CHAPTER 8

TRANSMISSION LINE DESIGN

8-1. General. This chapter includes procedures specifically related to transmission lines of 12 inches diameter and larger. Service connections are usually not permitted. Interconnections with the distribution system piping should be held to a minimum and are usually over 1,000 feet apart.

8-2. Design procedures. Transmission line design shall include the following procedures.

a. Layout. The new line will be designed to fall within existing utility or street right-of-way where available. The price of acquiring easements through private property must be considered as part of the alternative cost analysis. Easements must be wide enough to allow for initial construction and future maintenance. Installation close to physical features, such as buildings or other utilities, which would cause construction problems or future access problems for maintenance should be avoided. A set of plan and profile drawings shall be prepared which shall show as a minimum the following information:

(1) Survey base line with physical control points.

(2) Easements, rights-of-way, streets, and construction limits, etc.

(3) Existing physical features such as buildings, fences, structures, utilities, trees and drainage systems.

(4) Existing, and proposed if applicable, ground elevations along the centerline of the pipe shall be shown on the profile.

(5) In plan, the proposed pipeline and its relationship to the survey base line.

(6) In profile, the centerline elevation of the proposed pipeline.

(7) Beginning and ending points of the pipeline and all appurtenances.

(8) Construction details of the pipeline, connections, appurtenances, tunneling, bedding and surface restoration, etc. Typical information shown on plan and profile drawings is illustrated in figure 8-1.

b. Diameter vs pumping costs. Pump costs are dependent upon initial cost and horsepower requirements. The total dynamic head of the system is the sum of the suction lift, discharge head, friction head and velocity head, and is represented by the following equation:

$$TDH = H_S + H_D + H_F + \frac{V^2}{2g} \qquad \text{(eq 8-1)}$$

where:
- TDH = total dynamic head
- H_S = suction lift
- H_D = discharge head
- H_F = friction head
- $\frac{V^2}{2g}$ = velocity head

The most economical pipe diameter in a pumped system is determined by comparing pumping costs for various sizes of pipe. Only standard pipeline sizes should be considered. In order to hold friction losses to a minimum and to reduce the possibility of severe waterhammer, the diameter should be sized so that the velocity is 4 feet per second (fps) or less. Under special circumstances when approved by the appropriate authority, the maximum design velocity may exceed 4 fps.

c. Hydraulic calculations. The Hazen-Williams formula is often used to compute flow characteristics. Also, the Darcy-Weisbach equation is used in some computer programs. Depending on requirements, one of the following forms of the Hazen-Williams equation is used:

$$V = 0.55\, C\, D^{0.63} S^{0.54} \qquad \text{(eq 8-2)}$$

$$Q = 0.433\, C\, D^{2.63} S^{0.54} \qquad \text{(eq 8-3)}$$

$$S = \left(\frac{2.32Q}{C\, D^{2.63}}\right)^{1.85} \qquad \text{(eq 8-4)}$$

$$V = 1.318\, C\, R^{0.63} S^{0.54} \qquad \text{(eq 8-5)}$$

where:
- V = velocity of flow in feet per second
- C = coefficient of roughness
- D = diameter of pipe in feet
- S = head loss in feet per foot of length
- Q = flow in cubic feet per second
- R = hydraulic radius in feet

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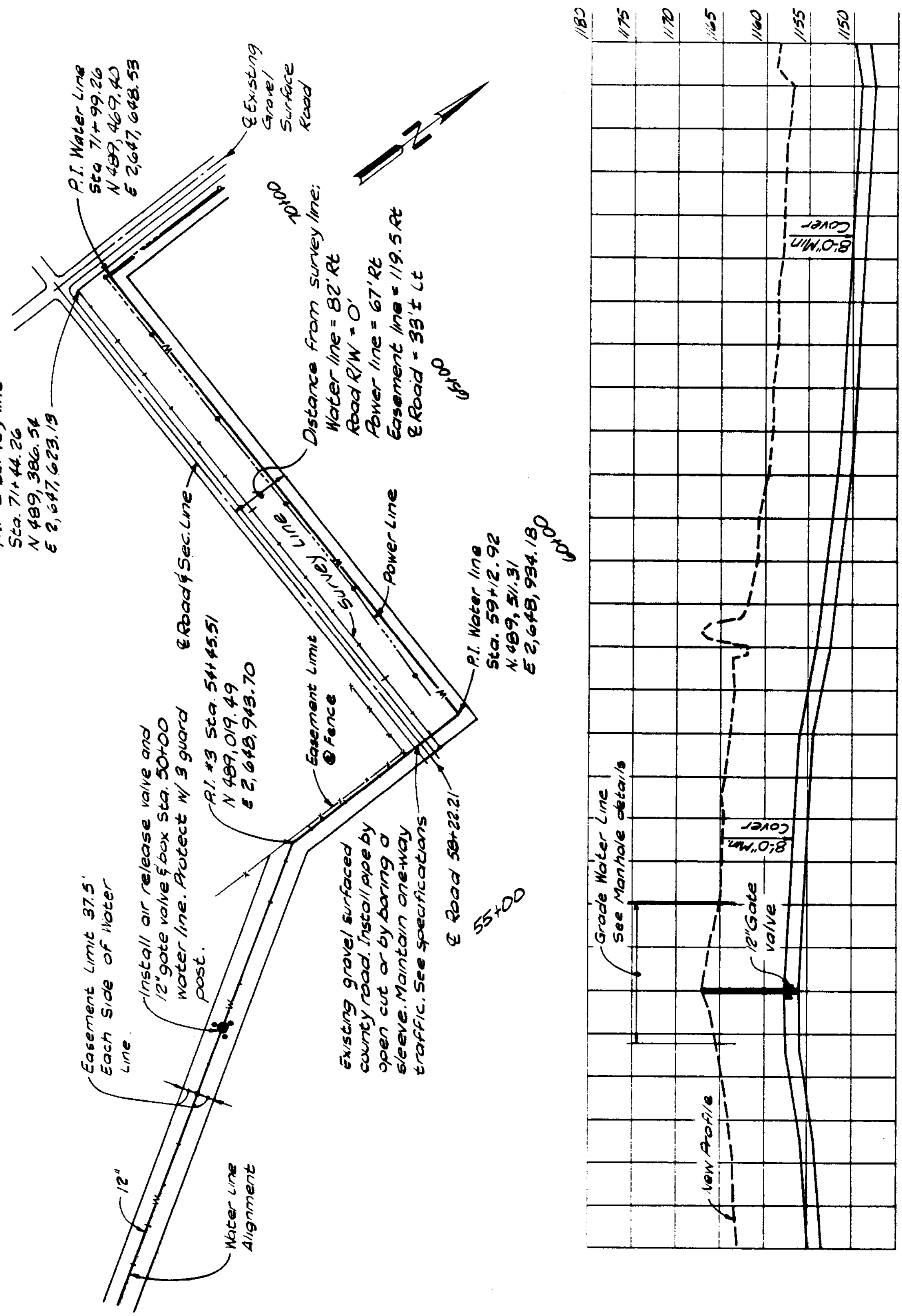

Figure 8-1. Typical plan and profile drawings.

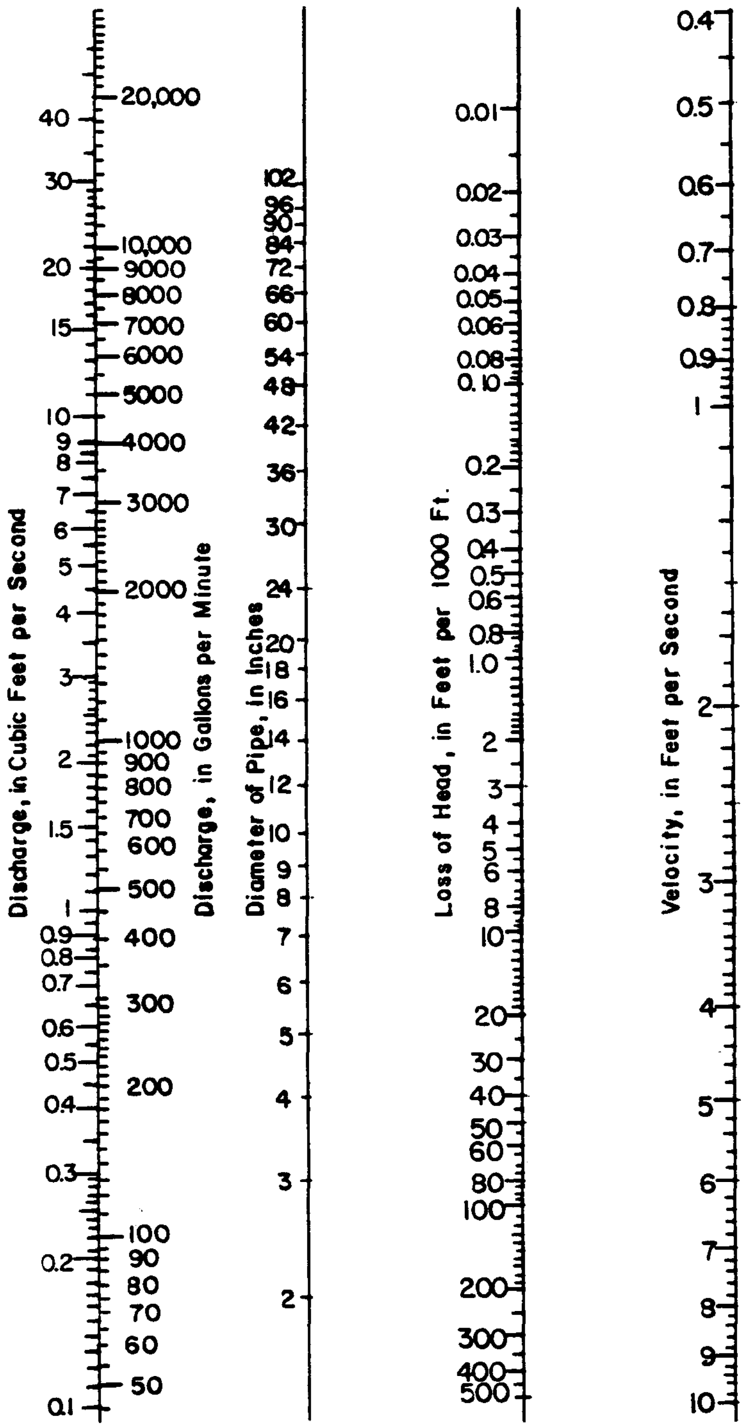

Figure 8-2. Nomograph for Hazen-Williams formula in which C = 100.

Values of C are 140 for smooth lined steel pipe, very smooth concrete pipe, cement lined ductile iron pipe and asbestos-cement pipe; 130 for ordinary ductile iron pipe in good condition; 110 to 120 for ductile or cast-iron pipe in service 5 to 10 years; 100 for older cast-iron pipe; and 40 to 80 for old cast-iron or steel pipe which is severely tuberculated or any pipe with heavy deposits. A quick solution for the equations may be found by use of the nomograph in figure 8-2. It is prepared from the Hazen-Williams formula by using C = 100. For larger or smaller values of C, the discharge or velocity obtained from the nomograph is multiplied by the ratio of the given value of C to 100. If the discharge or velocity is given, it should be multiplied by the ratio of 100 to the known value of C before the nomograph is used.

EXAMPLE 8-1. By using figure 8-2, determine the discharge, in cubic feet per second (cps), from a 12-inch pipe for which C = 120 when the loss of head is 5 feet per 1000 feet.

Solution: The discharge corresponding to the given diameter and loss of head for a value of C = 100 is found first. A straightedge passing through 12 on the diameter line and 5 on the loss-of-head line will intersect the discharge line at 2.5 cfs. Therefore, the discharge is:

$$2.5 \times \frac{120}{100} = 3.0 \text{ cfs}$$

EXAMPLE 8-2. A 30-inch pipe for which C = 130 is to discharge 10,000 gallons per minute (gpm). By using figure 8-2, find the loss of head per 1000 feet of pipe.

Solution: The first step is to determine the discharge that corresponds to a value of C = 100. This is 10,000 × 100/130 = 7,692 gpm. A straightedge through 30 on the diameter line and 7,692 on the discharge line intersects the loss-of-head line at 2.0 feet per 1000 feet.

Valves, bends, and other fittings in a pipeline and sudden enlargements or contractions cause loss of head. If a valve is partly closed, there is greater resistance to the flow and greater loss of head. Table 8-1 shows the loss in pipe fittings and appurtenances, expressed as equivalent lengths of straight pipe as a multiple of the diameter, due to various valves, fittings, contractions, and enlargements.

d. Internal pressure. The internal pressure is the difference in elevation between the conduit and the hydraulic grade line (HGL). The pressure at the beginning of a main may be generated by a pump, reservoir elevation or connection from another pipeline. Pressure losses are due to friction, bends and fittings, and changes in elevation. These are measured above a horizontal datum plane as shown on figure 8-3.

EXAMPLE 8-3. Assuming steady state conditions the pump in figure 8-3 delivers 5,000 gpm at a discharge pressure of 140 feet of head. The pipeline is 24-inch diameter, C = 100, and is 3,625 feet from pump to reservoir. Calculate the internal pressure at Station 20 + 00.

Solution: From figure 8-2, the head loss is found to be 2.7 feet per 1,000 feet. Assume other losses are neglible.

$h_L = 2 \times 2.7 = 5.4$ ft.

Elevation at pump =	230.0	
Discharge pressure =	+ 140.0	(60.0 psi)
Elevation of HGL at pump =	370.0	
Less h_L =	– 5.4	
Elevation of HGL at Station 20 =	365.6	
Pipe Elevation =	– 310.0	
Pressure =	55.6ft.	(24.1 psi)

e. Pipe materials. The materials allowed for use are steel, ductile iron, reinforced concrete, asbestos-cement, glass fiber reinforced and polyvinyl chloride pipe. Mains must be designed for the maximum internal working pressure plus an allowance for waterhammer. Design must include external stress due to earthfill and superimposed loads. Reductions in wall thickness at isolated regions of lower pressure or reduced external stress will not be made due to the possibility of construction personnel installing these sections in the wrong sections of the line. Pipe shall be designed and specified in accordance with applicable AWWA Standards, and specifically as indicated in table 5-3.

f. Anchorage and Expansion.

(1) Thrust restraint at bends and abrupt changes in direction is required. Certain types of pipe such as welded steel are designed as continuous conduits and some ductile iron joint systems are designed as restrained joints which may not require thrust blocking. When required, thrust restraint shall be designed in accordance with appendix C.

(2) Under empty conditions, lightweight conduit such as steel is bouyant and will float. This may occur if the water table is high enough even though the pipeline may be backfilled. If this is likely, the designer must add extra weight to the pipe. This

Table 8-1. Losses in pipe fittings and appurtenances

Description of Pipe Fitting or Appurtenances	Loss in Equivalent Length of Pipe Diameters (d)
Gate Valve	
3/4 Closed	900
1/2 Closed	160
1/4 Closed	35
Full Open	13
Angle Valve Open	170
Globe Valve Open	340
Swing Check Valve	80
Elbows	
90° Standard	
90° Long Radius	20
45° Standard	16
Tee Flow Through Run	20
Standard Tee Take-Off	75
Run of Tee Reduce One-Half	32
Sudden Contraction:*	
d/D = 0.25	15
d/D = 0.5	12
d/D = 0.75	7
Sudden Enlargement:*	
d/D = 0.25	32
d/D = 0.5	20
d/D = 0.75	19
Entrance to Basin	75

*For contractions and enlargements, d is diameter of smaller pipe and D is diameter of larger pipe; resistance is expressed in terms of d.

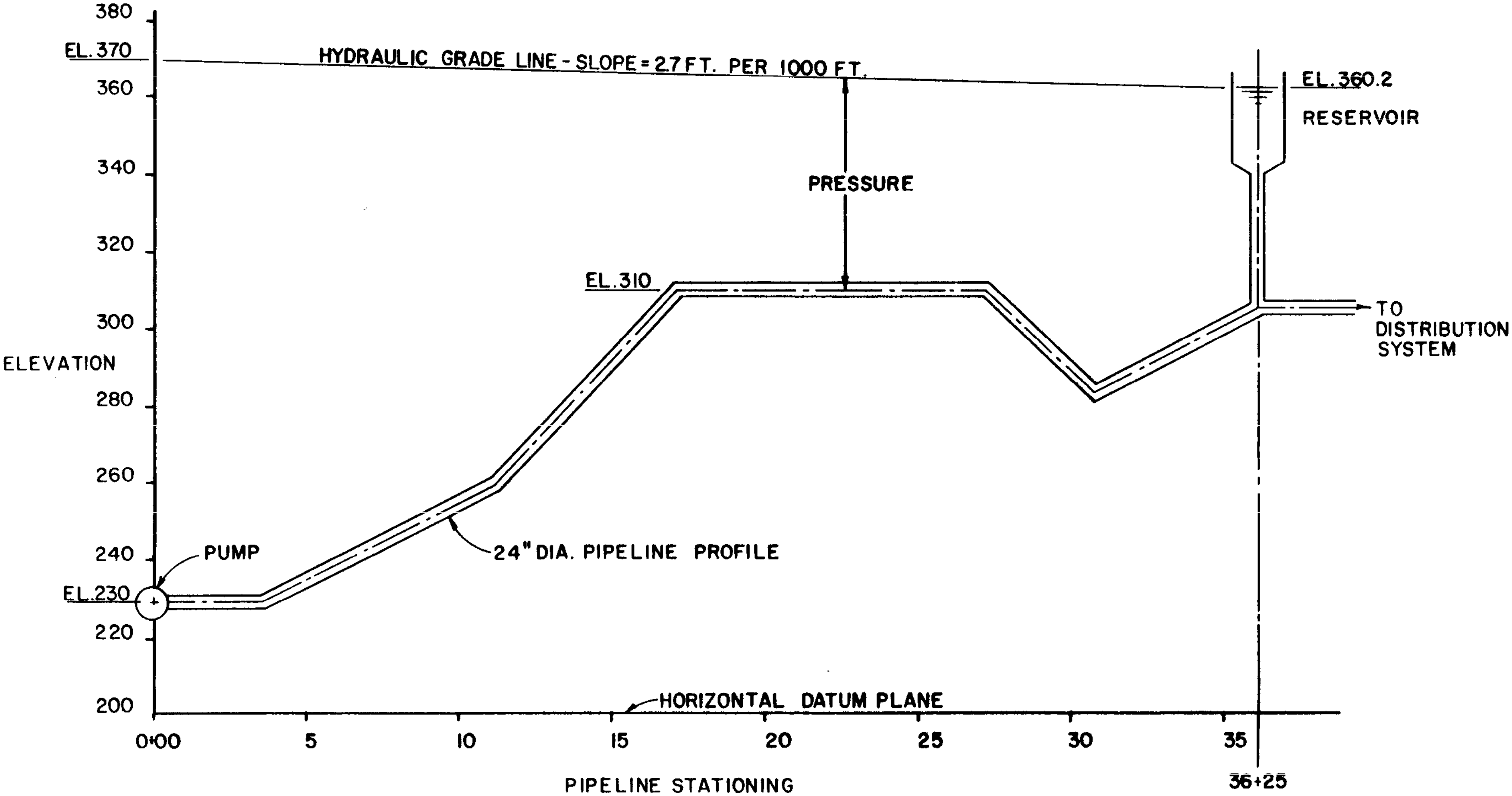

Figure 8-3. Illustration of pipeline pressure.

may be accomplished by the use of reinforced concrete collars, poured in place, and firmly anchored to the pipe.

(3) All pipe materials are subjected to expansion and contraction forces due to temperature changes. In colder climates, water temperature may vary from 32 degrees F. to over 80 degrees F., a range of over 50 degrees. Above ground installations, especially in hot temperature climates may also cause significant temperature variations. In bell and spigot joints, this effect usually may be neglected. However, the effects of expansion and contraction can be significant for long, straight, continuous pipelines. The designer shall include expansion joints designed for the pipe material and/or include appropriate stresses in the calculation for pipe wall thickness where required. However, it is not usually economical to increase the strength or thickness of the pipe wall as the sole means of resisting these stresses.

g. Valving. Sectionalizing valves are to be provided at all connections to the main. This includes pump discharge, distribution connections, fire hydrants, blowoffs, air valves and reservoir connections. Line valves are not usually required to be closer than one mile unless intermediate distribution connections are made. For larger size mains, the use of valves one standard size smaller than the pipeline is allowed as a cost-saving measure, provided that the velocity through the valve does not exceed 11 fps. Many large line valves have an integral by-pass arrangement. Valves may be the same as used in the distribution system, see paragraph 5-1. Valves shall be adequately designed for the actual internal pressure.

h. Air-vacuum valves. Air-release valves eliminate air pocket build up which causes a flow constriction and increased head loss. They are designed to expel air from a line during filling and close automatically when water reaches the valve. Vacuum valves are designed to allow air to enter the main when it is being drained. Also, vacuum valves are required to prevent the possible collapse of thin wall conduit which may be subject to a vacuum under certain conditions such as a break in the pipeline. Combination air release and vacuum valves are to be installed at the following locations:

(1) Peaks, where the pipe slope changes from positive to negative.

(2) Long relatively straight stretches at 1/4-to 1/2-mile intervals.

Air valves are to be sized to exhaust air at the pipe fill rate. Vacuum valves are to be designed to admit air at a rate equal to the flow generated by gravity. Consult manufacturer's literature for capacity and performance data. These valves are to be installed in pairs to prevent problems due to failure at one of the valves.

i. Blow-offs. Blow-offs, with a drain to a disposal area, should be installed near low points and other suitable locations to facilitate draining the conduit and disposal of the water. Blow-offs will be designed with an air-gap to prevent contaminated water from backing up into the main.

j. Hydrants. Hydrants for fire fighting purposes are not normally installed on transmission mains. If they are, design should be as specified in paragraph 5-2. Hydrants may be installed to facilitate filling and disinfection. For this purpose, a hydrant may be located adjacent to each line valve.

k. Access manholes. Manholes for access to the inside of large mains facilitate the construction and inspection of pipelines large enough to be entered by a workman. The minimum pipeline size is usually 20-inch diameter. They are useful if located adjacent to air valves, blow-offs, and line valves. Access manholes are to be designed as pipeline tees and fitted with a bolted blind flange.

l. Flow measurements. The design should allow for measurement of the volume of flow in the main. This may be done by pitot tube which requires the installation of a 1-inch corporation in the top of the main, or by a venturi installed as part of the pipeline or other commercially available equipment or methods. Sufficient straight pipe without flow interruption shall be provided ahead of and following the point of measurement as required by the manufacturer of the device.

m. External corrosion. The design, if the same as for distribution mains, refer to paragraph 7-5. Also use references cited in paragraph 8-2*e*.

n. Area restoration. Upon completion of the pipeline, the trench will be backfilled and compacted to prevent settlement. The surface will be brought to grade to match existing or design elevations. In previously grassy areas, the surface will be seeded or sodded. In paved or sidewalk areas, restoration shall match the original surface treatment as close as possible.

8-3. Filling procedures. Water should be admitted to the new transmission main at the lowest available point and be allowed to fill the pipe slowly up to higher elevations. Each section of main between line valves shall be filled separately and checked before proceeding to the next section. The progress of water in the pipeline shall be carefully and continuously monitored. It is usually neither feasible nor necessary to begin the filling process prior to the completion of construction of the entire pipeline.

a. On mains longer than a few thousand feet, where it would be unwieldy to continuously refer to construction drawings, a special profile drawing may be prepared at a smaller scale; e.g., 1″ = 100′ or 1″ = 200′. This profile drawing should show pipeline stationing, all appurtenances and other major physical and design features.

b. Prior to commencement of filling operations, all blow-offs, access manholes, other appurtenances, and temporary construction feaures should be checked to make sure they are closed and sealed. Check to see that air-release valves are free of debris and the control valves are open. Fire hydrants may be opened for additional air release and flushing purposes.

c. The rate of fill shall be carefully monitored and controlled. Use of two-way radios is desirable on longer pipelines. The point of fill should be continuously manned and personnel should be prepared to close valves in the event of leaks or other problems.

d. Water may be admitted through line valves on smaller lines. On larger mains, hydrants, distribution connections, or bypass connections of 6-inch or 8-inch diameter should be used. In any case, the valves being used must be capable of being closed under the conditions of flow with full head on one side only.

e. Progress shall be monitored by checking air-release valves and flow from hydrants. Hydrants may be closed when full-barrel flow is achieved without pulsing or surging. Each appurtenance must be checked for leaks during the filling process.

f. The filling process does not have to be a 24-hour-around-the-clock operation. It can be stopped any time, and later resumed. However, it cannot be carried on without being continuously monitored.

g. Upon completion of the filling process, the connection used shall be closed and each appurtenance shall be checked for leaks. Each section of main between line valves shall be individually filled, checked and disinfected before proceeding to the next section, and before putting it into service. Test pressures shall be in accordance with applicable AWWA Standards for the type of pipe used and the design pressure.

8-4. Syphons. Under special circumstances, a pipeline may be designed as a syphon. In these cases, a section of the main will be above the hydraulic grade line and therefore is under negative pressure. This design condition requires the specific approval of the installation's Facilities Engineer. Certain design details require special attention.

a. Pipe material and thickness. The pipe material and wall thickness shall be specifically designed for negative pressure. This requires a rigid pipe wall. Thin wall pipe, such as steel, may collapse under these conditions if not specially designed for negative pressure.

b. Air-vacuum valves. Air release and vacuum valves would defeat the design of a pipeline syphon. Their use must be carefully considered and should be limited to reaches of positive pressure if at all.