NFPA 291
Recommended Practice for Fire Flow Testing and Marking of Hydrants

1995 Edition

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An International Codes and Standards Organization

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Fire Flow Testing and Marking of Hydrants

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This edition of NFPA 291, *Recommended Practice for Fire Flow Testing and Marking of Hydrants*, was prepared by the Technical Committee on Private Water Supply Piping Systems and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 291 was approved as an American National Standard on August 11, 1995.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous 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 was completely rewritten and a chapter on the flow testing of hydrants was added.

The 1982 edition had been reconfirmed by the committee. The 1988 edition of the document noted several changed which clarified and reinforced certain recommendations. Specific guidance was added on the correct method of utilizing a Pitot tube to gain accurate test results.

The 1995 edition incorporated several changes in an attempt to make the document more user friendly. Changes were also incorporated with regard to the layout of hydrant and water flow tests.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on private piping systems supplying water for fire protection and for hydrants, hose houses, and valves. The Committee is also responsible for documents on fire flow testing and marking of hydrants.

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Fire Flow Testing and Marking of Hydrants

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Chapter 1 General Information

1-1 Introduction. Fire flow tests are conducted 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 ensure adequate fire flows as needed.

1-2 Definitions.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Rated Capacity. The flow available from a hydrant at the designated residual pressure (rated pressure), either measured or calculated.

Residual Pressure. The pressure that exists in the distribution system, measured at the residual hydrant at the time the flow readings are taken at the flow hydrants.

Should. Indicates a recommendation or that which is advised but not required.

Static Pressure. The pressure that exists at a given point under normal distribution system conditions measured at the residual hydrant with no hydrants flowing.

1-3 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed in Table 1-3 with conversion factors.

Table 1-3

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 3.785 L
liter per minute per square meter	$(L/min)/m^2$	1 gpm ft^2 = (40.746 L min)/m^2
cubic decimeter	dm^3	1 gal = 3.785 dm^3
Pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 10^5 Pa

For additional conversions and information, see ASTM E380-1989, *Standard for Metric Practice.*

1-3.1 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first valve stated is to be regarded as the requirement. A given equivalent value might be approximate.

Chapter 2 Flow Testing

2-1 Rating Pressure. For the purpose of uniform marking of fire hydrants, the ratings should be based on a residual pressure of 20 psi (1.4 bar) for all hydrants having a static pressure in excess of 40 psi (2.8 bar). Hydrants having a static pressure of less than 40 psi (2.8 bar) should be rated at one-half of the static pressure.

It is generally recommended that a minimum residual pressure of 20 psi (1.4 bar) be maintained at hydrants when delivering the fire flow. Fire department pumpers can be operated where hydrant pressures are less, but with difficulty. Where hydrants are well distributed and of the proper size and type (so that friction losses in the hydrant and suction line are not excessive), it might be possible to set a lesser pressure as the minimum pressure. A primary concern should be the ability to maintain sufficient residual pressure to prevent developing a negative pressure at any point in the street mains, which could result in the collapse of the mains or other water system components or back-siphonage of polluted water from some other interconnected source. It should be noted that the use of residual pressures of less than 20 psi (1.4 bar) is not permitted by many state health departments.

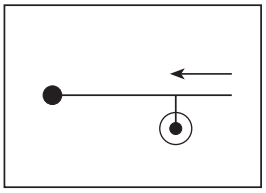
2-2 Procedure. Tests should be made during a period of ordinary demand. The procedure consists of discharging water at a measured rate of flow from the system at a given location and observing the corresponding pressure drop in the mains.

2-3 Layout of Test. After the location where the test is to be run has been determined, a group of test hydrants in the vicinity is selected. Once selected, due consideration should be given to potential interference with traffic flow patterns, damage to surroundings (e.g., roadways, sidewalks, land-

scapes, vehicles, and pedestrians), and potential flooding problems both local and remote from the test site. One hydrant, designated the residual hydrant, is chosen to be the hydrant where the normal static pressure will be observed with the other hydrants in the group closed, and where the residual pressure will be observed with the other hydrants flowing. This hydrant is chosen so it will be located between the hydrant to be flowed and the large mains that constitute the immediate sources of water supply in the area. In Figure 2-3, a test layout is indicated, showing the residual hydrant by means of a circle.

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. To obtain satisfactory test results of theoretical calculation of expected flows or rated capacities, sufficient discharge should be achieved to cause a drop in pressure at the residual hydrant of at least 25 percent, or to flow the total demand necessary for fire-fighting purposes. 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.

It is preferable to flow water past the residual hydrant.



Note: Circles drawn about residual hydrant.
Arrow denotes flow direction in main.

Figure 2-3 Suggested test layout for hydrants.

(Copyright, Insurance Services Office, 1963)

2-4 Equipment. The equipment necessary for field work consists of a single 200-psi (14-bar) bourdon pressure gauge with 1-psi (0.0689 bar) graduations, a number of Pitot tubes, hydrant wrenches, 50- or 60-psi (3.5- or 4.0-bar) bourdon pressure gauges with $^1/_2$-psi (0.03445 bar) graduations, and scales with $^1/_{16}$-in. (1.6-mm) graduations (one Pitot tube, a 50- or 60-psi [3.5- or 4.0-bar] gauge, 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 $^1/_4$-in. (6.35-mm) brass pipe is fitted. This pipe is provided with a T connection for the 200-psi (14-bar) gauge and a cock at the end for relieving air pressure. All pressure gauges should be calibrated at least every 12 months, or more frequently depending on use. When more than one hydrant is flowed, it may be desirable and necessary to use portable radios to facilitate communication between team members.

It is preferred to use an Underwriter's Playpipe, or other stream straightener, when testing hydrants due to a more streamlined flow and more accurate pitot reading.

2-5 Test Procedure. In a typical test, the 200-psi (14 bar) gauge is attached to one of the $2^1/_2$-in. (6.4-cm) outlets of the residual hydrant using the special cap, the cock on the gauge 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 (static pressure) 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. Hydrants should be opened one at a time. With all hydrants flowing, water should be allowed to flow for a sufficient time to clear all debris and foreign substances from the stream(s). At that time, a signal is given to the people 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, one at a time, to prevent undue surges in the system.

2-6 Pitot Readings. When measuring discharge from open hydrant butts, it is always preferable from the standpoint of accuracy to use $2^1/_2$-in. (6.4-cm) outlets rather than pumper outlets. In practically all cases, the $2^1/_2$-in. (6.4-cm) outlets are filled across the entire cross section during flow, while in the case of 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 downstream approximately one-half the diameter of the hydrant outlet or nozzle opening, and in the center of the stream. 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 (.7 bar) and more than 30 psi (2.0 bar) should be avoided, if possible. Opening additional hydrant outlets will aid in controlling 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. (*See Figure 2-6.*)

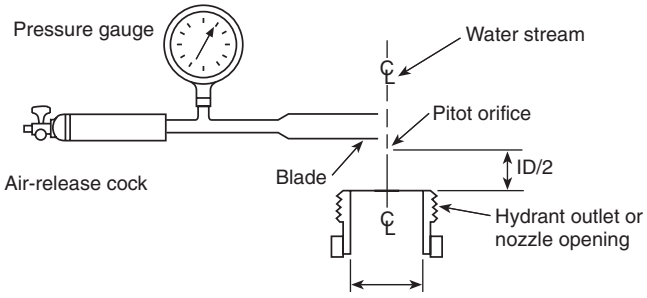


Figure 2-6 Pitot tube position.

2-7 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 pitot pressure (velocity head) of the streams as indicated by the Pitot gauge readings, and the coefficient of the outlet being flowed as determined from Figure 2-7. 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:

(a)

$$Q = 29.83\ cd^2\sqrt{p}$$

where c is the coefficient of discharge (*see Figure 2-7*),
d the diameter of the outlet in inches, and
p the pitot pressure (velocity head) in psi.

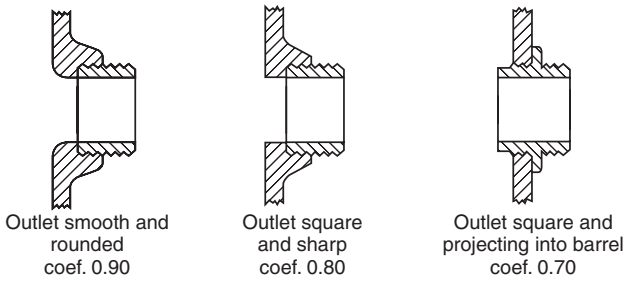


Figure 2-7 Three general types of hydrant outlets and their coefficients of discharge.

2-8 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 pitot pressure (velocity head) maintained between 5 psi and 10 psi (.3 bar and .7 bar). For pumper outlets, the approximate discharge can be computed from equation (a) using the pitot pressure (velocity head) at the center of the stream and multiplying the result by one of the coefficients in Table 2-8, depending upon the pitot pressure (velocity head). These coefficients are applied in addition to the coefficient in equation (a) and are for average type hydrants.

Table 2-8 Pumper Outlet Coefficients

Pitot Pressure (Velocity Head)	Coefficient
2 psi (0.14 bar)	0.97
3 psi (0.21 bar)	0.92
4 psi (0.28 bar)	0.89
5 psi (0.35 bar)	0.86
6 psi (0.41 bar)	0.84
7 psi (0.48 bar) and over	0.83

2-9 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 (3.5 or 4.0 bar) gauge tapped into a hydrant cap may be used. The hydrant cap with gauge attached is placed on one outlet, and the flow is allowed to take place through the other outlet at the same elevation. The readings obtained from a gauge so located, and the readings obtained from a gauge on a Pitot tube held in the stream, are approximately the same.

2-10 Calculation Results.

2-10.1 The discharge in gpm (L/min) for each outlet flowed is obtained from the discharge tables in 2-10.1 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):

(b)

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

Q_R = flow predicted at desired residual pressure
Q_F = total flow measured during test
h_r = pressure drop to desired residual pressure
h_f = pressure drop measured 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.

2-10.2 Discharge Calculations from Table. One means of solving this equation without the use of logarithms is by using Table 2-10.2. 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) solved for Q_R. Results are usually carried to the nearest 100 gpm (380 L/min) for discharges of 1,000 gpm (3,800 L/min) or more, and to the nearest 50 gpm (190 L/min) for smaller discharges, which is as close as can be justified by the degree of accuracy of the field observations.

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 of Q_R.

2-11 Data Sheet. The data secured during the testing of hydrants for uniform marking can be valuable for other purposes. With this in mind, it is suggested that the form shown in Figure 2-11 be used to record information that is 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.

2-12 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 gauge 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.

Table 2-10.1 Theoretical Discharge Through Circular Orifices
(United States Gallons of Water per Minute)
(See Notes)

Pitot Pressure psi[1] (kPa)	Feet[2] (m)	Velocity Discharge, ft/sec (m/s)	2 (51)	2 1/4 (57)	2 3/8 (60)	2 1/2 (64)	2 5/8 (67)	2 3/4 (70)	3 (76)	3 1/4 (83)	3 1/2 (89)	3 3/4 (95)	4 (101)	4 1/2 (114)
1	2.31	12.20	119	151	168	187	206	226	269	315	366	420	478	604
(6.89)	(0.70)	(3.72)	(451)	(571)	(637)	(705)	(778)	(854)	(1020)	(1190)	(1390)	(1590)	(1810)	(2290)
2	4.61	17.25	169	214	238	264	291	319	380	446	517	594	676	854
(13.8)	(1.41)	(5.26)	(639)	(808)	(900)	(1000)	(1100)	(1210)	(1440)	(1690)	(1960)	(2250)	(2560)	(3230)
3	6.92	21.13	207	262	292	323	356	391	465	546	633	727	827	1045
(20.7)	(2.11)	(6.44)	(782)	(990)	(1100)	(1220)	(1350)	(1480)	(1760)	(2070)	(2400)	(2750)	(3130)	(3960)
4	9.23	24.39	239	302	337	373	411	452	537	631	731	840	955	1210
(27.6)	(2.81)	(7.43)	(930)	(1140)	(1280)	(1410)	(1560)	(1710)	(2030)	(2390)	(2770)	(3180)	(3610)	(4570)
5	11.54	27.26	267	338	376	417	460	505	601	705	817	938	1068	1350
(34.5)	(3.52)	(8.31)	(1010)	(1280)	(1420)	(1580)	(1740)	(1910)	(2270)	(2670)	(3090)	(3550)	(4040)	(5110)
6	13.84	29.87	292	370	412	457	504	553	658	772	896	1028	1170	1480
(41.4)	(4.22)	(9.10)	(1110)	(1400)	(1560)	(1730)	(1910)	(2090)	(2490)	(2920)	(3390)	(3890)	(4420)	(5600)
7	16.15	32.26	316	400	445	494	544	597	711	834	967	1111	1263	1600
(48.3)	(4.92)	(9.83)	(1190)	(1510)	(1680)	(1870)	(2060)	(2260)	(2690)	(3160)	(3660)	(4210)	(4780)	(6050)
8	18.46	34.49	338	427	476	528	582	638	760	892	1034	1187	1351	1710
(55.2)	(5.63)	(10.51)	(1280)	(1620)	(1800)	(2000)	(2200)	(2410)	(2880)	(3380)	(3910)	(4490)	(5110)	(6470)
9	20.76	36.58	358	453	505	560	617	677	806	946	1097	1259	1433	1815
(62.0)	(6.33)	(11.15)	(1360)	(1710)	(1910)	(2120)	(2340)	(2560)	(3050)	(3580)	(4150)	(4770)	(5420)	(6860)
10	23.07	38.56	378	478	532	590	650	714	850	997	1156	1327	1510	1910
(68.9)	(7.03)	(11.75)	(1430)	(1810)	(2010)	(2230)	(2460)	(2700)	(3220)	(3770)	(4380)	(5020)	(5710)	(7230)
11	25.38	40.45	396	501	553	619	682	759	891	1046	1213	1392	1584	2010
(75.8)	(7.73)	(12.33)	(1500)	(1900)	(2110)	(2340)	(2580)	(2830)	(3370)	(3960)	(4590)	(5270)	(5990)	(7580)
12	27.68	42.24	414	524	583	646	712	782	931	1092	1267	1454	1655	2100
(82.7)	(8.44)	(12.87)	(1560)	(1980)	(2210)	(2450)	(2690)	(2960)	(3520)	(4130)	(4800)	(5500)	(6260)	(7920)
13	29.99	43.97	431	545	607	673	741	814	969	1137	1318	1515	1722	2180
(89.6)	(9.14)	(13.40)	(1630)	(2060)	(2300)	(2550)	(2800)	(3080)	(3670)	(4300)	(4990)	(5730)	(6520)	(8240)
14	32.30	45.63	447	566	630	698	769	845	1005	1180	1368	1572	1787	2260
(96.5)	(9.84)	(13.91)	(1690)	(2140)	(2380)	(2640)	(2910)	(3200)	(3800)	(4470)	(5180)	(5950)	(6760)	(8550)
15	34.61	47.22	463	586	652	722	796	874	1040	1221	1416	1626	1849	2340
(103)	(10.55)	(14.39)	(1750)	(2220)	(2470)	(2730)	(3010)	(3310)	(3940)	(4620)	(5360)	(6150)	(7000)	(8850)
16	36.91	48.78	478	605	673	746	822	903	1075	1261	1463	1679	1910	2420
(110)	(11.25)	(14.87)	(1810)	(2290)	(2550)	(2820)	(3110)	(3420)	(4070)	(4770)	(5540)	(6360)	(7230)	(9140)
17	39.22	50.28	493	623	694	769	848	931	1108	1300	1508	1731	1969	2500
(117)	(11.95)	(15.33)	(1870)	(2360)	(2630)	(2910)	(3210)	(3520)	(4190)	(4920)	(5710)	(6550)	(7540)	(9430)
18	41.53	51.73	507	642	714	791	872	958	1140	1338	1551	1781	2026	2570
(124)	(12.66)	(15.77)	(1920)	(2430)	(2700)	(2990)	(3300)	(3630)	(4310)	(5060)	(5870)	(6740)	(7670)	(9700)
19	43.83	53.15	521	659	733	813	896	984	1171	1374	1594	1830	2082	2640
(131)	(13.36)	(16.20)	(1970)	(2490)	(2770)	(3080)	(3390)	(3720)	(4430)	(5200)	(6030)	(6920)	(7870)	(9970)
20	46.14	54.54	534	676	753	834	920	1010	1201	1410	1635	1877	2136	2710
(138)	(14.06)	(16.62)	(2020)	(2560)	(2850)	(3160)	(3480)	(3820)	(4540)	(5330)	(6180)	(7100)	(8080)	(10200)
22	50.75	57.19	560	709	789	875	964	1059	1260	1479	1715	1969	2240	2840
(152)	(15.47)	(17.43)	(2120)	(2680)	(2990)	(3310)	(3650)	(4000)	(4770)	(5590)	(6490)	(7540)	(8470)	(10700)
24	55.37	59.74	585	741	824	914	1007	1106	1316	1545	1791	2056	2340	2970
(165)	(16.88)	(18.21)	(2210)	(2800)	(3120)	(3460)	(3810)	(4180)	(4980)	(5840)	(6770)	(7780)	(8850)	(11200)
26	59.98	62.18	609	771	858	951	1048	1151	1370	1608	1864	2140	2435	3090
(179)	(18.28)	(18.95)	(2300)	(2910)	(3250)	(3600)	(3970)	(4350)	(5180)	(6080)	(7050)	(8100)	(9210)	(11700)
28	64.60	64.52	632	800	890	987	1088	1194	1422	1668	1935	2221	2527	3210
(193)	(19.69)	(19.67)	(2390)	(3020)	(3370)	(3730)	(4120)	(4520)	(5380)	(6310)	(7320)	(8400)	(9560)	(12100)
30	69.21	66.79	654	828	922	1022	1126	1236	1472	1727	2003	2299	2616	3320
(207)	(21.10)	(20.36)	(2470)	(3130)	(3490)	(3860)	(4260)	(4680)	(5570)	(6530)	(7570)	(8700)	(9890)	(12500)
32	73.82	68.98	676	856	952	1055	1163	1277	1520	1784	2069	2375	2702	3430
(221)	(22.50)	(21.03)	(2550)	(3230)	(3600)	(3990)	(4400)	(4830)	(5750)	(6750)	(7820)	(8980)	(10200)	(12900)
34	78.44	71.10	697	882	981	1088	1199	1316	1566	1838	2132	2448	2785	3540
(234)	(23.91)	(21.67)	(2640)	(3340)	(3710)	(4120)	(4540)	(4980)	(5930)	(6960)	(8070)	(9270)	(10540)	(13300)
36	83.05	73.16	717	908	1010	1119	1233	1354	1612	1892	2194	2519	2866	3640
(248)	(25.31)	(22.30)	(2710)	(3440)	(3820)	(4240)	(4670)	(5120)	(6100)	(7160)	(8300)	(9530)	(10850)	(13800)
38	87.67	75.17	736	932	1037	1150	1267	1392	1656	1944	2254	2588	2944	3740
(262)	(26.72)	(22.91)	(2790)	(3530)	(3930)	(4350)	(4800)	(5270)	(6270)	(7360)	(8530)	(9800)	(11140)	(14100)
40	92.28	77.11	755	956	1064	1180	1300	1428	1699	1994	2313	2655	3021	3840
(276)	(28.13)	(23.50)	(2860)	(3620)	(4030)	(4470)	(4920)	(5400)	(6430)	(7550)	(8750)	(10050)	(11430)	(14500)

Table 2-10.1 Theoretical Discharge Through Circular Orifices
(United States Gallons of Water per Minute)
***(See Notes)* Continued**

Pitot Pressure psi[1] (kPa)	Feet[2] (m)	Velocity Discharge, ft/sec (m/s)	2 (51)	2 1/4 (57)	2 3/8 (60)	2 1/2 (64)	2 5/8 (67)	2 3/4 (70)	3 (76)	3 1/4 (83)	3 1/2 (89)	3 3/4 (95)	4 (101)	4 1/2 (114)
42	96.89	79.03	774	980	1091	1209	1332	1463	1741	2043	2370	2721	3095	3935
(290)	(29.53)	(24.09)	(2930)	(3710)	(4130)	(4580)	(5040)	(5540)	(6590)	(7730)	(8970)	(10300)	(11710)	(14800)
44	101.51	80.88	792	1003	1116	1237	1364	1497	1782	2091	2426	2785	3168	4030
(303)	(30.94)	(24.65)	(3000)	(3800)	(4220)	(4680)	(5160)	(5670)	(6740)	(7910)	(9180)	(10540)	(11990)	(15200)
46	106.12	82.70	810	1025	1141	1265	1394	1531	1822	2138	2480	2847	3239	4120
(317)	(32.35)	(25.21)	(3070)	(3880)	(4320)	(4790)	(5280)	(5790)	(6900)	(8090)	(9390)	(10780)	(12260)	(15500)
48	110.74	84.48	828	1047	1166	1293	1424	1564	1861	2184	2533	2908	3309	4205
(331)	(33.75)	(25.75)	(3130)	(3960)	(4410)	(4890)	(5390)	(5920)	(7040)	(8270)	(9587)	(11010)	(12520)	(15800)
50	115.35	86.22	845	1069	1190	1319	1454	1596	1900	2229	2586	2968	3377	4290
(345)	(35.16)	(26.28)	(3200)	(4050)	(4500)	(4990)	(5500)	(6040)	(7190)	(8440)	(9790)	(11230)	(12780)	(16200)
52	119.96	87.93	861	1091	1213	1345	1482	1628	1937	2274	2637	3027	3444	4375
(358)	(36.57)	(26.80)	(3260)	(4130)	(4590)	(5090)	(5610)	(6160)	(7330)	(8610)	(9980)	(11460)	(13040)	(16500)
54	124.58	89.61	878	1111	1237	1371	1511	1659	1974	2317	2687	3085	3510	4460
(372)	(37.97)	(27.31)	(3320)	(4200)	(4680)	(5190)	(5720)	(6280)	(7470)	(8770)	(10170)	(11680)	(13290)	(16800)
56	129.19	91.20	894	1132	1259	1396	1538	1689	2010	2359	2736	3141	3574	4540
(386)	(39.38)	(27.80)	(3380)	(4280)	(4770)	(5280)	(5820)	(6390)	(7610)	(8930)	(10360)	(11890)	(13530)	(17100)
58	133.81	92.87	909	1152	1282	1421	1566	1719	2046	2401	2785	3197	3637	4620
(400)	(40.78)	(28.31)	(3440)	(4350)	(4850)	(5370)	(5920)	(6500)	(7740)	(9080)	(10530)	(12090)	(13760)	(17400)
60	138.42	94.45	925	1171	1303	1445	1592	1749	2081	2442	2832	3252	3700	4700
(414)	(42.19)	(28.79)	(3500)	(4430)	(4930)	(5460)	(6030)	(6610)	(7870)	(9240)	(10710)	(12300)	(13990)	(17700)
62	143.03	96.01	941	1191	1325	1470	1619	1777	2115	2483	2879	3305	3761	4775
(427)	(43.60)	(29.26)	(3560)	(4500)	(5010)	(5560)	(6130)	(6720)	(8000)	(9390)	(10890)	(12500)	(14220)	(18000)
64	147.65	97.55	956	1210	1346	1493	1645	1806	2149	2522	2925	3358	3821	4850
(441)	(45.00)	(29.73)	(3610)	(4570)	(5090)	(5640)	(6220)	(6830)	(8130)	(9540)	(11060)	(12700)	(14450)	(18300)
66	152.26	99.07	971	1228	1367	1516	1670	1834	2183	2561	2971	3410	3880	4925
(455)	(46.41)	(30.20)	(3670)	(4640)	(5170)	(5730)	(6320)	(6940)	(8260)	(9690)	(11240)	(12900)	(14680)	(18600)
68	156.88	100.55	985	1247	1388	1539	1695	1862	2215	2600	3015	3462	3938	5000
(469)	(47.82)	(30.65)	(3720)	(4710)	(5250)	(5820)	(6420)	(7040)	(8380)	(9830)	(11400)	(13090)	(14900)	(18900)
70	161.49	102.03	999	1265	1408	1561	1720	1889	2248	2638	3059	3512	3996	5075
(483)	(49.22)	(31.10)	(3780)	(4780)	(5330)	(5900)	(6510)	(7140)	(8500)	(9980)	(11570)	(13280)	(15110)	(19100)
72	166.10	103.47	1014	1283	1428	1583	1745	1916	2280	2675	3103	3562	4053	5140
(496)	(50.63)	(31.54)	(3830)	(4850)	(5400)	(5990)	(6600)	(7250)	(8620)	(10120)	(11730)	(13470)	(15330)	(19400)
74	170.72	104.90	1028	1301	1448	1605	1769	1942	2311	2712	3146	3611	4109	5200
(510)	(52.03)	(31.97)	(3880)	(4920)	(5480)	(6070)	(6690)	(7350)	(8740)	(10260)	(11900)	(13660)	(15540)	(19700)
76	175.33	106.30	1041	1318	1467	1627	1792	1968	2342	2749	3188	3660	4164	5265
(524)	(53.44)	(32.71)	(3940)	(4980)	(5550)	(6150)	(6780)	(7440)	(8860)	(10400)	(12060)	(13840)	(15750)	(19900)
78	179.95	107.69	1055	1335	1486	1648	1816	1994	2373	2785	3230	3708	4218	5340
(538)	(54.85)	(32.82)	(3990)	(5050)	(5620)	(6230)	(6870)	(7540)	(8970)	(10530)	(12210)	(14020)	(15950)	(20200)
80	184.56	109.08	1068	1352	1505	1669	1839	2019	2403	2820	3271	3755	4272	5405
(552)	(56.25)	(33.25)	(4040)	(5110)	(5690)	(6310)	(6960)	(7640)	(9090)	(10670)	(12370)	(14200)	(16160)	(20400)
82	189.17	110.42	1082	1369	1524	1689	1862	2044	2433	2855	3311	3801	4325	5470
(565)	(57.66)	(33.66)	(4090)	(5180)	(5770)	(6390)	(7040)	(7730)	(9200)	(10800)	(12520)	(14380)	(16360)	(20700)
84	193.79	111.76	1095	1386	1542	1710	1884	2069	2462	2890	3351	3847	4377	5535
(579)	(59.07)	(34.06)	(4140)	(5240)	(5840)	(6466)	(7130)	(7830)	(9310)	(10930)	(12670)	(14550)	(16560)	(21000)
86	198.40	113.08	1170	1402	1561	1730	1907	2094	2491	2924	3391	3893	4429	5600
(593)	(60.47)	(34.47)	(4190)	(5300)	(5900)	(6540)	(7210)	(7920)	(9420)	(11070)	(12820)	(14720)	(16750)	(21200)
88	203.02	114.39	1120	1419	1579	1750	1929	2118	2520	2958	3430	3938	4480	5665
(607)	(61.88)	(34.87)	(4240)	(5360)	(5970)	(6620)	(7300)	(8010)	(9530)	(11190)	(12970)	(14890)	(16950)	(21400)
90	207.63	115.68	1133	1434	1596	1770	1950	2142	2549	2991	3469	3983	4531	5730
(620)	(63.29)	(35.26)	(4280)	(5420)	(6040)	(6690)	(7380)	(8100)	(9640)	(11310)	(13120)	(15060)	(17140)	(21700)
92	212.24	116.96	1146	1450	1614	1789	1972	2165	2577	3024	3507	4027	4581	5795
(634)	(64.69)	(35.65)	(4330)	(5480)	(6110)	(6770)	(7460)	(8190)	(9750)	(11440)	(13260)	(15230)	(17330)	(21900)
94	216.86	118.23	1158	1466	1632	1809	1993	2189	2605	3057	3545	4070	4631	5865
(648)	(66.10)	(36.04)	(4380)	(5540)	(6170)	(6840)	(7540)	(8280)	(9850)	(11560)	(13410)	(15390)	(17510)	(22200)
96	221.47	119.48	1170	1481	1649	1828	2014	2212	2632	3089	3583	4113	4680	5925
(662)	(67.50)	(36.42)	(4420)	(5600)	(6240)	(6910)	(7620)	(8370)	(9960)	(11680)	(13550)	(15560)	(17700)	(22400)
98	226.09	120.71	1182	1497	1666	1847	2035	2235	2660	3121	3620	4156	4728	5985
(676)	(68.91)	(36.79)	(4470)	(5660)	(6300)	(6980)	(7700)	(8450)	(10060)	(11810)	(13690)	(15720)	(17880)	(22600)
100	230.70	121.94	1194	1512	1683	1866	2056	2258	2687	3153	3657	4198	4776	6045
(689)	(70.32)	(37.17)	(4520)	(5720)	(6370)	(7050)	(7780)	(8540)	(10160)	(11930)	(13830)	(15880)	(18060)	(22900)

Table 2-10.1 Theoretical Discharge Through Circular Orifices
(United States Gallons of Water per Minute)
***(See Notes)* Continued**

Pitot Pressure psi[1] (kPa)	Feet[2] (m)	Velocity Discharge, ft/sec (m/s)	2 (51)	2 1/4 (57)	2 3/8 (60)	2 1/2 (64)	2 5/8 (67)	2 3/4 (70)	3 (76)	3 1/4 (83)	3 1/2 (89)	3 3/4 (95)	4 (101)	4 1/2 (114)
102	235.31	123.15	1206	1527	1699	1884	2076	2280	2713	3184	3693	4240	4824	6100
(703)	(71.72)	(37.54)	(4560)	(5770)	(6430)	(7130)	(7860)	(8620)	(10260)	(12040)	(13970)	(16040)	(18240)	(23100)
104	239.93	124.35	1218	1542	1716	1903	2097	2302	2740	3215	3729	4281	4871	6150
(717)	(73.13)	(37.90)	(4610)	(5830)	(6490)	(7190)	(7930)	(8710)	(10360)	(12160)	(14100)	(16190)	(18420)	(23300)
106	244.54	125.55	1230	1556	1733	1921	2117	2324	2766	3246	3765	4322	4917	6200
(731)	(74.54)	(38.27)	(4650)	(5890)	(6560)	(7260)	(8010)	(8790)	(10460)	(12280)	(14240)	(16350)	(18600)	(23500)
108	249.16	126.73	1241	1571	1749	1939	2137	2346	2792	3277	3800	4363	4963	6260
(745)	(75.94)	(38.63)	(4690)	(5940)	(6620)	(7330)	(8080)	(8870)	(10560)	(12390)	(14370)	(16500)	(18770)	(23800)
110	253.77	127.89	1253	1586	1765	1957	2156	2368	2818	3307	3835	4403	5009	6320
(758)	(77.35)	(38.98)	(4640)	(6000)	(6680)	(7400)	(8160)	(8960)	(10660)	(12510)	(14500)	(16650)	(18950)	(24000)
112	258.38	129.05	1264	1600	1781	1974	2176	2389	2843	3337	3870	4443	5054	6380
(772)	(78.76)	(39.33)	(4780)	(6050)	(6740)	(7470)	(8230)	(9040)	(10750)	(12620)	(14640)	(16800)	(19120)	(24200)
114	263.00	130.20	1275	1614	1797	1992	2195	2410	2869	3367	3904	4482	5099	6440
(786)	(80.16)	(39.68)	(4820)	(6100)	(6800)	(7530)	(8310)	(9120)	(10850)	(12730)	(14770)	(16950)	(19290)	(24400)
116	267.61	131.33	1286	1628	1812	2009	2214	2431	2894	3396	3938	4521	5144	6500
(800)	(81.57)	(40.03)	(4860)	(6160)	(6860)	(7600)	(8380)	(9200)	(10940)	(12840)	(14890)	(17100)	(19460)	(24600)
118	272.23	132.46	1297	1642	1828	2027	2233	2452	2918	3425	3972	4560	5188	6560
(813)	(82.97)	(40.37)	(4910)	(6210)	(6920)	(7660)	(8450)	(9280)	(11040)	(12950)	(15020)	(17250)	(19620)	(24800)
120	276.84	133.57	1308	1656	1843	2044	2252	2473	2943	3454	4006	4599	5232	6620
(827)	(84.38)	(40.71)	(4950)	(6260)	(6970)	(7730)	(8520)	(9350)	(11130)	(13060)	(15150)	(17390)	(19790)	(25000)
122	281.45	134.69	1319	1670	1859	2061	2271	2494	2967	3483	4039	4637	5275	6680
(841)	(85.79)	(41.05)	(4990)	(6310)	(7030)	(7790)	(8590)	(9430)	(11220)	(13170)	(15270)	(17540)	(19950)	(25300)
124	286.07	135.79	1330	1684	1874	2077	2289	2514	2992	3511	4072	4675	5318	6740
(855)	(87.19)	(41.39)	(5030)	(6370)	(7090)	(7860)	(8660)	(9510)	(11320)	(13280)	(15400)	(17680)	(20120)	(25500)
126	290.68	136.88	1341	1697	1889	2094	2308	2534	3016	3539	4105	4712	5361	6800
(869)	(88.60)	(41.72)	(5070)	(6420)	(7150)	(7920)	(8730)	(9580)	(11410)	(13390)	(15520)	(17820)	(20280)	(25700)
128	295.30	137.96	1351	1711	1904	2111	2326	2554	3040	3567	4137	4749	5403	6850
(882)	(90.01)	(42.05)	(5110)	(6470)	(7200)	(7980)	(8800)	(9660)	(11500)	(13490)	(15650)	(17960)	(20440)	(25900)
130	299.91	139.03	1362	1724	1919	2127	2344	2574	3063	3595	4169	4786	5445	6900
(896)	(91.41)	(42.38)	(5150)	(6520)	(7260)	(8040)	(8870)	(9740)	(11590)	(13600)	(15770)	(18100)	(20600)	(26100)
132	304.52	140.10	1372	1736	1933	2144	2362	2594	3087	3623	4201	4823	5487	6950
(910)	(92.82)	(42.70)	(5190)	(6570)	(7320)	(8110)	(8940)	(9810)	(11670)	(13700)	(15890)	(18240)	(20750)	(26300)
134	309.14	141.16	1382	1749	1948	2160	2380	2613	3110	3650	4233	4860	5529	7000
(924)	(94.23)	(43.03)	(5230)	(6620)	(7370)	(8170)	(9010)	(9880)	(11760)	(13800)	(16010)	(18380)	(20910)	(26500)
136	313.75	142.21	1392	1762	1962	2176	2398	2633	3133	3677	4625	4896	5570	7050
(938)	(95.63)	(43.35)	(5270)	(6670)	(7430)	(8230)	(9070)	(9960)	(11850)	(13910)	(16130)	(18520)	(21070)	(26700)

*1 psi—2.307 ft of water, 1 kPa—0.102 m of water. For pressure in bars, multiply by 0.01.

Notes to Table 2-10.1

Note 1. This corresponds to velocity head.

Note 2. This table is computed from the formula $Q = 29.83cd^2\sqrt{p}$ ($Q_m = 0.0666cd^2p_m$) with c = 1.00. The theoretical discharge of sea water, as from fireboat nozzles, can be found by subtracting 1 percent from the figures in the following table, or from the formula $Q = 29.83cd^2\sqrt{p}$ ($Q_m = 0.065cd^2m\ p_m$).

Appropriate coefficient should be applied where it is read from hydrant outlet. Where more accurate results are required, a coefficient appropriate on 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 can readily be computed by applying the principle that quantity discharged under a given head varies as the square of the diameter of the opening.

Table 2-10.2 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