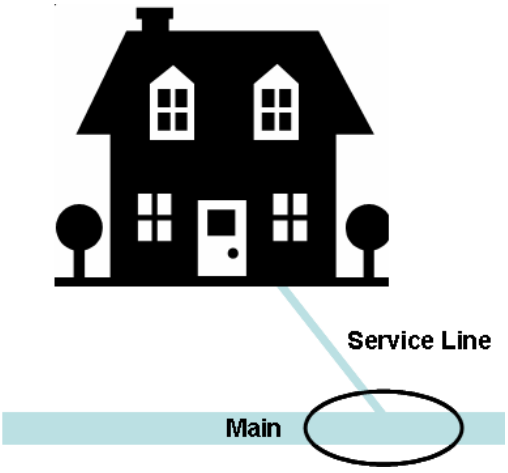
Distribution System Guideline for Obtaining a Representative Sample For Optimization

Objective

It is important for water systems pursuing optimization to have a good understanding and accurate characterization or "picture" of water quality in all areas of their distribution system. Developing this "picture" allows the system to:

- Assess water quality relative to optimization performance goals.
- Understand where critical areas of the system are located (e.g., areas with potential for increased microbial activity or DBP formation).
- Identify anomalies in water quality data that may indicate contamination, cross connections, impacts of tank or DS operations, etc.

This guidance is intended to help systems establish a consistent, technically sound approach for collecting a representative water quality sample in the distribution system. In this context, a representative sample should accurately capture the water in the distribution system main, not the service line, immediately adjacent to the sample location[1]. As such, the water that is located in the service line or piping from the home/business/ hydrant to the main should be wasted or "flushed" before a sample is collected so that the sampler can ensure that he/she is sampling water from the distribution system main (see Figure below). The sampler should avoid over-flushing, as this may draw water from another area of the distribution system, which would not represent the water quality at the intended sample site, thus skewing the "picture" of the water quality at that location in the distribution system.



1. This guideline is intended for water systems where the customer owns the service line beyond the meter. However, if the responsibility of the water system includes the service line and premise plumbing (e.g., privately owned restaurant or government owned park) or if the sampler desires to collect a sample from the service line or tap to assess water quality, this guideline is not appropriate.

Need for this Guideline

It has been observed that flushing practices prior to sample collection vary dramatically from system to system, but the different approaches seem to have no technical foundation. Many systems use temperature change by "feel" as an indicator that they have flushed the service line. Others wait for a designated time (anywhere from 5 to 15 minutes) at all sample locations before collecting a sample.

Further influencing sampling approaches is the need to get a "good" compliance sample – one that is free of contamination, has an "adequate" chlorine residual, and will not trigger a violation. In order to ensure meeting these criteria, the sampler may flush for several minutes or several hours. As a result, the sample could represent water quality somewhere within the distribution, but not at the intended location.

In contrast, a "good" sample for optimization purposes is one that represents the water in the immediate area of the sample site. This guidance is intended to provide a sound, consistent approach for establishing an appropriate sample flush time, which is the first critical step in collecting a representative sample for optimization purposes. Without paying attention to the sample flush times, samplers are inaccurately characterizing their distribution system's water quality and, perhaps, compromising public health.

Approach for Developing this Guideline

A special study was conducted to evaluate and establish this representative sampling guideline. Thirty-eight unique sampling events were conducted and analyzed from two chlorinated distribution systems in Kentucky. Sample taps (residential and business) and hydrants were used for sample sites. Chlorine residual, temperature, and flushing time were used as criteria to determine if adequate flushing had been achieved and water was coming from the main. Both chlorine residual and temperature were used to indicate the effectiveness of flushing, since these have traditionally been used to indicate flushing effectiveness. Calculated Flush time (CFT) (i.e., theoretical detention time) was determined at each individual site by estimating the pipe length and diameter from the sample tap to the main coupled with a pre-selected flow-rate.

At each sample site, at least three consecutive samples were collected in order to track the changes in chlorine and temperature during the period of flushing. One sample was collected at time zero as soon as the sample tap was opened (to get a baseline), and at least two other samples (one at the calculated flush time and another at twice the calculated flush time). Temperature measurements were read and recorded with a digital temperature probe. Chlorine residual samples were analyzed immediately after the sample was collected using free chlorine AccuVac ampules. Pipe lengths and diameters were estimated using distribution system maps, water system personnel experience, and on-site estimates of pipe lengths (e.g., pacing). Tap and hydrant flow-rates were measured by timing the fill of a 1-liter bottle or 5-gallon bucket, respectively. Hydrant samples were collected from a hydrant sampling device that was constructed for this purpose.

After each sample event the chlorine and temperature data were analyzed to assess if these values stabilized during the flushing period. It was theorized that temperature and chlorine stabilization could be used as indicators that the water from the service line had been flushed and

that the stable readings indicated that the water was coming from the main. The chlorine and temperature readings obtained were then compared relative to the initial sample time, the calculated flush time and to twice the calculated flush time.

The results of the studies indicated that both chlorine and temperature are not consistently reliable indicators that the service line has been flushed. Reasons for the inconsistencies are likely site specific and were not investigated further. Based on this finding, the use of CFT is the suggested approach.

Guideline for Obtaining a Representative Sample

Before a representative distribution system water quality sample can be collected from a distribution system, a sampler must determine an appropriate sample flushing time. The objective of flushing a sample line is to waste or "flush" the water that is in the piping (service line or hydrant) from the home/ business/ hydrant to the main. The determination of this flushing time should ensure that water is coming from the distribution system main in the *immediate area of the identified sample site,* not in the service line or at a non-representative distance from the intended site. The sampler should avoid over-flushing, as this may draw water from another area of the distribution system that would not represent the water quality at the intended sample site.

In general, samplers should take the following steps to ensure that proper flushing has been conducted at the sample site:

1. Estimate the length and diameter of the pipe or hydrant that is to be flushed. Guidance is provided in Appendix A.
2. Determine CFT based on an estimated pipe length, diameter, and flow-rate (see approaches described below)
3. Open the hydrant or tap, start the timer and, if not using a flow-regulator, verify that the flow is at the desired rate (e.g., by quickly timing the fill of a 5-gallon bucket or liter bottle).
4. At **two times the CFT or time designated by the rule of thumb** (this conservative approach accounts for inaccuracies in flow-rate and piping assumptions) stop flushing and collect the water sample(s). If multiple samples are collected over a significant span of time relative to the flushing time, turn off the tap in between samples.

Hydrant samplers were designed and used by the team in developing this guideline. The hydrant sampler was designed to allow the hydrant to be fully open, while allowing the hydrant to flush at a constant rate (20 gpm) and to permit collecting a sidestream sample. A tap sampler, which regulated the flow to 2 gpm, was also designed. A parts list is available in Appendix B.

Note: The estimated CFTs using these tools are not precise measurements since pipe length, diameter, and flow-rate estimates are imprecise. However, these tools provide a reasonable estimate and a controlled safety factor that should ensure quick, easy determinations and prevent gross overestimation.

Rule of Thumb Approach

The rule of thumb approach is appropriate for sample sites that may only be sampled once (e.g., a sampling study) and have a common configuration relative to the main. For all other sites and sampling needs, the CFT matrix approach is recommended.

> ***Rule of Thumb for Hydrants*:** In many cases, the configuration of a hydrant relative to the main is similar from location to location. In other words, if the hydrant type is typical (5 ¼ or 4 ½" main valve opening), lead pipe (horizontal pipe from the main to the hydrant) is 6", and the pipe length is less than approximately 20 feet (typical of a hydrant that is on the same side of the street as the main), the line will flush in approximately 1.5 minutes at 20 gpm. **Assume a 3 minute total flush time for this configuration to allow for an adequate factor of safety**. This conservative flush time should account for flow-rate variations and inaccurate length estimates.
>
> ***Rule of Thumb for Taps:*** Residential service lines are typically ¾" in diameter and less than 100 feet long. A pipe of this diameter will flush up to 100 ft of pipe length in about 1 minute at a flow-rate of about 2 gpm. **Assume a 2 minute total flush time for this configuration to allow for an adequate factor of safety.** This conservative flush time should allow for an adequate safety factor and inaccurate length estimates.

Calculated Flush Time (CFT) Matrix Approach

In all water systems there are sites that are sampled on a routine basis for bacteriological or disinfection byproduct (DBP) compliance sampling. At these sites water systems should establish a unique flush time that is appropriate for each sample site, rather than use the rule of thumb at these sites. This flush time can be established ***once*** and be used each time a sample is collected at that location, provided that the piping at this sample site stays the same.

> ***CFT matrix for Hydrants*:** Determine a conservative CFT from the matrix (Table 1) below using the estimated hydrant and lead pipe lengths and diameters. Guidance on estimating these lengths and diameters is provided in Appendix A. **Collect a sample after the hydrant has flushed for approximately two times the CFT to allow for an adequate factor of safety**.

Table 1. Number of Minutes needed to Flush Hydrant at 20 gpm						
Length of Pipe	Inside (Nominal) Diameter of Hydrant/ Pipe (inches)					
	2	4	6	8	12	16
1	0.0	0.0	0.1	0.1	0.3	0.5
5	0.0	0.2	0.4	0.7	1.5	2.6
10	0.1	0.3	0.7	1.3	2.9	5.2
15	0.1	0.5	1.1	2.0	4.4	7.8
20	0.2	0.7	1.5	2.6	5.9	10.4
25	0.2	0.8	1.8	3.3	7.3	13.1
30	0.2	1.0	2.2	3.9	8.8	15.7
35	0.3	1.1	2.6	4.6	10.3	18.3
40	0.3	1.3	2.9	5.2	11.8	20.9
45	0.4	1.5	3.3	5.9	13.2	23.5
50	0.4	1.6	3.7	6.5	14.7	26.1
55	0.4	1.8	4.0	7.2	16.2	28.7
60	0.5	2.0	4.4	7.8	17.6	31.3
65	0.5	2.1	4.8	8.5	19.1	33.9
70	0.6	2.3	5.1	9.1	20.6	36.6
75	0.6	2.4	5.5	9.8	22.0	39.2
80	0.7	2.6	5.9	10.4	23.5	41.8
85	0.7	2.8	6.2	11.1	25.0	44.4
90	0.7	2.9	6.6	11.8	26.4	47.0
95	0.8	3.1	7.0	12.4	27.9	49.6
100	0.8	3.3	7.3	13.1	29.4	52.2

1. Depending on the type of pipe material and degree of corrosion inside the pipe, the inner diameter will vary. These diameters are meant to be approximations.

***CFT matrix for Taps*:** Determine a conservative CFT from the matrix (Table 2) below using the estimated service line and premise plumbing lengths and diameters. Guidance on estimating these lengths and diameters is provided in Appendix A. **Collect a sample after the tap has flushed for approximately <u>two times the CFT</u> to allow for an adequate safety factor**.

Table 2. Number of Minutes needed to Flush Tap at 2 gpm											
Length of Pipe	Inside (Nominal) Diameter of Pipe (inches)										
	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
1	0.00	0.01	0.01	0.01	0.02	0.03	0.05	0.1	0.1	0.2	0.3
5	0.01	0.03	0.04	0.1	0.1	0.2	0.2	0.4	0.6	0.9	1.6
10	0.03	0.05	0.08	0.1	0.2	0.3	0.5	0.8	1.3	1.8	3.3
15	0.04	0.08	0.12	0.2	0.3	0.5	0.7	1.2	1.9	2.8	4.9
20	0.1	0.1	0.2	0.2	0.4	0.6	0.9	1.6	2.6	3.7	6.5
25	0.1	0.1	0.2	0.3	0.5	0.8	1.1	2.0	3.2	4.6	8.2
30	0.1	0.2	0.2	0.3	0.6	1.0	1.4	2.4	3.8	5.5	9.8
35	0.1	0.2	0.3	0.4	0.7	1.1	1.6	2.9	4.5	6.4	11.4
40	0.1	0.2	0.3	0.5	0.8	1.3	1.8	3.3	5.1	7.3	13.1
45	0.1	0.2	0.4	0.5	0.9	1.4	2.1	3.7	5.7	8.3	14.7
50	0.1	0.3	0.4	0.6	1.0	1.6	2.3	4.1	6.4	9.2	16.3
55	0.2	0.3	0.4	0.6	1.1	1.8	2.5	4.5	7.0	10.1	18.0
60	0.2	0.3	0.5	0.7	1.2	1.9	2.8	4.9	7.7	11.0	19.6
65	0.2	0.3	0.5	0.7	1.3	2.1	3.0	5.3	8.3	11.9	21.2
70	0.2	0.4	0.6	0.8	1.4	2.2	3.2	5.7	8.9	12.9	22.8
75	0.2	0.4	0.6	0.9	1.5	2.4	3.4	6.1	9.6	13.8	24.5
80	0.2	0.4	0.6	0.9	1.6	2.6	3.7	6.5	10.2	14.7	26.1
85	0.2	0.4	0.7	1.0	1.7	2.7	3.9	6.9	10.8	15.6	27.7
90	0.3	0.5	0.7	1.0	1.8	2.9	4.1	7.3	11.5	16.5	29.4
95	0.3	0.5	0.8	1.1	1.9	3.0	4.4	7.8	12.1	17.4	31.0
100	0.3	0.5	0.8	1.1	2.0	3.2	4.6	8.2	12.8	18.4	32.6
1. If service line diameter is 3" or greater consider selecting a different site as CFT could be long											
2. If plumbing is less than 3/8", assume this pipe volume is negligible											
3. Depending on the type of pipe material and degree of corrosion inside the pipe, the inner diameter will vary. These diameters are meant to be approximations.											

"Cheat Sheets" for estimating the CFT for hydrants and taps, which can be used in the field, are included in Appendix C.

> ***CFT matrix for Other Flowrates*:** If the flow-rate is less or greater than that provided in the CFT matrices above, the matrices and calculations provided in Appendix D should be used. **Once the CFT is determined collect a sample after the hydrant/ tap has flushed for <u>two times the CFT</u> to allow for an adequate factor of safety**.

At some sampling locations, a sampler may determine that the CFT matrices are not adequate (i.e., pipe diameter is not included on the table, etc.) and the CFT will need to be calculated using the equations provided in Appendix E.

Other Tips for Representative Sampling

From its experience with distribution system sampling, the optimization team suggests these additional considerations and tips for collecting representative samples in the distribution system:

- Consider sampling from hydrants to allow the system more flexibility in sampling at all areas of the distribution system, even remote sites.
- Sample sites with straightforward, easy-to-estimate piping configurations, such as hydrants and designated sample stations, are preferred.
- A hydrant should *not* be "scoured" by opening and flowing the hydrant in the fully open position before collecting a sample, because this could change the sample's water chemistry (e.g., introducing air into the sample that could impact pH).
- Since dry-barrel hydrants are designed to be opened fully, a hydrant sampling device should be constructed (a parts list is available in Appendix B) to allow a sampler to fully open the hydrant, throttle back the flow to flush at 20 gpm (or desired flow-rate), and to collect a representative sample. Hydrants should always be opened slowly to minimize hydraulic surges.
- Samplers should be aware of looped portions or distribution locations where two mains come together, because slight over-flushing could pull water from either or both mains or from unknown directions. Understanding the water quality at these sites can be challenging.
- Samplers should use caution, especially when sampling in businesses or homes, where the service line and premise plumbing length is unknown. Any major inaccuracies could significantly over or under-estimate the CFT.
- In cases where premise plumbing length is unknown and an alternative sample site cannot be located, temperature and CFT, together, may indicate when adequate flushing time has been reached. If the CFT isn't long enough, the temperature *may* indicate that a longer flush time is needed. Temperature should stabilize to within 0.2 °C, as indicated by a digital thermometer, between readings. When the CFT has been established it can be documented and used for future sampling at the site.
- If the sampler desires to characterize the water quality in a small area where sample sites could be located next to each other, such as neighboring businesses, CFT should be more carefully estimated in order to avoid over-flushing.
- In cases where the sampler is concerned about over-flushing, the CFT matrix should be used rather than the rule of thumb guidelines.

Based on their experience, the optimization team feels that this guideline is one of the first – of many – steps in a process to increase awareness among distribution system operators about the importance of understanding distribution system water quality and collecting representative samples.

Acknowledgements

Thanks to TSC's Optimization team members and Distribution System workgroup members for their support in developing this important guideline, as well as, the cities and water system staff of Falmouth and Nicholasville, KY for allowing samples to be taken and procedures to be tested in their distribution systems. Thank you to Jon "the Plumber", the Falmouth staff, Kentucky Division of Water AWOP team, and Pennsylvania Department of Environmental Protection AWOP team for their help in designing and testing the hydrant and tap samplers.

Appendix A

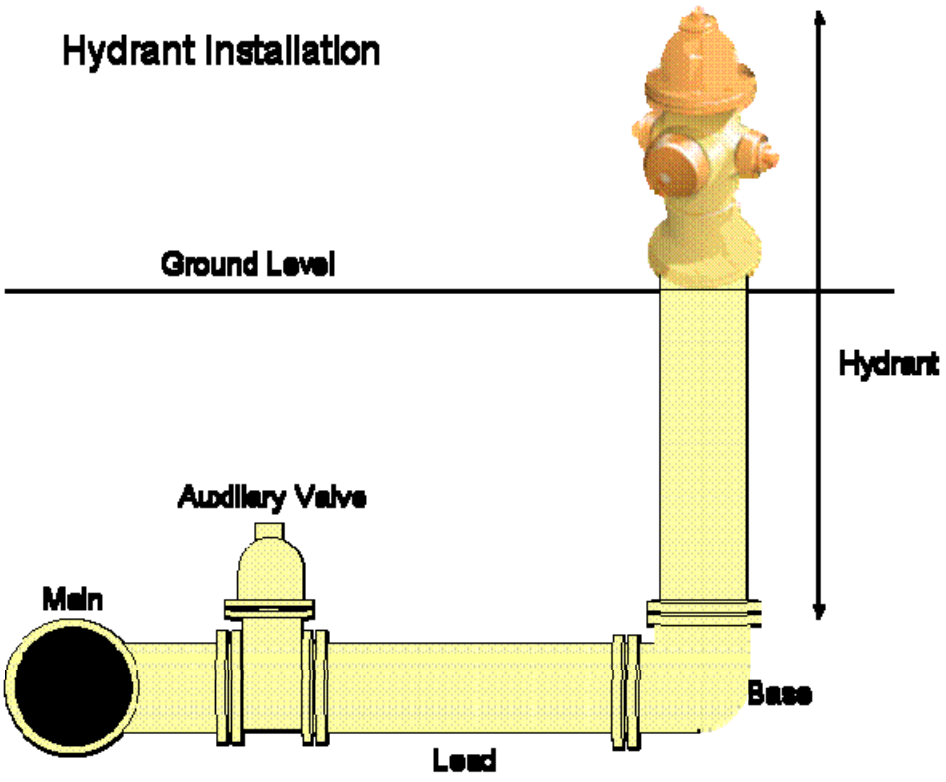
Recommendations for Estimating Pipe Length and Diameter at Hydrants and Residential/ Business Taps

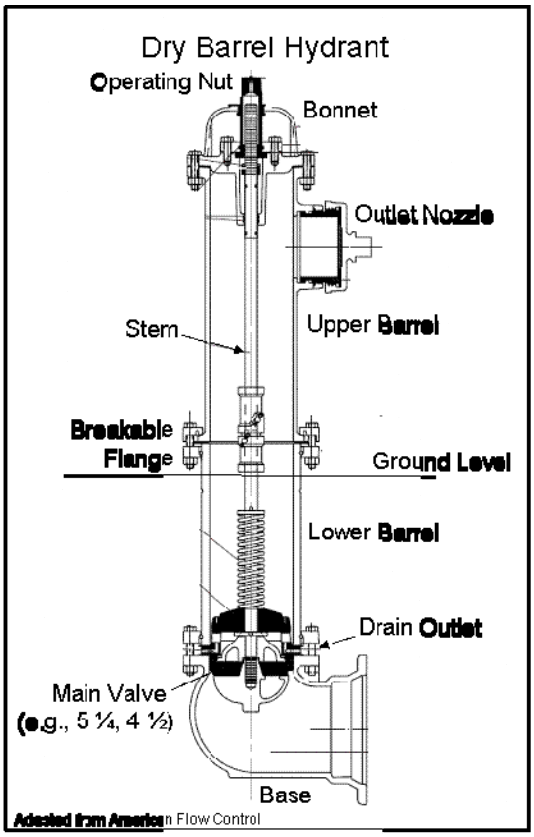
Recommendations for Estimating Pipe Length and Diameter at Hydrants and Residential/ Business Taps

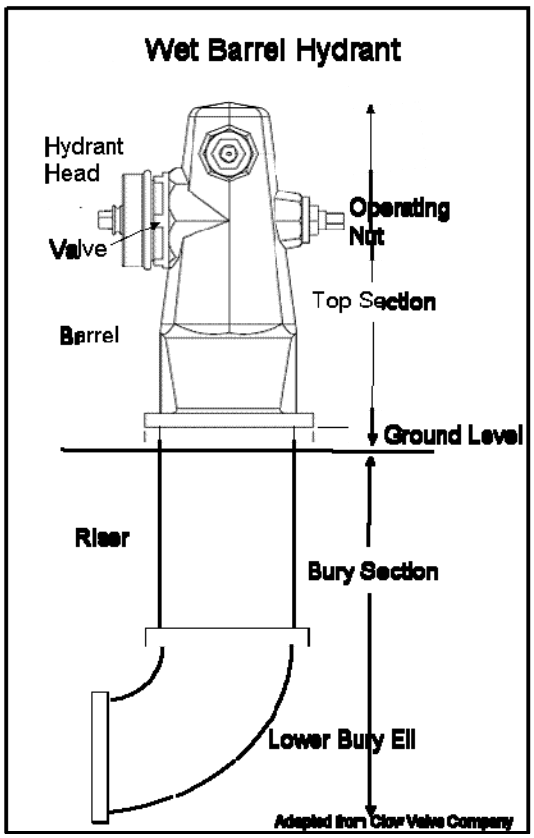
HYDRANTS

Understanding Hydrant Construction and Installation

The following diagrams were adapted from AWWA M17, Installation, Field Testing and Maintenance of Fire Hydrants, along with manufacturer's hydrant drawings. Understanding hydrant construction, installation, and operation is important in order to calculate the hydrant flush volume.







Understanding Dry Barrel Hydrant Operating Sequence (From ACR Publications, www.acrp.com, Operation of Water Distribution Systems)

"Opening Sequence - When a dry barrel hydrant is in a closed position, the main valve is closed and the drain valve is completely open. The drain valve will remain open during the first 1 to 5 turns of the stem. As the main valve is opened, the drain valve begins to close. This will allow a positive pressure to develop in the hydrant prior to the closing of the drain valve, thus helping to clear the drain valve opening. After about 1 to 5 turns, the drain valve is completely closed and all flow is directed out through the outlet nozzles.

Closing Sequence – During closing of the hydrant, the drain valve remains closed until the main valve is within 1 to 5 turns of being closed. At this time the drain valve will begin to open, allowing water under pressure to once again clear the drain holes. As the main valve reaches full closure, the drain valve returns to full open position. All remaining water in the barrel of the hydrant will drain through the drain valves. This assumes that the drain valve is not below the water table, plugged, or frozen." (Fire Hydrant Operation and Inspection, p. 159-160)

Dry Barrel Hydrant Operating Recommendations (From ACR Publications, www.acrp.com, Operation of Water Distribution Systems)

1. "Do not trap air – With all dry barrel hydrants, it is important that the hydrant be opened slowly. The air that is in the barrel should be allowed to exit the barrel before the hydrant is fully opened. It is good practice to open the hydrant only enough to start a flow of water but not enough to close the drain valve. This allows the air to exit slowly and the drain valve to be cleared. Should you open the hydrant too quickly, you could produce water hammer.

2. Do not throttle – After all the air has exited, the hydrant should be fully opened. At no time should a hydrant be left in a partially open condition. In this condition, water may exit the drain valve and erode the base under the hydrant causing failure of the hydrant or lateral.
3. The last 5 to 8 turns – Closing is similar to the opening process. The hydrant may be closed rather quickly down to the last 5 to 8 turns. Slowly moving through these last few turns is critical in order to prevent water hammer. Considerable damage to main lines, service connections, and household water heaters can be attributed to water hammer created by closing hydrants too rapidly. All hydrants can be closed with sufficient speed to cause water hammer. However, the center stem hydrants that close with the pressure can cause considerably more damage.
4. Check drain valve – After the hydrant is closed, wait until the barrel has drained before replacing the nozzle caps (you will notice a slight suction by placing your hand over the open nozzle). If the nozzle caps are replaced prematurely, they may prevent the hydrant from draining and allow water to stand in the barrel.
5. Should be Easy to Operate – It should not take excessive pressure to close the hydrant. If is does, then there is probably some damage to the main valve, stem, or operating nut, and the hydrant should be scheduled for repair.
6. Back off ¼ turn – After the hydrant is closed, back off on the opening nut about ¼ turn. This removes the pressure from the operating nut and stem. The main valve will remain closed. This also allows the next person who opens the hydrant to determine quickly if they are turning the operating nut in the wrong direction. If they are, it will move easily for ¼ turn, then stop." (Fire Hydrant Operation and Inspection, p. 161)

Calculating Hydrant Flush Volume

At hydrant sites there are two parts of the water volume calculation, the piping from the main to the hydrant base (or hydrant lead) and the piping from the hydrant nozzle to the hydrant base. The sum of these two volumes will equal your total flush volume, and along with your flush rate, a CFT (an example Hydrant Sample Site Information sheet is provided below).

1. Diameter and length of hydrant (vertical piping from dry barrel hydrant base to hydrant nozzle). In a dry barrel hydrant this volume of pipe should be dry since the drain valve is open when the main valve is closed, however if the nozzle caps are replaced before the hydrant has had a chance to drain there could be standing water in the hydrant. To be conservative calculate the volume for the hydrant:
    a. Diameter of hydrant: Currently, the majority of hydrants in the industry are 5 ¼ or 4 ½. This indicates the diameter of the main valve on a dry barrel hydrant. A 5 ¼ hydrant has an inside diameter ranging between 6 and 7 inches depending on the manufacturer. A 4 ½ hydrant has an inside diameter of approximately 6 inches depending on the manufacturer (based on information from American Flow Control, Mueller). <u>For ease of calculation, assume a 6-inch hydrant diameter.</u>
    b. Length of hydrant: A hydrant is comprised of the upper barrel (above-ground section) plus the lower barrel (below ground section). The desired pipe length is the vertical distance between the hydrant nozzle on the upper barrel to hydrant base on the lower barrel. AWWA standards for hydrant installation recommend 18 inches (from nozzle to ground level), plus a minimum of 42 inches below

ground (from ground level to top of hydrant lead pipe). Assume 6 ft from hydrant nozzle to hydrant base to be conservative.

2. Diameter and length of hydrant lead (lateral pipe from main to hydrant base)
    a. Diameter of hydrant lead: The hydrant lead diameter is typically 6-inch (AWWA Manual M17, p. 4).
    b. Length of hydrant lead: Locate the auxiliary valve in the street or yard (this is typically marked with a round cover that says "WATER"). AWWA standards and common practice is to place the valve as close to the main as possible. Assume that the valve is next to the main. Measure the distance from the valve to the hydrant using a distance measurement wheel or tape measure. Assume the pipe length to be this horizontal distance plus 1 ft to be conservative.

Other tips:

- Conduct sampling with an experienced operator or look at detailed drawings when possible. Use the water system's information in lieu of the recommendations provided above.
- When a dry barrel hydrant is open the main valve is open and the drain valve is closed. If you have reason to believe that the drain valve is malfunctioning and is open while the hydrant is fully open, do not use the hydrant for collecting a water sample. Potential contamination may occur from outside sources entering the hydrant.

TAPS

Residential/ Business Taps

At residential or business taps there are several important things to look for when selecting a tap for sampling. First, and most importantly, identify a tap that is closest to the main. Selecting a tap that is inside the building far from where the service line enters the building will make estimating pipe length difficult. Next, verify that there are no filters or treatment systems prior to the sample tap, as this could impact water quality at that site. Ideally, identify a tap where the tap sampler can be installed (which has a garden hose fitting), so that the flow can be regulated to 2 gpm. Beware of sampling from industries or large buildings where the service line has a large diameter. For example, a 4 inch service line flushing at 2 gpm would take 10 minutes or more to flush the service line and building piping.

1. Identify the diameter and length of service line:
    a. Diameter of Service Line: Using the judgment of an experienced operator or best engineering judgment, determine the diameter of service line. AWWA Manual M17 notes that for single-family residences, a ¾ inch service line is typical. For customers located at a higher elevation than the main, if the service line is long, or if the customer has large water uses (e.g., fire or irrigation sprinkler system) this may not be adequate.
    b. Length of Service Line: Identify the meter/ curb stop and estimate the length of service line by measuring the distance from that location to the building (to approximately where the service enters the building).
2. Identify the diameter and length of premise plumbing:

a. Diameter of Premise Plumbing: The diameter of premise plumbing may be reduced to a smaller diameter than the service line once it enters the building. If possible, go into the building to where the service enters and estimate the pipe diameter inside the building. Note: If the tap is close to where the service line enters the building, the volume of premise plumbing may be negligible. Use the judgment of an experienced operator or best engineering judgment to estimate the premise plumbing pipe volume.
b. Length of Premise Plumbing: If possible, go into the building to where the service enters and estimate the length of pipe inside the building. Note: If the tap is close to where the service line enters the building, the volume of premise plumbing may be negligible. Use the judgment of an experienced operator or best engineering judgment to estimate the premise plumbing pipe volume.

An example Tap Sample Site Information sheet is provided below.

References

AWWA Manual M17, Installation, Field Testing, and Maintenance of Fire Hydrants
AWWA Manual M22, Sizing Water Service Lines and Meters
ACR Publications, www.acrp.com, Operation of Water Distribution Systems, Fire Hydrant Operation and Inspection

Hydrant Sample Site Information
Volume and CFT Estimate

Site Name: **Edward Jones Investments**

Address: 119 N Ft Thomas Ave
Fort Thomas, KY 41075

Description of site: Across from City Building, on 16"line

Other:

Siting issues: drain water to street, needs to be dechlorinated

Hydrant Type (dry or wet barrel, 5 ¼, 4 ½, other): dry barrel, 5 ¼ (assume 6" inner diameter barrel)

Flush rate (gpm): 20

Hydrant Nozzle to hydrant base:
Diameter of hydrant: 6"
Approximate length of hydrant: 6 ft
CFT (from matrix) = 0.5 min

Hydrant Lead (main to hydrant base):
Diameter of hydrant lead = 6"
Approximate length of pipe (main to auxiliary valve) = 1 ft
Approximate length of pipe (auxiliary valve to hydrant base) = 14 ft
TOTAL length of hydrant lead = 15 ft
CFT (from matrix) = 1.1 min

Calculated Flush Time (CFT):
CFT hydrant = 0.5 min
CFT hydrant lead = 1.1 min
TOTAL = 1.6 min

CFT*2: **3 min 12 sec**

Tap Sample Site Information
Volume and CFT Estimate

Site Name: **Newport Plant**

Address: 2055 Memorial Parkway
Ft Thomas, KY 41075

Description of site: Outside sample site, inside plant fencing, off of 20" DIP

Type of sample site (residential/ business tap, designated sample station): business tap

Description of tap: garden hose spigot on side of building, near corner of building

Tap sampler can be used? yes

Other:

Siting issues: drain water to grass

Flush rate (gpm): 2 gpm

Outside building:
Diameter of service line pipe: 1.5"
Length of service line (meter to building): 28 ft
CFT (from matrix) = 1.3 min

Inside building:
Diameter of premise plumbing = 3/4"
Approximate length of plumbing (when service enters building to tap) = 10 ft
CFT (from matrix) = 0.1 min

Calculated Flush Time (CFT):
CFT inside = 1.3 min
CFT outside = 0.1 min
TOTAL = 1.4 min

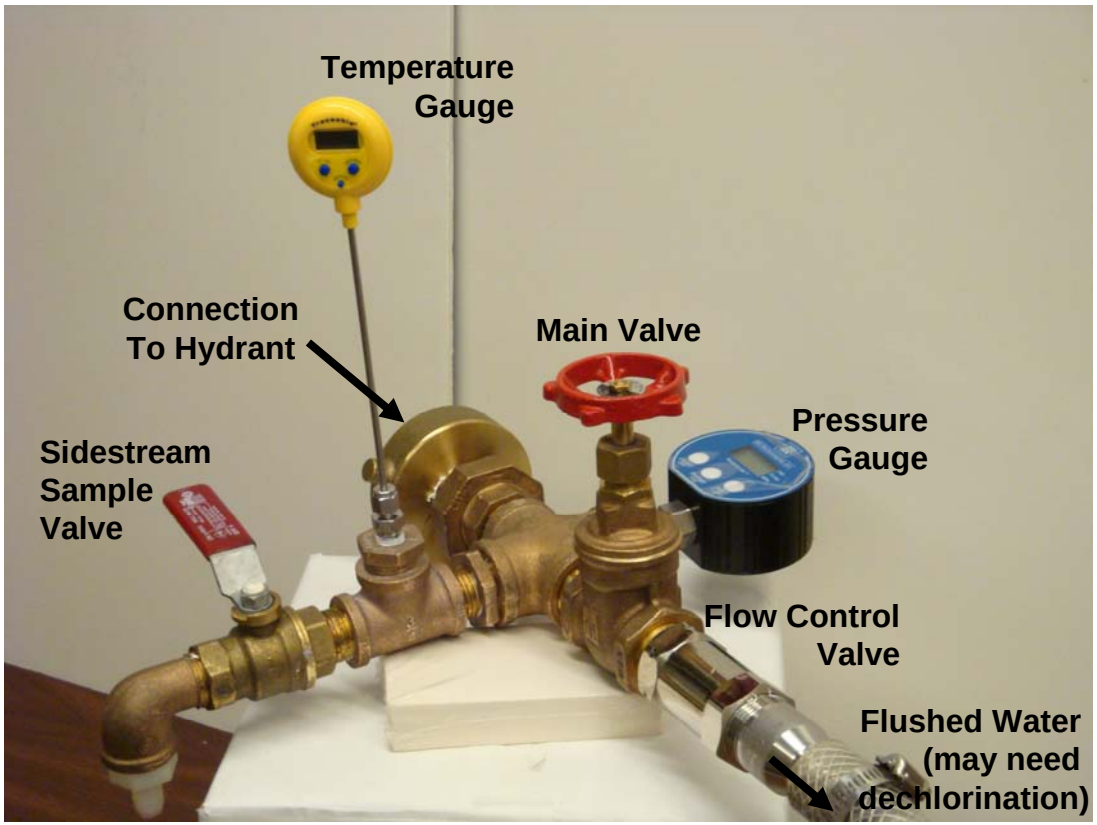
CFT*2: **2 min 48 sec**

Appendix B

Hydrant and Tap Sampler Parts List

US EPA TSC “Falmouth” Hydrant Sampler

In distribution system sampling, oftentimes residential or business taps are not available to sample at (especially in remote areas of the system), so hydrants are used. Since hydrants are designed to be fully open, a device is needed to keep the hydrant open, but allow the sampler to sample the water in controlled, safe manner. See details provided below.

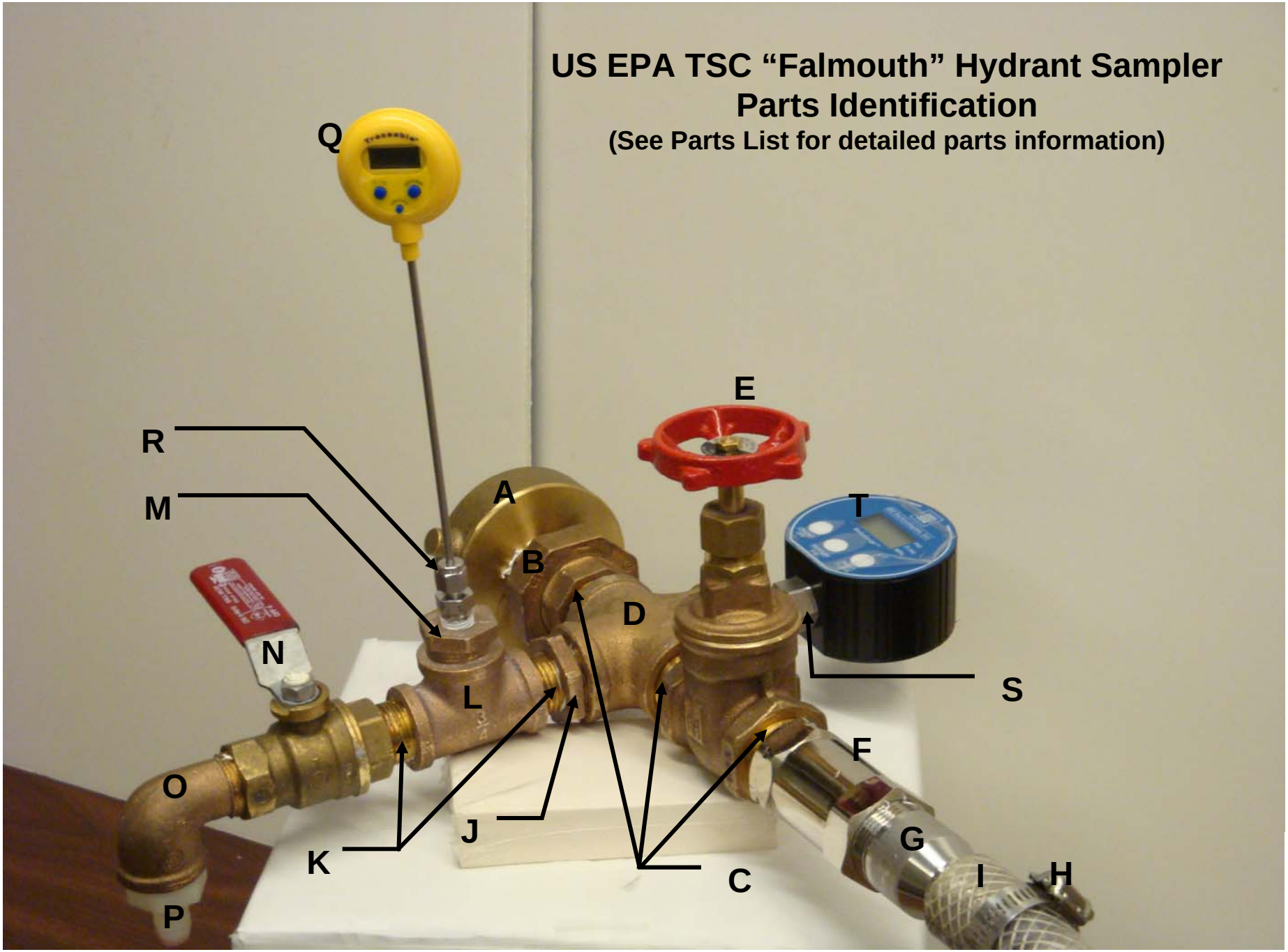


Procedure for Using Hydrant Sampler

1. Determine calculated flush time (CFT) based on an estimated pipe length, diameter, and flow-rate (see methods described in *Guideline*)
2. Close all valves on sampler and connect to hydrant
3. Open hydrant (slowly) until fully open
4. Open main valve on sampler, start the timer. The flowrate should be set to 20 gpm based on the flow control valve.
5. At twice the CFT or time designated by the rule of thumb close the main valve, open the sidestream sample valve, and collect the water sample(s). If multiple samples are collected over a significant span of time relative to the flushing time, turn off the tap in between samples.
6. Take water temperature reading at time of sample. If CFT is unknown track temperature stabilization along with CFT to estimate adequate flush.
7. Take water pressure reading at time of sample (if desired).
8. When sampling is completed shut off all valves and (slowly) close hydrant.

US EPA TSC "Falmouth" Hydrant Sampler Parts Identification

(See Parts List for detailed parts information)



TSC "Falmouth" Hydrant Sampler Parts List [A]

Section of Sampler	Item	Photo Letter	Number Required	Potential Source
Main Section	Hydrant Adapter/Reducer (2½" FNST Inlet by 1" MNPT Outlet), item # P67302 [B]	A	1	1
	1" NPT union	B	1	2,6
	1" NPT close nipple	C	3	2,6
	1" NPT cross	D	1	2,6
	1" NPT gate valve	E	1	2,6
	Dole Flow Control Valve - 20.0 gpm, FRGX10200, 1" FNPT inlet/outlet	F	1	5
	1" NPT X 1" ID hose adapter	G	1	2,6
	#16 Hose clamp for 1" ID hose	H	1	3
	1" ID hose (reinforced PVC)	I	5 ft	3
Sampling Section	1" X 3/4" NPT reducing bushing	J	1	2,6
	3/4 " NPT close nipple	K	2	2,6
	3/4" NPT tee	L	1	2,6
	3/4" X 1/4" NPT reducing bushing	M	1	2,6
	3/4" NPT ball valve	N	1	2,6
	3/4" NPT street ell	O	1	2,6
	3/4" NPT X 1/4 " ID hose adapter	P	1	3
Temperature Probe	Temperature probe with **X**" probe diameter (Must have accurate measurement of probe diameter)	Q	1	7
	X" X 1/4" NPT male connector, bored through with teflon ferrule [C]	R	1	4
Pressure Gauge	1" NPT x1/4" NPT reducing bushing	S	1	2,6
	Weksler 160 PSI Pressure Gauge, 1/4"MNPT connector	T	1	6

Footnotes

A. Fittings are rated for maximum of 150 psi, sampler may not be safe when system pressures exceed this value. Sampler could be modified to include a pressure reducing valve (PRV).

B. Some systems have special hydrant threads specific to their system, however the majority of systems use FNST.

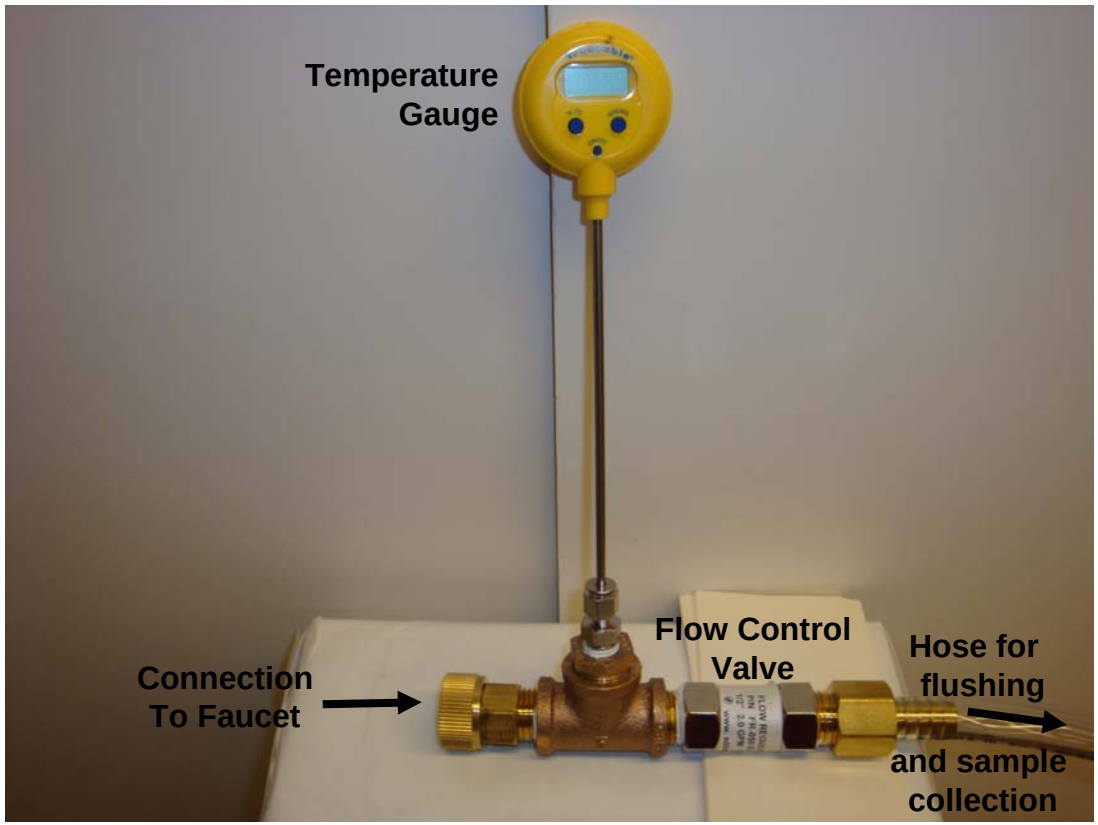
C. Size of male connector (**X**) depends on probe diameter of temperature probe used

Potential Sources

1. Pollard Water - www.Pollardwater.com, or 800/437-1146
2. Pipe fittings are available at plumbing supply and hardware stores
3. Hose, fittings and hardware available at Lowes and Home Depot
4. Swaqelock - Check at swagelock.com for local supplier
5. Ferguson Waterworks - www.Furgeson.com, stores nationwide
6. Grainger - www.grainger.com, stores nationwide
7. Scientific equipment suppliers

US EPA TSC Tap Sampler

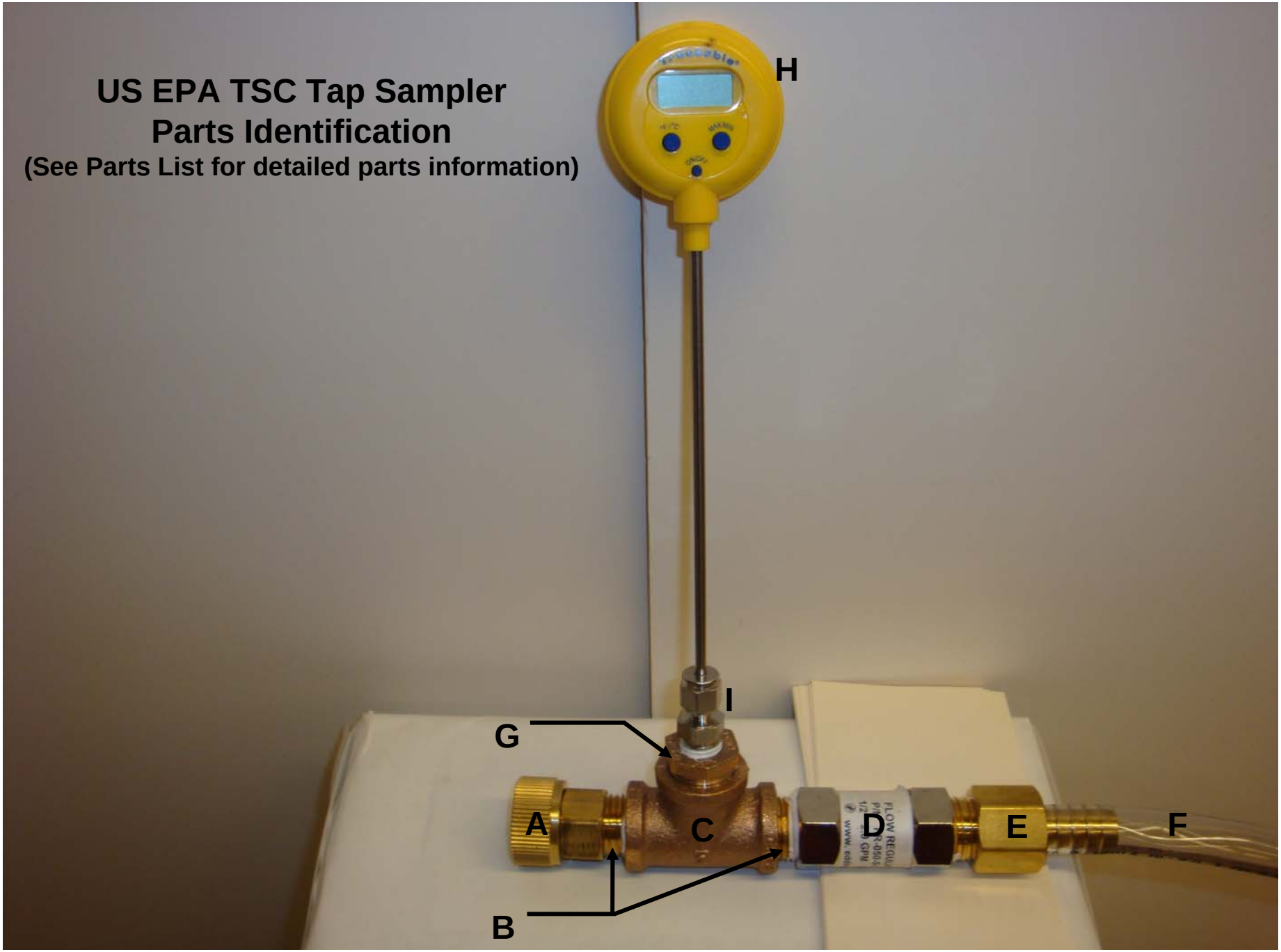
After the hydrant sampler was designed and constructed, a tap sampler was later designed for sampling at residential and business taps that would allow the sampling team to measure an accurate calculated flush time at the desired 2 gpm flowrate. See details provided below.



Procedure for Using Tap Sampler

1. Determine calculated flush time (CFT) based on an estimated pipe length, diameter, and flow-rate (see methods described in *Guideline*)
2. Remove aerator and connect sampler to faucet.
3. Turn on cold water tap fully and start the timer. The flowrate should be set to 2 gpm based on the flow control valve.
4. At twice the CFT or time designated by the rule of thumb turn off the tap and collect the water sample(s). If multiple samples are collected over a significant span of time relative to the flushing time, turn off the tap in between samples.
5. Take water temperature reading at time of sample. If CFT is unknown track temperature stabilization along with CFT to estimate adequate flush.
6. When sampling is completed disconnect from faucet.

US EPA TSC Tap Sampler
Parts Identification
(See Parts List for detailed parts information)



Tap Sampler Parts List

Section of Sampler	Item	Photo Letter	Number Required	Potential Source
Main Section	Garden hose coupling, 1/2" FNPT outlet	A	1	1,5
	1/2" NPT close nipple	B	2	1,5
	1/2" NPT Tee	C	1	1,5
	Dole Flow Control Valve - 2.0 gpm, model 2GB, 1/2" FNPT inlet/outlet	D	1	1,5
	1/2" MNPT X 1/2" ID hose adapter	E	1	1,5
	1/2" ID hose	F	2ft	2
Temperature Probe	Reducing bushing 1/2" NPT X 1/4" NPT	G	1	1,5
	Temperature probe with **X**" probe diameter (Must have accurate measurement of probe diameter)	H	1	6
	X" X 1/4" NPT male connector, bored through with teflon ferrule[A]	I	1	3

Footnotes

A. Size of male connector (**X**) depends on probe diameter of temperature probe used

Potential Sources

1. Pipe fittings are available at plumbing supply and hardware stores
2. Hose, fittings and hardware available at Lowes and Home Depot
3. Swaqelock - Check at swagelock.com for local supplier
4. Eddington Industries, LLC, (888) 813-9900
5. Grainger - www.grainger.com, stores nationwide
6. Scientific equipment suppliers

Appendix C

Hydrant and Tap Cheat Sheets

Hydrant Sampling Cheat Sheet

In general, the following steps should be taken to ensure that the sampler has properly flushed at the sample site:

1. Estimate the length and diameter of the pipe or hydrant that is to be flushed.
2. Determine CFT based on an estimated pipe length, diameter, and flow-rate (see methods described below)
3. Open the hydrant, start the timer and, if not using a flow-regulator, verify that the flow is at the desired rate (e.g., by quickly timing the fill of a 5-gallon bucket).
4. At **two times the CFT or time designated by the rule of thumb** (this conservative approach accounts for inaccuracies in flow-rate and piping assumptions) stop flushing and collect the water sample(s). If multiple samples are collected over a significant span of time relative to the flushing time, turn off the tap in between samples.

Number of Minutes needed to Flush Hydrant at 20 gpm						
Length of Pipe	Inside (Nominal) Diameter of Hydrant/ Pipe (inches)					
	2	4	6	8	12	16
1	0.0	0.0	0.1	0.1	0.3	0.5
5	0.0	0.2	0.4	0.7	1.5	2.6
10	0.1	0.3	0.7	1.3	2.9	5.2
15	0.1	0.5	1.1	2.0	4.4	7.8
20	0.2	0.7	1.5	2.6	5.9	10.4
25	0.2	0.8	1.8	3.3	7.3	13.1
30	0.2	1.0	2.2	3.9	8.8	15.7
35	0.3	1.1	2.6	4.6	10.3	18.3
40	0.3	1.3	2.9	5.2	11.8	20.9
45	0.4	1.5	3.3	5.9	13.2	23.5
50	0.4	1.6	3.7	6.5	14.7	26.1
55	0.4	1.8	4.0	7.2	16.2	28.7
60	0.5	2.0	4.4	7.8	17.6	31.3
65	0.5	2.1	4.8	8.5	19.1	33.9
70	0.6	2.3	5.1	9.1	20.6	36.6
75	0.6	2.4	5.5	9.8	22.0	39.2
80	0.7	2.6	5.9	10.4	23.5	41.8
85	0.7	2.8	6.2	11.1	25.0	44.4
90	0.7	2.9	6.6	11.8	26.4	47.0
95	0.8	3.1	7.0	12.4	27.9	49.6
100	0.8	3.3	7.3	13.1	29.4	52.2

1. Depending on the type of pipe material and degree of corrosion inside the pipe, the inner diameter will vary. These diameters are meant to be approximations.

***Rule of Thumb for Hydrants*:** In many cases, the configuration of a hydrant relative to the main is similar from location to location. In other words, if the hydrant type is typical (5 ¼ or 4 ½" main valve opening), lead pipe (horizontal pipe from the main to the hydrant) is 6", and the pipe length is less than approximately 20 feet (typical of a hydrant that is on the same side of the street as the main), the line will flush in approximately 1.5 minutes at 20 gpm. **Assume a 3 minute total flush time for this configuration to allow for an adequate factor of safety**. This conservative flush time should account for flow-rate variations and inaccurate length estimates.

***CFT matrix for Hydrants*:** Determine a conservative CFT from the matrix below using the estimated hydrant and lead pipe lengths and diameters. **Collect a sample after the hydrant has flushed for approximately two times the CFT to allow for an adequate factor of safety**.

Tap Sampling Cheat Sheet

In general, the following steps should be taken to ensure that the sampler has properly flushed at the sample site:

1. Estimate the length and diameter of the pipe or hydrant that is to be flushed.
2. Determine CFT based on an estimated pipe length, diameter, and flow-rate (see methods described below)
3. Open the tap, start the timer and, if not using a flow-regulator, verify that the flow is at the desired rate (e.g., by quickly timing the fill of a 1-liter bottle).
4. At **two times the CFT or time designated by the rule of thumb** (this conservative approach accounts for inaccuracies in flow-rate and piping assumptions) stop flushing and collect the water sample(s). If multiple samples are collected over a significant span of time relative to the flushing time, turn off the tap in between samples.

Rule of Thumb for Taps: Residential service lines are typically ¾" in diameter and less than 100 feet long. A pipe of this diameter will flush up to 100 ft of pipe length in about 1 minute at a flow-rate of about 2 gpm. **Assume a 2 minute total flush time for this configuration to allow for an adequate factor of safety.** This conservative flush time should allow for an adequate safety factor and inaccurate length estimates.

***CFT matrix for Taps*:** Determine a conservative CFT from the matrix (Table 2) below using the estimated service line and premise plumbing lengths and diameters. Guidance on estimating these lengths and diameters is provided in Appendix A. **Collect a sample after the tap has flushed for approximately two times the CFT to allow for an adequate safety factor**.

Number of Minutes needed to Flush Tap at 2 gpm											
Length of Pipe	Inside (Nominal) Diameter of Pipe (inches)										
	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
1	0.00	0.01	0.01	0.01	0.02	0.03	0.05	0.1	0.1	0.2	0.3
5	0.01	0.03	0.04	0.1	0.1	0.2	0.2	0.4	0.6	0.9	1.6
10	0.03	0.05	0.08	0.1	0.2	0.3	0.5	0.8	1.3	1.8	3.3
15	0.04	0.08	0.12	0.2	0.3	0.5	0.7	1.2	1.9	2.8	4.9
20	0.1	0.1	0.2	0.2	0.4	0.6	0.9	1.6	2.6	3.7	6.5
25	0.1	0.1	0.2	0.3	0.5	0.8	1.1	2.0	3.2	4.6	8.2
30	0.1	0.2	0.2	0.3	0.6	1.0	1.4	2.4	3.8	5.5	9.8
35	0.1	0.2	0.3	0.4	0.7	1.1	1.6	2.9	4.5	6.4	11.4
40	0.1	0.2	0.3	0.5	0.8	1.3	1.8	3.3	5.1	7.3	13.1
45	0.1	0.2	0.4	0.5	0.9	1.4	2.1	3.7	5.7	8.3	14.7
50	0.1	0.3	0.4	0.6	1.0	1.6	2.3	4.1	6.4	9.2	16.3
55	0.2	0.3	0.4	0.6	1.1	1.8	2.5	4.5	7.0	10.1	18.0
60	0.2	0.3	0.5	0.7	1.2	1.9	2.8	4.9	7.7	11.0	19.6
65	0.2	0.3	0.5	0.7	1.3	2.1	3.0	5.3	8.3	11.9	21.2
70	0.2	0.4	0.6	0.8	1.4	2.2	3.2	5.7	8.9	12.9	22.8
75	0.2	0.4	0.6	0.9	1.5	2.4	3.4	6.1	9.6	13.8	24.5
80	0.2	0.4	0.6	0.9	1.6	2.6	3.7	6.5	10.2	14.7	26.1
85	0.2	0.4	0.7	1.0	1.7	2.7	3.9	6.9	10.8	15.6	27.7
90	0.3	0.5	0.7	1.0	1.8	2.9	4.1	7.3	11.5	16.5	29.4
95	0.3	0.5	0.8	1.1	1.9	3.0	4.4	7.8	12.1	17.4	31.0
100	0.3	0.5	0.8	1.1	2.0	3.2	4.6	8.2	12.8	18.4	32.6
1. If service line diameter is 3" or greater consider selecting a different site as CFT could be long											
2. If plumbing is less than 3/8", assume this pipe volume is negligible											
3. Depending on the type of pipe material and degree of corrosion inside the pipe, the inner diameter will vary. These diameters are meant to be approximations.											

Appendix D

Matrices to Determine the CFT at Different Flow-rates For Hydrants and Taps

Matrix to Determine CFT for Different Flow-rates (Hydrant Sampling)

Number of Minutes needed to Flush Hydrant at 10 gpm						
Length of Pipe	Inside (Nominal) Diameter of Hydrant/ Pipe (inches)					
	2	4	6	8	12	16
1	0.0	0.1	0.1	0.3	0.6	1.0
5	0.1	0.3	0.7	1.3	2.9	5.2
10	0.2	0.7	1.5	2.6	5.9	10.4
15	0.2	1.0	2.2	3.9	8.8	15.7
20	0.3	1.3	2.9	5.2	11.8	20.9
25	0.4	1.6	3.7	6.5	14.7	26.1
30	0.5	2.0	4.4	7.8	17.6	31.3
35	0.6	2.3	5.1	9.1	20.6	36.6
40	0.7	2.6	5.9	10.4	23.5	41.8
45	0.7	2.9	6.6	11.8	26.4	47.0
50	0.8	3.3	7.3	13.1	29.4	52.2
55	0.9	3.6	8.1	14.4	32.3	57.4
60	1.0	3.9	8.8	15.7	35.3	62.7
65	1.1	4.2	9.5	17.0	38.2	67.9
70	1.1	4.6	10.3	18.3	41.1	73.1
75	1.2	4.9	11.0	19.6	44.1	78.3
80	1.3	5.2	11.8	20.9	47.0	83.6
85	1.4	5.5	12.5	22.2	49.9	88.8
90	1.5	5.9	13.2	23.5	52.9	94.0
95	1.6	6.2	14.0	24.8	55.8	99.2
100	1.6	6.5	14.7	26.1	58.8	104.4

1. Depending on the type of pipe material and degree of corrosion inside the pipe, the inner diameter will vary. These diameters are meant to be approximations.

To Determine CFT for flow-rates less or greater than 10 gpm:

1. Estimate the length of pipe (to the nearest 5 feet) and pipe diameter.
2. Set the desired flow-rate at the hydrant.
3. Use the matrix provided to the left to determine the CFT at 10 gpm. If the flow is not 10 gpm, determine the actual CFT by multiplying the value in the table times 10 gpm÷flow-rate. For example:
   Pipe length = 25 ft, pipe diameter = 8", and flow-rate = 40 gpm

   CFT at 10 gpm = 6.5 minutes

   *CFT at 40 gpm = 6.5 minutes * (10 gpm/40 gpm) = 1.6 minutes*
4. **After the hydrant has been running for <u>two times the adjusted CFT</u>** (this conservative approach accounts for inaccuracies in flow-rate and piping assumptions) stop flushing and collect the water sample(s). If multiple samples are collected over a significant span of time relative to the flushing time, turn off the tap in between samples.

Matrix to Determine CFT for Different Flow-rates (Tap Sampling)

Number of Minutes needed to Flush Tap at 1 gpm											
Length	Inside (Nominal) Diameter of Pipe (inches)										
of Pipe	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
1	0.01	0.01	0.02	0.02	0.04	0.06	0.09	0.2	0.3	0.4	0.7
5	0.03	0.05	0.08	0.1	0.2	0.3	0.5	0.8	1.3	1.8	3.3
10	0.06	0.10	0.16	0.2	0.4	0.6	0.9	1.6	2.6	3.7	6.5
15	0.09	0.15	0.24	0.3	0.6	1.0	1.4	2.4	3.8	5.5	9.8
20	0.1	0.2	0.3	0.5	0.8	1.3	1.8	3.3	5.1	7.3	13.1
25	0.1	0.3	0.4	0.6	1.0	1.6	2.3	4.1	6.4	9.2	16.3
30	0.2	0.3	0.5	0.7	1.2	1.9	2.8	4.9	7.7	11.0	19.6
35	0.2	0.4	0.6	0.8	1.4	2.2	3.2	5.7	8.9	12.9	22.8
40	0.2	0.4	0.6	0.9	1.6	2.6	3.7	6.5	10.2	14.7	26.1
45	0.3	0.5	0.7	1.0	1.8	2.9	4.1	7.3	11.5	16.5	29.4
50	0.3	0.5	0.8	1.1	2.0	3.2	4.6	8.2	12.8	18.4	32.6
55	0.3	0.6	0.9	1.3	2.2	3.5	5.0	9.0	14.0	20.2	35.9
60	0.3	0.6	1.0	1.4	2.4	3.8	5.5	9.8	15.3	22.0	39.2
65	0.4	0.7	1.0	1.5	2.7	4.1	6.0	10.6	16.6	23.9	42.4
70	0.4	0.7	1.1	1.6	2.9	4.5	6.4	11.4	17.9	25.7	45.7
75	0.4	0.8	1.2	1.7	3.1	4.8	6.9	12.2	19.1	27.5	49.0
80	0.5	0.8	1.3	1.8	3.3	5.1	7.3	13.1	20.4	29.4	52.2
85	0.5	0.9	1.4	2.0	3.5	5.4	7.8	13.9	21.7	31.2	55.5
90	0.5	0.9	1.4	2.1	3.7	5.7	8.3	14.7	23.0	33.0	58.8
95	0.5	1.0	1.5	2.2	3.9	6.1	8.7	15.5	24.2	34.9	62.0
100	0.6	1.0	1.6	2.3	4.1	6.4	9.2	16.3	25.5	36.7	65.3
1. If service line diameter is 3" or greater consider selecting a different site as CFT could be long											
2. If plumbing is less than 3/8", assume this pipe volume is negligible											
3. Depending on the type of pipe material and degree of corrosion inside the pipe, the inner diameter will vary. These diameters are meant to be approximations.											

To Determine CFT for flow-rates less or greater than 1 gpm:

1. Estimate the length of pipe (to the nearest 5 feet) and pipe diameter.
2. Set the desired flow-rate at the tap.
3. Use the matrix provided to the left to determine the CFT at 1 gpm. If the flow is not 1 gpm, determine the actual CFT by multiplying the value in the table times 1 gpm÷flow-rate. For example:
   Pipe length = 60 ft, pipe diameter = 1", and flow-rate = 2.5 gpm

   CFT at 1 gpm = 2.45 minutes

   *CFT at 2.5 gpm = 2.45 minutes * (1 gpm/2.5 gpm) = 0.98 minutes*
4. **After the tap has been running for <u>two times the adjusted CFT</u>** (this conservative approach accounts for inaccuracies in flow-rate and piping assumptions) stop flushing and collect the water sample(s). If multiple samples are collected over a significant span of time relative to the flushing time, turn off the tap in between samples.

Appendix E

CFT Long-Hand Calculations

CFT Long-Hand Calculations

In general, the following steps should be taken to ensure that the sampler has properly flushed at the sample site:

1. Estimate the length and diameter of the pipe or hydrant that is to be flushed.
2. Determine CFT based on an estimated pipe length, diameter, and flow-rate (see method described below)
3. Open the hydrant or tap, start the timer and, if not using a flow-regulator, verify that the flow is at the desired rate (e.g., by quickly timing the fill of a 5-gallon bucket or liter bottle).
4. At **two times the CFT** (this conservative approach accounts for inaccuracies in flow-rate and piping assumptions) stop flushing and collect the water sample(s). If multiple samples are collected over a significant span of time relative to the flushing time, turn off the tap in between samples.

CFT Long-hand Calculations: If the sampler determines that the CFT matrices are not adequate, the sampler can calculate the CFT long-hand using the equations below.

Estimated pipe length from hydrant/tap to the main: _____feet

Diameter of pipe between main and hydrant/tap: _____ inches

Estimated flow-rate at the hydrant/tap: _____gpm

Volume of pipe from hydrant/tap to main =

$$(\underset{Pipelength}{_____}\ ft) * (\underset{Pipediameter}{_____}\ in)^2 * 0.0408 \frac{gal * ft^2}{ft^3 * in^2} = _____\ gal$$

Calculated Flushing Time (CFT) $= \dfrac{\underset{Volume}{_____}\ gal}{\underset{EstimatedFlowrate}{_____}\ gpm} = _____$ min