

# NFPA 1911

## Standard for Service Tests of Fire Pump Systems on Fire Apparatus

1997 Edition



National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101  
An International Codes and Standards Organization

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**NFPA 1911**  
**Standard for**  
**Service Tests of Fire Pump Systems on Fire Apparatus**  
**1997 Edition**

This edition of NFPA 1911, *Standard for Service Tests of Fire Pump Systems on Fire Apparatus*, was prepared by the Technical Committee on Fire Department Apparatus and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 19–22, 1997, in Los Angeles, CA. It was issued by the Standards Council on July 24, 1997, with an effective date of August 15, 1997, and supersedes all previous editions.

This edition of NFPA 1911 was approved as an American National Standard on August 15, 1997.

**Origin and Development of NFPA 1911**

The first edition of NFPA 1911 was issued in 1987 and was titled *Acceptance and Service Tests of Fire Department Pumping Apparatus*. It incorporated much of the material formerly included in the pamphlet *Fire Department Pumper Tests and Fire Stream Tables*, published by the National Board of Fire Underwriters and later the Insurance Services Office.

With the 1991 edition, the requirements for acceptance tests of new apparatus were transferred to the standards for new fire apparatus. Material previously referenced from other documents was added to make this document self-contained. The requirements were changed to include pumps that were of 250 gpm (950 L/min) and larger and were rated at 150 psi (1035 kPa). Requirements were added for an engine speed test, a vacuum test, a pressure control test, an operational check of the transfer valve, and a check for the accuracy of the gauges and flow meters. The provision allowing testing from a hydrant or other positive pressure source was deleted.

This edition restores the alternative of testing pumps from a hydrant or other positive pressure source, expands the tables to include data for pumps to 3000 gpm (11,356 L/min), adds accuracy requirements for flow and speed measuring equipment, requires a tank-to-pump flow-rate check, and adds a pass/fail point for either derating the pump or correcting the deficiency. The name of the standard was changed to reflect that components of the pumping system, such as the tank-to-pump piping, are now being checked.

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**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.

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**NFPA 1911**  
**Standard for**  
**Service Tests of Fire Pump Systems on**  
**Fire Apparatus**

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NOTICE: An asterisk (\*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 4 and Appendix D.

**Chapter 1 Administration**

**1-1 Scope.** This standard covers the service testing of fire pump systems on automotive fire apparatus.

**1-2 Purpose.** This standard establishes the site, environmental, and equipment requirements for proper pump system performance testing, as well as the frequency and procedures to be followed in performing tests.

**1-3\* Application.** This standard applies to the conduct of in-service tests of fire pump systems on fire apparatus to ensure that the pump continues to be capable of the performance for which it was designed.

**1-4 Definitions.**

**Approved.\*** Acceptable to the authority having jurisdiction.

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

**Automatic Electrical Load Management System.** A device that continuously monitors the electrical system voltage and sheds predetermined loads in a selected order to prevent over-discharging of the apparatus' batteries. Shedding of the loads occurs without human intervention but is capable of being manually overridden.

**Carbon Monoxide Monitor.** A monitoring device that samples the purified air stream for trace elements of carbon monoxide (CO).

**Compound Gauge.** A gauge that indicates pressure both above and below atmospheric pressure. On most gauges, zero equals atmospheric pressure. Gauges typically measure pressure above atmospheric pressure in pounds per square inch (psi) and below atmospheric pressure in inches of mercury (Hg).

**Defect.** A discontinuity in a part or a failure to function that interferes with the service or reliability for which the part was intended.

**Discharge Pressure.** The water pressure on the discharge manifold of the fire pump at the point of gauge attachment.

**Fire Apparatus.** A vehicle used for fire suppression or support by a fire department, fire brigade, or other agency responsible for fire protection.

**Fire Pump.** A water pump with a rated capacity of 250 gpm (950 L/min) or greater at 150 psi (1035 kPa) net pump pressure. The pump is mounted on an apparatus and used for fire fighting.

**Gallons.** U. S. gallons.

**Gauge.** A round, analog pressure-indicating device that uses mechanical means to measure pressure.

**Gauge Pressure.** Pressure measured by an instrument where the pressure indicated is relative to atmospheric pressure.

**gpm.** Gallons per minute.

**Intake Pressure.** The pressure on the intake passageway of the pump at the point of gauge attachment.

**Labeled.** Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

**Lift.** The height that water must be raised during a drafting operation as measured from the surface of a static source of water to the centerline of the pump.

**Listed.\*** Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

**Manufacturer.** The person(s), company, firm, corporation, partnership, or organization that is responsible for turning raw materials or components into a finished product.

**Negative Pressure.** Pressure less than atmospheric pressure.

**Net Pump Pressure.\*** The sum of the discharge pressure and the suction lift converted to psi or kPa when pumping at draft, or the difference between the discharge pressure and the intake pressure when pumping from a hydrant or other source of water under positive pressure.

**psi.** Pounds per square inch.

**psig.** Pounds per square inch gauge.

**Pump Operator's Panel.** The area on a fire apparatus that contains the gauges, controls, and other instruments used for operating the pump.

**Pump Operator's Position.** The location from which the pump operator operates the pump.

**Rated Capacity.** The flow rate at which the pump manufacturer certifies compliance of the pump, when new, with the requirements set forth in the edition of NFPA 1901, *Standard for Automotive Fire Apparatus*, that was in effect on the date of manufacture.

**Service Tests.** Tests made after a fire pump has been put into service to determine if its performance is still acceptable.

**Shall.** Indicates a mandatory requirement.

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

**Suction Lift.** The sum of the vertical lift and the friction and entrance loss caused by the flow through the intake strainers and hose. Suction lift is expressed in feet of water head.

**Vacuum.** The reduction in atmospheric pressure inside a pump or suction hose. Typically, vacuum is expressed in inches of mercury (Hg).

**Vertical Lift.** The vertical distance from the surface of the water to the center of the pump intake.

**1-5 Conversion Factors.** Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The liter unit is outside of but recognized by SI and commonly is used in international fire protection. In this standard, values for measurement are followed by an equivalent in SI units, but only the value that first appears shall be considered as the requirement since the value in SI units could be approximate. Table 1-5 provides the conversion factors to be used where SI units are not provided in the text or where more precision is desired.

**Table 1-5 Conversion Factors**

One gallon per minute (gpm)	= 3.785 liters per minute (L/min)
One gallon per minute (gpm)	= 0.833 imperial gallons per minute
One pound per square inch (psi)	= 6.895 kilopascals (kPa)
One pound per square inch (psi)	= 0.0690 bar
One pound per square inch (psi)	= 2.31 ft of water
One inch of mercury (in. Hg)	= 3.386 kilopascals (kPa)
One inch of mercury (in. Hg)	= 0.0340 bar
One inch (in.)	= 25.40 millimeters (mm)
One foot (ft)	= 0.305 meters (m)
One cubic foot (ft <sup>3</sup> )	= 0.0283 cubic meters (m <sup>3</sup> )
One square inch (in. <sup>2</sup> )	= 645.2 square millimeters (mm <sup>2</sup> )
One mile per hour (mph)	= 1.609 kilometers per hour (kmph)
One pound (lb)	= 0.454 kilograms (kg)
One horsepower (hp)	= 0.746 kilowatts (kW)

## Chapter 2 Equipment and Site Requirements

### 2-1 Test Site.

**2-1.1\* Test Site from Draft.** The test site shall be adjacent to a supply of clear water at least 4 ft (1.2 m) deep, with the water level not more than 10 ft (3 m) below the center of the pump intake and close enough to allow the suction strainer to be submerged at least 2 ft (0.6 m) below the surface of the water when connected to the pump by 20 ft (6 m) of suction hose.

**2-1.2\* Test Site from Hydrant.** When a suitable site for drafting is not available, the site shall provide a level area for stationing the apparatus, a source of hydrant water with sufficient flow, and an area that is suitable for discharging the water.

**2-2\* Environmental Conditions.** Tests shall be performed when conditions are as follows:

Air temperature:	0°F to 100°F (−18°C to 38°C)
Water temperature:	35°F to 90°F (2°C to 32°C)
Barometric pressure:	29 in. Hg (98.2 kPa), minimum (corrected to sea level)

### 2-3 Equipment.

#### 2-3.1 Suction/Intake Hose.

**2-3.1.1\* Suction Hose and Strainer from Draft.** When testing a pump at elevations up to 2000 ft (610 m), 20 ft (6.1 m) of suction hose of the appropriate size for the rated capacity of the pump as shown in Table 2-3.1.1(a) shall be used. A suction strainer and hose that will allow flow with total friction and entrance loss not greater than that specified in Table 2-3.1.1(b) shall be used.

**Table 2-3.1.1(a) Rated Capacities and Maximum Suction Hose Size, Number of Suction Lines, and Lift for Fire Pump**

Rated Capacity		Suction Hose Size		Number of Suction Lines	Maximum Lift	
(gpm)	(L/min)	(in.)	(mm)		(ft)	(m)
250	(950)	3	(76)	1	10	(3)
300	(1136)	3	(76)	1	10	(3)
350	(1325)	4	(100)	1	10	(3)
450	(1700)	4	(100)	1	10	(3)
500	(1900)	4	(100)	1	10	(3)
600	(2270)	4	(100)	1	10	(3)
700	(2650)	4	(100)	1	10	(3)
750	(2850)	4 <sup>1/2</sup>	(113)	1	10	(3)
1000	(3785)	5	(125)	1	10	(3)
1250	(4732)	6	(150)	1	10	(3)
1500	(5678)	6	(150)	2	10	(3)
1750	(6624)	6	(150)	2	8	(2.4)
2000	(7570)	6	(150)	2	6	(1.8)
2250	(8516)	8	(200)	3	6	(1.8)
2500	(9463)	8	(200)	3	6	(1.8)
2750	(10,410)	8	(200)	4	6	(1.8)
3000	(11,356)	8	(200)	4	6	(1.8)

**2-3.1.2 Intake Hose from Hydrant.** When testing a pump, the intake hose shall be of a convenient length that will permit the necessary amount of water to reach the pump with a minimum intake gauge pressure of 20 psi (138 kPa). Only the strainer at the pump intake connection is required.

**2-3.2\* Discharge Hose.** Sufficient fire hose shall be provided to allow discharge of rated capacity to the nozzles or other flow-measuring equipment without exceeding a flow velocity of 35 ft per sec (10.7 m/sec) (approximately 500 gpm for 2<sup>1/2</sup>-in. hose). To ascertain if the hose and coupling are starting to separate, the hose shall be scribed with a mark immediately behind each coupling. If the hose separates from the coupling more than <sup>3</sup>/<sub>8</sub> in. (0.95 mm), the test shall be stopped and that section of hose shall be replaced.

### 2-3.3 Flow-Measuring Equipment.

#### 2-3.3.1\* Nozzles.

**2-3.3.1.1** Where nozzles are used for flow measurements, they shall be smoothbore and of a size sufficient for the anticipated flows. Pitot tubes shall be used to measure the flow. (See Appendix B, Tables B-3.1(a), (b), (c), and (d), for information on determination of flow rates with nozzles.)

**2-3.3.1.2** When nozzles are used, a monitor or other device to mount the nozzle shall be used.

**2-3.3.2 Other Flow-Measuring Equipment.** Other equipment—such as flow meters, volumetric tanks, or weigh tanks—shall be permitted to be used for measuring the flow if approved by the authority having jurisdiction. Any flow-measuring equipment that is used shall be capable of measuring the volume to within a ±5 percent accuracy.

#### 2-3.4 Pressure-Measuring Equipment.

**2-3.4.1\*** All test gauges shall meet the requirements for Grade A gauges as defined in ASME B40.1, *Gauges — Pressure Indicating Dial Type — Elastic Element*.

Table 2-3.1.1(b) Friction and Entrance Loss in 20 ft (6 m) of Suction Hose, Including Strainer

Flow Rate (gpm)	Suction Hose Size (inside diameter)									
	3 in.		3 1/2 in.		4 in.		4 1/2 in.		5 in.	
	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg
250	5.2 (1.2)	4.6								
175	2.6 (0.6)	2.3								
125	1.4 (0.3)	1.2								
300	7.5 (1.7)	6.6	3.5 (0.8)	3.1						
210	3.8 (0.8)	3.4	1.8 (0.4)	1.6						
150	1.9 (0.4)	1.7	0.9 (0.2)	0.8						
350			4.8 (1.1)	4.2	2.5 (0.7)	2.1				
245			2.4 (0.5)	2.1	1.2 (0.3)	1.1				
175			1.2 (0.3)	1.1	0.7 (0.1)	0.6				
450					4.1 (1.0)	3.6	2.7 (0.4)	2.6		
315					2.0 (0.5)	1.8	1.2 (0.2)	1.1		
225					1.0 (0.2)	0.9	0.6 (0.1)	0.5		
500					5.0 (1.3)	4.4	3.6 (0.8)	3.2		
350					2.5 (0.7)	2.1	1.8 (0.4)	1.6		
250					1.3 (0.4)	1.1	0.9 (0.3)	0.8		
600					7.2 (1.8)	6.4	5.3 (1.0)	4.7	3.1(0.6)	2.7
420					3.5 (1.0)	3.1	2.5 (0.5)	2.2	1.6(0.3)	1.4
300					1.8 (0.4)	1.6	1.3 (0.2)	1.0	0.6(0.1)	0.5
700					9.7 (2.7)	8.6	7.3 (1.3)	6.4	4.3(0.8)	3.8
490					4.9 (1.1)	4.3	3.5 (0.7)	3.1	2.0(0.4)	1.8
350					2.5 (0.7)	2.2	1.6 (0.3)	1.4	0.9(0.2)	0.8

Flow Rate (gpm)	Suction Hose Size (inside diameter)											
	4 in.		4 1/2 in.		5 in.		6 in.		Two 4 1/2 in.		Two 5 in.	
	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg
750	11.4 (2.9)	9.8	8.0 (1.6)	7.1	4.7 (0.9)	4.2	1.9 (0.4)	1.7				
525	5.5 (1.5)	4.9	3.9 (0.8)	3.4	2.3 (0.5)	2.0	0.9 (0.2)	0.8				
375	2.8 (0.7)	2.5	2.0 (0.4)	1.8	1.2 (0.2)	1.1	0.5 (0.1)	0.5				
1000			14.5 (2.8)	12.5	8.4 (1.6)	7.4	3.4 (0.6)	3.0				
700			7.0 (1.4)	6.2	4.1 (0.8)	3.7	1.7 (0.3)	1.5				
500			3.6 (0.8)	3.2	2.1 (0.4)	1.9	0.9 (0.2)	0.8				
1250					13.0 (2.4)	11.5	5.2 (0.9)	4.7	5.5 (1.2)	4.9		
875					6.5 (1.2)	5.7	2.6 (0.5)	2.3	2.8 (0.7)	2.5		
625					3.3 (0.7)	2.9	1.3 (0.3)	1.1	1.4 (0.3)	1.2		
1500							7.6 (1.4)	6.7	8.0 (1.6)	7.1	4.7 (0.9)	4.2
1050							3.7 (0.7)	3.3	3.9 (0.8)	3.4	2.3 (0.5)	2.0
750							1.9 (0.4)	1.7	2.0 (0.4)	1.8	1.2 (0.2)	1.1
1750							10.4 (1.8)	9.3	11.0 (2.2)	9.7	6.5 (1.2)	5.7
1225							5.0 (0.9)	4.6	5.3 (1.1)	4.7	3.1 (0.7)	2.7
875							2.6 (0.5)	2.3	2.8 (0.6)	2.5	1.6 (0.3)	1.4
2000									14.5 (2.8)	12.5	8.4 (1.6)	7.4
1400									7.0 (1.4)	6.2	4.1 (0.8)	3.7
1000									3.6 (0.8)	3.2	2.1 (0.4)	1.9
2250											10.8 (2.2)	9.5
1575											5.3 (1.1)	4.7
1125											2.8 (0.5)	2.5
2500											13.0 (2.4)	11.5
1750											6.5 (1.2)	5.7
1250											3.3 (0.7)	2.9

Table 2-3.1.1(b) Friction and Entrance Loss in 20 ft (6 m) of Suction Hose, Including Strainer (continued)

Flow Rate (gpm)	Suction Hose Size (inside diameter)									
	Two 6 in.		Three 6 in.		Four 6 in.		8 in.		Two 8 in.	
	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg	ft water*	in. Hg
1500	1.9 (0.4)	1.7								
1050	0.9 (0.3)	0.8								
750	0.5 (0.1)	0.5								
1750	2.6 (0.5)	2.3								
1225	1.2 (0.3)	1.1								
875	0.7 (0.2)	0.6								
2000	3.4 (0.6)	3.0								
1400	1.7 (0.3)	1.5								
1000	0.9 (0.2)	0.8								
2250	4.3 (0.8)	3.8								
1575	2.2 (0.4)	1.9								
1125	1.1 (0.2)	1.0								
2500	5.2 (0.9)	4.7								
1750	2.6 (0.5)	2.3								
1250	1.3 (0.3)	1.1								
3000	7.6 (1.4)	6.9	3.4 (0.6)	3.0			8.5 (1.6)	7.5		
2100	3.7 (0.7)	3.4	1.7 (0.3)	1.5			4 (0.8)	3.5		
1500	1.9 (0.4)	1.7	0.9 (0.2)	0.8			1.9 (0.4)	1.7		

\*Figures in parentheses indicate increment to be added or subtracted for each 10 ft (3 m) of hose less than or greater than 20 ft (6 m).

**2-3.4.2** The pump intake gauge shall be at least a size 3<sup>1</sup>/<sub>2</sub> per ASME B40.1, paragraph 3.1, and shall have a range of 30 in. Hg (100 kPa) vacuum to zero for a vacuum gauge, or 30 in. Hg (100 kPa) vacuum to 150 psi (1035 kPa) for a compound gauge. A mercury manometer shall be permitted to be used in lieu of a pump intake gauge if the tests are being conducted from draft.

**2-3.4.3** The discharge pressure gauge shall be at least a size 3<sup>1</sup>/<sub>2</sub> per ASME B40.1, paragraph 3.1, and shall have a range of 0 psi to 400 psi (0 kPa to 2758 kPa).

**2-3.4.4** Pitot gauges shall be at least a size 2<sup>1</sup>/<sub>2</sub> per ASME B40.1, paragraph 3.1, and shall have a range of at least 0 psi to 160 psi (0 kPa to 1103 kPa).

**2-3.4.5** All gauges shall have been calibrated in the month preceding the tests. Calibrating equipment shall consist of a dead-weight gauge tester or a master gauge meeting the requirements for Grade 3A or 4A gauges, as defined in ASME B40.1, that has been calibrated by its manufacturer within the preceding year.

**2-3.4.6** All gauge connections to the pump shall include "snubbing" means, such as a needle valve, that can be used to damp out rapid gauge needle movements unless the gauges are liquid-filled.

**2-3.5** Speed-measuring equipment shall consist of either a tachometer, measuring revolutions per minute, or a revolution counter and stopwatch which are used on a checking shaft outlet. Such speed-measuring means shall be accurate to within ±50 rpm of actual speed.

## Chapter 3 Service Tests

**3-1\* Frequency.** Service tests shall be conducted at least annually and whenever major repairs or modifications to the

pump or any component of the apparatus that is used in pump operations have been made.

### 3-2\* Conditions for Test.

**3-2.1** Service tests shall be conducted at a site meeting the conditions outlined in Section 2-1 and at a time when the environmental conditions are as defined in Section 2-2. If it is impractical to provide all specified conditions, the authority having jurisdiction shall be permitted to authorize tests under other conditions.

**3-2.2\*** Engine-driven accessories shall not be functionally disconnected or otherwise rendered inoperative during the tests. If the chassis engine drives the pump, all headlights, running lights, warning lights, and air conditioner(s), if provided, shall be operating during the pumping portion of this test. If they are connected through an electric load management system, that system shall be permitted to automatically disconnect the lights or other equipment during the course of the test.

**3-2.3** Where tests are performed inside a structure or anywhere having limited air circulation, carbon-monoxide-monitoring equipment shall be used. Such equipment shall be checked and calibrated regularly and shall include a suitable warning device.

### 3-3 Procedure.

**3-3.1\*** The ambient air temperature, water temperature, vertical lift, elevation of test site, and atmospheric pressure (corrected to sea level) shall be determined and recorded prior to the pump test. Any significant changes in these conditions during the test should be noted on the test record.

**3-3.2 Engine Speed Check.** A check of the no-load governed engine speed shall be made. If the engine speed does not equal the no-load governed engine speed at the time the apparatus was new, the reason for the discrepancy shall be determined and corrected prior to starting any testing.

**3-3.3 Vacuum Test.** A vacuum test shall be conducted on the pump.

**3-3.3.1** With all intake valves open, all intakes capped, and all discharge valves closed and uncapped, a vacuum of at least 22 in. Hg (74.5 kPa) shall be developed using the pump's priming device. The maximum vacuum attained shall be permitted to be reduced by 1 in. Hg (3.4 kPa) for each 1000 ft (305 m) of elevation of the test site above 1000 ft (305 m).

**3-3.3.2** The vacuum shall not drop more than 10 in. Hg (33.9 kPa) in 5 minutes. The pump priming device shall not be operated once the 5-min test has begun.

### 3-3.4 Pumping Test.

**3-3.4.1\*** The pump shall be subjected to a pumping test of at least 40-min duration, consisting of at least 20 minutes of pumping 100 percent of rated capacity at 150 psi (1035 kPa) net pump pressure, at least 10 minutes of pumping 70 percent of rated capacity at 200 psi (1380 kPa) net pump pressure, and at least 10 minutes of pumping 50 percent of rated capacity at 250 psi (1725 kPa) net pump pressure. The pump shall not be throttled down except when discharges are closed to permit changing the hose or a nozzle, or to change the position of a transfer valve.

**3-3.4.2\*** If the pump is a two-stage, parallel/series-type pump, the test at 100 percent of capacity shall be run with the pump in parallel mode, the test at 70 percent of capacity shall be permitted to be run with the pump in either series or parallel mode, and the 50 percent of capacity test shall be run with the pump in series mode.

**3-3.5\* Pressure Control Test.** The pressure control device on the pump shall be tested in three steps as follows:

(a) The pump shall be delivering rated capacity at 150 psi (1035 kPa) net pump pressure. The pressure control device shall be set in accordance with the manufacturer's instructions to maintain the discharge at 150 psi (1035 kPa) net pump pressure. All discharge valves shall be closed no more rapidly than in 3 seconds and no more slowly than in 10 seconds. The rise in discharge pressure shall not exceed 30 psi (207 kPa).

(b) The original conditions of pumping rated capacity at 150 psi (1035 kPa) net pump pressure shall be reestablished. The discharge pressure shall be reduced to 90 psi (620 kPa) net by throttling the engine fuel supply with no change to the discharge valve setting, hose, or nozzles. The pressure control device shall be set in accordance with the manufacturer's instructions to maintain the discharge at 90 psi (620 kPa) net pump pressure. All discharge valves shall be closed no more rapidly than in 3 seconds and no more slowly than in 10 seconds. The rise in discharge pressure shall not exceed 30 psi (207 kPa).

(c) The pump shall be delivering 50 percent of rated capacity at 250 psi (1725 kPa) net pump pressure. The pressure control device shall be set in accordance with the manufacturer's instructions to maintain the discharge at 250 psi (1725 kPa) net pump pressure. All discharge valves shall be closed no more rapidly than in 3 seconds and no more slowly than in 10 seconds. The rise in discharge pressure shall not exceed 30 psi (207 kPa).

**3-3.6\* Gauge and Flow Meter Test.** Each water pressure gauge or flow meter shall be checked for accuracy. Pressure gauges shall be checked at a minimum of 3 points including 150 psi (1035 kPa), 200 psi (1380 kPa), and 250 psi (1725 kPa). Any gauge that is off by more than 10 psi (69 kPa) shall be recalibrated, repaired, or replaced. Flow meters shall be

tested at the test flows shown in Table 3-3.6. Any flow meter that is off by more than 10 percent shall be recalibrated, repaired, or replaced.

**Table 3-3.6 Flow-Measuring Points for Flow Meters**

Pipe Size		Test Flow	
(in.)	(mm)	(gpm)	(L/min)
1 <sup>1</sup> / <sub>2</sub>	(38)	128	(454)
2	(51)	180	(682)
2 <sup>1</sup> / <sub>2</sub>	(65)	300	(1135)
3	(76)	700	(2650)
4	(100)	1000	(3785)

**3-3.7 Tank-to-Pump Flow Rate.** If the apparatus is equipped with a water tank, the tank-to-pump flow rate also shall be checked using the following procedure:

- The water tank shall be filled until it overflows.
- All intakes to the pump shall be closed.
- The tank fill line and bypass cooling line shall be closed.
- Hose lines and nozzles that are suitable for discharging water at the anticipated flow rate shall be connected to one or more of the discharge outlets.
- The tank to the pump valve(s) and the discharge valves leading to the hose lines and nozzles shall be fully opened.
- The engine throttle shall be adjusted until the maximum consistent pressure reading on the discharge pressure gauge is obtained.
- The discharge valve(s) shall be closed and the water tank refilled. The bypass line shall be permitted to be opened temporarily if needed to keep the water temperature in the pump within acceptable limits.
- The discharge valves shall be reopened fully and a pitot reading or other flow measurement shall be taken while the water is being discharged. If necessary, the engine throttle shall be adjusted to maintain the discharge pressure noted in (f).
- The flow rate shall be compared with the rate designated by the manufacturer when the apparatus was new or with the rate established in previous testing. Rates less than the rate when the apparatus was new or as established in previous testing indicate problems in the tank-to-pump line or tank pump.

**3-3.8 Other Tests.** Other tests shall be conducted at the discretion of the authority having jurisdiction.

### 3-4\* Test Results.

**3-4.1\*** The pumping system (i.e., engine, pump, transmission) shall exhibit no undue heating, loss of power, or other defect during the entire test. The average flow rate, discharge pressure, intake pressure, and engine speed shall be calculated and recorded at the end of each phase of the pumping test and the records shall be placed on file.

**3-4.2** Results of other tests shall be satisfactory to the authority having jurisdiction and shall be recorded and placed on file.

**3-4.3** When any of these pump test results fall below 90 percent of the original test and rating of the pump, the pump system shall either be derated to a lower capacity or the apparatus shall be taken out of service and the cause(s) for the deficiency(ies) corrected.

**3-4.4** Data that is submitted at the time of the delivery test and all results of service tests shall be maintained in a permanent file so that the condition of the pump can be compared over years of operation.

## Chapter 4 Referenced Publications

**4-1** The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix D.

**4-1.1 NFPA Publication.** National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 1901, *Standard for Automotive Fire Apparatus*, 1996 edition.

**4-1.2 ASME Publication.** American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME B40.1, *Gauges — Pressure Indicating Dial Type — Elastic Element*, 1991.

## Appendix A Explanatory Material

*This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.*

**A-1-3** Investigation has shown that where regular and systematic tests of pumps are not made, defects often exist and can continue undetected for considerable periods under the light demands at ordinary fires; these defects only become apparent at a large fire where the pump is called on to perform at or near rated capacity. Furthermore, regular tests are valuable training for pump operators. The breakdown of a pump at a fire or the inability of the crew to operate it properly can cause loss of life and property.

Environmental concerns and other considerations or circumstances, such as water shortages, should not relieve a fire department from the requirements set forth herein. Where such circumstances make complying difficult, alternative means for complying should be found (i.e., drafting pits, etc.).

**A-1-4 Approved.** The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

**A-1-4 Authority Having Jurisdiction.** 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.

**A-1-4 Listed.** The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations 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.

**A-1-4 Net Pump Pressure.** When operating from a hydrant, the net pump pressure typically is less than the discharge pressure. For example, if the discharge pressure gauge reads 150 psi (1034 kPa) and the intake (suction) gauge reads 20 psi (138 kPa), the net pump pressure equals 130 psi (896 kPa). When operating from draft, the net pump pressure will be above the discharge pressure. For example, if the discharge pressure gauge reads 145 psi (1000 kPa) and the intake (suction) gauge reads 10 in. of mercury (Hg) (34 kPa) vacuum, the net pump pressure will be 150 psi (1034 kPa) (1 in. Hg = 0.5 psi = 3.38 kPa).

**A-2-1.1** It is preferable to test apparatus at draft. It is important that a proper site be selected for the testing.

The site should, if possible, be located along an improved roadway or on solid ground where the water is from 4 ft to 8 ft (1.2 m to 2.4 m) below the grade. It should be possible to reach the water from the pump intake with not more than 20 ft (6 m) of hard suction hose with the strainer submerged at least 2 ft (0.6 m) and with no humps in the hose. The water should be at least 4 ft (1.2 m) deep where the strainer is located to provide clearance below the strainer and sufficient depth above it. If drafting from shallow water is necessary, a special basket or container should be used to prevent particles from the stream bed being drawn into the hose. Clean, fresh water is desirable, but where salt water is drafted, the pump, piping, fittings, and pressure-regulating governors should be thoroughly flushed out after testing.

The apparatus should be parked as close as possible to the water's edge. It is usually more convenient to have the pump-control panel-side away from the water. Front or rear intakes should be avoided as the piping between the pump and inlet is usually more restrictive than the side intakes.

The size of the suction hose to be used will depend on the altitude and the lift as well as the rated capacity of the pump to be tested. Chafing pads should be provided to prevent injury to the suction hose when the hose is in contact with sharp edges of docks, manholes, walls, and rocks.

**A-2-1.2** Testing the pump at draft is preferable to testing from a hydrant. The true performance of the pump is easier to evaluate while pumping from draft. If no suitable drafting site is available, testing the pump from a hydrant is acceptable. Care must be taken to ensure the discharge gauge readings reflect the pressure necessary for the pump to be performing at the needed net pump pressure. For example, if the intake pressure gauge reads 30-psi and the test requires a 150-psi net pump pressure, the discharge test gauge should read 180 psi.

**A-2-2** If conditions are not within the specified limits, the test should be delayed until they are satisfactory; otherwise, the results will need to be confirmed by another test at a later date. It is particularly important that the water supply be nonaerated and not over 90°F (32°C). If this criteria is not met, the pump performance could be affected seriously.

**A-2-3.1.1** Table 2-3.1.1(a) shows the suction hose size and number of suction lines to be used for testing at elevations up to 2000 ft (610 m). For elevations greater than 2000 ft, suction hose size and quantity might have to be increased to maintain the desired pump performance.

**A-2-3.2** Table A-2-3.2 shows suggested hose and nozzle layouts using 2<sup>1</sup>/<sub>2</sub>-in. (65-mm) hose. Where two or more lines are indicated for use with one nozzle, they are to be siamesed into a heavy-stream appliance. The purpose of the hose is to convey water from the discharge side of the pump to the nozzle, monitor, or flow-measuring device where the volume will be measured and the water will be discharged to atmosphere. Single or multiple, larger diameter hose lines can be used for this purpose as well. The length and size of the hose are not factors unless the length and size together create excessive friction loss that requires the pump to operate above the net pump pressure that is required for the test to achieve the rated flow. If relatively short lengths of hose are used, total friction loss that is necessary to reduce the pump discharge pressure to the required nozzle pressure can be increased by partially closing the discharge valves on the apparatus.

For the protection of the operator, hose lines should not be connected to the pump at the operator's position. The hose that is used should be "attack hose" as defined by NFPA 1961, *Standard on Fire Hose*, and should have been recently tested in accordance with NFPA 1962, *Standard for the Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles*.

**Table A-2-3.2 Hose and Nozzle Layout Suggestions**

Discharge (gpm)	Hose and Nozzle Layout
2500	Three 100-ft lines into 2 <sup>1</sup> / <sub>4</sub> -in. nozzle, in duplicate.
2250	Three 100-ft lines into 2 <sup>1</sup> / <sub>4</sub> -in. nozzle, in duplicate.
2000	Two 100-ft lines into 2-in. nozzle, in duplicate.
1750	Two 100-ft lines into 2-in. nozzle, in duplicate.
1500	Three 100-ft lines into 2-in. nozzle, and one 50-ft line into 1 <sup>3</sup> / <sub>8</sub> -in. or 1 <sup>1</sup> / <sub>2</sub> -in. nozzle.
1250	Three 100-ft lines and one 50-ft line into 2 <sup>1</sup> / <sub>4</sub> -in. nozzle, or two 100-ft lines into 1 <sup>3</sup> / <sub>4</sub> -in. nozzle and one 50-ft line into 1 <sup>1</sup> / <sub>2</sub> -in. nozzle.
1000	Two or three 100-ft lines into 2-in. nozzle.
600-750	Two 100-ft lines into 1 <sup>1</sup> / <sub>2</sub> -in. or 1 <sup>3</sup> / <sub>4</sub> -in. nozzle.
400-500	One 50-ft line into 1 <sup>3</sup> / <sub>8</sub> -in. or 1 <sup>1</sup> / <sub>2</sub> -in. nozzle.
250-350	One 50-ft line into 1 <sup>1</sup> / <sub>8</sub> -in. or 1 <sup>1</sup> / <sub>4</sub> -in. nozzle.

**A-2-3.3.1** Nozzles that are suitable for testing usually can be found in the regular equipment of a fire department. However, the actual coefficient of discharge of each nozzle should be known; otherwise, test results could be erroneous. The actual coefficient of discharge must be determined by tests conducted by competent persons who are using equipment such as weigh tanks or calibrated flow meters. Nozzles should be used with portable or mounted monitors. Hand-held nozzles should not be used.

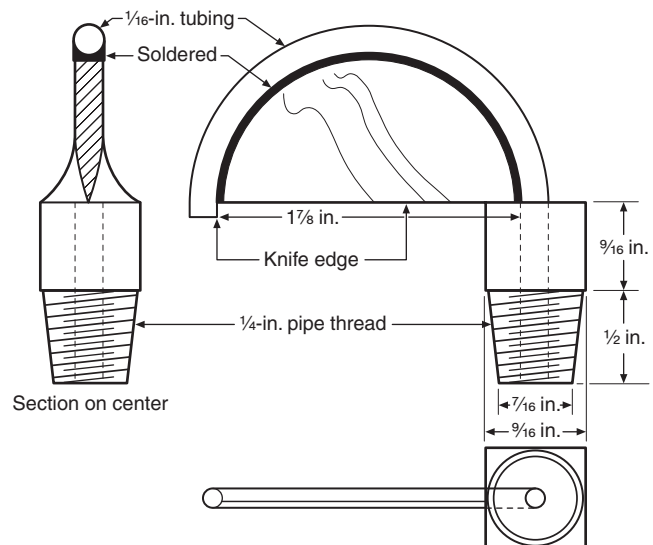
The size of the nozzle that is used usually is chosen to give the desired discharge at a nozzle pressure between 60 psi and 70 psi (414 kPa and 483 kPa). This pressure is neither so high

that the pitot is difficult to handle in the stream nor so low that the normal inaccuracies of a gauge that is used at low pressure would come into play. Nozzle (pitot) pressures less than 50 psi (345 kPa) or higher than 100 psi (690 kPa) should be avoided. The nozzle should always be used in conjunction with a securely placed monitor; a test should never be conducted while any person holds the nozzle. Failure to abide by this precaution can cause serious injuries.

Only smoothbore nozzles should be used. Care should be taken that washers or gaskets do not protrude into the nozzle because a perfectly smooth waterway is essential. Nozzle tips from <sup>3</sup>/<sub>4</sub>-in. (19-mm) to 2<sup>1</sup>/<sub>4</sub>-in. (57-mm) inside diameter are desirable for use during various capacity and pressure tests. They should be free of nicks and scratches to ensure a smooth stream. Tips should be measured, preferably after being attached and made ready for the test, to ensure that there is no mistake about the size of the tip being used.

A pitot tube with air chamber and pressure gauge is necessary for determining the velocity pressure of the water at the nozzle. The pitot tube can be of several suitable types; the type shown in Figure A-2-3.3.1(a) can be readily constructed of brass and should be finished smooth. It should be connected by brass or other nonferrous metal pipe fittings to an air chamber and pressure gauge as shown in Figure A-2-3.3.1(b). A typical commercially available style is shown in Figure A-2-3.3.1(c). The pitot tube should be kept free of dirt and the air chamber free of water. Any water that accumulates in the air chamber should be removed after each test. The knife edges, indicated in Figure A-2-3.3.1(a), will get battered in service and must be kept sharp to reduce as much spray as possible caused by inserting the pitot into the stream.

To ensure accurate and consistent readings, pitot tubes should be fixed in the proper position. The proper position is in the center of the stream with the end of the tube away from the end of the nozzle by a distance that is equal to half of the nozzle diameter. A mechanical device might be desirable to hold the pitot tube rather than holding it by hand [see Figure A-2-3.3.1(d)].



**Figure A-2-3.3.1(a) Nozzle stream pitot tube.**

**A-2-3.4.1** It is important that gauges be sufficiently accurate to ensure that test results are reliable. Grade A gauges per ASME B40.1 *Gauges — Pressure Indicating Dial Type — Elastic Element*, must be accurate within 2 percent of the span over the entire scale and within 1 percent over the middle half of the scale.

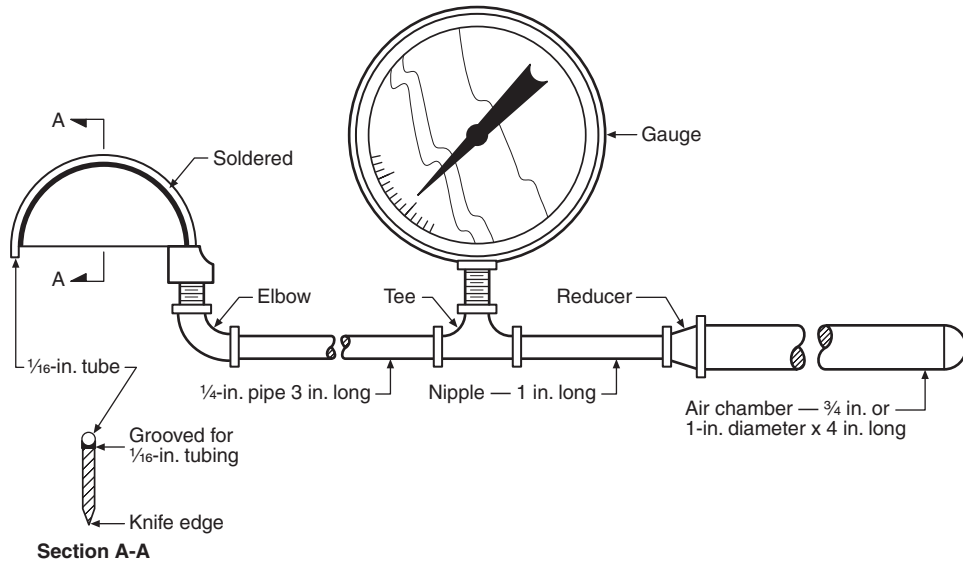


Figure A-2-3.3.1(b) Pitot tube assembly.

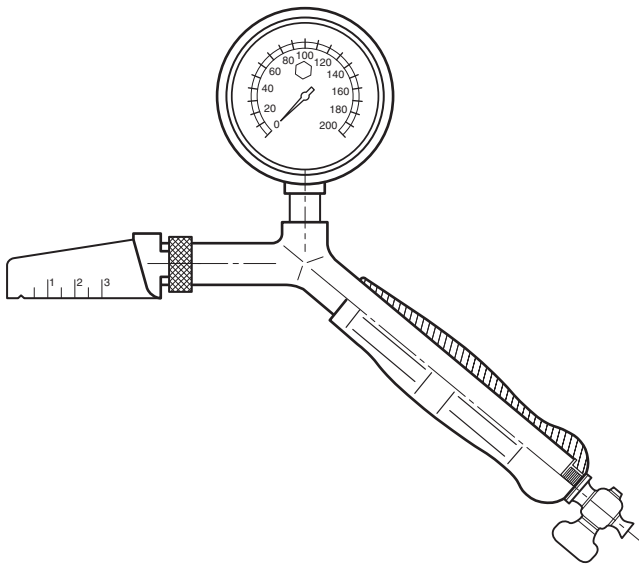


Figure A-2-3.3.1(c) Commercial pitot tube.

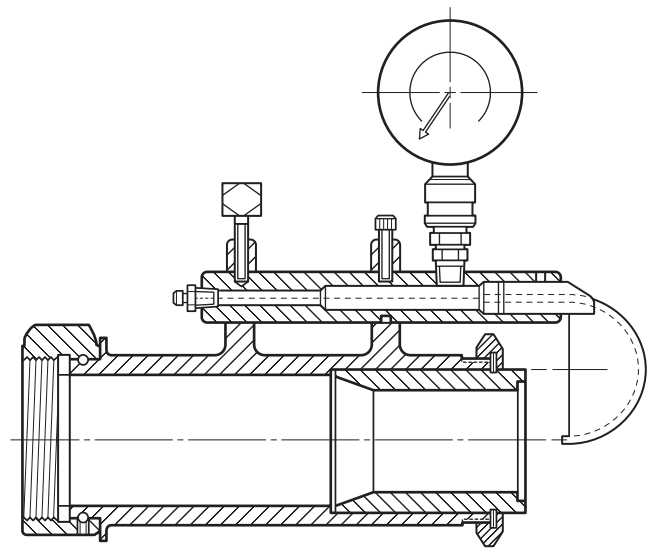


Figure A-2-3.3.1(d) Pitot tube attached to nozzle.

This means that a 0–400-psi (0–2750-kPa) gauge will be accurate within 4 psi (28 kPa) from 100 psi to 300 psi (690 kPa to 2070 kPa). Grade 3A or 4A gauges, which are used for calibrating other gauges, must be accurate within 0.25 percent or 0.10 percent, respectively, over the entire span.

While a 0–400-psi (0–2750-kPa) range is not preferred per ASME B40.1, such gauges are readily available. Graduation increments should be no greater than twice the allowable error in the middle of the scale [8 psi maximum on a 0–400-psi Grade A gauge (28 kPa maximum on a 0–2750-kPa Grade A gauge)], and smaller increments are recommended. Many variations and special constructions are available, and gauge manufacturers can be contacted for their recommendations.

**A-3-1** Major repair does not necessarily refer to the length of time that a repair takes but rather whether or not a repair affects a major component of the pump assembly so as to require assurance after the repair that the pump is still operating properly.

**A-3-2** It is recommended that the fire department duplicate the test conditions to the extent possible from year to year to allow more accurate comparison of data over a period of time. These conditions should include lift; atmospheric pressure; air and water temperature; suction hose size, length, and style; strainer type; and intake and discharge hose layout.

**A-3-2.2** The engine compartment should remain closed during the pumping test unless the apparatus was designed to an older standard which allowed testing with the compartment open.

**A-3-3.1** Other data that should be obtained are indicated on the test form. The layout of the hose and nozzle and data about the pump and engine should be recorded.

**A-3-3.4.1** The test should not be started officially until the pump pressure and the discharge quantity are satisfactory. Readings should be taken to determine the apparatus' performance with sufficient frequency to obtain a good average. A complete set of readings should be taken a minimum of four times during the 20-min test for 100 percent rated capacity and a minimum of three times during each of the 10-min tests for 70 percent capacity and 50 percent capacity. If any of the readings during a particular test vary by more than 5 percent, the reason for the fluctuation should be determined, the cause corrected, and the test repeated.

**A-3-3.4.2** If the pump is a two-stage, parallel/series-type unit, then operation of the transfer (i.e., change-over) valve should be checked thoroughly. Conducting the pumping test with the transfer valve positioned as specified in 3-3.4.2 will ensure that the valve is exercised. If a comparison with the original engine speeds shows a significant difference for any of the tests, one of the problems could be with the transfer valve.

**A-3-3.5** Closing all discharges in less than 3 seconds could cause instantaneous pressure rises that the pressure control device might not be able to respond to rapidly enough to avoid damage to the pumping system. Taking more than 10 seconds to close the discharges is not a reasonable test of the pressure control device response capability. Controlling closure of the discharges can be done manually or otherwise.

Care must be taken to perform the pressure control tests using net pump pressure and net pressure rise readings. Some pressure control systems might not operate correctly if the hydrant pressure is too high; the system manufacturer's manual should be consulted for information.

**A-3-3.6** Pressure gauges can be checked quickly against the test gauges for accuracy. Individual discharge lines with gauges should be capped and the discharge valve opened slightly. The test gauge, the master discharge gauge, and the discharge gauges should all read the same.

Flow meters need to be checked individually using a hose stream with a smoothbore tip and a pitot tube to measure the actual flow.

**A-3-4** Some test data forms for recording the test readings and other necessary data should be provided. Figure A-3-4 is an example of a suitable form. The use of such a form will help to ensure that all needed data are obtained.

**A-3-4.1** When a pump is operating at or near full engine power while stationary, the generated heat can raise the temperature of certain chassis and/or pumping system components above the level that can be touched without extreme discomfort or injury. However, as long as the apparatus can be operated and used satisfactorily for the required duration of the test under such conditions and the engine coolant temperature is within normal range, it should be considered acceptable.

Normal wear in the pumping system can require speeds greater than those required at the time of delivery for the pumping test. Such variances are acceptable as long as the apparatus passes the pumping test without exceeding the no-load governed engine speed.

#### Service Test Results

Apparatus number: \_\_\_\_\_

Manufacturer: \_\_\_\_\_ Year built: \_\_\_\_\_

Manufacturer's model: \_\_\_\_\_ Serial no: \_\_\_\_\_

Engine make: \_\_\_\_\_ Model: \_\_\_\_\_

Pump make: \_\_\_\_\_ Model: \_\_\_\_\_

Pump capacity: \_\_\_\_\_ gpm \_\_\_\_\_ psi \_\_\_\_\_

Suction hose size: \_\_\_\_\_ in. Length: \_\_\_\_\_ ft Lift: \_\_\_\_\_ ft

Speed check taken from: \_\_\_\_\_

Ratio to engine: \_\_\_\_\_

Test site location: \_\_\_\_\_

Tests performed from [  ] Draft [  ] Hydrant

Atmospheric pressure: \_\_\_\_\_ Air temperature: \_\_\_\_\_

Water temperature: \_\_\_\_\_ Elevation of test site: \_\_\_\_\_

No-load engine speed: \_\_\_\_\_ rpm

Primer system max vacuum: \_\_\_\_\_ in. Hg

Vacuum drop in 5 min: \_\_\_\_\_ in. Hg

Pressure control device test: Rise at capacity at 150 psi: \_\_\_\_\_

Capacity at 90 psi: \_\_\_\_\_ 50% Capacity at 250 psi: \_\_\_\_\_

Tank-to-pump water flow test: \_\_\_\_\_ gpm

Figure A-3-4 Service test results

**Capacity Test**

Layout: \_\_\_\_\_  
 Nozzle size: \_\_\_\_\_ Position of transfer valve: \_\_\_\_\_

Time	Counter	rpm	Tach	Pump Intake		Pump Discharge		Pitot
				Appar. Gauge	Test Gauge	Appar. Gauge	Test Gauge	

**200-psi Test**

Layout: \_\_\_\_\_  
 Nozzle size: \_\_\_\_\_ Position of transfer valve: \_\_\_\_\_

Time	Counter	rpm	Tach	Pump Intake		Pump Discharge		Pitot
				Appar. Gauge	Test Gauge	Appar. Gauge	Test Gauge	

**250-psi Test**

Layout: \_\_\_\_\_  
 Nozzle size: \_\_\_\_\_ Position of transfer valve: \_\_\_\_\_

Time	Counter	rpm	Tach	Pump Intake		Pump Discharge		Pitot
				Appar. Gauge	Test Gauge	Appar. Gauge	Test Gauge	

**Final Results**

	Capacity	200 psi	250 psi
Duration			
Average nozzle pressure			
Corrected pressure			
Gallons per minute			
Average pump pressure			
rpm-Engine			
rpm-Pump			

Remarks: \_\_\_\_\_  
 \_\_\_\_\_

Tested at: \_\_\_\_\_ Witnessed by: \_\_\_\_\_ Date: \_\_\_\_\_

Figure A-3-4 Service test results (continued)

## Appendix B Conducting Pumping Tests

### B-1 Test Parameters.

At the start of the test, attention should be paid to the ease with which the pump can develop a vacuum. Before starting to prime the pump, close all discharge, drain, and water tank valves and petcocks; make sure that the gaskets in the suction hose are in place and free of foreign matter; open all intake valves; and tighten all intake caps and couplings.

Start the priming mechanism, noting the starting time and the time after prime is obtained. The starting time is defined as the instant the priming device begins to operate. The pump is considered primed when water under pressure has entered a discharge hose. For pumps of less than 1500 gpm (5678 L/min), the priming device should be able to create the necessary vacuum in 30 seconds to lift water 10 ft (3 m) through 20 ft (6 m) of suction hose of the appropriate size. The priming device on pumps of 1500 gpm or larger should be able to accomplish this in 45 seconds. An additional 15 seconds might be needed where the pump system includes an auxiliary 4-in. (100-mm) or larger intake pipe having a volume of 1 ft<sup>3</sup> (28317 cm<sup>3</sup>) or more. Operate the controls as necessary to develop pressure, and then open one discharge valve to permit the flow of water.

In testing a pump there are three, interrelated, variable factors—pump speed, net pump pressure, and pump discharge rate—and a change in one factor will always produce a change in at least one of the others. For example, an increase in speed of the pump will increase the discharge, the pressure, or both. Adjustments of variables through changing the position of the engine throttle (which modifies pump speed), changing the hose layout or discharge valve positions (which modifies pump pressure), or changing the nozzle size (which modifies discharge) are the only ways to reach the desired standard test condition.

The pump should be operated at reduced capacity and pressure for several minutes to allow the engine and transmission to warm up. Gradually, the pump speed is increased until the desired pressure at the pump is reached. If the desired pressure is not attained, a length or two of hose might have to be added, a smaller nozzle used, or a discharge valve throttled. When the desired pressure is obtained at the pump, the pitot should be read to see if the required amount of water is being delivered.

If the discharge is not as great as desired and it is believed that the pump will deliver a greater quantity of water, the discharge can be increased by further speeding up the pump; but if speeding up the pump increases the pump pressure more than 5 psi or 10 psi (34 kPa or 68 kPa), a length of hose should be taken out, a discharge valve should be opened slightly, or a larger nozzle should be used.

A speed reading should be taken at frequent intervals, corresponding to the time that the pressure readings were taken. Counting the revolutions for one minute generally ensures that readings will be sufficiently accurate.

When using a stopwatch, the best and most accurate method is to leave the stopwatch running at all times, engaging the revolution counter at a chosen instant and disengaging when the hand of the stopwatch passes the same point on the dial one minute later.

After the engine has warmed up, there should be little change in the engine speed. It should be realized that any change in engine speed must, of necessity, produce a corresponding change in pump discharge pressure and hence in pitot reading, and that other things being equal, any change in pitot reading indicates a change in engine speed. A change in pump speed will also cause a change in discharge pressure so that whenever pump speed, discharge pressure, and pitot readings do not show

corresponding changes, it is safe to say that some reading is in error or some condition has arisen that affects the readings and needs correction. Engine speeds can be changed by working the hand throttle at the operator's position.

Automatic relief valves or pressure regulators controlling the speed of the pump should be disengaged during the test.

It is common but faulty practice to read a pressure gauge at the highest point in the swing of its needle; the center of the needle swing should always be read, as this is the average pressure. A needle valve ("snubber") in the line to the gauge can be throttled to prevent excessive vibration, but if the valve is throttled too much, the gauge pointer will no longer indicate the pressure correctly. It may not be possible to eliminate all of the pointer movement. Leaks in the line to the test gauge also can result in an incorrect gauge reading.

Special care should be taken in reading the pitot pressure; the pitot tube should be held in the center of the stream with the tip about half the nozzle diameter away from the end of the nozzle. If the pitot is brought closer to the nozzle, the reading will be increased erroneously.

Short lines of hose are always more convenient for a test layout than long ones. Generally, it is better to use a single line of 100 ft (30.5 m) for the pressure tests and to restrict the discharge at the pump discharge valve enough to increase the friction loss so that the desired discharge pressure will be obtained. By closely watching the pitot reading, the valve gradually can be closed as the engine speed is increased until the discharge pressure and pitot pressure readings are both as desired. Care should be taken to make sure that the valve does not jar either open or closed as, in either case, both the capacity and discharge pressure will be affected.

When operating a pump, it is important that the engine temperature be kept within the proper range; neither a cold engine nor an excessively hot engine will give as good service as one run at the proper temperature.

The oil pressure on the engine should be watched to see that the engine is being lubricated properly. The transmission gears should be watched for overheating. Any unusual vibration of the engine or the pump or any leak in the pump casing or connections should be noted and taken care of. Centrifugal pumps are not self-priming and could lose their prime if there is a leak in the suction line.

Other defects in the performance of the engine or the pump should be recorded. Minor defects should be corrected immediately if possible.

### B-2 Troubleshooting.

Most tests are conducted without incident. Nevertheless, trouble does develop during some tests, and an effort should be made to locate the source of trouble while the apparatus remains at the test site. Some difficulties that could be experienced, and suggestions on how to trace and correct them, are discussed in the following paragraphs.

Failure to prime a centrifugal pump is a frequent source of trouble, and the usual reason for the failure is an air leak in the suction hose or pump. One way to trace this trouble is to remove all discharge hose lines, cap all discharge openings and the suction hose, and operate the priming mechanism in accordance with the manufacturer's recommendations. Study the intake gauge to determine the maximum vacuum that is developed, which should be at least 22 in. (560 mm) of mercury at altitudes of less than 1000 ft (305 m). Stop the primer. If the vacuum drops 10 in. (254 mm) or more in less than 5 minutes, there is a leak in the suction hose or pump assembly; it could be in a valve, drain cock, piping, casing, or pump packing. The leakage might be located by listening for air movement. Another method is to connect the pump to a convenient hydrant, cap the pump dis-

charge outlets, open the hydrant, and watch for water leaks. A leak can usually be corrected at the test site.

Two possible causes for failure of the pump to deliver the desired capacity and/or pressure are insufficient power and restrictions in the intake arrangement. Insufficient power is indicated by the inability of the engine to reach the required speed for the desired pumping condition. Some possible causes of insufficient power are as follows: the operator might have failed to advance the throttle far enough or might be using the wrong transmission gear position; the engine might be in need of a tune-up; the grade of fuel might be improper for adequate combustion; or there might be vaporization in the fuel line.

Restriction in the intake arrangement is indicated if the pump speed is too high for the capacity and attained pressure levels and could be the result of any one or combination of the following conditions:

- (a) Suction hose is too small
- (b) Altitude is too high
- (c) Suction lift is too high
- (d) Strainer type is incorrect
- (e) Intake strainer is clogged at the pump or at the end of the suction hose
- (f) Water is aerated
- (g) Water is too warm [above 90°F (32°C)]
- (h) Suction hose is collapsed or defective
- (i) Foreign material is in pump

An air leak in the suction hose connections or in the pump intake manifold also will result in excessive pump speed and eventually could cause loss of prime and complete cessation of flow.

Insufficient pressure when operating a centrifugal pump could be the result of pumping too much water for the available power and, in multistage pumps, pumping in “volume” position instead of the required “pressure” position. This can be checked by partially closing off all discharge valves until only a small flow is observed and then opening the throttle until the desired pressure is reached, followed by slowly opening discharge valves and increasing engine speed as necessary to maintain pressure until the desired capacity is obtained. An improperly adjusted or inoperative transfer valve can prevent the development of adequate pressure. Likewise, the automatic pressure control might be set too low or be defective.

Engine speed differences from the original pump test could be the result of any one or combination of the following conditions:

- (a) Operating the apparatus with the wrong transmission gear in use
- (b) Stuck throttle control cable
- (c) Restrictions in the intake arrangement
- (d) Suction hose under an insufficient depth of water
- (e) Air leak on the intake side of the pump
- (f) Changes in environmental conditions
- (g) Pump or engine wear

A slip of the revolution counter or its fitting will show an apparently decreased speed, and frequent checks should be made with the apparatus tachometer to verify a change in speed. A clogged pitot tube will cause a drop in the gauge reading.

### B-3 Calculating the Results.

If nozzles and pitot tubes have been used to measure pump capacity, the values of capacity are determined by the following formula:

$$\text{gallons per minute} = 29.83 \, c(d)^2 \sqrt{p}$$

where:

$d$  = diameter of nozzle (in.)

$p$  = pressure of pitot gauge (psi)

$c$  = coefficient of discharge of the nozzle used

The pitot pressure should be the average of several readings and corrected for gauge error.

For nozzles sized from  $1/4$  in. (6.3 mm) to  $2 1/4$  in. (57 mm), values of capacity can be approximated from

Tables B-3.1(a), (b), (c), and (d); however, as these values are based on certain assumed coefficients of discharge, they can be considerably at variance with the actual values. For nozzles larger than  $2 1/4$  in. (57 mm), approximate values of capacity can be obtained from Table B-3.2.

### B-4 Lift.

The lift is the difference in elevation between the water level and the center of the pump intake when an apparatus is drafting water. The maximum lift is the greatest difference in elevation at which the apparatus can draft the required quantity of water under the established physical characteristics of operation; these include the following:

- (a) Design of the pump
- (b) Adequacy of the engine
- (c) Condition of pump and engine
- (d) Size and condition of suction hose and strainers
- (e) Elevation of the pumping site above sea level
- (f) Atmospheric pressure
- (g) Temperature of the water

The theoretical values of lift and maximum lift must be reduced by the entrance and friction losses in the suction hose equipment to obtain the actual or measurable lift.

The vacuum, or negative pressure, on the intake side of a pump is measured in inches of mercury, usually written as “in. Hg” or “in. Hg” (Hg is the chemical symbol for mercury). A vacuum of one in. of mercury is equal to a negative pressure of 0.49 lb per in.<sup>2</sup>; or 1 in. Hg = 0.49 psi. A positive pressure of 0.49 psi at the bottom of a 1-in.<sup>2</sup> container will support a column of water that is 1.13 ft high; therefore, a negative pressure of 0.49 psi at the top of the container will support the same column of water. This means 1 in. Hg = 0.49 psi = 1.13 ft of water head.

Table B-3.1(a) Discharge Table for Smooth Nozzles (nozzle pressure measured by pitot gauge)

Nozzle Pressure (psi)	gpm Nozzle Diameter (in.)*				Nozzle Pressure (psi)	gpm Nozzle Diameter (in.)*			
	1/4	5/16	3/8	7/16		1/4	5/16	3/8	7/16
5	4	6	9	13	60	14	22	31	43
6	4	6	10	14	62	14	22	32	44
7	4	7	11	15	64	14	22	32	45
8	5	7	11	16	66	14	23	33	46
9	5	8	12	17	68	14	23	33	46
10	6	9	13	18	70	15	24	34	47
12	6	10	15	19	72	15	24	34	48
14	7	11	15	21	74	15	24	35	48
16	7	12	16	22	76	15	24	35	49
18	7	12	17	24	78	15	24	36	50
20	8	13	18	25	80	16	25	36	50
22	8	13	19	26	82	16	25	37	51
24	8	13	20	27	84	16	25	37	51
26	9	14	21	29	86	16	26	37	52
28	9	14	21	30	88	16	26	38	53
30	10	15	22	31	90	17	27	39	53
32	10	15	23	32	92	17	27	39	54
34	11	16	23	33	94	17	27	39	54
36	11	16	24	34	96	17	27	40	55
38	11	17	25	35	98	17	27	40	55
40	11	18	26	35	100	18	28	41	56
42	11	18	26	36	105	18	29	42	57
44	12	18	27	37	110	19	29	43	59
46	12	19	28	38	115	19	30	43	60
48	12	19	28	39	120	19	31	44	61
50	13	20	29	40	125	20	31	45	63
52	13	20	29	40	130	20	32	46	64
54	13	20	30	41	135	21	33	47	65
56	13	21	30	42	140	21	33	48	66
58	13	21	31	43	145	21	34	49	68
60	14	22	31	43	150	22	34	50	69

\*Assumed coefficient of discharge = 0.983, 0.983, 0.985, 0.985

Table B-3.1(b) Discharge Table for Smooth Nozzles (nozzle pressure measured by pitot gauge)

Nozzle Pressure (psi)	gpm Nozzle Diameter (in.)*				Nozzle Pressure (psi)	gpm Nozzle Diameter (in.)*			
	1/2	5/8	3/4	7/8		1/2	5/8	3/4	7/8
5	16	26	37	50	60	57	89	130	174
6	18	28	41	55	62	58	90	132	177
7	19	30	44	59	64	59	92	134	180
8	21	32	47	64	66	60	93	136	182
9	22	34	50	67	68	60	95	138	185
10	23	36	53	71	70	61	96	140	188
12	25	40	58	78	72	62	97	142	191
14	27	43	63	84	74	63	99	144	193
16	29	46	67	90	76	64	100	146	196
18	31	49	71	95	78	65	101	148	198
20	33	51	75	101	80	66	103	150	201
22	34	54	79	105	82	66	104	152	204
24	36	56	82	110	84	67	105	154	206
26	37	59	85	115	86	68	107	155	208
28	39	61	89	119	88	69	108	157	211
30	40	63	92	123	90	70	109	159	213
32	41	65	95	127	92	70	110	161	215
34	43	67	98	131	94	71	111	162	218
36	44	69	100	135	96	72	113	164	220
38	45	71	103	138	98	73	114	166	223
40	46	73	106	142	100	73	115	168	225
42	47	74	109	146	105	75	118	172	230
44	49	76	111	149	110	77	121	176	236
46	50	78	114	152	115	79	123	180	241
48	51	80	116	156	120	80	126	183	246
50	52	81	118	159	125	82	129	187	251
52	53	83	121	162	130	84	131	191	256
54	54	84	123	165	135	85	134	195	262
56	55	86	125	168	140	87	136	198	266
58	56	87	128	171	145	88	139	202	271
60	57	89	130	174	150	90	141	205	275

\*Assumed coefficient of discharge = 0.985, 0.988, 0.988, 0.988

Table B-3.1(c) Discharge Table for Smooth Nozzles (nozzle pressure measured by pitot gauge)

Nozzle Pressure (psi)	gpm Nozzle Diameter (in.)*					Nozzle Pressure (psi)	gpm Nozzle Diameter (in.)*				
	1	1 1/8	1 1/4	1 3/8	1 1/2		1	1 1/8	1 1/4	1 3/8	1 1/2
5	66	84	103	125	149	60	229	290	357	434	517
6	72	92	113	137	163	62	233	295	363	441	525
7	78	99	122	148	176	64	237	299	369	448	533
8	84	106	131	158	188	66	240	304	375	455	542
9	89	112	139	168	200	68	244	308	381	462	550
10	93	118	146	177	211	70	247	313	386	469	558
12	102	130	160	194	231	72	251	318	391	475	566
14	110	140	173	210	249	74	254	322	397	482	574
16	118	150	185	224	267	76	258	326	402	488	582
18	125	159	196	237	283	78	261	330	407	494	589
20	132	167	206	250	298	80	264	335	413	500	596
22	139	175	216	263	313	82	268	339	418	507	604
24	145	183	226	275	327	84	271	343	423	513	611
26	151	191	235	286	340	86	274	347	428	519	618
28	157	198	244	297	353	88	277	351	433	525	626
30	162	205	253	307	365	90	280	355	438	531	633
32	167	212	261	317	377	92	283	359	443	537	640
34	172	218	269	327	389	94	286	363	447	543	647
36	177	224	277	336	400	96	289	367	452	549	654
38	182	231	285	345	411	98	292	370	456	554	660
40	187	237	292	354	422	100	295	374	461	560	667
42	192	243	299	363	432	105	303	383	473	574	683
44	196	248	306	372	442	110	310	392	484	588	699
46	200	254	313	380	452	115	317	401	495	600	715
48	205	259	320	388	462	120	324	410	505	613	730
50	209	265	326	396	472	125	331	418	516	626	745
52	213	270	333	404	481	130	337	427	526	638	760
54	217	275	339	412	490	135	343	435	536	650	775
56	221	280	345	419	499	140	350	443	546	662	789
58	225	285	351	426	508	145	356	450	556	674	803
60	229	290	357	434	517	150	362	458	565	686	817

\*Assumed coefficient of discharge = 0.99, 0.99, 0.99, 0.993, 0.995

Table B-3.1(d) Discharge Table for Smooth Nozzles (nozzle pressure measured by pitot gauge)

Nozzle Pressure (psi)	gpm Nozzle Diameter (in.)*					Nozzle Pressure (psi)	gpm Nozzle Diameter (in.)*				
	1 5/8	1 3/4	1 7/8	2	2 1/4		1 5/8	1 3/4	1 7/8	2	2 1/4
5	175	203	234	266	337	60	607	704	810	920	1167
6	192	223	256	292	369	62	617	716	823	936	1187
7	207	241	277	315	399	64	627	727	836	951	1206
8	222	257	296	336	427	66	636	738	850	965	1224
9	235	273	314	357	452	68	646	750	862	980	1242
10	248	288	330	376	477	70	655	761	875	994	1260
12	271	315	362	412	522	72	665	771	887	1008	1278
14	293	340	391	445	564	74	674	782	900	1023	1296
16	313	364	418	475	603	76	683	792	911	1036	1313
18	332	386	444	504	640	78	692	803	924	1050	1330
20	350	407	468	532	674	80	700	813	935	1063	1347
22	367	427	490	557	707	82	709	823	946	1076	1364
24	384	446	512	582	739	84	718	833	959	1089	1380
26	400	464	533	606	769	86	726	843	970	1102	1396
28	415	481	554	629	799	88	735	853	981	1115	1412
30	429	498	572	651	826	90	743	862	992	1128	1429
32	443	514	591	673	854	92	751	872	1002	1140	1445
34	457	530	610	693	880	94	759	881	1012	1152	1460
36	470	546	627	713	905	96	767	890	1022	1164	1476
38	483	561	645	733	930	98	775	900	1032	1176	1491
40	496	575	661	752	954	100	783	909	1043	1189	1506
42	508	589	678	770	978	105	803	932	1070	1218	1542
44	520	603	694	788	1000	110	822	954	1095	1247	1579
46	531	617	710	806	1021	115	840	975	1120	1275	1615
48	543	630	725	824	1043	120	858	996	1144	1303	1649
50	554	643	740	841	1065	125	876	1016	1168	1329	1683
52	565	656	754	857	1087	130	893	1036	1191	1356	1717
54	576	668	769	873	1108	135	910	1056	1213	1382	1750
56	586	680	782	889	1129	140	927	1076	1235	1407	1780
58	596	692	796	905	1149	145	944	1095	1257	1432	1812
60	607	704	810	920	1168	150	960	1114	1279	1456	1843

\*Assumed coefficient of discharge = 0.995, 0.995, 0.996, 0.997, 0.997

Table B-3.2 Nozzle Factors

Diameter of the Nozzle Q (in.)	Factors (F)	
	Fresh Water	Salt (sea) Water
2	119	117
2 1/4	150	148
2 1/2	186	183
2 3/4	225	222
3	267	264
3 1/4	314	310
3 1/2	364	359
3 3/4	418	413
4	476	470
4 1/4	537	530
4 1/2	602	594
4 3/4	671	662
5	743	734
6	1070	1057

Capacity in gallons per minute is determined by the following formula:

$$gpm = (F)\sqrt{p}$$

where:

F = factor from the table

p = pressure at pitot gauge (psi)

**B-5 Effect of Altitude.**

When drafting water, the pump produces a partial vacuum in the suction hose, and the atmospheric pressure on the surface of the water forces water into the suction hose and the pump. As the elevation above sea level of the pumping site increases, the atmospheric pressure decreases. The loss of lift at various elevations is given in Table B-5.

The data in Table B-5 assume that the engine of the apparatus is adequate at all elevations. However, the available power for driving a pump from naturally aspirated gasoline engines decreases about 4 percent (up to 3 percent for diesel engines that are naturally aspirated) for each 1000 ft (305 m) of elevation. Therefore, a gasoline engine that was just adequate at sea

level would be about 35 percent deficient at a 7000-ft (2135-m) altitude.

A difference in atmospheric pressure due to weather conditions will have the same result as a change in altitude. The difference in atmospheric pressure due to operation on a rainy day instead of a cool, clear day could easily mean a 1-ft (0.3-m) difference in lift.

**Table B-5 Loss of Lift at Various Elevations**

Elevation Above Sea Level		Loss of Lift	
(ft)	(m)	(ft of water)	(m)
1000	305	1.22	0.37
2000	610	2.38	0.73
3000	915	3.50	1.07
4000	1220	4.75	1.45
5000	1525	5.80	1.77
6000	1830	6.80	2.07
7000	2135	7.70	2.35

**B-6 Pump Design and Suction Hose.**

At the time of purchase, a pump must be able to develop a vacuum of 22 in. of mercury (Hg) (74.5 kPa) with a capped suction hose and must hold the vacuum with a drop not in excess of 10 in. Hg (33.9 kPa) in 5 minutes. This is basically a test of the priming system and the tightness of the pump and fittings, not a test of the ability to maintain a vacuum while pumping water.

The number, length, and condition of suction hose, as well as altitude, water temperature, atmospheric pressure, and lift are all factors that affect pumping from draft.

The suction hose and lift are the two most common factors that affect pumping from draft. Table B-6 illustrates this effect on capacity. This table is for the purpose of illustration. If your

department routinely operates at higher or lower than standard test suction lift conditions, or with a suction hose size other than as shown in Table 2-3.1.1(a), you should conduct tests to determine your pump's maximum capability. The pump's approximate capacities shown in Table B-6 indicate typical performances under various, nonstandard conditions.

Table B-6 illustrates the following:

(a) The rated pump capacity increases below 10-ft (3-m) lift and decreases above 10-ft (3-m) lift.

(b) Larger diameter suction hose or dual suction hose can increase the capacity.

(c) When required to pump at higher lifts or elevation, capacity can be increased by using a bigger pump, larger diameter suction hose, or dual suction hose.

Example: Effect of larger suction hose:

1000-gpm capacity	
10-ft lift with 5-in. suction hose	1000 gpm
10-ft lift with 6-in. suction hose	1170 gpm
Typical increase most pumps	170 gpm

From Table 2-3.1.1(b) for suction hose and strainer loss:

1000 gpm through 5-in. hose and strainer	8.4 ft
1000 gpm through 6-in. hose and strainer	3.4 ft
Difference	5.0 ft

This 5 ft of difference has the potential to compensate for either 5 ft of additional lift or the ability to pump rated capacity to 4250 ft of elevation (see Table B-6).

**Table B-6 Minimum Discharge Expected of a Pump in Good Condition Operating at Draft at Various Lifts**

Lift in Feet	Rated Capacity at 150 psi		500 gpm		750 gpm		1000 gpm		1250 gpm	1500 gpm		
	Suction Hose Size		4"	4 1/2"	4 1/2"	5"	5"	6"	6"	6"	Dual 5"	Dual 6"
4 6 8 10 12 14 16	20' Suction Hose (two sections)	4	590	660	870	945	1160	1345	1435	1735	1990	2250
		6	560	630	830	905	1110	1290	1375	1660	1990	2150
		8	530	595	790	860	1055	1230	1310	1575	1810	2040
		10	500	560	750	820	1000	1170	1250	1500	1720	1935
		12	465	520	700	770	935	1105	1175	1410	1615	1820
		14	430	480	650	720	870	1045	1100	1325	1520	1710
18 20 22 24	30' Suction Hose (three sections)	16	390	430	585	655	790	960	1020	1225	1405	1585
		18	325	370	495	560	670	835	900	1085	1240	1420
		20	270	310	425	480	590	725	790	955	1110	1270
		22	195	225	340	375	485	590	660	800	950	1085
24	65	70	205	235	340	400	495	590	730	835		

## Appendix C History of Pump Testing

A pamphlet entitled *Fire Department Pumper Tests and Fire Stream Tables*, published in 1910 by the National Board of Fire Underwriters, described the methods of testing steam fire engines, which had been in use for years, and stated that these tests had been found practicable, exact, and of great value. Until then, the character of tests made in many cities, and especially those for acceptance, were usually more spectacular than exact.

At the convention of the International Association of Fire Engineers (IAFE) in Milwaukee in 1911, the Committee on Exhibits conducted some performance tests on automobile pumping engines. The following year at Denver, the Committee on Exhibits, with the assistance of engineers of the National Board of Fire Underwriters, conducted tests on seven pumping engines discharging under net pumping pressures of 120 psi, 200 psi, and 250 psi; duration of various runs was from 3 to 11 minutes. By the next convention of the IAFE in New York City in 1913, the Committee had developed the test procedure that consisted of 6 hours running at 100 percent capacity at 120 psi, 3 hours running at 50 percent capacity at 200 psi, and 3 hours running at 33 percent capacity at 250 psi. This test procedure was used for many years.

The 1939 and 1941 editions of the *Suggested Specifications for Motor Fire Apparatus*, issued by the National Board of Fire Underwriters, outlined the above-mentioned tests, which were later termed “Class B” requirements; the “Class A” requirements—delivery of 100 percent capacity at 150 psi, 70 percent of capacity at 200 psi, and 50 percent of capacity at 250 psi—were noted as an optional specification. The 1947 edition defined the two classes, and the 1956 edition eliminated the Class B designation.

As a result of this gradual change, most pumpers built prior to 1939 were Class B, those built from 1939 through 1956 were Class A or B, and those built from 1957 on are Class A.

In January 1981, the Insurance Services Office, successor to the former National Board of Fire Underwriters, transferred all publishing centers of this pamphlet to the National Fire Protection Association. The NFPA published the document with several changes including the following:

- (a) A modification of the description of the type of tests performed to correlate with requirements contained in NFPA 1901, *Standard for Automotive Fire Apparatus*
- (b) Reduction in the test dealing with positive displacement pumps, especially rotary gear pumps
- (c) Insertion of additional, cautionary statements and increased emphasis on safety precautions that should be followed during tests

(d) A new table showing the relative carrying capacity of hose from 63 mm to 150 mm in diameter

In 1982, the NFPA Technical Committee on Fire Department Equipment began the development of this standard which incorporates much of the material formerly included in the pamphlet *Fire Department Pumper Tests and Fire Stream Tables*. However, it was presented in proper form for incorporation in specifications and other formal documents. This standard was adopted by the NFPA in 1987 and was titled *Acceptance and Service Tests of Fire Department Pumping Apparatus*.

With the 1991 edition, the requirements for acceptance tests of new apparatus were transferred to the standards for new fire apparatus. Material that was previously referenced from other documents was added to make this document self-contained. The requirements were changed to include pumps of 250 gpm (950 L/min) and larger that were rated at 150 psi (1035 kPa). Requirements were added for an engine speed test, a vacuum test, a pressure control test, an operational check of the transfer valve, and a check for the accuracy of the gauges and flow meters.

The 1997 edition added accuracy requirements for flow and speed measuring equipment, required a tank-to-pump flow-rate check, expanded the tables to include data for pumps to 3000 gpm (11,356 L/min), and added a pass/fail point for either derating the pump or correcting the deficiency.

## Appendix D Referenced Publications

**D-1** The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 4. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

**D-1.1 NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 1901, *Standard for Automotive Fire Apparatus*, 1996 edition.

NFPA 1961, *Standard on Fire Hose*, 1997 edition.

NFPA 1962, *Standard for the Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles*, 1993 edition.

**D-1.2 ASME Publications.** American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME B40.1, *Gauges — Pressure Indicating Dial Type — Elastic Element*, 1991.

## Index

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