CASE EXAMPLES OF DISINFECTION "CT" CALCULATIONS WHEN USING CHLORINE FOR DISINFECTION OF GROUNDWATER SYSTEMS (EXCLUDING GWUDI)

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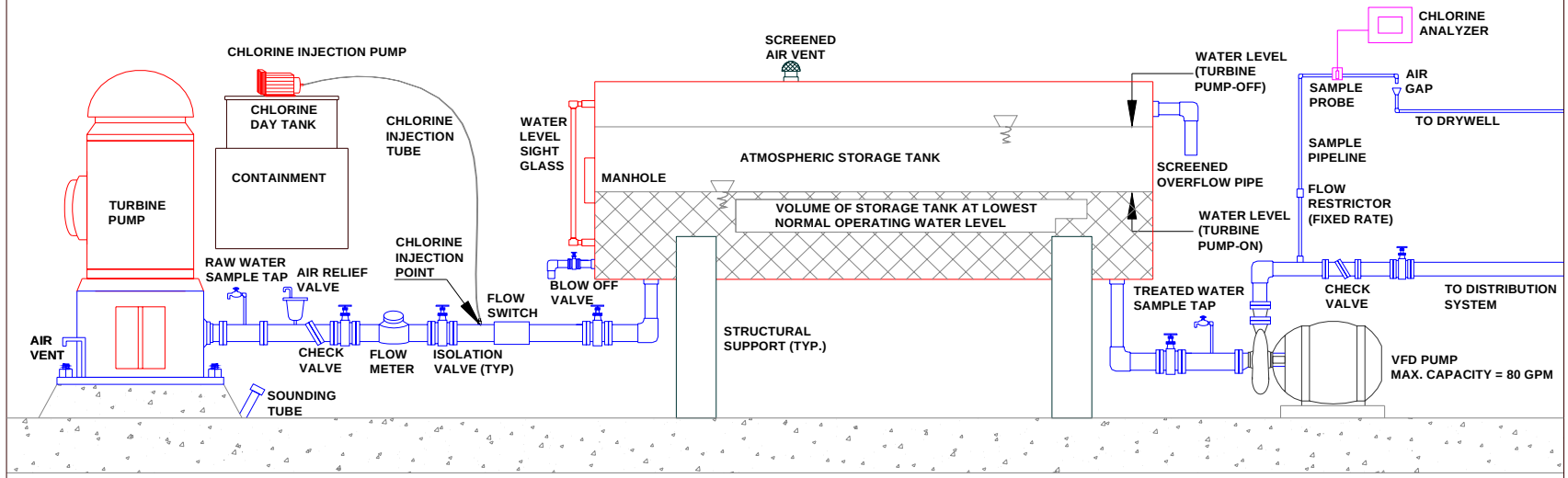
PWS DATA:

PEAK FLOW RATE = 80 GALLONS PER MINUTE (GPM)
STORAGE TANK DIMENSIONS:
DIAMETER = 10 FEET
LENGTH = 20 FEET
POPULATION SERVED: 34,000 PEOPLE

WATER QUALITY DATA:

WATER TEMPERATURE = 10 DEGREES CELSIUS
pH LEVEL = 6.0 - 9.0

FIGURE 1



TYPICAL CHLORINATION SYSTEM INSTALLATION WITH STORAGE TANK & BOOSTER PUMP

Disinfection "CT" Calculations

Example 1

Using a typical chlorination system as shown in Figure 1, calculate the "disinfectant contact time" (T) for the storage tank:

Using equation, $T = \frac{V}{Q} \times BF$

where:

V = volume of the tank at **lowest normal operating water level**

Q = maximum expected flow rate through the tank [maximum capacity of the booster pump(s)]

BF = baffling factor of storage tank

Calculate the gross volume of the storage tank

Using equation, $V = 0.785 (d^2) \times L \times 7.48$

Using: d = 10 feet, L = 20 feet

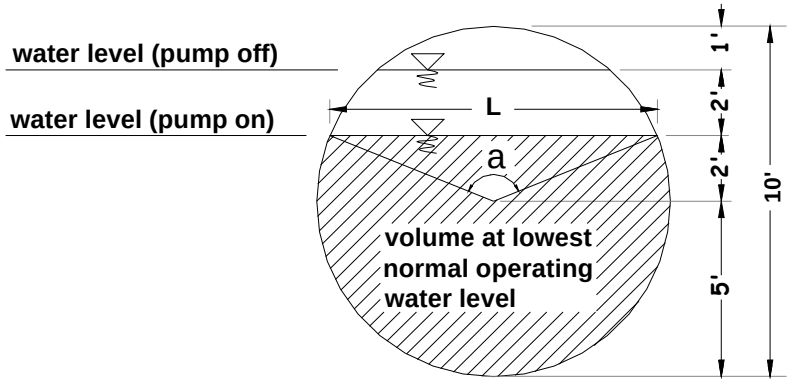
Substituting the values: V = 11,700 gallons (gross volume)

Estimating the volume of water in the tank at lowest normal operating water level and assigning a baffling factor of 0.3 (for tank with separate inlet pipe and outlet pipe) V = 8,808 gallons (see next page for calculation of tank volume)

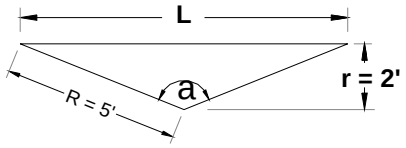
$$T = \frac{8{,}808}{80} \times 0.3$$

$$= 33 \text{ min.}$$

Calculation of volume for partially filled cylindrical (atmospheric) storage tank



Cross Section - Cylindrical Tank



solve for L:

$L = 2\sqrt{(R)^2 - (r)^2}$

$= 9.16'$

solve for a:

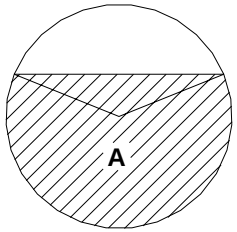
$a = 2 \tan^{-1}\left(\frac{L}{2r}\right)$

$a = 132^{o}$

solve for A of isosceles triangle:

$A = \frac{L \times r}{2}$

$= 9.16$ SQ. FT.

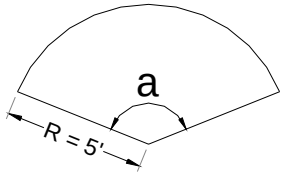


solve for shaded A of circle:

$A = A_{\bigcirc} - A_{\text{lens}} + A_{\text{wedge}}$

$= 87.5 - 28.78 + 9.16$

$= 58.88$ sq. ft.



solve for A of sector circle:

$A = 3.1416 \times R^2 \times \frac{a}{360^{o}}$

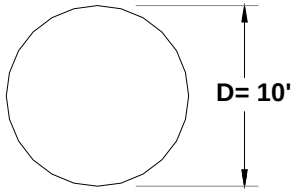
$= 28.78$ sq. ft.

Using a 20 feet long atmospheric storage tank,
solve for the usable volume (V):

V = 58.88 sq. ft. x 20 feet

= 1,177.6 cubic ft.

= 8,808 gallons



solve for A of circle :

$A = \frac{3.1416 \times D^2}{4}$

$= 87.5$ sq. ft.

Calculate the CT value of the treated water leaving the storage tank.

Using equation, CT = C x T

where:

C = target free residual chlorine concentration in mg/L

T = disinfectant contact time in min.

Maintaining a free residual chlorine of 0.20 mg/L [minimum concentration per RCSA Section 19-13-B102(e)(7)(M)] in the treated water leaving the storage tank.

Substituting the values,

CT= 0.20 x 33

= 6.6 mg-min/L

The calculated CT value of the treated water entering the distribution system is in compliance with the minimum required CT value of 2 mg-min/L per RCSA Section 19-13-B102(e)(7)(M) and in accordance with the required CT value of 6 mg-min/L to achieve 4-log treatment of viruses per GWR provided that the pH level of the water is within 6.0-9.0 range and water temperature is 10 degrees Celsius.

Residual Chlorine Compliance Monitoring

The residual chlorine for compliance monitoring of the treated water can be measured directly from the outlet pipe of the storage tank since the calculated CT value at this location meets the requirements of the RCSA Section 19-13-B102(e)(7)(M) and the GWR for 4-log treatment of viruses.

The minimum residual chlorine concentration in the treated water must be maintained no less than 0.20 mg/L at all times to ensure that the treatment system is providing the required 4-log inactivation of viruses per GWR.

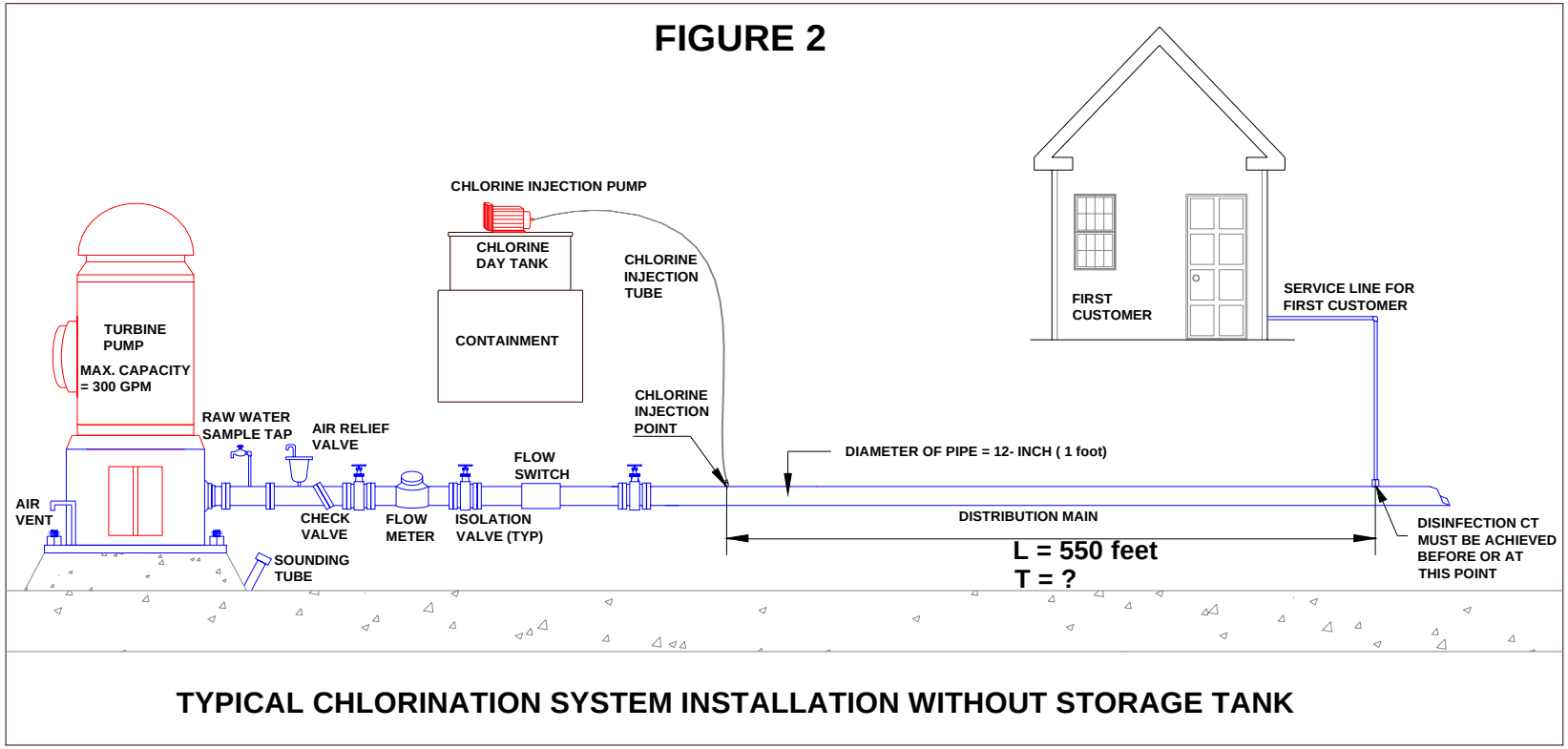
PWS DATA:

MAXIMUM WITHDRAWAL RATE OF WELL
= 300 GALLONS PER MINUTE (GPM)
DIAMETER OF DISTRIBUTION MAIN = 12-INCH (1 FOOT)
DISTANCE OF SERVICE LINE FOR THE FIRST CUSTOMER
FROM CHLORINE INJECTION POINT = 550 FEET
POPULATION SERVED: 34,000 PEOPLE

WATER QUALITY DATA:

WATER TEMPERATURE = 10 DEGREES CELSIUS
pH LEVEL = 6.0 - 9.0

FIGURE 2



TYPICAL CHLORINATION SYSTEM INSTALLATION WITHOUT STORAGE TANK

Example 2

Using a typical chlorination system installation as shown in Figure 2, calculate the T:

Using equation, $T = \frac{0.785 (d^2) \times L \times 7.48}{Q}$

where:

d= diameter of pipe in feet = 1 foot

L= length of pipe in feet = 550 feet

Q = maximum expected flow rate in pipe in gpm = 300 gpm

Substituting the values:

T = 10.76 min.

Calculate the CT value at the intersection point between the distribution main and the service line of the first customer.

Using equation, $CT = C \times T$

where:

C = target free residual chlorine concentration

T = 10.76 min.

Maintaining a free residual chlorine of 0.20 mg/L in the treated water at the intersection point between the main and the service line of the first customer.

Substituting the values,

CT= 0.20 x 10.76

= 2.15 mg-min/L

Notes:

1. The calculated CT value (2.15 mg-min/L) is in compliance with the minimum required CT value of 2 mg-min/L per RCSA Section 19-13-B102(e)(7)(M) [current regulation].
2. Since the above calculated CT value is less than 6 mg-min/L, therefore, the chlorination system does not provide 4-log treatment of viruses [new regulation under GWR].

Recommended Options to Achieve 4-log Treatment of Viruses

A. Increase the residual chlorine concentration in the treated water leaving the station
B. Installation of storage tank for additional contact time
C. Replacement of the distribution main with a larger diameter pipe
D. Relocation of the service pipe for the first customer

PWS Component Parameters	Summary of Recommended Options for 4-log Treatment of Viruses			
	A Increase residual chlorine	**B** Install storage tank	**C** Replace distribution main w/ larger pipe	**D** Relocate service line for the 1st customer
Residual chlorine conc. (C)	**0.60 mg/L**	**0.20 mg/L**	**0.20 mg/L**	**0.20 mg/L**
Disinfectant contact time (T)	**10 min.**	**30 min.**	**30 min.**	**30 min.**
CT value (before or at the first customer)	6.0 mg-min/L	6.0 mg-min/L	6.0 mg-min/L	6.0 mg-min/L
Req. size of tank/water main	same (1 ft.)	D =11.45 ft (a) L = 25 feet	D = 20-inch (1.66')	same (1 ft.)
Req. length of water main	same (550 ft.)	same (550 ft.)	same (550 ft.)	1,533 ft.
Length of sample line	**88 feet** (b)	**96 feet** (c)	**209 feet** (d)	**270 feet** (e)

(a) Larger diameter tank must be used based on the system's operational set points (pump on & pump off)

(b) Minimum length of the sample line [¾ inch (0.0625 ft.) diameter, fixed flow rate = 0.25 gpm] required for compliance monitoring of residual chlorine, installed on the distribution main approximately 100 feet downstream from the chlorine injection point.

(c) Minimum length of the sample line [¾ inch (0.0625 ft.) diameter, fixed flow rate=0.25 gpm] required for compliance monitoring of residual chlorine, installed on the discharge pipe of booster pump approx. 100 feet downstream from the outlet of the storage tank.

(d) Minimum length of the sample line [¾ inch (0.0625 ft.) diameter, fixed flow rate = 0.25 gpm] required for compliance monitoring of residual chlorine, installed on the distribution main approximately 200 feet downstream from the chlorine injection point.

(e) Minimum length of the sample line [¾ inch (0.0625 ft.) diameter, fixed flow rate = 0.25 gpm] required for compliance monitoring of residual chlorine, installed on the distribution main approximately 270 feet downstream from the chlorine injection point.

Recommended Option:

A. Increase the residual chlorine concentration in the treated water.

Using equation, $C = \frac{CT}{T}$

where: CT = 6 mg-min/L

T = 10.76 min.

Substituting the values,

C = 0.60 mg/L (rounded up to nearest tenth)

If PWS chooses to maintain a minimum residual chlorine concentration of 0.20 mg/L in the treated water, measured at a location before or at the first customer, the following other options may be considered:

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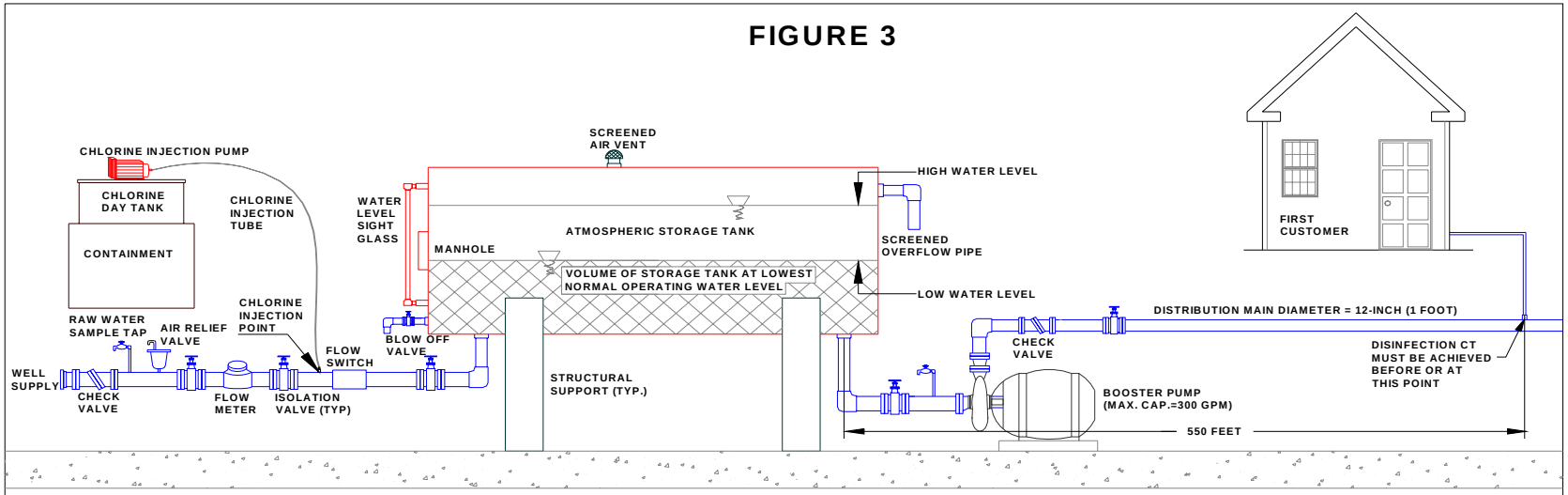
FIGURE 3



OPTION B - INSTALLATION OF STORAGE TANK FOR ADDITIONAL CONTACT TIME

B. Installation of storage tank for additional contact time:

Determine the T(st) required for the storage tank.

T(st) = 30 min. – T

T(st) = 30 - 10.76

= 19.24 min.

The storage tank should be sized to provide a minimum T(st) of 19.24 min.

Calculate the approximate size of the storage tank:

Using equation, $T = \frac{V}{Q} \times BF$

where:

V = volume of the tank at **lowest normal operating water level.**

$= .785(d^2) \times L \times 7.48$

Q = maximum expected flow rate through the tank

(booster pump maximum flow rate = 300 gpm)

BF = baffling factor of storage tank = 0.30

Installing a 25 feet long storage tank for contact time,

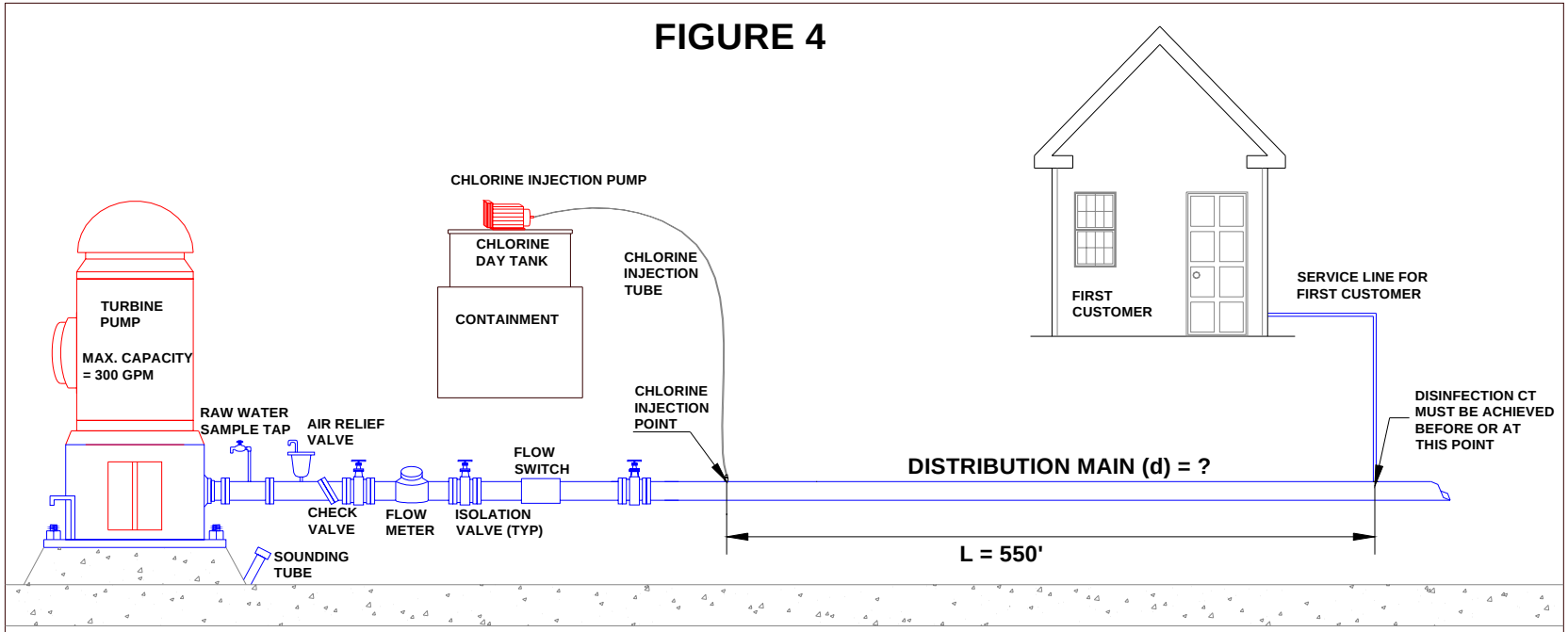
Substituting the values:

$$19.24 = \frac{0.785\,(d^2) \times 25 \times 7.48}{300} \times 0.3$$

d = 11.45 feet

A larger diameter tank must be used based on the gross volume of the tank taking into account the system's operational set points (pump on & pump off).

FIGURE 4



OPTION C - REPLACEMENT OF DISTRIBUTION MAIN WITH A LARGER DIAMETER PIPE

C. Replace the distribution main with a larger diameter pipe.

Determine the required diameter (d) of a new main.

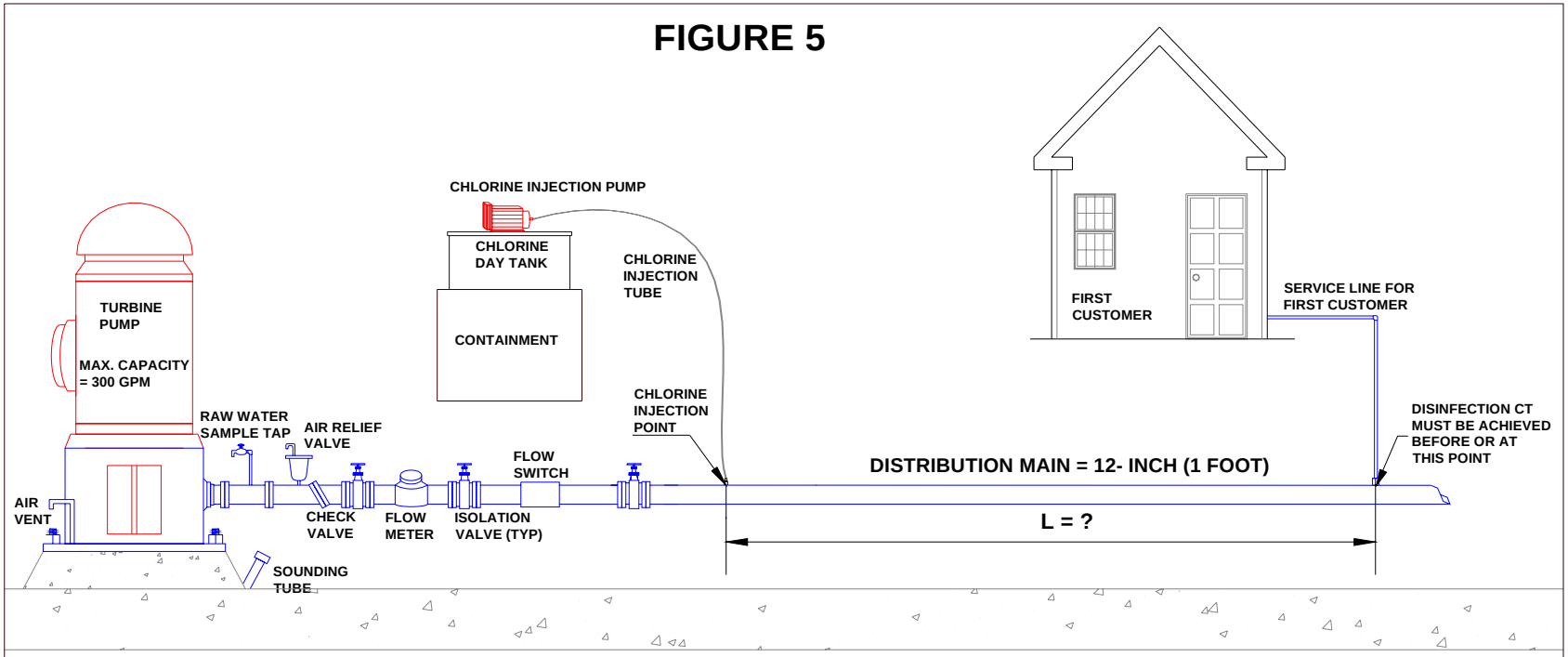
Using equation, $T = \frac{0.785\ (d^2) \times L \times 7.48}{Q}$

where: T = 30 min., L = 550 feet, Q = 300 gpm

solve for d = 1.66 feet diameter or 20 inch diameter pipe

Replacing the 12 inch diameter distribution main with 20 inch diameter would provide sufficient contact time to achieve 4-log treatment of viruses.

FIGURE 5



OPTION D - RELOCATION OF SERVICE LINE FOR FIRST CUSTOMER

D. Relocation of the service pipe for the first customer.

Determine the required length (L) of the main.

Using equation, $T = \frac{0.785 (d^2) \times L \times 7.48}{Q}$

where: T = 30 min., d = 1 ft., Q = 300 gpm

Solve for : L = 1,533 feet

Relocating the service line for the first customer approximately 1,533 feet downstream from the point of chlorine solution injection would provide sufficient contact time to achieve 4-log treatment of viruses.

Residual Chlorine Compliance Monitoring

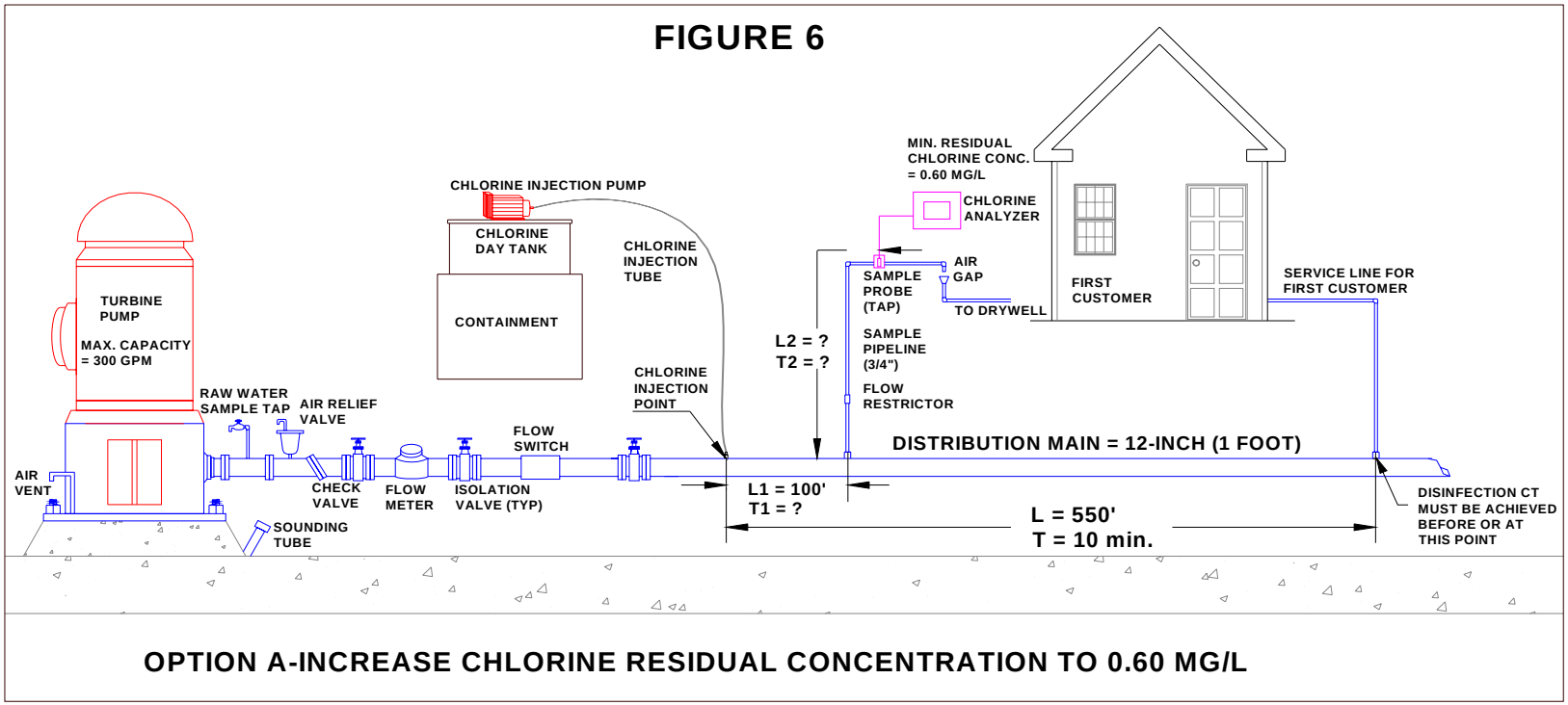


FIGURE 6
CHLORINE INJECTION PUMP
CHLORINE DAY TANK
CONTAINMENT
CHLORINE INJECTION TUBE
MIN. RESIDUAL CHLORINE CONC. = 0.60 MG/L
CHLORINE ANALYZER
AIR GAP
SAMPLE PROBE (TAP)
TO DRYWELL
FIRST CUSTOMER
SERVICE LINE FOR FIRST CUSTOMER
L2 = ?
T2 = ?
SAMPLE PIPELINE (3/4")
FLOW RESTRICTOR
TURBINE PUMP
MAX. CAPACITY = 300 GPM
RAW WATER SAMPLE TAP
AIR RELIEF VALVE
FLOW SWITCH
CHLORINE INJECTION POINT
DISTRIBUTION MAIN = 12-INCH (1 FOOT)
AIR VENT
CHECK VALVE
FLOW METER
ISOLATION VALVE (TYP)
L1 = 100'
T1 = ?
L = 550'
T = 10 min.
DISINFECTION CT MUST BE ACHIEVED BEFORE OR AT THIS POINT
SOUNDING TUBE
OPTION A-INCREASE CHLORINE RESIDUAL CONCENTRATION TO 0.60 MG/L

For option A (increase the chlorine residual concentration to 0.60 mg/L)

Demonstrate the equivalency of T1 & T2 relative to the required T before or at the first customer.

T = T1 + T2 = 10 min.

Determine the value of T1 and T2.

Using equation, $T1 = \frac{0.785\ (d1^2) \times L1 \times 7.48}{Q1}$

$$T2 = \frac{0.785\ (d2^2) \times L2 \times 7.48}{Q2}$$

where: d1 = 1 ft., L1 = 100 feet (variable), Q1 = 300 gpm

Using: d2 = ¾ inch (0.0625 ft.), Q2 = 0.25 gpm (fixed rate)

Substituting the values:

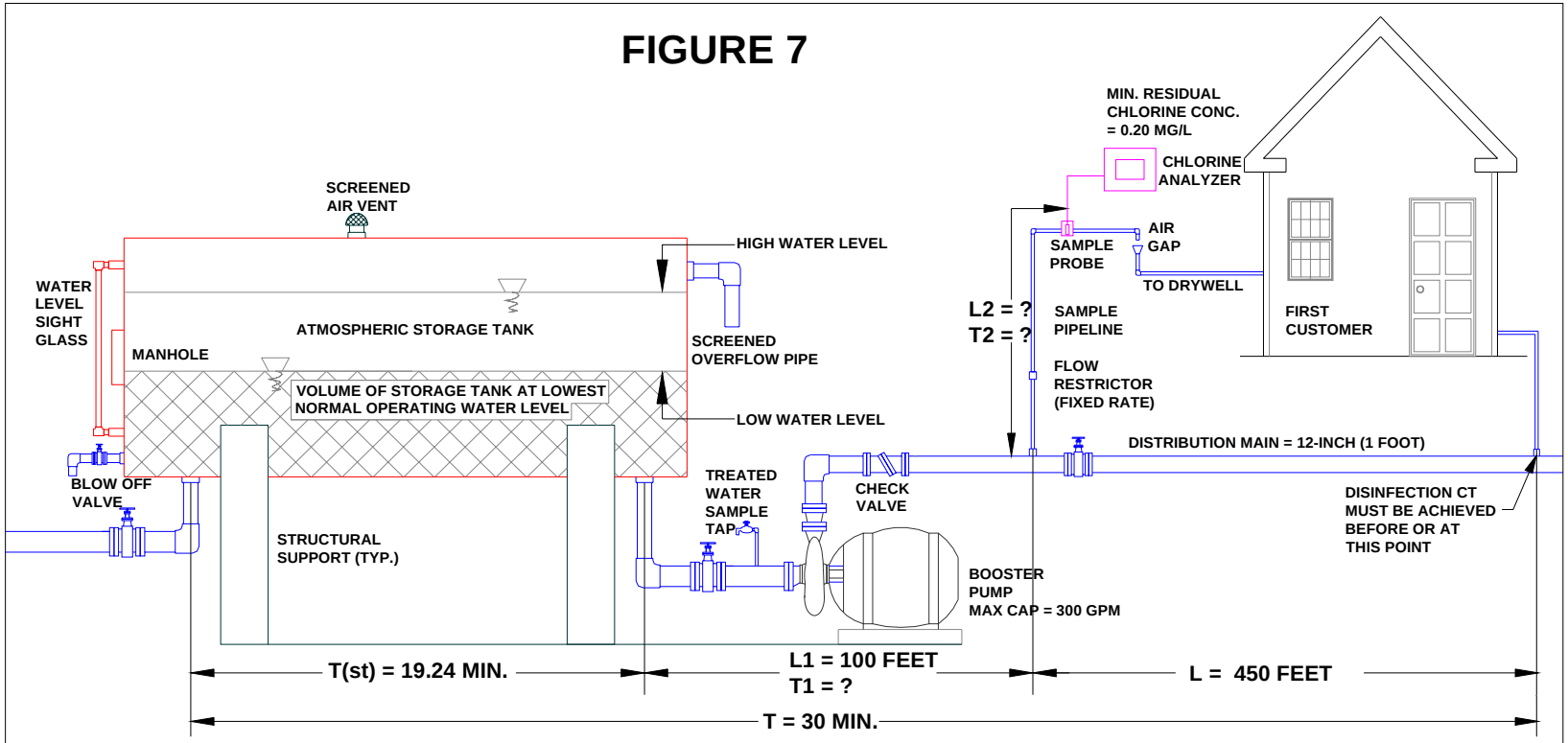
T1 = 1.96 min.

T2 = 10 – 1.96 = 8.04 min.

L2 = 87.77 feet or 88 feet

The minimum length of the sample line for compliance monitoring of residual chlorine must be 88 feet, installed on the distribution main approximately 100 feet downstream from the point of chlorine injection.

FIGURE 7



OPTION B - INSTALLATION OF STORAGE TANK FOR ADDITIONAL CONTACT TIME

For option B (installation of storage tank for additional contact time)

Demonstrate the equivalency of T(st), T1 & T2 relative to the required T before or at the first customer.

Determine the value of T1, T2 and L2.

T = T(st) + T1 + T2 = 30 min., T(st) = 19.24 min.

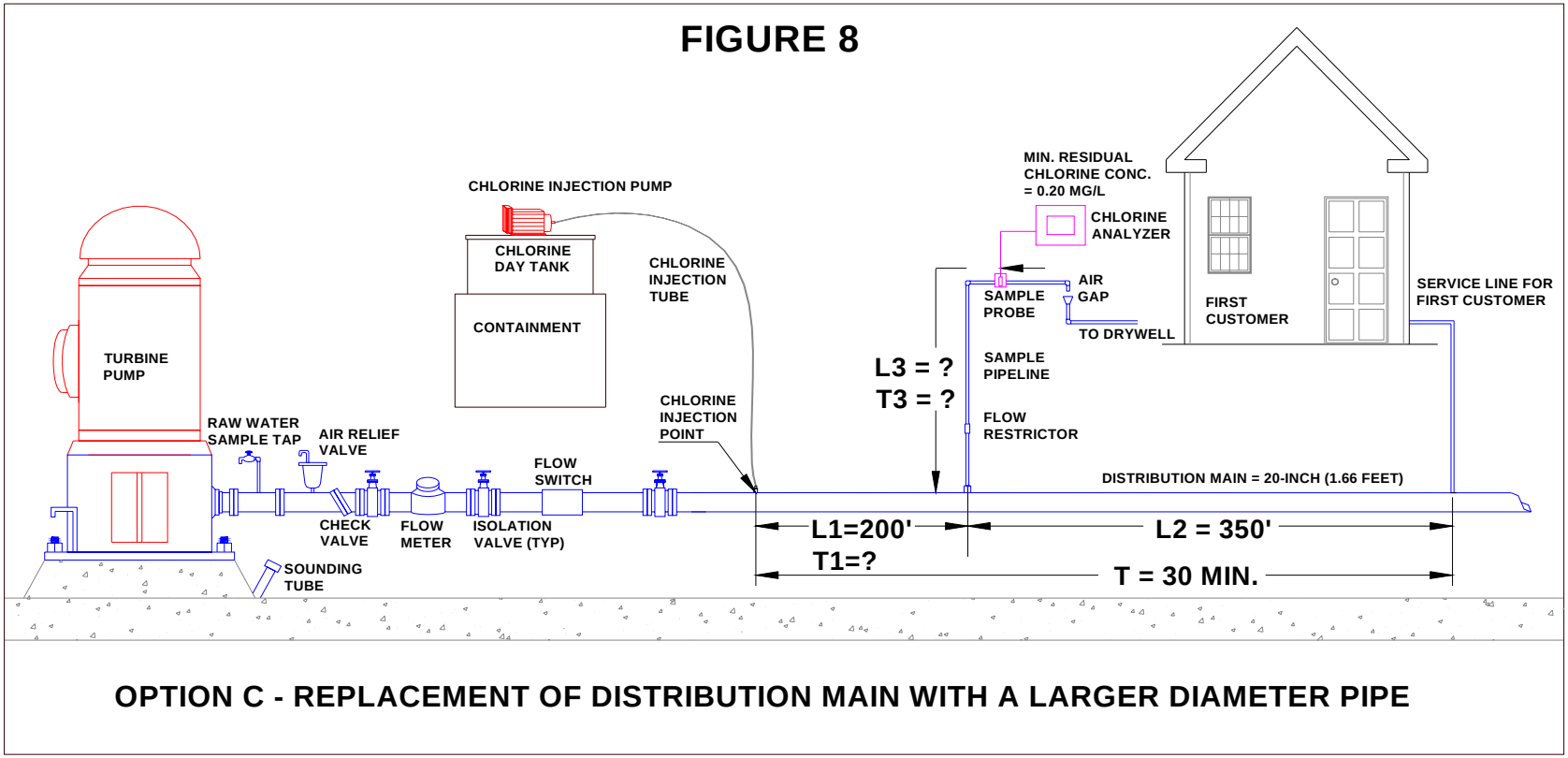
Using equation,

$$T1 = \frac{0.785\,(d1^2) \times L1 \times 7.48}{Q1}, \quad T2 = \frac{0.785\,(d2^2) \times L2 \times 7.48}{Q2}$$

where: d1 = 1 ft., L1 = 100 feet (variable), Q1 = 300 gpm

Using: d2 = ¾ inch (0.0625 ft.), Q2 = 0.25 gpm (fixed rate)

Solve for: T1 = 1.96 min., T2 = 8.8 min., L2 = 96 feet



OPTION C - REPLACEMENT OF DISTRIBUTION MAIN WITH A LARGER DIAMETER PIPE

For option C (replace the distribution main with a larger diameter pipe)

Demonstrate the equivalency of T1 & T3 relative to the required T before or at the first customer.

T = T1 + T3 = 30 min.

Determine the value of T1, T3, and L2

Using equation, $T1 = \frac{0.785\ (d1^2) \times L1 \times 7.48}{Q1}$

where: d1 = 20-inch (1.66 ft.), L1 = 200 feet, Q1 = 300 gpm

Substituting the values:

T1 = 10.87 min., T3 = 30 – 10.87 = 19.13 min.

Using equation, $T3 = \frac{0.785 (d3^2) \times L3 \times 7.48}{Q3}$

Assuming: d3 = ¾ inch (0.0625 ft.), Q3 = 0.25 gpm

Substituting the values:

L3 = 208.8 feet or 209 feet

The minimum length of the sample line for compliance monitoring of residual chlorine must be 209 feet, installed on the main approximately 200 feet downstream from the point of chlorine injection.

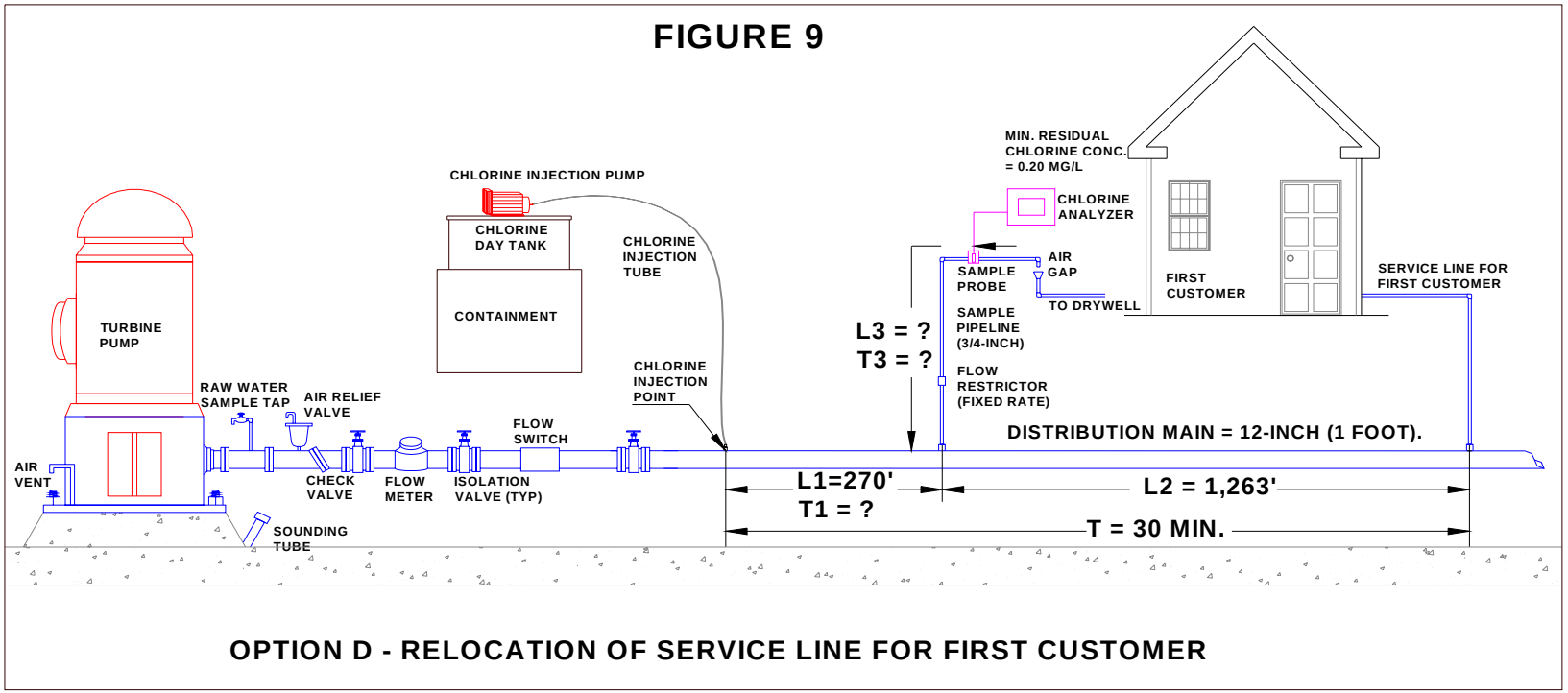


FIGURE 9
MIN. RESIDUAL CHLORINE CONC. = 0.20 MG/L
CHLORINE INJECTION PUMP
CHLORINE ANALYZER
CHLORINE DAY TANK
CHLORINE INJECTION TUBE
AIR GAP
SAMPLE PROBE
FIRST CUSTOMER
SERVICE LINE FOR FIRST CUSTOMER
TO DRYWELL
CONTAINMENT
L3 = ?
T3 = ?
SAMPLE PIPELINE (3/4-INCH)
TURBINE PUMP
FLOW RESTRICTOR (FIXED RATE)
CHLORINE INJECTION POINT
RAW WATER SAMPLE TAP
AIR RELIEF VALVE
FLOW SWITCH
DISTRIBUTION MAIN = 12-INCH (1 FOOT).
AIR VENT
CHECK VALVE
FLOW METER
ISOLATION VALVE (TYP)
L1=270'
T1 = ?
L2 = 1,263'
T = 30 MIN.
SOUNDING TUBE
OPTION D - RELOCATION OF SERVICE LINE FOR FIRST CUSTOMER

For option D (relocation of the service pipe for the first customer)

Demonstrate the equivalency of T1 & T3 relative to the required T before or at the first customer.

T = T1 + T3 = 30 min.

Determine the value of T1, T3, and L3

Using equation, $T1 = \frac{0.785 (d1^2) \times L1 \times 7.48}{Q1}$

where: d1 = 12-inch (1 ft.), L1 = 270 feet, Q1 = 300 gpm

Substituting the values:

T1 = 5.28 min.

T3 = 30 – 5.28 = 24.72 min.

Using equation, $T3 = \frac{0.785\ (d3^2) \times L3 \times 7.48}{Q3}$

Using: d3 = ¾ inch (0.0625 ft.), Q3 = 0.25 gpm

Substituting the values:

L3 = 270 feet

The minimum length of the sample line for compliance monitoring of residual chlorine must be 270 feet, installed on the distribution main approximately 270 feet downstream from the chlorine injection point.

Thank you

If you have any technical questions on CT calculations, please feel free to contact the DWS at 860-509-7333.