NFPA

291

FIRE FLOW TESTING AND MARKING OF HYDRANTS 1977

NATIONAL FIRE PROTECTION ASSOCIATION

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Official Interpretations

The Committee responsible for this document will render official interpretations of the literal text and of the intent of the Committee when the text was adopted.

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Licensing Provision

Statement on NFPA Procedures

See Official NFPA Definitions at the back of this pamphlet.

Recommended Practice for

Fire Flow Testing and Marking of Hydrants

NFPA 291 — 1977

1977 Edition of NFPA 291

This recommended practice was adopted by the National Fire Protection Association in its present form at the NFPA Fall Meeting, November 14–17, 1977 in Atlanta, Georgia and supersedes the 1974 edition.

Origin and Development of NFPA 291

The NFPA Committee on Public Water Supplies for Private Fire Protection presented the idea of indicating the relative available fire service water supply from hydrants in its 1934 report. The committee felt then and feels now that such an indication is of substantial value to water and fire departments. The following recommendations were initially adopted in 1935. The Committee agreed that tests of individual hydrants did not give as complete and satisfactory results as group testing but expressed the opinion that tests of individual hydrants did have sufficient value to make the following recommendations worthy of adoption. This was reconfirmed with minor editorial changes in 1974.

The 1977 edition has been completely rewritten and a chapter on the flow testing of hydrants has been added.

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Contents

Recommended Practice for

Fire Flow Testing and Marking of Hydrants

NFPA 291 — 1977

Chapter 1 Flow Testing

1-1 Introduction. Fire flow tests are made on water distribution systems to determine the rate of flow available at various locations for fire fighting purposes. A certain residual pressure in the mains is specified at which the rate of flow should be available. Additional benefit is derived from fire flow tests by the indication of possible deficiencies (such as tuberculation of piping or closed valves or both) which could be corrected to insure adequate fire flows as needed.

1-2 Rating Pressure. For the purpose of uniform marking of fire hydrants, the ratings should be based on a residual pressure of 20 psi for all hydrants having a static pressure in excess of 40 psi. Hydrants having a static pressure of less than 40 psi should be rated at one-half of the static pressure.

1-3 Procedure. Tests should be made during a period of ordinary demand. The procedure consists of discharging water at a measured rate of flow from the system at a given location and observing the corresponding pressure drop in the mains.

1-4 Data Sheet. The data secured during the testing of hydrants for uniform marking may be valuable for other purposes. With this in mind, it is suggested that the form shown in Figure 1-4 should be used to record information taken. The back of the form should include a location sketch. When the tests are complete the forms should be filed for future reference by interested parties.

1-5 Layout of Test. After the location at which the test is to be run has been determined, a group of test hydrants in the vicinity is selected. Hydrants and hydrant outlets chosen for use should be so located that no damage to surrounding property will result. One hydrant is chosen to be the residual hydrant at which the normal pressure will be observed with the other hydrants in the group closed, and the residual pressure will be observed with the other hydrants flowing. This hydrant is chosen so that the hydrants which will be flowed are the next hydrants between it and the larger mains which constitute the immediate sources of supply in the area. In Figure 1-5, several test layouts are indicated showing the residual hydrant in each case by means of a circle.

Hydrant 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	A_4	
Size Nozzle					
Pitot Reading					
Discharge Coefficient					TOTAL GPM
GPM					

STATIC B __________ psi RESIDUAL B __________ psi

PROJECTED RESULTS @ 20 psi Residual ______ gpm, or @ ______ 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, A_4. Show location of Static and Residual - Label B

Indicate B Hydrant ______ Sprinkler ______ Other (Identify) ______________

Figure 1-4

The number of hydrants to be used in any test depends upon the strength of the distribution system in the vicinity of the test location. In order to obtain satisfactory test results, sufficient hydrants should be flowed to cause a drop in pressure at the residual hydrant of not less than 10 psi but preferably dropping the residual pressure as close to 20 psi as practical. If the mains are small and the system weak, only one or two hydrants need to be flowed. If, on the other hand, the mains are large and the system strong, it may be necessary to flow as many as seven or eight hydrants.

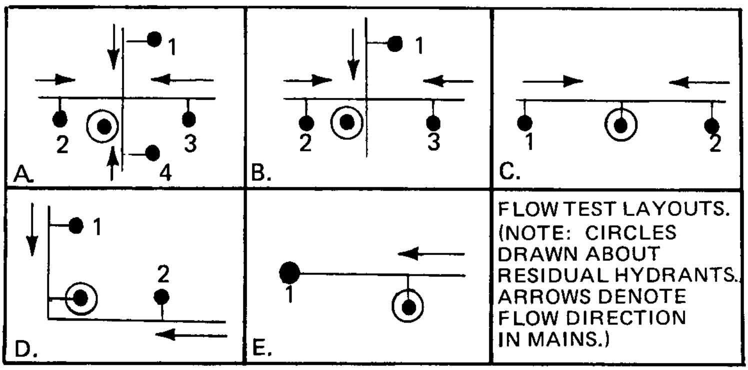

Figure 1-5

(Copyright, Insurance Services Office, 1963)

1-6 Equipment. The equipment necessary for field work consists of a single 200 psi bourdon pressure gage with 1-psi graduations, a number of pitot *tubes*, *hydrant wrenches*, 50- or 60-psi bourdon pressure gages with ½-psi graduations, and scales with 1/16-inch graduations (one pitot *tube*, a 50- or 60-psi gage, a *hydrant wrench* and a scale for each hydrant to be flowed), and a special hydrant cap tapped with a hole into which a short length of ¼-inch brass pipe is fitted. This pipe is provided with a T connection for the 200-psi gage and a cock at the end for blowing off air.

1-7 Test Procedure. In a typical test the 200-psi gage is attached to one of the 2½-inch outlets of the residual hydrant using the special cap, the cock on the gage piping is opened, and the hydrant valve is opened full. As soon as the air is exhausted from the barrel, the cock is closed. A reading is taken when the needle comes to rest. At a given signal, each of the other hydrants is opened in succession with discharge taking place directly from the open hydrant butts. As each hydrant is flowed and with all hydrants flowing, a signal is given to the men at the hydrants to read the pitot pressure of the streams simultaneously while the residual pressure is being read. The final magnitude of the pressure drop can be controlled by the number of hydrants used and the number of outlets opened on each.

After the readings have been taken, hydrants should be shut down slowly, and one at a time, to prevent undue surges in the system.

1-8 Pitot Readings. When measuring discharge from open hydrant butts, it is always preferable from the standpoint of accuracy to use 2½-inch outlets rather than pumper outlets. In practically all cases the 2½-inch outlets are filled across the entire cross-section during flow, while with the larger outlets there is very frequently a void near the bottom. When measuring the pitot pressure of a stream of practically uniform velocity, the orifice in the pitot tube is held at the center of the stream with the edge of the blade resting against the face of the hydrant outlet. The center line of the orifice should be at right angles to the plane of the face of the hydrant outlet. The air chamber on the pitot tube should be kept elevated. Pitot readings of less than 10 psi and over 30 psi should be avoided if possible. Opening additional hydrant outlets will aid in controlling the pitot reading. Partial closing of the hydrant valve will control the pitot reading. With dry barrel hydrants, the hydrant valve should be wide open. This minimizes problems with underground drain valves. With wet barrel hydrants, the valve for the flowing outlet should be wide open. This gives a more streamlined flow and a more accurate pitot reading.

1-9 Determination of Discharge. At the hydrants used for flow during the test, the discharges from the open butts are determined from measurements of the diameter of the outlets flowed, the velocity pressures of the streams as indicated by the pitot gage readings, and the coefficient of the outlet being flowed as determined from Figure 1-9. If flow tubes (stream straighteners) are being utilized a coefficient of 0.95 is suggested unless the coefficient of the tube is known.

The formula used to compute the discharge, Q, in gpm from these measurements is:

$$Q = 29.83 c d^2 \sqrt{p} \qquad \text{(a)}$$

where c is the coefficient of discharge (*see Figure 1-9*),

d the diameter of the outlet in inches, and

p the velocity pressure in psi.

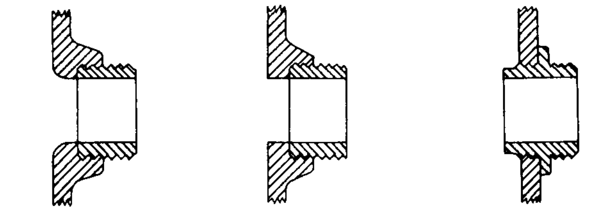

Figure 1-9. Three general types of hydrant outlets and their coefficients of discharge.

1-10 Use of Pumper Outlets. If it is necessary to use a pumper outlet and flow tubes (stream straighteners) are not available, the best results are obtained with the velocity pressure maintained between 5 and 10 psi. For pumper outlets, the approximate discharge can be computed from equation (a) using the velocity pressure at the center of the stream and multiplying the result by one of the coefficients in Table 1-10, depending upon the velocity pressure. These coefficients are applied in addition to the coefficient in equation (a) and are for average type hydrants.

Table 1-10 Pumper Outlet Coefficients

Velocity Pressure	Coefficient
2 psi	0.97
3 psi	0.92
4 psi	0.89
5 psi	0.86
6 psi	0.84
7 psi and over	0.83

1-11 Determination of Discharge Without a Pitot. If a pitot tube is not available for use to measure the hydrant discharge, a 50- or 60-psi gage tapped into a hydrant cap may be used. The hydrant cap with gage attached is placed on one outlet and the flow allowed to take place through the other outlet at the same elevation. The readings obtained from a gage so located and the readings obtained from a gage on a pitot tube held in the stream are approximately the same.

Table 1-12.1 Theoretical Discharge Through Circular Orifices (United States Gallons of Water per Minute)

(See Notes on Page 291-12.)

Velocity Head psi	Feet*	Velocity of Discharge fps	Diameter of Orifice in Inches									Velocity Head psi
			2	2¼	2½	2¾	3	4	4½	5	6	
1	2.31	12.15	119	151	186	226	268	477	604	746	1074	1
2	4.61	17.26	169	214	264	319	380	675	854	1055	1519	2
3	6.92	21.14	207	262	323	391	465	827	1046	1292	1860	3
4	9.23	24.41	239	302	373	451	537	955	1208	1492	2148	4
5	11.54	27.27	267	338	417	504	600	1067	1351	1668	2401	5
6	13.84	29.82	292	370	457	553	658	1169	1480	1827	2630	6
7	16.15	32.27	316	400	493	597	710	1263	1598	1973	2841	7
8	18.46	34.42	337	427	527	638	759	1350	1709	2109	3037	8
9	20.76	36.56	358	453	559	677	805	1432	1812	2237	3222	9
10	23.07	38.50	377	478	590	713	849	1509	1910	2358	3396	10
11	25.38	40.44	396	501	618	748	890	1583	2003	2473	3562	11
12	27.68	42.18	413	523	646	781	930	1653	2093	2583	3720	12
13	29.99	43.91	430	544	672	813	968	1721	2178	2689	3872	13
14	32.30	45.55	446	565	698	844	1005	1786	2260	2790	4018	14
15	34.61	47.18	462	585	722	874	1040	1848	2340	2888	4159	15
16	36.91	48.71	477	604	746	902	1074	1909	2416	2983	4296	16
17	39.22	50.25	492	623	769	930	1107	1968	2491	3075	4428	17
18	41.53	51.68	506	641	791	957	1139	2025	2562	3164	4556	18
19	43.83	53.10	520	658	813	983	1170	2080	2633	3251	4681	19
20	46.14	54.53	534	675	834	1009	1201	2134	2701	3335	4803	20
22	50.75	57.19	560	708	874	1058	1259	2239	2833	3497	5037	22
24	55.37	59.74	585	740	913	1105	1315	2338	2959	3653	5261	24
26	59.98	62.09	608	770	951	1150	1369	2434	3080	3802	5476	26
28	64.60	64.44	631	799	987	1194	1421	2526	3196	3946	5682	28
30	69.21	66.79	654	827	1021	1236	1470	2614	3309	4085	5882	30
32	73.82	68.93	675	854	1055	1276	1519	2700	3417	4218	6075	32
34	78.44	71.08	696	882	1087	1315	1565	2783	3522	4348	6262	34
36	83.05	73.12	716	906	1119	1354	1611	2864	3624	4475	6443	36
38	87.67	75.16	736	931	1149	1391	1655	2942	3724	4597	6620	38
40	92.28	77.10	755	955	1179	1427	1698	3019	3820	4716	6792	40
42	96.89	78.94	773	979	1209	1462	1740	3093	3915	4833	6960	42
44	101.51	80.78	791	1002	1237	1496	1781	3166	4007	4947	7123	44
46	106.12	82.62	809	1024	1264	1530	1820	3237	4097	5058	7283	46
48	110.74	84.46	827	1046	1292	1563	1860	3307	4185	5167	7440	48
50	115.35	86.19	844	1068	1318	1595	1898	3375	4271	5273	7593	50

52	**119.96**	**87.83**	860	1089	1344	1627	1936	3442	4356	5378	7744	**52**
54	**124.58**	**89.56**	877	1110	1370	1658	1973	3507	4439	5480	7891	**54**
56	**129.19**	**91.20**	893	1130	1395	1688	2009	3572	4520	5581	8036	**56**
58	**133.81**	**92.83**	909	1150	1420	1718	2045	3635	4600	5679	8178	**58**
60	**138.42**	**94.36**	924	1170	1444	1747	2080	3697	4679	5776	8318	**60**
62	**143.03**	**96.00**	940	1189	1468	1776	2114	3758	4756	5872	8456	**62**
64	**147.65**	**97.53**	955	1208	1491	1805	2148	3818	4832	5966	8591	**64**
66	**152.26**	**98.96**	969	1227	1515	1833	2181	3877	4907	6059	8724	**66**
68	**156.88**	**100.49**	984	1245	1537	1860	2214	3936	4981	6150	8855	**68**
70	**161.49**	**101.92**	998	1263	1560	1887	2246	3993	5054	6239	8985	**70**
72	**166.10**	**103.35**	1012	1281	1582	1914	2278	4050	5126	6327	9112	**72**
74	**170.72**	**104.78**	1026	1299	1604	1941	2309	4106	5196	6415	9238	**74**
76	**175.33**	**106.21**	1040	1317	1625	1967	2340	4161	5266	6501	9362	**76**
78	**179.95**	**107.64**	1054	1334	1647	1992	2371	4215	5335	6586	9484	**78**
80	**184.56**	**108.97**	1067	1351	1668	2018	2401	4269	5403	6670	9605	**80**
82	**189.17**	**110.30**	1080	1367	1688	2043	2431	4322	5470	6753	9724	**82**
84	**193.79**	**111.72**	1094	1384	1708	2068	2461	4374	5536	6835	9842	**84**
86	**198.40**	**112.95**	1106	1400	1729	2092	2490	4426	5602	6916	9959	**86**
88	**203.02**	**114.28**	1119	1417	1749	2116	2518	4477	5667	6996	10074	**88**
90	**207.63**	**115.61**	1132	1433	1769	2140	2547	4528	5731	7075	10188	**90**
92	**212.24**	**116.83**	1144	1448	1788	2164	2575	4578	5794	7153	10300	**92**
94	**216.86**	**118.16**	1157	1464	1808	2187	2603	4627	5856	7230	10411	**94**
96	**221.47**	**119.38**	1169	1480	1827	2210	2630	4676	5919	7307	10521	**96**
98	**226.09**	**120.61**	1181	1495	1846	2233	2658	4725	5980	7383	10630	**98**
100	**230.70**	**121.84**	1193	1510	1864	2256	2685	4773	6041	7458	10739	**100**
102	**235.31**	**123.06**	1205	1525	1883	2278	2711	4820	6101	7532	10846	**102**
104	**239.93**	**124.29**	1217	1540	1901	2301	2738	4867	6160	7605	10951	**104**
106	**244.54**	**125.41**	1228	1555	1919	2323	2764	4914	6219	7678	11056	**106**
108	**249.16**	**126.64**	1240	1569	1938	2344	2790	4960	6278	7750	11160	**108**
110	**253.77**	**127.76**	1251	1584	1955	2366	2816	5006	6335	7821	11263	**110**
112	**258.38**	**128.98**	1263	1598	1973	2387	2841	5051	6393	7892	11365	**112**
114	**263.00**	**130.11**	1274	1612	1991	2409	2866	5096	6450	7962	11466	**114**
116	**267.61**	**131.23**	1285	1626	2008	2430	2892	5140	6506	8032	11566	**116**
118	**272.23**	**132.35**	1296	1640	2025	2451	2916	5184	6562	8101	11665	**118**
120	**276.84**	**133.48**	1307	1654	2042	2471	2941	5228	6617	8169	11764	**120**
122	**281.45**	**134.60**	1318	1668	2059	2492	2965	5272	6672	8237	11861	**122**
124	**286.07**	**135.72**	1329	1681	2076	2512	2990	5315	6726	8304	11958	**124**
126	**290.68**	**136.75**	1339	1695	2093	2532	3014	5357	6781	8371	12054	**126**
128	**295.30**	**137.87**	1350	1709	2109	2552	3037	5400	6834	8437	12150	**128**
130	**299.91**	**138.89**	1360	1722	2126	2572	3061	5442	6887	8503	12244	**130**
132	**304.52**	**140.01**	1371	1735	2142	2592	3084	5484	6940	8568	12338	**132**
134	**309.14**	**141.03**	1381	1748	2158	2611	3108	5525	6992	8633	12431	**134**
136	**313.75**	**142.06**	1391	1761	2174	2631	3131	5565	7044	8697	12523	**136**

* 1 psi = 2.307 ft of water.

Notes to Table 1-12.1

This table is computed from the formula $Q = 29.83cd^2\sqrt{p}$ with $c = 1.00$. The theoretical discharge of sea water, as from fireboat nozzles, may be found by subtracting 1 percent from the figures in the following table, or from the formula $Q = 29.47cd^2\sqrt{p}$.

Appropriate coefficients should be applied where it is read from a hydrant outlet. Where more accurate results are required, a coefficient appropriate to the particular nozzle must be selected and applied to the figures of the table.

The discharge from circular openings of sizes other than those in the table may readily be computed by applying the principle that quantity discharged under a given head varies as the square of the diameter of the opening.

1-12 Calculation Results.

1-12.1 The discharge in gallons-per-minute for each outlet flowed is obtained from the discharge tables in 1-12.1 or by the use of formula (a). If more than one outlet is used, the discharges from all are added to obtain the total discharge.

The formula which is generally used to compute the discharge at the specified residual pressure or for any desired pressure drop is formula (b):

$$Q_R = Q_F \times \frac{h_r^{0.54}}{h_f^{0.54}} \qquad \text{(b)}$$

Q_R = flow available at desired residual pressure

Q_F = flow during test

h_r = pressure drop to desired residual pressure

h_f = pressure drop during test

In this equation any units of discharge or pressure drop may be used as long as the same units are used for each value of the same variable. In other words, if Q_R is expressed in gpm, Q_F must be in gpm, and if h_r is expressed in psi, h_f must be expressed in psi. These are the units which are normally used in applying formula (b) to fire flow test computations.

1-12.2 Discharge Calculations from Table. One means of solving this equation without the use of logarithms is by using Table 1-12.2. This table gives the values of the *0.54* power of the numbers from 1 to 175. Knowing the values of h_f, h_r and Q_F, the values of $h_f^{0.54}$ and $h_r^{0.54}$ can be read from the table and formula (b)

Table 1-12.2 Values of "*h*" to the *0.54* Power

h	$h^{0.54}$	h	$h^{0.54}$	h	$h^{0.54}$	h	$h^{0.54}$	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	2.11	39	7.23	74	10.22	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	10.73	116	13.03	151	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	15.60
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

Method of Use

Insert in formula (b) the values of $h_r^{0.54}$ and $h_f^{0.54}$ determined from the table and the value of Q_F and solve the equation for Q_R.

solved for Q_R. Results are usually carried to the nearest 100 gpm for discharges of 1000 gpm or more, and to the nearest 50 gpm for smaller discharges, which is as close as can be justified by the degree of accuracy of the field observations.

1-13 System Corrections. It must be remembered that flow test results show the strength of the distribution system and do not necessarily indicate the degree of adequacy of the entire water works system. Consider a system supplied by pumps at one location and having no elevated storage. If the pressure at the pump station drops during the test, it is an indication that the distribution system is capable of delivering more than the pumps can deliver at their normal operating pressure. It is necessary to use a value for the drop in pressure for the test which is equal to the actual drop obtained in the field during the test, minus the drop in discharge pressure at the pumping station. If sufficient pumping capacity is available at the station and the discharge pressure could be maintained by operating additional pumps, the water system as a whole could deliver the computed quantity. If, however, additional pumping units are not available, the distribution system would be capable of delivering the computed quantity, but the water system as a whole would be limited by the pumping capacity. The portion of the pressure drop for which a correction can be made for tests on systems with storage is generally estimated upon the basis of a study of all the tests made and the pressure drops observed on the recording gage at the station for each. The corrections may vary from very substantial portions of the observed pressure drops for tests near the pumping station, to zero for tests remote from the station.