Fire Flow Testing

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 flows from a hydrant is less than what is expected or has occurred in previous test, it could indicate one or more of the following problems:

- Tuberculation or other deposits in mains are reducing the flow-carrying capacity of the pipes
- There are valves in the system that have inadvertently been left closed
- Increased customer use is straining the capacity of the system

Layout of Tests

After the general area if a test is selected, it is necessary to decide on specific hydrants that are to be used. All hydrants 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 Hydrants: one hydrant, designated as 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).

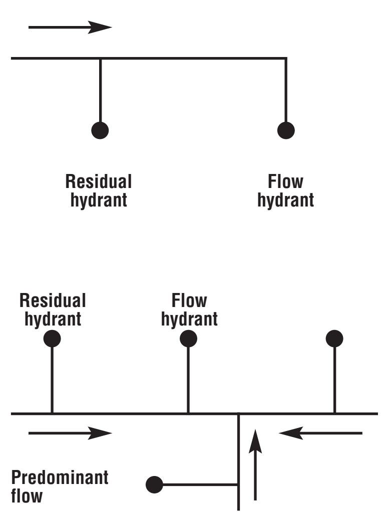


Figure 1

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 a 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 to property

It is important to plan pedestrian and traffic control in advance. Flooding the street with water and allowing vehicles to drive through it creates the potential for accidents, as well as irate drivers. Damage to lawns can usually be prevented by laying an anchored plastic sheet or piece of plywood on the discharge area. Storm drains should be checked in advance to make sure they 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.

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 wither 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 2½" 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. A typical installation of the flow gauge is shown in Figure 2.

Figure 2

Residual Hydrant Gauge

The pressure gauge that is installed on the residual hydrant should have a top reading of about 25 psi above the maximum pressure that may be expected on the system. Most water system operations 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 bleed valve. When the needle comes to rest, the *static pressure* (Fig3) reading is made and recorded before the flow hydrant is opened.

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.

Figure 3

With all hydrant open, water should be allowed to flow for sufficient time to allow all air and debris to clear from the streams. The flow gauge should not be installed on a hydrant while the 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 flow gauge is installed on each flowing hydrant. A signal is then given to a worker at each hydrant to record the flow at their hydrant 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

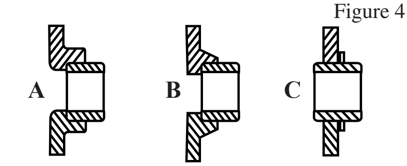
The rate of discharge from a flowing hydrant relative to the Pitot pressure reading is dependent on three factors:

- 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 new 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



Outlet smooth and rounded coef. 0.90 | Outlet square and sharp coef. 0.90 | Outlet square and projecting into barrel coef. 0.70

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:

$$Q = 29.83\, cd^2 \sqrt{P}$$

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

The Dual Read Psi/ GPM NNI Hydrant Flow Pressure gauge furnished has been calibrated to read flow directly in gallons per minute if the inside diameter of the nozzle is 2 1/2" and the hydrant nozzle coefficient is 0.90. This is the most common configuration in hydrants manufactured in recent years.

If the nozzle measures other than 2 1/2" or inspection of the nozzle entry indicates a coefficient other than 0.9, the actual flow must be computed using Table 1.

To use the table, first find the theoretical flow by locating the Pitot pressure in the left column, and then going to the column for the actual inside diameter of the hydrant nozzle. This number must then be multiplied by the appropriate coefficient for entry loss. If the hydrant nozzle you are using has rounded inlet (Figure 4, style A) you must multiply the table value by 0.9 to determine the actual flow valve. If the hydrant has a style B inlet, you must multiply by 0.8, and if it is style C, you must use 0.7. If more than one hydrant is used in the flow test, the discharge from all hydrants must be added 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 than 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 pressure.

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
Q_F = flow obtained during the flow test
h_r = pressure drop to the desired residual pressure (usually 20 psi)
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 gpm h_r = 60 - 20 = 40 psi h_f = 60 - 35 = 25 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. This is as close as can be justified by the degree of accuracy of the field observations.

Nomograph for Determining Available Flow

Using the previous example:

Place a straight edge from 25 psi on line h_f to 40 psi on line h_r and mark the intersection with line S.

Place the straight edge on the point on line S and 900 gpm on line Q_f. The intersection of the extended line with Q_R indicates the theoretical available flow (1,200 gpm).

Conversation 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 5 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. Quincy 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	426	476	528	582	638	760	892	1034	1187	1351	1710
9	358	453	505	560	617	677	806	496	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	1548	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	1787	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	564	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	1345	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	3687	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

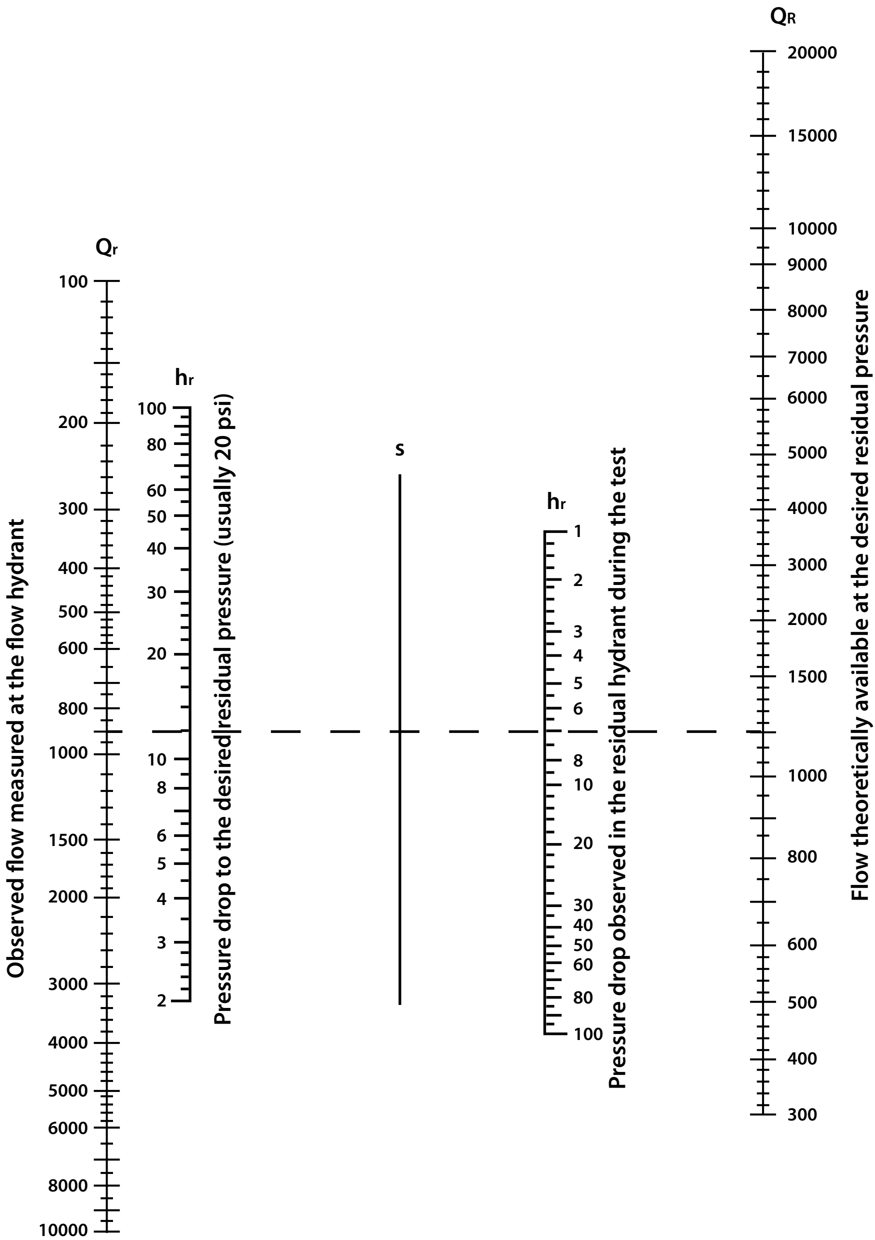
Table 1 (continued): Theoretical Discharge Through Circular Orifices in U.S. Gallons per Minute

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"
60	925	1171	1303	1445	1592	1749	2081	2442	2832	3252	3700	4700
62	941	1191	1325	1470	1619	1777	2115	2483	2879	3305	2761	4475
64	956	1210	1346	1493	1645	1806	2149	2522	2925	3358	3821	4850
66	971	1228	1367	1516	1670	1834	2183	2561	2971	3410	3880	4925
68	985	1247	1388	1539	1695	1862	2215	2600	3015	3462	3938	5000
70	999	1265	1408	1561	1720	1889	2248	2638	3059	3512	3996	5075
72	1014	1283	1426	1583	1745	1916	2280	2675	3103	3562	4053	5140
74	1028	1301	1448	1605	1769	1942	2311	2712	3146	3611	4109	5200
76	1041	1318	1467	1627	1792	1968	2342	2749	3188	3660	4164	5265
78	1055	1335	1468	1648	1816	1994	2373	2785	3230	3708	4218	5340
80	1068	1352	1505	1669	1839	2019	2403	2820	3217	3577	4272	5404
82	1082	1369	1524	1689	1862	2044	2433	2855	3311	3801	4325	5470
84	1095	1386	1542	1710	1882	2096	2462	2890	3351	3847	4377	5535
86	1170	1402	1561	1730	1907	2094	2491	2924	3391	3893	4429	5600
88	1120	1419	1579	1750	1929	2118	2520	2958	3430	3938	4480	5665
90	1133	1434	1596	1770	1950	2142	2549	2991	3469	3982	4531	5730
92	1146	1450	1614	1789	1972	2165	2577	3024	3507	4027	4581	5795
94	1158	1466	1632	1809	1993	2189	2605	3057	3545	4070	4631	5865
96	1170	1481	1649	1828	2014	2212	2632	3089	3583	4113	4680	5925
98	1182	1497	1666	1847	2035	2235	2660	3121	3620	4156	4728	5985
100	1194	1512	1683	1866	2056	2258	2687	3153	3657	4189	4776	6045
102	1206	1527	1699	1884	2076	2280	2713	3184	3693	4240	4824	6100
104	1218	1542	1716	1903	2097	2302	2740	3215	3729	4281	4871	6150
106	1230	1556	1733	1921	2117	2324	2766	3246	3765	4322	4917	6200
108	1241	1571	1749	1939	2137	2346	2792	3277	3800	4363	4963	6260
110	1253	1586	1765	1957	2156	2368	2818	3307	3835	4403	5009	6320
112	1264	1600	1781	1974	2176	2389	2843	3337	3870	4443	5054	6380
114	1275	1614	1797	1992	2195	2410	2869	3367	3904	4482	5099	6440
116	1286	1628	1812	2009	2214	2431	2894	3396	3938	4521	5144	6500
118	1297	1642	1828	2027	2233	2452	2918	3425	3972	4560	5188	6560
120	1308	1656	1843	2044	2252	2473	2946	3454	4006	4599	5235	6620
122	1319	1670	1859	2061	2271	2494	2967	3483	4039	4637	5273	6680
124	1330	1684	1874	2077	2289	2514	2992	3511	4072	4675	5318	6740
126	1341	1697	1889	2094	2308	2534	3016	3539	4105	4712	5361	6800
128	1351	1711	1904	2111	2326	2554	3040	3567	4137	4749	5403	6850
130	1362	1724	1919	2127	2344	2574	3063	3595	4169	4786	5445	6900
132	1372	1736	1933	2144	2362	2594	3087	3623	4201	4823	5487	6950
134	1382	1749	1984	2160	2380	2613	3110	3650	4233	4860	5529	7000
136	1392	1762	1962	2176	2398	2633	3133	3677	4625	4896	5570	7050

Table 2: Values of "h" to the 0.54 Power

h	$h^{0.54}$	h	$h^{0.54}$	h	$h^{0.54}$	h	$h^{0.45}$	h	$h^{0.54}$
1	1.00	36	6.93	71	9.99	106	12.41	141	14.47
2	1.45	37	7.03	72	10.07	107	12.47	142	14.53
3	1.81	38	7.13	73	10.14	108	12.53	143	14.58
4	3.11	39	7.23	74	10.33	109	12.60	144	14.64
5	2.39	40	7.33	75	10.29	110	12.66	145	14.69
6	2.63	41	7.43	76	10.37	111	12.72	146	14.75
7	2.86	42	7.53	77	10.44	112	12.78	147	14.80
8	3.07	43	7.62	78	10.51	113	12.84	148	14.86
9	3.28	44	7.72	79	10.59	114	12.90	149	14.91
10	3.47	45	7.81	80	10.66	115	12.96	150	14.97
11	3.65	46	7.91	81	10.75	116	13.03	131	15.02
12	3.83	47	8.00	82	10.80	117	13.09	152	15.07
13	4.00	48	8.09	83	10.87	118	13.15	153	15.13
14	4.16	49	8.18	84	10.94	119	13.21	154	15.18
15	4.32	50	8.27	85	11.01	120	13.27	155	15.23
16	4.48	51	8.36	86	11.08	121	13.33	156	15.29
17	4.62	52	8.44	87	11.15	122	13.39	157	15.34
18	4.76	53	8.53	88	11.22	123	13.44	158	15.39
19	4.90	54	8.62	89	11.29	124	13.50	159	15.44
20	5.04	55	8.71	90	11.36	125	13.56	160	15.50
21	5.18	56	8.79	91	11.43	126	13.62	161	15.55
22	5.31	57	8.88	92	11.49	127	13.68	162	15.00
23	5.44	58	8.96	93	11.56	128	13.74	163	15.65
24	5.56	59	9.04	94	11.63	129	13.80	164	15.70
25	5.69	60	9.12	95	11.69	130	13.85	165	15.76
26	5.81	61	9.21	96	11.76	131	13.91	166	15.81
27	5.93	62	9.29	97	11.83	132	13.97	167	15.86
28	6.05	63	9.37	98	11.89	133	14.02	168	15.91
29	6.16	64	9.45	99	11.96	134	14.08	169	15.96
30	6.28	65	9.53	100	12.02	135	14.14	170	16.01
31	6.39	66	9.61	101	12.09	136	14.19	171	16.06
32	6.50	67	9.69	102	12.15	137	14.25	172	16.11
33	6.61	68	9.76	103	12.22	138	14.31	173	16.16
34	6.71	69	9.84	104	12.28	139	14.36	174	16.21
35	6.82	70	9.92	105	12.34	140	14.42	175	16.26

Nomograph for Determining Available Flow



Flow Test Report

Location ______________________________________ Date ___________

Test Made by __________________________________ Time __________

Representative of ____

Witness ____

State Purpose of Test ____

____

Consumptions 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 Stactic and Residual—label B.

Indicate *B* Hydrant _______ Sprinkler _______ Other (identify) _______

Figure 5