERTICAL SEPARATION
WATER AND SEWER SEPARATION REQUIREMENTS (VERTICAL SEPARATION)

FIGURE 2

PROPOSED WATER MAIN BELOW EXISTING SEWER LINE WITH 18" MINIMUM VERTICAL SEPARATION.



NOTE: "S" THE LENGTH NECESSARY TO PROVIDE 10 FEET OF SEPARATION AND MEASURED PERPENDICULAR TO EXISTING SEWER LINE.

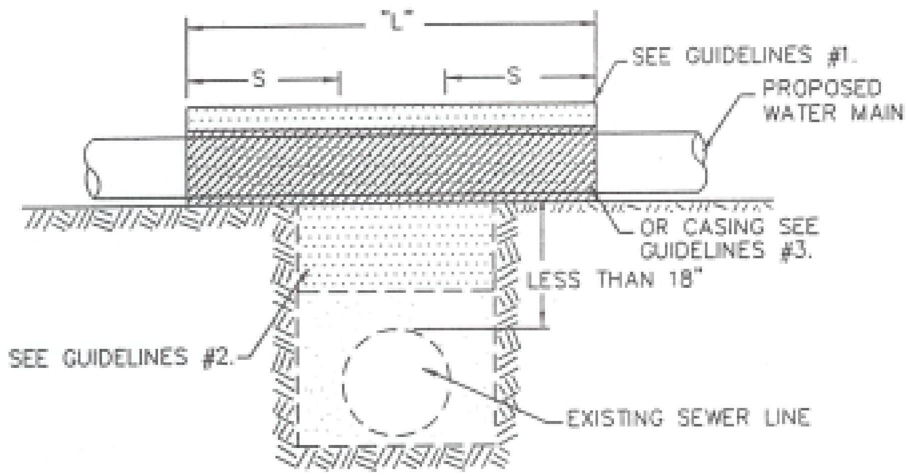
GUIDELINES

1. OMIT SELECT GRANULAR EMBEDMENT AND GRANULAR BACKFILL TO ONE (1) FOOT OVER TOP OF WATER MAIN AND USE SELECT EXCAVATED MATERIAL (CLASS IV) AND COMPACT THE LENGTH OF "L".
2. IF SELECT GRANULAR BACKFILL EXISTS, REMOVE WITHIN WIDTH OF EXISTING SEWER LINE TRENCH AND REPLACE WITH SELECT EXCAVATED MATERIAL (CLASS IV) AND COMPACT.
3. PROVIDE ADEQUATE SUPPORT FOR EXISTING SEWER LINE TO PREVENT DAMAGE DUE TO SETTLEMENT.
4. USE "L" FEET OF WATER MAIN MATERIAL FOR CASING OF PROPOSED WATER MAIN AND SEAL ENDS OF CASING.

WATER AND SEWER SEPARATION REQUIREMENTS (VERTICAL SEPARATION)

FIGURE 3

PROPOSED WATER MAIN ABOVE EXISTING SEWER LINE WITH LESS THAN 18" VERTICAL SEPARATION.



NOTE: "S" THE LENGTH NECESSARY TO PROVIDE 10 FEET OF SEPARATION AS MEASURED PERPENDICULAR TO EXISTING SEWER LINE.

GUIDELINES

1. OMIT SELECT GRANULAR EMBEDMENT AND GRANULAR BACKFILL TO ONE (1) FOOT OVER TOP OF WATER MAIN AND USE SELECT EXCAVATED MATERIAL (CLASS IV) AND COMPACT THE LENGTH OF "L".
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3. USE "L" FEET OF WATER MAIN MATERIAL FOR CASING OF PROPOSED WATER MAIN AND SEAL ENDS OF CASING.
4. POINT LOADS SHALL NOT BE ALLOWED BETWEEN WATER MAIN CASING AND SEWER.

WATER AND SEWER SEPARATION REQUIREMENTS (VERTICAL SEPARATION)

FIGURE 4

Whenever a new watermain is constructed, the plans will have to be reviewed by the local EPA agency. If the plans are acceptable, a permit to allow for construction of the new facility will be granted. In many cases the local EPA agency has a tremendous backlog of projects to review and the length of time needed to obtain the permit can take several months. It is important to find out about the local permitting process and keep in close contact with the EPA in order to ensure that the project is able to be built within a timeframe that is acceptable to the client.

THE WATER SUPPLY SYSTEM

Water to supply urbanized areas can come from various sources. In some cases large wells draw water out of aquifers which may be large sandstone deposits typically several hundred feet deep. This porous rock absorbs groundwater from underground springs and acts like a sponge that can be tapped to obtain water. In other cases rivers or streams are dammed to collect water in reservoirs to ensure a constant water supply. In many areas lakes or large rivers are used to supply water to adjacent communities. In some parts of the country desalinization plants are constructed to create drinking water from ocean salt water by removing the salt via reverse osmosis.

The collected water is pumped to a water treatment plant where the water is assessed and various treatment methods are utilized to ensure safe drinking water. Some water is passed through sand and or charcoal filters to remove sediments and contaminants. Chlorine is typically added to the incoming water to eliminate bacteria, however, other promising technologies like ultraviolet purification are being examined for feasibility.

Once treated, the potable water is now pumped to storage tanks. Typically these tanks are elevated in order to provide a constant pressure to the distribution network. In communities without significant topographic difference, the tanks are usually the large "bulb" type tanks that rise over 100 feet in the air. The bulbous shape allows for a concentration of water at a higher elevation that provides the pressure and volume needed to supply an area with an adequate amount of water at a pressure that is acceptable.

In communities where one part of area being served is higher than the rest, the tanks can be on the ground, but they must be located high enough to produce enough static pressure to provide acceptable pressure to supply the rest of the community. Typical water pressure in a main is approximately 50 to 70 psi.

In most instances water is pumped to the tanks at night when electric rates are less expensive and the tanks then drain by gravity during the day to provide a constant pressure throughout the water distribution system. The main factor that affects water pressure in a distribution system is the loss of pressure otherwise known as head loss.

HEAD LOSS AND HOW IT IMPACTS WATERMAIN DESIGN

Just in case it's been a while since you were in a classroom, Bernoulli's equation helps to determine the biggest factor affecting water system pressure, frictional head loss. For each foot of pipe there is a frictional head loss that occurs just from water passing through the pipe. In addition, each time the water is forced through a directional change in a distribution system, there is head loss. The greater the shift in direction the more the head loss.

When designing a water distribution system where directional changes may occur, one of the factors to consider is how quickly that change should occur. Most communities discourage the use of 90 degree watermain fittings and prefer that directional changes occur at no greater than 45 degrees. A 90 degree bend can be achieved with two 45 degree fittings that result in less head loss than a single 90 degree fitting.

HOW CLIMATE AFFECTS WATERMAIN DESIGN

Depending on the climate of where the watermain is being constructed, the design of the watermain and how deep the watermain is buried in the ground can vary dramatically. While vacationing in Mexico recently I noticed a pipe on the ground adjacent to the roadway. Upon closer inspection I observed that this pipe was the local watermain. It was constructed in a manner where the joints in the pipe were supported by concrete blocks and restrained at intervals to prevent movement.

In freezing climates the watermain must be buried deep enough below the frost line to prevent the watermain or water services tapped off of the main from freezing. In the Chicago area the frostline is typically at about four feet. Watermains in this area are typically designed so that the top of the main is greater than five feet below the ground. This allows for water services which are generally tapped off the top of the main (see the section on WATER SERVICE CONNECTIONS below) to be at depth that is below the frostline.

WATERMAIN FITTING NOMENCLATURE

In order to know how a watermain is actually constructed it is helpful to know what parts or fittings are commonly used and how they interact to create the new watermain. The first and most basic part is the actual watermain pipe itself. Most watermains today are designed using Class 52 ductile iron and are cement lined in order to minimize or reduce corrosion. Typically these pipes come from the manufacturer in 18 to 20 foot lengths. While older cast iron mains are brittle and can be broken with a small hammer, newer ductile iron mains are extremely tough and cannot be damaged even by pounding on them with a sledge hammer.

The pipes have a bell end and a spigot end. The bell end is flared out wide enough to accommodate a groove for a rubber gasket that fits in the interior of the pipe inside the groove. The gaskets are shipped separately and must be fitted into each pipe prior to placing it in the ground. The spigot end is tapered slightly inward and is designed to fit snugly inside the gasket in the bell section. To seat the pipe the spigot end must be pushed into the bell end approximately 5" into what is know as the "home" position. There is typically a line painted around the outside of the pipe to let the installer know when a pipe has been pushed home completely.

If only a small piece of pipe is needed to complete a section, the pipe can be cut, however a taper must be made on the one end of the piece going into the bell end of the previous pipe, essentially creating a new spigot end. The taper or bevel is usually made using a gas powered rotary blade cut off saw with an abrasive blade. The side of the blade is used to grind the pipe to create enough of a bevel to enable the piece to slide into the gasket of the bell.

When a change in direction of the main is desired or if the pipe is being connected to a valve, a mechanical joint connection is typically utilized. Fittings like 45 degree, 22 1/2 degree and 11 1/4 degree bends or "T's" are specified as mechanical joint or MJ fittings. These fittings have a flange on the ends that receive the pipe and these flanges have a series of holes around the outside of the flange. The ends of the fitting also have an internal depression that accommodates a rubber gasket.

It should be noted that all bends should be restrained in some manner with thrust blocks. This physical restraint prevents movement of the joint from the force of the water moving through the pipe. This force comes from the frictional head loss of the fitting described above. One method is to place solid concrete blocks against the back side of the bend or fitting and place enough blocks so that the fittings is restrained in place against undisturbed ground. Another method is to pour concrete around the fittings as shown in Figure 5.

The fitting is held in place on the pipe with a device called a gland. This is a circular flanged shaped piece of cast or ductile iron that has a series of holes that align with the holes on the fitting. There is also a lip protruding from one side that is used to force the gasket into place in the depression on the end of the fitting. Bolts are inserted into the holes in the fitting and gland and as the bolts are tightened they compress the rubber gasket around the pipe creating a water tight seal.

It is generally a good idea to utilize a specific type of gland called a retainer gland. The retainer gland either has a series of set screws around the perimeter of the gland that are tightened into the main thus holding the gland in place. The set screws on this gland are perpendicular to the main and are screwed into place after the bolts on the gland have been firmly tightened to the fitting.

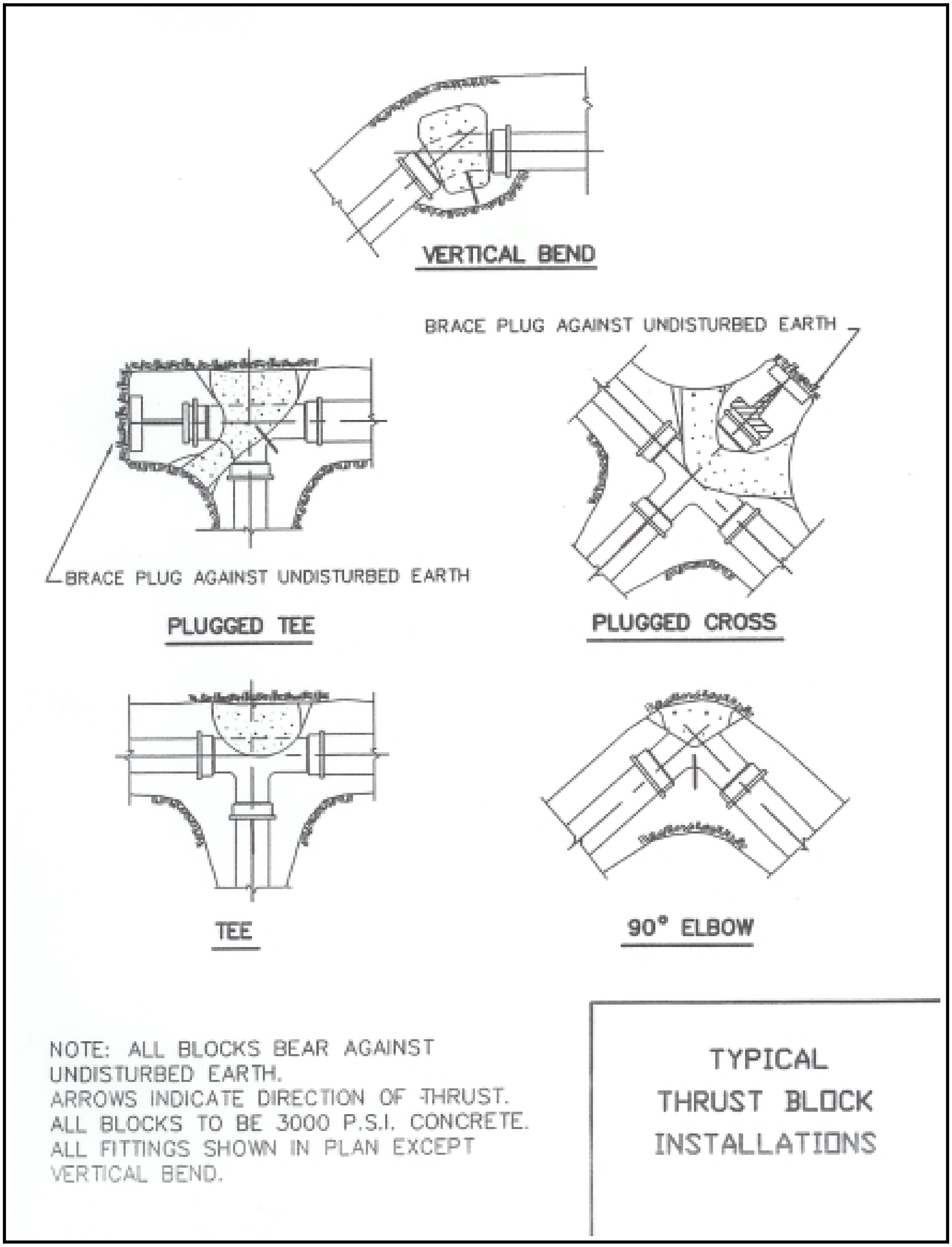
VERTICAL BEND
BRACE PLUG AGAINST UNDISTURBED EARTH
BRACE PLUG AGAINST UNDISTURBED EARTH
PLUGGED TEE
PLUGGED CROSS
TEE
90° ELBOW
NOTE: ALL BLOCKS BEAR AGAINST UNDISTURBED EARTH.
ARROWS INDICATE DIRECTION OF THRUST.
ALL BLOCKS TO BE 3000 P.S.I. CONCRETE.
ALL FITTINGS SHOWN IN PLAN EXCEPT VERTICAL BEND.
TYPICAL THRUST BLOCK INSTALLATIONS

FIGURE 5

Another widely used type of retaining gland is called a Meg-a-lug. This gland has three wedges at even intervals around the gland with ribbed faces that are tightened into place with bolts that have break away heads. Once the intended pressure on the main from the wedges has been achieved the large heads break off leaving a smaller square head in place that can be loosened in the event that the gland needs to be removed.
This type of fitting performs better that a standard retaining gland and is typically specified and used by municipalities to ensure that the fittings joints will not fail.

There are also restraining rubber gaskets called Field-lock gaskets that have small internal metal wedges built into the rubber gasket. These are made for restraining both sections of pipe and for fittings. It should be noted that there are different shaped gaskets for pipe than there is for fittings.

PVC & HDPE WATERMAINS

Other watermain materials that are becoming more common are PVC and HDPE watermains. PVC watermain is similar to ductile iron watermain in that the pipes come in 18 to 20 foot lengths and have a bell on one end and a spigot on the other end. They have gaskets similar to ductile iron and with the proper transitional fittings, the same ductile iron fittings that are used for ductile iron pipe can be utilized.

The biggest advantage in using PVC watermains is the ease with which the material can be cut and they are easier to handle with regards to the weight of the pipe. PVC watermain pipe is also useful in areas where corrosive ground exists as this pipe is resistant to corrosion.

Another related type of watermain material is HDPE or high density polyethylene. This pipe comes in 20 foot lengths, however it is smooth on the ends and must be mechanically welded together. This process involves a special machine that trims both ends of the pipes to be joined smooth. A special pad like heater is then applied to both ends and once the pipes reach the proper temperature, the heater is removed and the pipes are pressed together forming a watertight joint.

This pipe is extremely useful in situations where a continuous length of flexible pipe is needed for something like directional boring operations. On one project I was involved with we had to construct a watermain that ran beneath a creek with a short distance to get back to normal watermain depth. The only way to install a watermain in this situation was to directionally bore the main under the creek. HDPE was used for the creek crossing and special fittings were then used at the ends of the pipe to connect this pipe to conventional ductile iron pipe.

This process must be tightly controlled and the joints must be kept clean in order to assure proper adhesion. During a demonstration of this process, one of the manufacturer’s representatives told us a story about a crew that was assembling their pipe and was having problems with the joints falling apart. In analyzing what was going wrong it was noticed that the joints were only failing after the crew had taken lunch. The representative worked with the crew one day to see what was happening and noticed that during their lunch-break, the crew was using the special heating pad to heat up their lunch. The grease from their tacos and sandwiches was left behind on the heating pad resulting in contaminated joints that wouldn't hold.

VALVES AND HYDRANTS

Some of the other features that are an integral part of a watermain are valves and hydrants. Valves are used to control the flow of water in a system and are used to isolate areas so that new watermains can be built or repairs performed without affecting the rest of the watermain system. The more valves in a system and the more strategic in the placement of the valves, the more the municipality can minimize disruptions to customers.

This is an important factor when designing and building watermains as customers can include medical facilities, factories, restaurants and many other businesses that cannot function without water. In some cases shutdowns to facilitate construction must be planned around business schedules so that disruptions do not affect or minimally affect consumers that are important to the community. Never underestimate the importance of a business or what impact it has on the municipality. I've been involved in ugly situations where a shutdown lasted longer than planned and the most vocal business that complained to the City was a beauty salon that had to cancel appointments at the last minute, one of the ladies inconvenienced was the Mayors wife and we heard about it.

Valves are bolted onto the main directly like other fittings and have the same flanges and utilize gaskets identical to the fittings described above. Valves are either constructed so that they're buried in the ground with access via a valve box or are placed in a valve vault. The valve box (See Figure 6) is simply a metal tube with a shoe over the valve operating nut. The valve box installation costs less but does not allow the valve to be serviced. Most municipalities require that valves be constructed in valve vaults (See Figure 7). These are typically round concrete structures similar to manholes and access to the valve is gained via an opening in the top of the structure. Usually the valve vaults are four feet in diameter for smaller valves like 6 to 8 inch valves and are five feet in diameter or greater for larger valves.

For new mains where a valve vault is installed just prior to the point of re-connection to the existing main, the valve must be blocked in the valve vault to prevent movement of the valve during pressurization of the main for testing. This is typically done with 4x4 pieces of lumber that are placed tightly between the valve and the inner wall of the valve vault. This blocking is usually temporary and only needed until the new main is connected to the existing main.

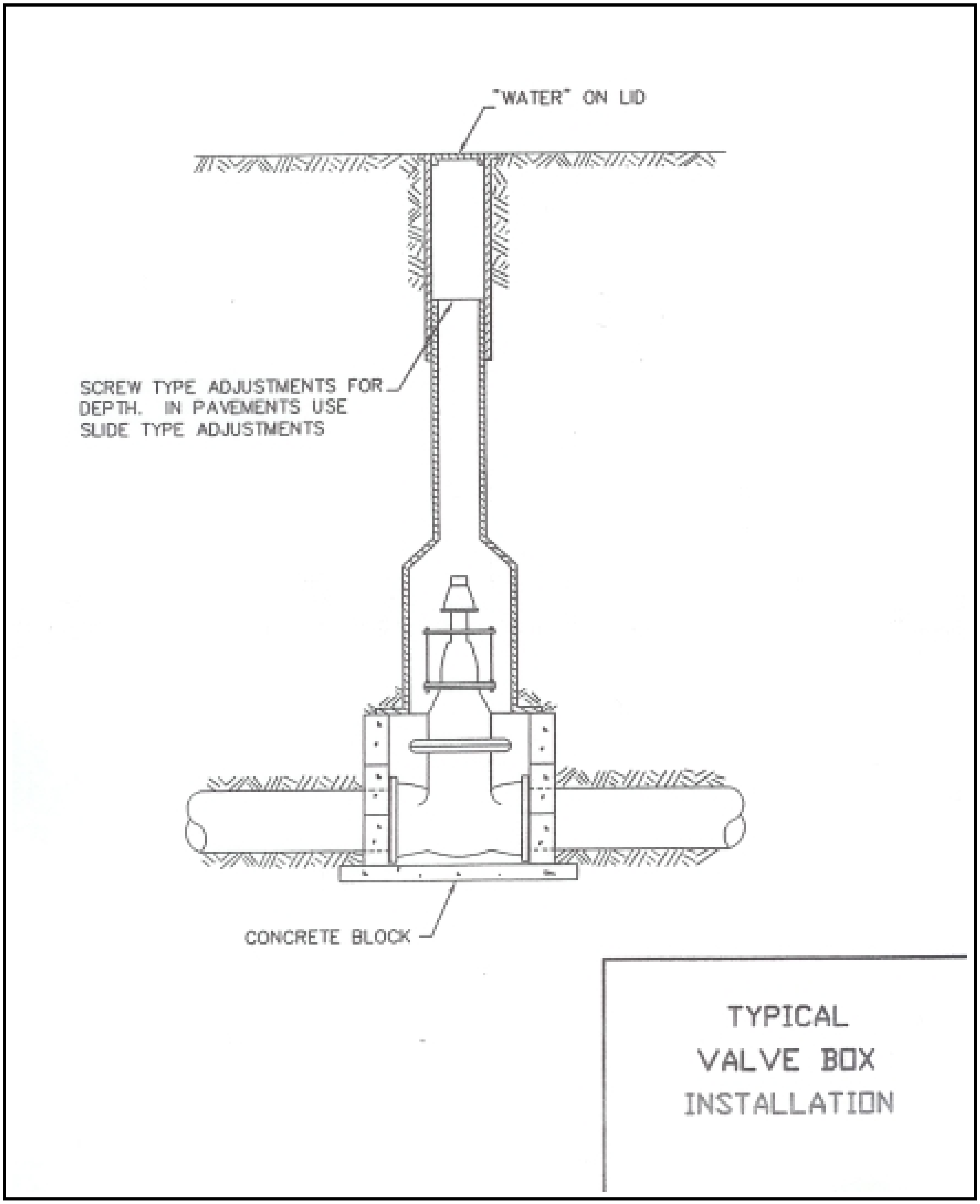
"WATER" ON LID
SCREW TYPE ADJUSTMENTS FOR DEPTH. IN PAVEMENTS USE SLIDE TYPE ADJUSTMENTS
CONCRETE BLOCK
TYPICAL VALVE BOX INSTALLATION

FIGURE 6

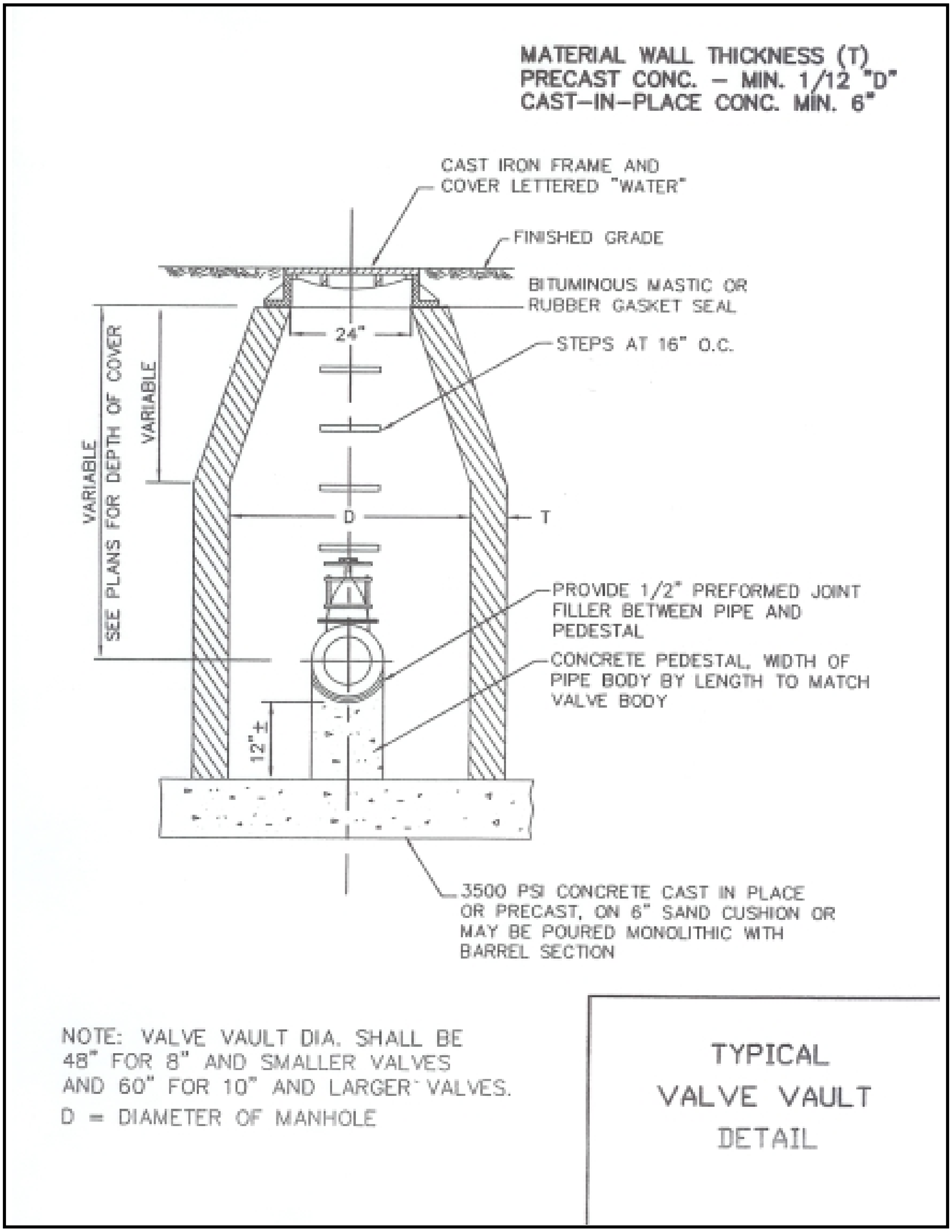

FIGURE 7

Fire hydrants (See Figure 8) are strategically placed to provide convenient access to the water supply system for the Fire Department. The typical spacing on fire hydrants is approximately 300 feet. This is generally the maximum distance of hose that Fire

Department would like to deploy in the event that they need to use a hydrant. It is also generally a good idea to put a fire hydrant at the end of a new section of watermain, just prior to the point of reconnection to the existing system. This will allow for a good flushing of the new watermain for pressure testing and chlorination purposes.

Fire hydrants are typically mounted on a "T" fitting off of the watermain and have a separate shut off valve typically called an auxiliary valve and the valve is operated via a valve box typically called an auxiliary box. The fire hydrant must have cement blocks behind the bottom of the hydrant in line with the pipe that supplies the water and the blocks are placed so that they distribute any forces back to virgin ground behind the hydrant. Hydrants are ordered with specific bury depths which relate to the depth that the main is buried in the ground. It is usually desirable to have the center of the main hose connection port be no lower than 18" above the ground and no higher than 24".

The hydrant is made so that the valve that allows water to enter the hydrant is underground at about the same depth as the watermain. There is a break away operating stem that connects to the operating nut on top of the hydrant. At the base of the hydrant there is a break away flange that allows the top portion of the hydrant to be broken off with the valve staying shut. The scene you see in every movie that has a car hitting a fire hydrant and releasing a geyser of water into the air typically cannot happen because of this arrangement. This construction also allows for hydrant extensions to be added to the hydrant in the event that the hydrant is set too low.

Hydrant extensions are inserted between the break-away flange and the buried section of the hydrant. They come in six inch increments and consist of a barrel section that bolts to the upper portion of the hydrant and the buried section. They also contain an operating shaft extension that extends the operating shaft that opens and closes the valve at the base of the hydrant.

All fire hydrants have a drain at the base of the hydrant that drains the body of the hydrant once the hydrant is shut off. This drain hole gets plugged once the valve at the base of the hydrant is opened fully and thus it is very important to open a hydrant fully to operate it. If the hydrant is only partially opened, pressurized water will shoot out the drain hole and erode the soil around the base of the hydrant. The base of the hydrant must also be surrounded by ¾ inch washed stone which allows the water in the body of the hydrant to drain into the surrounding soil once the hydrant is shut off. It is important to cover this washed stone with a geotextile filter fabric prior to backfilling the hydrant to prevent the stone from becoming contaminated with fines from the backfill material.

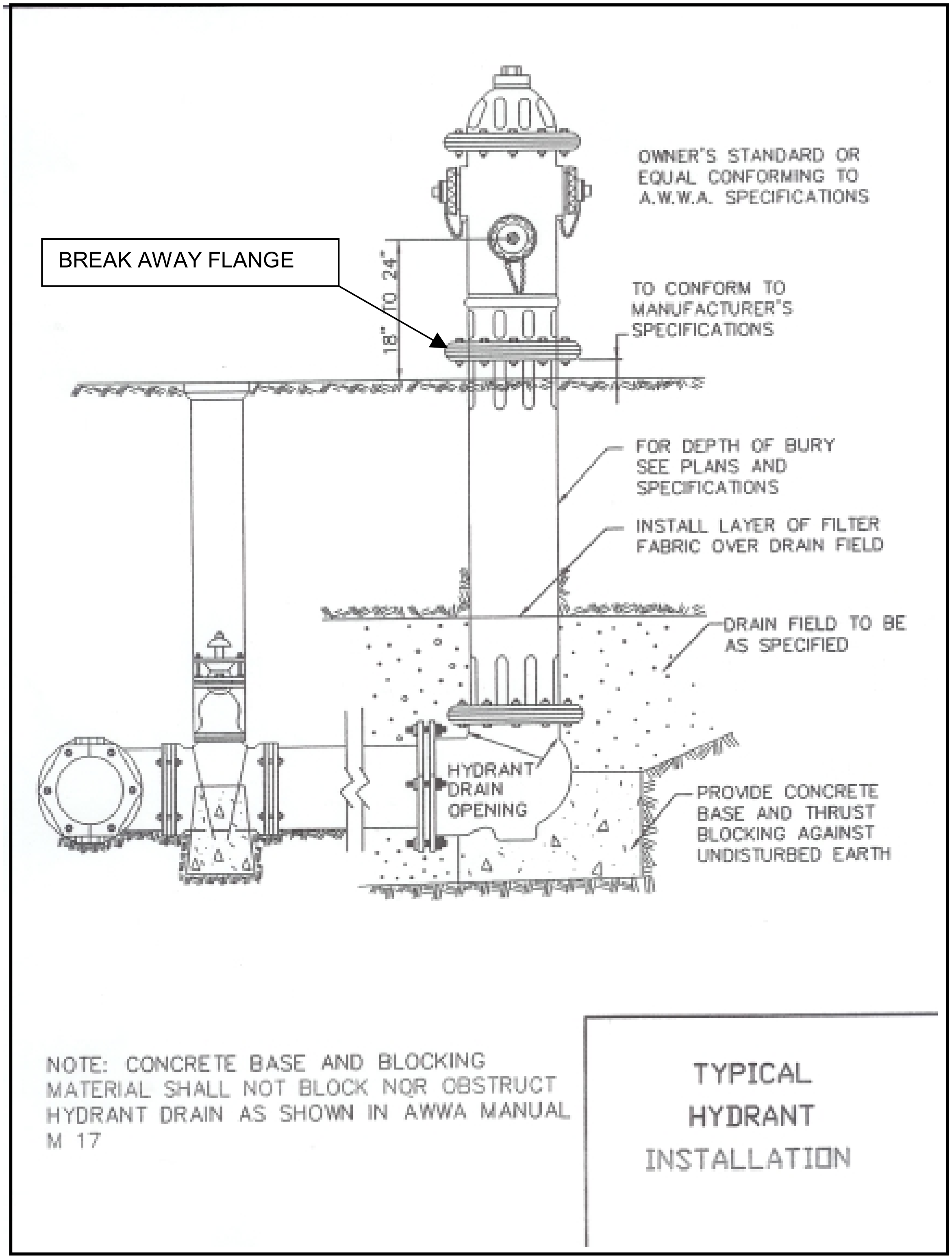
OWNER'S STANDARD OR
EQUAL CONFORMING TO
A.W.W.A. SPECIFICATIONS
BREAK AWAY FLANGE
18" TO 24"
TO CONFORM TO
MANUFACTURER'S
SPECIFICATIONS
FOR DEPTH OF BURY
SEE PLANS AND
SPECIFICATIONS
INSTALL LAYER OF FILTER
FABRIC OVER DRAIN FIELD
DRAIN FIELD TO BE
AS SPECIFIED
HYDRANT
DRAIN
OPENING
PROVIDE CONCRETE
BASE AND THRUST
BLOCKING AGAINST
UNDISTURBED EARTH
NOTE: CONCRETE BASE AND BLOCKING
MATERIAL SHALL NOT BLOCK NOR OBSTRUCT
HYDRANT DRAIN AS SHOWN IN AWWA MANUAL
M 17
TYPICAL
HYDRANT
INSTALLATION

FIGURE 8

HOW A WATERMAIN IS BUILT

In order to design a watermain, the design engineer should know how a watermain is actually constructed. Once the client has identified the type of need for the new watermain, the location where the new watermain to be constructed should be determined. The first step in determining where the new main will be located is examining the existing utilities in the area and establishing a clear corridor with minimal conflicts. It must also be noted where the existing storm and sanitary sewers are located so that the EPA separation rules can be followed. Once the watermain corridor is established the designer must decide where the initial connection of the new main will be made to the existing watermain system.

If a new main is being installed to replace an older existing main, a piece of the existing main will be removed. A 45 degree bend is connected to the existing main and then a piece of pipe is connected to the other end of the 45 to align the new main to the desired location. If the new main is running parallel to the old main, another 45 degree fitting is then connected to the new piece of pipe so that the mains can run parallel. Generally a new valve is installed just past the second 45 degree bend so that the new main will have a controlled source of water with a watertight valve to test against once it’s constructed.

It should be noted that once the old piece of main has been removed, the end that is not connected to the new main must be capped so that the old main can be placed back in service until the new main is constructed. This cap is held in place with a retainer gland and is also blocked in place with concrete blocks that are fit between the cap and the new 45 degree fitting.

If a new main is being installed to supply water to a previously unserved area from an existing main, a “T” fitting needs to be cut into the existing main. This requires a section of the existing main several feet long to be cut out of the existing main and a “T” fitting being connected to the existing main on one end of the “T” with a “sleeve” fitting being used. The sleeve slides over the existing main and connects a short piece of new pipe that is bolted to the other end of the “T”. Once the “T” is installed it is general practice to install a valve so that the new main can have a controlled source of water. Also the valve can be closed once it is blocked properly and the existing main can be put back into service.

This process can take several hours depending on the size of the main and the ability to close adjacent valves that shut down the section of watermain where the connection will take place. If an area is served by older watermains, typically these mains have valves that are older with seals that cannot completely shut off all of the water. In addition if there is a long segment of existing main, the entire main from the valve that is shut off to the point of connection must be drained before attempting to install the fittings to make the connection possible. This water must be pumped out of the excavation in order for the workers to be able to perform their duties and this process can be lengthy for large diameter mains.

The key in determining where the connection will take place is usually dictated by how many customers will be out of service during the connection process. It is usually best to try and plan a connection in a segment of the watermain that will affect the least number of customers. In some cases where it is not possible or practical to shut down a watermain a different type of connection called a pressure connection should be considered.

The pressure connection is achieved with a tapping sleeve that encapsulates the existing main. A tapping valve is then attached to the tapping sleeve and the tapping machine is attached to the valve. With the valve open, a round cutting wheel from the tapping machine drills a large circular hole in the existing main and removes a piece of the existing main called a coupon. The coring bit is then drawn back, the new valve is closed and the tapping machine is removed. The construction of the new main from the new valve can then be performed without having to shut down the existing main and without inconvenience to customers.

Once the connection to the existing main is achieved and the alignment of the main via the needed fittings is reached, the pipe can be laid to the point of connection to another point in the existing watermain system. The pipe is typically laid one piece at a time with the excavator digging the trench to the desired depth and placing the pipe in the bottom of the trench and pushing the newly laid piece into the pieces of pipe that had been laid previously. There is usually a line on the spigot end pipe that indicates when the pipe has been pushed together to the proper depth which is called pushing the pipe "home".

Typically it is wise to "bed" the bottom of the trench with washed stone. This is usually a ¾ inch gradation stone with no fines that conforms to the bottom of the pipe and fills in the irregularities in the bottom of the trench and gives the pipe a uniform firm support. The trench is then backfilled with various materials depending on the specifications.

If the watermain trench is located outside a paved area in the parkway, the material that was removed from the trench can be used for backfill thus saving on disposal and backfill costs. If the trench is located in a paved area then a backfill material like sand or CA-6 must be used to provide proper support for the pavement surface that will be constructed over the trench once the watermain is completed. With the exception of sand which cannot be compacted, the backfill material should typically be compacted in lifts or layers usually no more than one to two feet thick.

Just prior to the point of re-connection to the existing watermain system, it is generally a good idea to install another valve so that the new watermain can be isolated. This is typically done to facilitate the replacement of the older existing watermain.

PUTTING THE WATERMAIN INTO SERVICE

Once the watermain has been constructed to the point of re-connection, it must be tested and chlorinated prior to being put in service and connected to the existing watermain system. The first step in this process is the pressure test. During this process the watermain is filled with water and flushed thoroughly through a fire hydrant or corporation stop to ensure that no air is trapped in the system. The filled main is then pumped up with a water pump capable of pumping the system up to three times the normal operating pressure. Usually this is 150 psi and the pressure must be held with minimal loss (less than 10 psi) for a period of two hours.

Once the time period has been reached, the system is pumped back up to the pressure that was present at the time of the initial pressurization unless no loss has occurred. The system is then bled back to the pressure that was present at the end of the test with the bleed water being collected in a graduated container. The amount of allowable water loss is then determined based on the length of main being tested. Usually for a main four to five hundred feet long, it is desired to lose no more than one half gallon of water.

If the main does not pass the pressure test, the source of the leak must be found. Typically the leaks occur at fittings and are usually the result of not tightening the fittings sufficiently or properly. Occasionally the "leak" is actually air that is present in the main and trapped in a high spot or fitting. This can be determined easily as the main will appear to lose less and less pressure during subsequent pumpings. A significant pressure loss is usually the result of improper blocking. In one instance my workers failed to block a valve in a valve vault and eventually blew the end piece of pipe off the main. We noticed the problem after we realized that the valve had been pushed against the far wall of the valve vault.

Once the pressure test has been passed the main is flushed thoroughly and then chlorine gas is added to the main near the source of water. The presence of chlorine is then determined at the end of the main where it is being flushed via chemicals that change color in the presence of chlorine. The chlorine gas is left in place overnight and then flushed again the following morning until the chlorine is no longer detected in the main. At this point a sample is taken and analyzed for bacteria. The process of flushing the main is repeated the following day and another sample is taken.

The main can be put into service after two successive samples with bacteria limits below the acceptable levels are found. If the main does not pass, the main is re-chlorinated and the process is repeated. In some cases the municipal source of water can actually cause the new main to fail. This typically happens when the source of water for the new main is far from the water treatment plant. In this case the chlorine that is added to the public water supply is at a low level that deteriorates the farther you get from the plant resulting in water with bacteria levels that cause the samples to fail. In these cases after repeated failures the source water must also be sampled to determine if chlorine levels at the treatment plant need to be boosted in order to get the main to pass.

WATER SERVICE CONNECTIONS

Once the main is placed into service water services for homes or businesses can be tapped off of the new main (See Figure 9). This is done with a device called uniquely enough a tapping machine. This machine is strapped to the new main with chains and has rubber seals to create a watertight seal between the main and the machine. It has a drill bit that drills a hole into the main and then taps threads into the new main at the same time. Once the hole is made and the threads are cut, the bit is backed out and the machine has a chamber that creates a watertight seal. The bit is removed and the drilling shaft accepts a shut off valve and service connection point for the water service called a corporation stop, corporation cock or simply a corp. The corp is then screwed into the new threads in the main and the machine is removed.

At this point typically new copper tubing in a continuous roll is attached to the corporation stop and rolled out to a point beyond the main where a roundway or curb stop (the municipal shut off valve) is installed. Access for the municipality to shut off the water from the surface is gained via a tubular device similar to the valve box called a b-box or buffalo box. From the roundway the copper is continued to the existing home or business where it is connected to the existing service connection coming out of the building. If no home is present sometimes a copper stub is put in for future use.

It is important to recognize what pipe you are tapping for the service as many times there are numerous other utilities in the ground. In one instance I had a worker mistakenly tap a large diameter gas main that was located near the watermain and almost at the same depth. The worker didn’t realize his error until he smelled gas upon drilling through the gas main. He was using an electric power head that was driving the bit in the tapping machine and fortunately shut it off just in time to avoid an explosion. However, gas was leaking from the gas main at this point and we had to figure out how to safely remove the tapping machine.

With the go-ahead from a gas company supervisor and the Fire Department nervously standing by, we had the laborer finish the tap by hand and install the water service corporation stop. This prevented any further gas from escaping and the gas company then welded a cap over the corp.

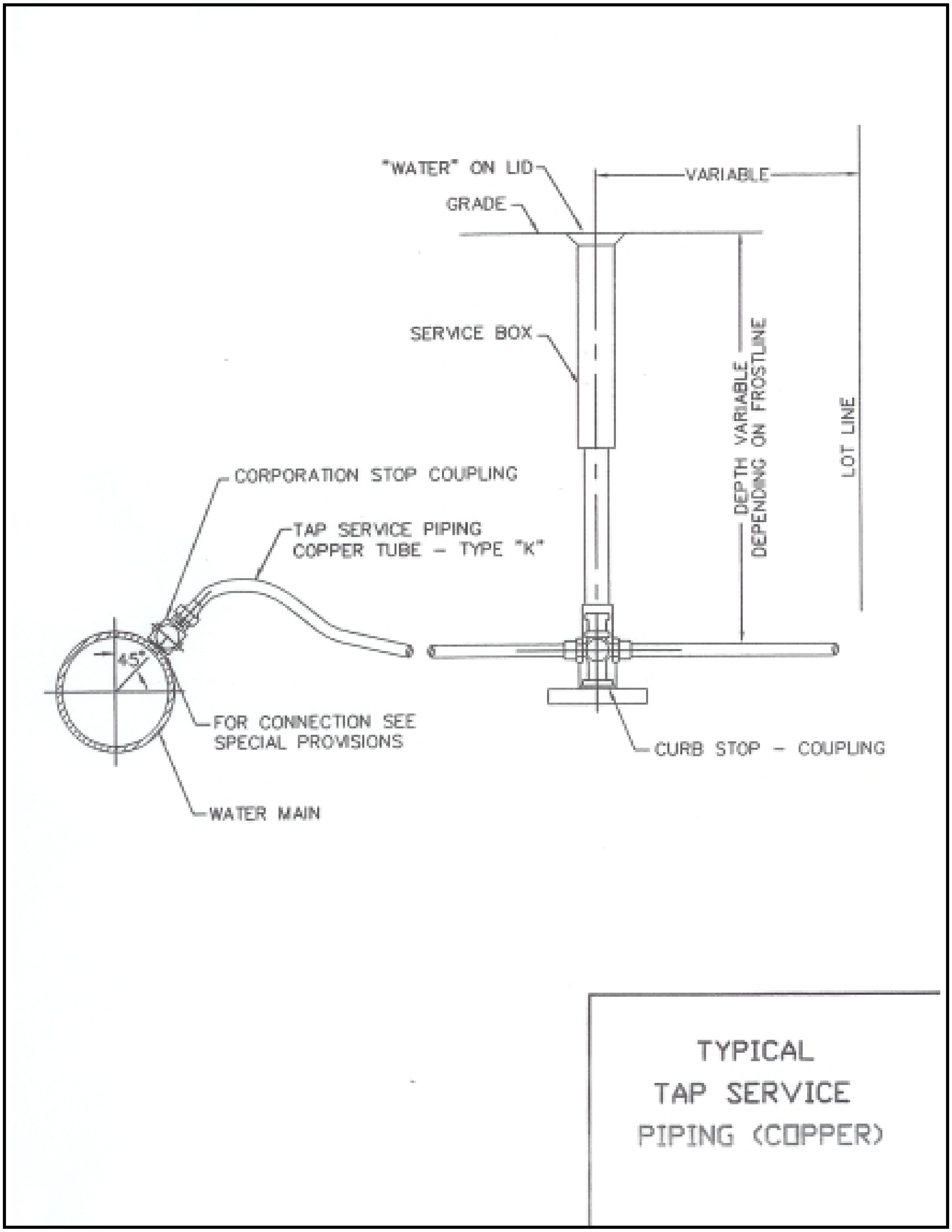

FIGURE 9

CLOSING THOUGHTS

When designing a watermain it is important to check all of the drafting work that goes into a set of plans. Typically todays plans are developed using a Computer Aided Drafting and Design system (CADD) and the line-work showing the location of existing streets, utilities and the proposed watermain is done by a technician. In many cases lines or text are copied quickly from one part of the drawing to another and the finished product looks professional and very convincing.

It is the Engineer's duty to carefully check all of the line-work to make sure that the information shown on the plans is correct and accurate. I have seen numerous sets of plans that have inaccurate notes, missing utilities and incorrect information that results in change orders for the project. These change orders can be embarrassing and cost your firm future work if the client is forced to pay the contractor for the additional work.

COURSE SUMMARY

In this course you learned that watermains are constructed to serve new areas that were previously unserved or are constructed to replace older or undersized existing watermains. The type of materials from ductile iron to plastic watermains was discussed with reasons for their use. The types of fittings and other various watermain components was also covered along with how these parts are assembled in the field. Numerous points regarding municipal concerns over watermain design were brought up throughout the course. Information on how mains are put into service and how services are connected to homes and businesses was also discussed.

REFERENCES

1. Standard Specifications for Water & Sewer Main Construction in Illinois, 5th Edition, May 1996