Fire Flow Testing Using the PlantPRO® Hand-Held Pitot Tube

The primary purpose of conducting fire flow tests on a water distribution system is to determine the rate of flow available for fighting fires at a specific location. The owners and insurers of large buildings often require flow tests adjacent to the property to make sure an adequate supply of water is available if required for fighting a fire.

Fire flow tests also provide an indication of the condition of the distribution system. If the test flow from a hydrant is less than what is expected or has occurred in previous tests, it could indicate one or more of the following problems:

- tuberculation or other deposits in mains is reducing the flow-carrying capacity of the pipes
- there are valves on the system that have inadvertently been left closed
- increased customer use is straining the capacity of the system

The American Water Works Association recommends that flow tests be conducted on all parts of the water system approximately every 10 years, or sooner if there have been significant changes in the system piping or customer use.

Layout of Tests

After the general area of a test is selected, it is necessary to decide on specific hydrants that are to be used. All hydrants used in the test should be at approximately the same elevation. If this isn't possible, pressure corrections will have to be made to allow for the elevation differences.

Residual hydrant. One hydrant, designated the "residual hydrant," is where the static pressure is observed. It should preferably be located between the hydrant to be flowed and the source of water. In other words, water should be flowing past the residual hydrant to reach the flowing hydrant. In most situations, on a grid-type distribution system, water may be flowing in several directions, so the residual hydrant must be selected in the direction that is probably furnishing predominant flow (Figure 1).

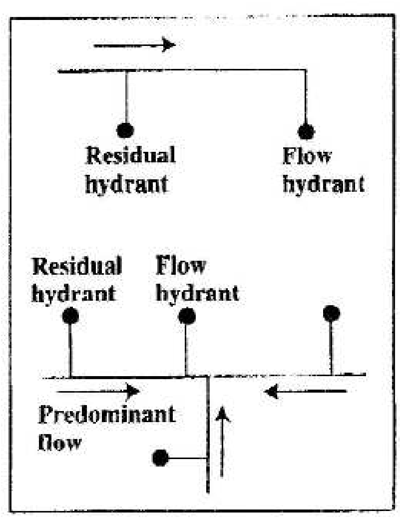

Figure 1

Flow hydrant. If the flow test is being performed to determine the water distribution system flow capacity available at a specific piece of property, the flowed hydrant should ideally be adjacent to that property. But, when selecting the hydrant (or hydrants) to be used in a test, consideration must also be given to potential problems that might be caused by the test, including:

- interference with traffic
- danger to pedestrians
- damage to both public and private property, and
- flooding of property

Advanced planning must particularly be made for control of pedestrian and automobile traffic. Not only does flooding the street create potential for traffic accidents, but getting cars dirty can result in irate drivers. Lawns can often be protected by laying an anchored plastic sheet or piece of plywood on the discharge area. Storm drains should also be checked to be sure they are open and will accept the flow without causing flooding.

Time of Testing

Flow tests should ideally be performed during a period of "normal" system demand and when weather conditions are reasonable. The staff in charge of the utility's water production should be notified in advance, where and when flow testing is to take place, so they can be prepared for any drop in system pressure that might occur.

Test Procedure

The hydrant test procedure consists of discharging water at a measured rate of flow and simultaneously measuring the pressure drop that occurs in the adjacent water mains. The number of hydrants to be used in the test depends on the strength of the distribution system. To obtain satisfactory results, the hydrant flow should cause either of the following:

- a drop in pressure in the residual hydrant of at least 10 psi, or
- flow sufficient to meet the fire-fighting requirements of the location

If the mains are small or pressure is weak, only one flowing hydrant should be required. If the mains are large, it may be necessary to flow two or more hydrants to obtain the desired pressure drop in the residual hydrant. If two or more hydrants are used, the readings should all be taken at the same time.

It is recommended that the pressure in the residual hydrant not be allowed to drop below 20 psi during the test. The primary concern is that, at lesser pressure, there is a danger of developing a negative pressure at some point on the distribution system. This could result in the collapse of a main or backsiphonage of polluted water into the potable water system.

Pitot Readings

When measuring flow from a hydrant, it is preferable to use one of the smaller (usually 2 1/2") outlets rather than the pumper outlet. Unless the hydrant is connected to a very strong system, flow from the pumper outlet may not completely fill the nozzle opening during flow, so the measurement may not be accurate.

To use a hand-held Pitot tube, the instrument's orifice should be held in the center of the stream, and approximately 1/2 of the outlet diameter away from the face of the outlet (Figure 2). If the orifice is held too close to the hydrant nozzle, the reading will be erroneously increased. If you are using the optional notched plastic blade, holding the proper notch against the face of the nozzle will keep the Pitot correctly positioned.

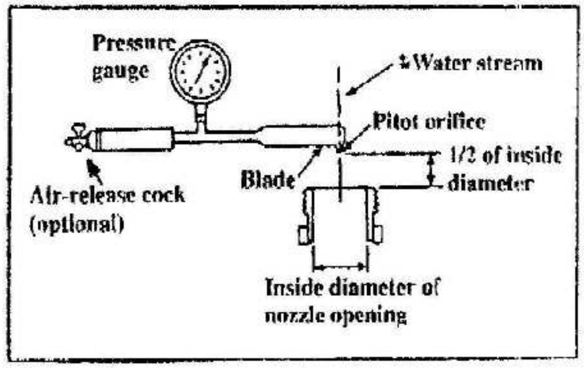

Figure 2

The pressure gauge on the hand-held Pitot instrument is supplied with a range of either 0 to 100 or 0 to 160 psi. The handle of the instrument contains an air chamber that is intended to absorb the fluctuations in Pitot pressure and stabilize gauge movement. The handle of the instrument should therefore be kept elevated so the air chamber will not fill with water.

Some operators find that they get better results when the air is released from the chamber. The PlantPro® hand-held Pitot gauges are therefore furnished with a blind plug at the end of the handle that can be replaced with an optional stop cock if desired.

Residual Hydrant Gauge

The pressure gauge that is installed on the residual hydrant (Figure 3) should have a top reading of about 25 psi above the maximum pressure that may be expected on the system. Most water system operators find that a 0 to 100 psi gauge is sufficient.

In performing a typical flow test, the gauge is installed on the residual hydrant, the hydrant valve is fully opened, and air is exhausted from the barrel through the stop cock. When the needle comes to rest, the static pressure reading is made and recorded before the flow hydrant is opened.

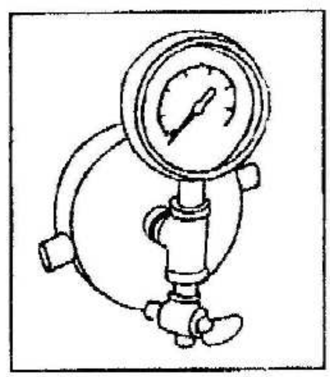
Figure 3

Flow Testing

After the static pressure reading is made, the flowing hydrant may be opened. The hydrant valve should be opened slowly to full open to make sure maximum flow is being obtained. Keep in mind that opening a hydrant rapidly might cause a negative pressure fluctuation in the system. If more than one hydrant is to be flowed, they should be opened in succession.

With all hydrants open, water should be allowed to flow for sufficient time to allow all air and debris to clear from the streams. The Pitot should not be held in the water stream while a hydrant is "blowing off." If there is debris in the flow, it could damage or clog the Pitot orifice.

When the flow from all hydrants is clear, a signal is given to a worker at each flowing hydrant to measure the Pitot pressure in the streams simultaneously. At the same time, the pressure at the residual hydrant is read, and all readings recorded.

After the readings have been taken, the hydrants should be shut slowly, one at a time, to prevent undue surges in the distribution system. After the test, the hydrant barrels should be allowed to drain before tightening the nozzle cap. Tightening the cap prematurely could prevent the barrel from draining properly.

Computing the Discharge Flow Rate

The rate of discharge from a flowing hydrant relative to the Pitot pressure reading is dependent on three factors:

- the Pitot pressure reading
- the interior diameter of the hydrant nozzle, and
- the "coefficient" of the hydrant nozzle

The hydrant nozzle interior diameter should be carefully measured, to the nearest 1/8". Most newer hydrants have a nozzle interior diameter of 2 1/2".

The hydrant nozzle coefficient is a factor that allows for the hydraulic entrance losses as the water enters the nozzle from the hydrant barrel. Most newer hydrants have a rounded shoulder at the nozzle entrance as shown in Figure 4A. The coefficient of this type of nozzle has been determined to be 0.9, which means that actual flow is approximately 90% of the theoretical flow under ideal conditions.

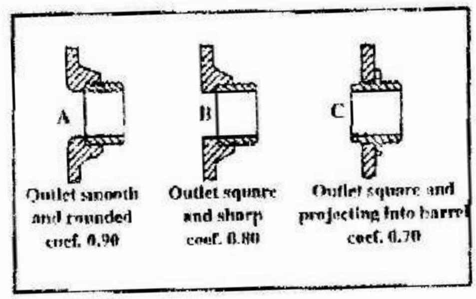

Figure 4

Some older hydrants have a square shoulder, as illustrated in Figure 4B, and a coefficient of 0.80, or a nozzle that projects into the hydrant barrel as shown in Figure 4C and have a coefficient of 0.70.

The interior of each nozzle to be used for flow testing should be checked to determine the coefficient to be used.

The quantity of discharge based on the three factors can be computed using the following equation: $Q = 29.83\, c d^2 \sqrt{P}$

where:

- Q = discharge is US gallons per minute
- c = the nozzle coefficient
- d = the inside diameter of the nozzle in inches
- P = the Pitot pressure in psi

Using the Flow Table

Rather than compute the flow, discharge tables can be used to quickly obtain the flow rate relative to the Pitot reading obtained in your test.

Table 1 provides the theoretical flow from various nozzle sizes that would occur under ideal conditions. This table must be used if either the nozzle diameter is other than 2 1/2" or if the nozzle entrance coefficient is 0.80 or 0.70. To use the table, find the Pitot pressure in the left column, and then move to the right to the flow value in the column for the actual nozzle inside diameter. This number must then be multiplied by the appropriate nozzle coefficient to obtain the actual hydrant flow.

Table 4, on the back cover of this booklet, is intended to directly provide flow compared to Pitot pressure for most hydrants manufactured in recent years. This table is to be used only if inspection of the hydrant determines that the discharge nozzle is exactly 2 1/2" and the nozzle entrance has a coefficient of 0.90.

A 2 1/4" flow tube (stream straightener) is available as an option from USABlueBook (part #44742). The tube can be mounted to the 2 1/2" nozzle of any hydrant to standardize the flow coefficient of the hydrant to 0.88. A special flow table is provided with the tube.

If more than one hydrant is used, the discharge for each outlet is obtained from the table, then they are all added together to obtain the total discharge.

Flow measurements are usually expressed to just the nearest 10 gallons per minute. There are many variables in flow testing, and expressing the flow to the nearest gallon could give someone the false impression that the flow is more accurate that it really is.

Determining Available Flow

The standard condition for determining the maximum available flow at a point on the system is at a residual pressure of 20 psi, but it is obviously not practical to perform a flow test in a way that will obtain this exact residual. The results of any flow test can be converted to the theoretical quantity of flow that would be available at 20 psi residual by doing a little mathematics. The equation is:

$$Q_R = Q_F \times \frac{h_r^{0.54}}{h_f^{0.54}}$$

where:
- Q_R = flow available at the desired residual pressure (usually 20 psi)
- Q_F = flow obtained during the flow test
- h_r = pressure drop to the desired residual pressure
- h_f = pressure drop during the test

This equation can be solved without use of logarithms by using Table 2, which provides the values of the 0.54 power of numbers. The values can be easily obtained from the table and substituted in the equation.

Example:

— The static pressure at the residual hydrant before the test was 60 psi
— The residual pressure during the flow test was 35 psi
— The flow from the hydrant during the test was 900 gpm
— Determine the theoretical flow that would be available at a residual pressure of 20 psi

$$Q_F = 900 \text{ gpm}$$
$$h_r = 60 - 20 = 40 \text{ psi}$$
$$h_f = 60 - 35 = 25 \text{ psi}$$
$$Q_R = 900 \times \frac{40^{0.54}}{25^{0.54}} = 900 \times \frac{7.33}{5.69} = 900 \times 1.29$$

= 1,161 gpm, this can be rounded off to 1,200 gpm

For a discharge over 1,000 gpm, the results are usually expressed to the nearest 100 gpm, and for lower flows, to the nearest 50 gpm. This is as close as can be justified by the degree of accuracy of the field observations.

Conversion Factors

The information provided in this pamphlet is in US Customary Units. Conversion to other measurement systems may be made by using the following conversion factors:

gallons, US	x	0.83267	=	gallons, Imperial
gallons, US	x	3.7894	=	liters
gallons, US	x	0.0037854	=	cubic meters
gallons per minute	x	0.06308	=	liters per second
pounds per sq. inch	x	6.8948	=	kilopascals

Recording Flow Test Results

The American Water Works Association suggests use of the form shown in Figure 3 for recording hydrant flow test data.

Sources of Additional Information

NFPA 291, Recommended Practice for Fire Flow Testing and Marking Hydrants. 1995 edition. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269.

Installation, Field Testing, and Maintenance of Fire Hydrants. Manual M17. American Water Works Association, 6666 W. Qunicy Ave., Denver, CO 80235.

Table 1
Theoretical Discharge Through Circular Orifices In U.S. Gallons per Minute

Pitot Pressure psi	2"	2 1/4"	2 3/8"	2 1/2"	2 5/8"	2 3/4"	3"	3 1/4"	3 1/2"	3 3/4"	4"	4 1/2"
1	119	151	168	187	206	226	269	315	366	420	476	604
2	169	214	238	264	291	319	380	446	517	594	676	854
3	207	262	292	323	356	391	465	546	633	727	827	1045
4	239	302	337	373	411	452	537	631	731	840	955	1210
5	267	338	376	417	460	505	601	705	817	938	1068	1350
6	292	370	412	457	504	553	658	772	896	1028	1170	1480
7	316	400	445	494	544	597	711	834	967	1111	1265	1600
8	338	427	476	528	582	638	760	892	1034	1187	1351	1710
9	358	453	505	560	617	677	806	946	1097	1259	1433	1815
10	378	478	532	590	650	714	830	997	1156	1237	1510	1910
11	396	501	553	619	682	759	891	1046	1213	1392	1584	2010
12	414	524	583	646	712	782	931	1092	1267	1454	1635	2100
13	431	545	607	673	741	814	969	1137	1318	1515	1722	2180
14	447	566	630	698	769	843	1005	1180	1368	1572	1787	2260
15	463	586	652	722	796	874	1040	1221	1416	1626	1849	2340
16	478	605	673	746	822	903	1075	1261	1463	1679	1910	2420
17	493	623	694	769	848	931	1108	1300	1508	1731	1969	2500
18	507	642	714	791	872	958	1140	1338	1551	1781	2026	2570
19	521	659	733	813	896	984	1171	1374	1594	1830	2082	2640
20	534	676	753	834	920	1010	1201	1410	1635	1877	2136	2710
22	560	709	789	875	964	1059	1260	1479	1715	1969	2240	2840
24	585	741	824	914	1007	1106	1316	1545	1791	2056	2340	2970
26	609	771	858	951	1048	1151	1370	1608	1864	2140	2435	3090
28	632	800	890	987	1088	1194	1422	1668	1935	2221	2527	3210
30	654	828	922	1022	1126	1236	1472	1727	2003	2299	2616	3320
32	676	856	952	1053	1163	1277	1520	1784	2096	2375	2702	3430
34	697	882	981	1088	1199	1316	1566	1838	2132	2448	2785	3540
36	717	908	1010	1119	1233	1354	1612	1892	2194	2519	2866	3640
38	736	932	1037	1150	1267	1392	1656	1944	2254	2588	2944	3740
40	755	956	1064	1180	1300	1428	1699	1994	2313	2655	3021	3840
42	774	980	1091	1209	1332	1463	1741	2043	2370	2721	3095	3935
44	792	1003	1116	1237	1364	1497	1782	2091	2426	2785	3168	4030
46	810	1025	1141	1265	1394	1531	1822	2138	2480	2847	3239	4120
48	828	1047	1166	1293	1424	1564	1861	2184	2533	2908	3309	4205
50	845	1069	1190	1319	1454	1596	1900	2229	2586	2968	3377	4290
52	861	1091	1213	1345	1482	1628	1937	2274	2637	3027	3444	4375
54	878	1111	1237	1371	1511	1659	1974	2317	2687	3085	3510	4460
56	894	1132	1259	1396	1538	1689	2010	2359	2736	3141	3574	4540
58	909	1152	1282	1421	1566	1719	2046	2401	2785	3197	3637	4620
60	925	1171	1303	1445	1592	1749	2081	2442	2832	3252	3700	4700

Figure 3

FLOW TEST REPORT

Location ______________________________ Date __________

Test Made by ______________________________ Time ________ M

Representative of ______________________________

Witness ______________________________

State Purpose of Test ______________________________

____

Consumption Rate During Test ______________________________

If Pumps Affect Test, Indicate Pumps Operating ______________________________

Flow Hydrants ____ A_1 ____ A_2 ____ A_3 ____

Size Nozzle ______________________________

Pitot Reading ______________________________ Total gpm __________

gpm ______________________________

Static B ______________ psi Residual B ______________ psi

Projected results:

at 20 psi Residual ________ gpm; or at ________ psi Residual ______ gpm

Remarks ______________________________

____

____

____

Location Map: Show line sizes and distance to next cross connected line. Show valves and hydrant branch size. Indicate North. Show flowing hydrants—label A_1, A_2, A_3. Show location of Static and Residual—label *B*.

Indicate B Hydrant ______ Sprinkler _____ Other (identify) ______________

Table 4
Theoretical Discharge from a 2 1/2" hydrant Nozzle with a 0.90 Coefficient

Pitot Pressure psi	Discharge gpm	Pitot Pressure psi	Discharge gpm
5	375	38	1035
6	411	40	1062
7	445	42	1088
8	475	44	1113
9	504	46	1139
10	531	48	1164
11	557	50	1187
12	581	52	1211
13	606	54	1234
14	628	56	1256
15	650	58	1279
16	671	60	1301
17	692	62	1323
18	712	64	1344
19	732	66	1364
20	751	68	1385
22	788	70	1405
24	823	72	1425
26	856	74	1445
28	888	76	1464
30	920	78	1482
32	948	80	1502
34	979	82	1520
36	1007	84	1539