LESSON PLAN #PO-2A

TITLE: **HYDRAULICS (Part II)**

TIME REQ'D: Eight (8) Hours
Four (4) hours (Classroom)
Four (4) hours (Drill Ground)

STANDARD: NFPA 1002 (1998 Edition)

INST. LEVEL: Levels 1 - 2 - 3
Knowledge - Comprehension - Application

MAT. NEEDED:
- Overhead Projector
- Overhead Transparencies
- Calculators (one for each student)

REFERENCE: IFSTA "Fire Stream Practices", 7th Edition
IFSTA "Water Supplies for Fire Protection", 4th Edition
IFSTA "Fire Department Pumping Apparatus", 7th Edition
Fire Service Hydraulics, 2nd Edition, Donnelley
Fire Apparatus Practices, 3rd Edition, Ervin
Engine Company Fireground Operations, 2nd Edition, Richman

OBJECTIVE: At the end of this class the apparatus operator shall be able to:
SM Pg. 1

1. Using written formulas, determine the following:
   a. friction loss in wyed lines when size of hose and gpm flow are given
   b. friction loss in multiple lines when the size of the hose and gpm flow are given
   c. an estimated remaining available volume from a hydrant while pumping a given volume
2. Describe variables which affect the pumper's ability to lift water

MOTIVATION: Water is the most widely used suppression agent in the world. It is cheap, easily attainable and absorbs tremendous amounts of heat.

Fire departments rely heavily on waters ability to extinguish fires. You, the apparatus operator, are a key element in water supply at the emergency scene. It's up to you to see that nozzles and relay engines are supplied with sufficient water and pressure to develop safe and effective fire streams. A basic understanding of hydraulics is essential to accomplish that task.

OVERVIEW: In this class we will cover:

1. Fluid and pressure
2. Determining friction loss
3. Calculating available water

PRESENTATION: I. FLUID AND PRESSURE

A. Theory of Pressure (Understanding Fluids)

1. Fluids have no shape
2. They can flow from place to place
3. Fluids have no adhesive quality
4. Fluids cannot be lifted
5. Fluids must be pushed
6. Fluids must be confined to have direction
7. Fluids are a liquid or gas
    a. Liquids
        (1) have a specific volume
        (2) cannot be compressed
        (3) cannot store pressure
        (4) have a mass
    b. Gases
        (1) have no volume

(2) fill total space available

(3) have no specific mass

(4) can be compressed

(5) can be changed into liquid

8. Physical states of water

a. Solid

b. Liquid

c. Gas

B. Fluids at Rest (Static)

SM Pg. 2

1. Have no physical action

2. Cannot be compressed

3. Will not store pressure

4. Is pumped easily

5. Flow to areas of less pressure

C. Fluids in Motion

1. Controlled by Law of Inertia

a. Definition of:

(1) "a body at rest will remain at rest, and a body in motion will remain in uniform motion along a straight line, unless it is acted upon by an unbalanced force"

2. Have velocity

3. Create friction

4. Have elevation loss / gain

5. Have pressure loss due to movement (friction loss)

D. Water Pressure

1. Generated three ways

   a. Naturally

      (1) gravity

   b. Mechanically

      (1) pump

   c. Chemically

      (1) chemical reaction

2. Types of pressure

   a. Atmospheric

      (1) defined as:

         (a) "the pressure exerted by the atmosphere at the surface of the earth due to the weight of air"

   b. Head

      (1) defined as:

         (a) "water pressure due to elevation"

SM Pg. 3

   c. Static

      (1) defined as:

         (a) "stored or potential energy that is available to force water through pipe, fittings, fire hose, and adapters"

   d. Normal operating

(1) defined as:

(a) " the pressure found in a water distribution system during normal consumption demands"

e. Residual

(1) defined as:

(a) "that part of total available pressure not used to overcome friction loss or gravity while forcing water through pipe, fittings, fire hose, and adapters"

f. Flow (velocity)

(1) defined as:

(a) "the speed of water as it leaves an orifice"

3. Measurement

a. Measured in pounds per square inch (psi) using gauge

b. Fire apparatus have two types of gauges:

(1) pressure

(2) compound

c. Pressure gauge

(1) defined as:

(a) "a gauge that registers pump discharge pressure"

d. Compound gauge

(1) defined as:

(a) "a gauge connected to the intake side of the pump that is capable of measuring positive or negative pressures"

e. Gauges are usually zeroed at normal atmospheric pressures, thus pressures registered at gauge will not include atmospheric pressure, ie:

(1) gauge reading 120 psig at sea level actually reading 134.7 psia

(a) atmospheric pressure is 14.7 psi at sea level

f. Fire service commonly refers to Pounds per Square Inch Gauge (PSIG) as Pounds per Square Inch (PSI)

NOTE
THROUGHOUT THIS CLASS, PSI MEANS PSIG

g. Pounds per Square Inch Absolute (PSIA) is pressure above absolute zero or perfect vacuum

(1) gauge reading -8 psi actually reading 8 psi less than normal atmospheric

(a) at sea level this would be 14.7 minus 8 or 6.7 psia

E. Lift

1. Definition of (for this class):

a. "The difference in elevation between the water level and the center of the pump"

2. Principles of lift

a. Air removed from hard suction hose and impeller housing during priming process

b. Creates negative pressure condition (vacuum)

c. Atmospheric pressure acting on water surface greater than pressure inside suction chamber

d. Water forced to rise inside suction until pressures equalize or pump fills with water

e. Height of lift:

(1) unaffected by angle of hard suction hose

(2) affected by:

(a) atmospheric pressure

(b) amount of vacuum pump can develop

3. Theoretical lift

a. Defined as:

(1) "the theoretical, scientific height that a column of water may be lifted by atmospheric pressure in a true vacuum"

b. Requires creation of perfect vacuum

NOTE
FIRE PUMPS ARE UNABLE TO CREATE A PERFECT VACUUM

c. Calculates to be 33.8' at sea level

d. Height will decrease as elevation increases

(1) atmospheric pressure decreases approximately .5 psi per 1000' increase in altitude

SM Pg. 4

4. Maximum lift

   a. Defined as:

      (1) "the maximum height to which any amount of water may be raised through a hard suction hose to a pump"

   b. Generally assumed to be 25'

NOTE

ALL COMPONENTS MUST BE IN GOOD WORKING ORDER TO ACHIEVE A 25' MAXIMUM LIFT.

5. Dependable lift

   a. Defined as:

      (1) "the height a column of water may be lifted in sufficient quantity to provide a reliable fire flow"

   b. Usually considered to be 14.7 feet at sea level with equipment in good condition

NOTE

FIRE PUMPS ARE DESIGNED TO PUMP THEIR RATED CAPACITY AT A MAXIMUM LIFT OF 10'.

6. Factors affecting lift distance:

   a. Altitude

   b. Weather

   c. Water temperature

   d. Hydraulic losses

   e. Condition of equipment

7. Altitude

   a. As altitude increases, atmospheric pressure decreases, reducing lifting ability

(1) water pushed through suction hose by atmospheric pressure

a. Engine power also decreases as altitude increases

(1) reduces power available to turn pump impeller

8. Weather

a. Poor weather causes decrease in barometric (atmospheric) pressure

(1) reduces pressure available to force water into suction hose

9. Water temperature

a. Hot water gives of water vapor when placed in partial vacuum

(1) reduces drafting ability of pump

NOTE
DO NOT TRY TO DRAFT WHEN WATER TEMPERATURE EXCEEDS 160° F.

10. Hydraulic losses

a. Friction loss in suction hose and fittings reduce pumps ability to draft

b. Pumps rated at 10' maximum lift using 20' of hard suction

c. Larger suction hose must be used if:

(1) more than 20' of hard suction must be used to reach water source

(2) elevation more than 10'

11. Condition of apparatus

a. Apparatus must be in good working order

b. Factors inhibiting drafting:

(1) bad gaskets

(2) excessive clearance in pump packing and impeller shaft

(3) separation of hose and lining

(4) other

II. DETERMINING FRICTION LOSS

A. Single Lines / Siamesed Lines of Equal Length

NOTE
REVIEW FROM APPARATUS OPERATOR I

1. Formula to calculate friction loss in fire hose:

OHT #H

a. $FL = CQ^2L$

(1) **FL** is friction loss in psi

(2) **C** is friction loss coefficient

(3) **Q** is GPM flow divided by 100

SM Pg. 5

(a) Q = GPM ÷ 100

(4) **L** is hose length divided by 100

(a) L = Hose Length ÷ 100

FRICTION LOSS COEFFICIENTS - SINGLE LINE	
Hose Diameter (in inches)	**Coefficient (C)**
3/4" booster	1100.0
1" booster	150.0

1 1/2"	24.0
1 3/4"	15.5
2 1/2"	2.0
3"	0.8
4"	0.2
4 1/2"	0.1
5"	0.08
6"	0.05

FRICTION LOSS COEFFICIENTS - SIAMESED LINES OF EQUAL LENGTH	
Hose Diameter (in inches)	**Coefficient (C)**
Two 2 1/2"	0.5
One 3" & One 2 1/2"	0.3
Three 2 1/2"	0.22
Two 3"	0.2
Two 2 1/2" & One 3"	0.16
Two 3" & One 2 1/2"	0.12

2. Find friction loss in 100' of 2 1/2" flowing 500 GPM (student manual example)

OHT #H

a. C = Friction Loss Coefficient for 2 1/2" hose

(1) C = 2

b. Q = GPM ÷ 100

(1) Q = 500 ÷ 100

(2) Q = 5

c. L = Hose Length ÷ 100

(1) L = 100 ÷ 100

(2) L = 1

d. $FL = CQ^2L$

SM Pg. 6

(1) $FL = (2)(5)^2(1)$

(2) FL = 2 x 25 x 1

(3) FL = 50 x 1

(4) FL = 50 PSI

3. Find friction loss in 500' of 2 1/2" hose flowing 300 GPM (student manual example)

OHT #H

a. C = Friction Loss Coefficient for 2 1/2" hose

(1) C = 2

b. Q = GPM ÷ 100

(1) Q = 300 ÷ 100

(2) Q = 3

c. L = Hose Length ÷ 100

(1) L = 500 ÷ 100

(2) L = 5

d. $FL = CQ^2L$

(1) $FL = (2)(3)^2(5)$

(2) FL = 2 x 9 x 5

(3) FL = 18 x 5

(4) FL = 90 PSI

4. Find friction loss in 100' of 1 3/4" hose flowing 200 GPM (student manual example)

OHT #H

a. C = Friction Loss Coefficient for 1 3/4" hose

(1) C = 15.5

b. Q = GPM ÷ 100

(1) Q = 200 ÷ 100

(2) Q = 2

SM Pg. 7

c. L = Hose Length ÷ 100

(1) L = 100 ÷ 100

(2) L = 1

d. $FL = CQ^2L$

(1) $FL = (15.5)(2)^2(1)$

(2) FL = 15.5 x 4 x 1

(3) FL = 62 x 1

(4) FL = 62 PSI

5. Find friction loss in 500' of 3" hose flowing 500 GPM (student manual example)

OHT #H

a. C = Friction Loss Coefficient for 3" hose

(1) C = .8

b. Q = GPM ÷ 100

(1) Q = 500 ÷ 100

(2) Q = 5

c. L = Hose Length ÷ 100

(1) L = 500 ÷ 100

(2) L = 5

d. $FL = CQ^2L$

(1) $FL = (.8)(5)^2(5)$

(2) FL = .8 x 25 x 5

(3) FL = 20 x 5

(4) FL = 100 PSI

6. Find friction loss in 150' of 1 1/2" flowing 60 GPM (student manual example)

OHT #H

a. C = Friction Loss Coefficient for 1 1/2" hose

(2) C = 24

SM Pg. 8

b. Q = GPM ÷ 100

(1) Q = 60 ÷ 100

(2) Q = .6

c. L = Hose Length ÷ 100

(1) L = 150 ÷ 100

(2) L = 1.5

d. $FL = CQ^2L$

(1) $FL = (24)(.6)^2(1.5)$

(2) FL = 24 x .36 x 1.5

(3) FL = 8.64 x 1.5

(4) FL = 12.96 PSI

7. Find friction loss in 500' of two 3" hoses flowing 1000 GPM (student manual example)

OHT #H

a. C = Friction Loss Coefficient for double 3" lines

(1) C = .2

b. Q = GPM ÷ 100

(1) Q = 1000 ÷ 100

(2) Q = 10

c. L = Hose Length ÷ 100

(1) L = 500 ÷ 100

(2) L = 5

d. FL = CQ^2L

(1) FL = $(.2)(10)^2(5)$

(2) FL = .2 x 100 x 5

(3) FL = 20 x 5

(4) FL = 100 PSI

SM Pg. 9

8. Find friction loss in 1000' of 5" flowing 1000 GPM

OHT #H

a. C = Friction Loss Coefficient for 5" hose

(1) C = .08

b. Q = GPM ÷ 100

(1) Q = 1000 ÷ 100

(2) Q = 10

c. L = Hose Length ÷ 100

(1) L = 1000 ÷ 100

(2) L = 10

d. FL = CQ^2L

(1) FL = $(.08)(10)^2(10)$

(2) FL = .08 x 100 x 10

(3) FL = 8 x 10

(4) FL = 80 PSI

9. Find friction loss in 150' of 1 1/2" flowing 125 GPM

a. C = Friction Loss Coefficient for 1 1/2" hose

(1) C = 24

b. Q = GPM ÷ 100

(1) Q = 125 ÷ 100

(2) Q = 1.25

c. L = Hose Length ÷ 100

(1) L = 150 ÷ 100

(2) L = 1.5

d. $FL = CQ^2L$

(1) $FL = (24)(1.25)^2 1.5$

(2) FL = 24 x 1.5625 x 1.5

(3) FL = 37.5 x 1.5

(4) FL = 56.25 PSI

10. Find friction loss in 750' of one 3" and one 2 1/2" hose flowing 750 GPM

a. C = Friction Loss Coefficient for one 3" and one 2 1/2" hose

(1) C = .3

b. Q = GPM ÷ 100

(1) Q = 750 ÷ 100

(2) Q = 7.5

c. L = Hose Length ÷ 100

(1) L = 750 ÷ 100

(2) L = 7.5

d. $FL = CQ^2L$

(1) $FL = (.3)(7.5)^2(7.5)$

(2) FL = .3 x 56.25 x 7.5

(3) FL = 16.875 x 7.5

(4) FL = 126.5625 PSI

11. Find friction loss in 200' of 3/4" booster hose flowing 20 GPM

a. C = Friction Loss Coefficient for 3/4" booster hose

(1) C = 1100

b. Q = GPM ÷ 100

(1) Q = 20 ÷ 100

(2) Q = .2

c. L = Hose Length ÷ 100

(1) L = 200 ÷ 100

(2) L = 2

d. $FL = CQ^2L$

(1) $FL = (1100)(.2)^2(2)$

(2) FL = 1100 x .04 x 2

(3) FL = 44 x 2

(4) FL = 88 PSI

12. Find friction loss in 1200' of one 3" and one 2 1/2" hose flowing 1000 GPM

a. C = Friction Loss Coefficient for one 3" and one 2 1/2" hose

(1) C = .3

b. Q = GPM ÷ 100

(1) Q = 1000 ÷ 100

(2) Q = 10

c. L = Hose Length ÷ 100

(1) L = 1200 ÷ 100

(2) L = 12

d. $FL = CQ^2L$

(1) $FL = (.3)(10)^2(12)$

(2) FL = .3 x 100 x 12

(3) FL = 30 x 12

(4) FL = 360 PSI

13. Find friction loss in 700' of one 3" and one 2 1/2" hose flowing 1000 GPM

a. C = Friction Loss Coefficient for one 3" and one 2 1/2" hose

(1) C = .3

b. Q = GPM ÷ 100

(1) Q = 1000 ÷ 100

(2) Q = 10

c. L = Hose Length ÷ 100

(1) L = 700 ÷ 100

(2) L = 7

d. $FL = CQ^2L$

(1) $FL = (.3)(10)^2(7)$

(2) FL = .3 x 100 x 7

(3) FL = 30 x 7

(4) FL = 210 PSI

14. Find friction loss in 1000' of two 3" and one 2 1/2" hoses flowing 1200 GPM

a. C = Friction Loss Coefficient for two 3" and one 2 1/2" hose

(1) C = .12

b. Q = GPM ÷ 100

(1) Q = 1200 ÷ 100

(2) Q = 12

c. L = Hose Length ÷ 100

(1) L = 1000 ÷ 100

(2) L = 10

d. $FL = CQ^2L$

(1) $FL = (.12)(12)^2(10)$

(2) FL = .12 x 144 x 10

(3) FL = 17.28 x 10

(4) FL = 172.8 PSI

SM Pg. 10

B. Pump Discharge Pressure (In PSI)

1. Formula for finding required Pump Discharge Pressure (PDP) is:

OHT #H

a. PDP = NP + FL

(1) **PDP** is pump discharge pressure

(2) **NP** is nozzle pressure

NOTE

MOST FOG NOZZLES ARE DESIGNED TO OPERATE AND DELIVER RATED GALLONAGES AT 100 PSI. FOR THIS CLASS, USE 100 PSI NOZZLE PRESSURE TO CALCULATE PUMP DISCHARGE PRESSURE WHEN UTILIZING FOG NOZZLES. WHEN YOU GO HOME, FLOW PRESSURES SHOULD BE DETERMINED FOR ALL FOG NOZZLES UTILIZED BY YOUR DEPARTMENT AND THESE PRESSURES SHOULD BE USED TO CALCULATE YOUR REQUIRED PUMP DISCHARGE PRESSURE.

(3) **FL** is friction loss

2. Find pump discharge pressure required for supplying 200' of 2 1/2" hose equipped with 200 GPM fog nozzle operating at 100 PSI nozzle pressure (student manual example)

OHT #H

a. C = Friction Loss Coefficient for 2 1/2" hose

(1) C = 2

b. Q = GPM ÷ 100

(1) Q = 200 ÷ 100

(2) Q = 2

c. L = Hose Length ÷ 100

(1) L = 200 ÷ 100

(2) L = 2

d. $FL = CQ^2L$

(1) $FL = (2)(2)^2(2)$

(2) FL = 2 x 4 x 2

(3) FL = 8 x 2

SM Pg. 11

(4) FL = 16 PSI

e. PDP = NP + FL

(1) PDP = 100 + 16

(2) PDP = 116 PSI

3. Find pump discharge pressure required for supplying 200' of 1 3/4" hose equipped with 200 GPM automatic fog nozzle (student manual example)

a. C = Friction Loss Coefficient for 1 3/4" hose

(1) C = 15.5

b. Q = GPM ÷ 100

(1) Q = 200 ÷ 100

(2) Q = 2

c. L = Hose Length ÷ 100

(1) L = 200 ÷ 100

(2) L = 2

d. $FL = CQ^2L$

(1) $FL = (15.5)(2)^2(2)$

(2) FL = 15.5 x 4 x 2

(3) FL = 62 x 2

(4) FL = 124 PSI

e. PDP = NP + FL

(1) PDP = 100 + 124

(2) PDP = 224 PSI

4. Find pump discharge pressure required for supplying 200' of 2 1/2" hose equipped with 350 GPM fog nozzle operating at 100 PSI nozzle pressure

a. C = Friction Loss Coefficient for 2 1/2" hose

(1) C = 2

b. Q = GPM ÷ 100

(1) Q = 350 ÷ 100

(2) Q = 3.5

c. L = Hose Length ÷ 100

(1) L = 200 ÷ 100

(2) L = 2

d. $FL = CQ^2L$

(1) $FL = (2)(3.5)^2(2)$

(2) FL = 2 x 12.25 x 2

(3) FL = 24.5 x 2

(4) FL = 49 PSI

e. PDP = NP + FL

(1) PDP = 100 + 49

(2) PDP = 149 PSI

SM Pg. 12

5. Find pump discharge pressure required for supplying 200' of 1 3/4" hose equipped with 350 GPM automatic fog nozzle

a. C = Friction Loss Coefficient for 1 3/4" hose

(1) C = 15.5

b. Q = GPM ÷ 100

(1) Q = 350 ÷ 100

(2) Q = 3.5

c. L = Hose Length ÷ 100

(1) L = 200 ÷ 100

(2) L = 2

d. $FL = CQ^2L$

(1) $FL = (15.5)(3.5)^2(2)$

(2) FL = 15.5 x 12.25 x 2

(3) FL = 189.875 x 2

(4) FL = 379.75 PSI

e. PDP = NP + FL

(1) PDP = 100 + 379.75

(2) PDP = 479.75 PSI

C. Determining Friction Loss in Multiple Lines

1. Lines of equal diameter and length

a. Find friction loss in two 200' handlines of 1 3/4" hose equipped with fog nozzles flowing 200 gpm each (student manual example)

(1) C = friction loss coefficient for 1 3/4" hose

(a) C = 15.5

(2) Q = GPM ÷ 100

(a) Q = 200 ÷ 100

(b) Q = 2

(3) L = hose length ÷ 100

(a) $L = 200 \div 100$

(b) $L = 2$

(4) $FL = CQ^2L$

(a) $FL = (15.5)(2)^2(2)$

(b) $FL = 15.5 X 4 X 2$

(c) $FL = 62 X 2$

(d) $FL = 124$ PSI

b. Find friction loss in two 150' handlines of 1 1/2" hose equipped with fog nozzles flowing 100 gpm each

(1) C = friction loss coefficient for 1 1/2" hose

(a) $C = 24$

(2) $Q = GPM \div 100$

(a) $Q = 100 \div 100$

(b) $Q = 1$

(3) $L = \text{hose length} \div 100$

(a) $L = 150 \div 100$

(b) $L = 1.5$

(4) $FL = CQ^2L$

(a) $FL = (24)(1)^2(1.5)$

(b) $FL = 24 X 1 X 1.5$

(c) $FL = 24 X 1.5$

(d) $FL = 36$ PSI

c. Find pump discharge pressure required to supply four 2 1/2" handlines, each 300' in length, equipped with fog nozzles flowing 250 gpm

(1) C = friction loss coefficient for 2 1/2" hose

(a) C = 2

(2) Q = GPM ÷ 100

(a) Q = 250 ÷ 100

(b) Q = 2.5

(3) L = hose length ÷ 100

(a) L = 300 ÷ 100

(b) L = 3

(4) $FL = CQ^2L$

(a) $FL = (2)(2.5)^2(3)$

(b) FL = 2 X 6.25 X 3

(c) FL = 12.5 X 3

(d) FL = 37.5 PSI

(5) PDP = NP + FL

(a) PDP = 100 + 37.5

(b) PDP = 137.5 PSI

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2. Lines of equal diameter and unequal length

a. Find pump discharge pressure required to supply two handlines of 1 3/4" hose, one 150' and one 200' in length, equipped with fog nozzles flowing 200 gpm each (student manual example)

(1) hose #1

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 150 ÷ 100

ii. L = 1.5

(d) $FL = CQ^2L$

i. $FL = (15.5)(2)^2(1.5)$

ii. FL = 15.5 X 4 X 1.5

iii. FL = 62 X 1.5

iv. FL = 93 PSI

(2) hose #2

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

SM Pg. 14

ii. L = 2

(d) FL = CQ^2L

i. FL = $(15.5)(2)^2(2)$

ii. FL = 15.5 X 4 X 2

iii. FL = 62 X 2

iv. FL = 124 PSI

(3) PDP = NP + FL

INSTRUCTOR NOTE

ASK THE STUDENTS WHICH FRICTION LOSS CALCULATION (Hose #1 or Hose #2) SHOULD BE USED TO CALCULATE THE REQUIRED PUMP DISCHARGE PRESSURE.

ANSWER

TO CALCULATE THE PUMP DISCHARGE PRESSURE WE SHOULD USE THE HIGHER FRICTION LOSS OF HOSE #2. ANY PUMP DISCHARGE PRESSURE LESS THAN THIS WILL RESULT IN INADEQUATE WATER FOR HOSE #2. THIS PRESSURE CAN THEN BE GATED DOWN FOR THE LOWER PRESSURE REQUIREMENT OF HOSE #1.

(a) PDP = 100 + 124

(b) PDP = 224 PSI

b. Find pump discharge pressure required to supply two handlines of 1 1/2" hose, one 100' and one 150' in length, equipped with fog nozzles flowing 100 gpm each

(1) Hose #1

(a) C = friction loss coefficient for 1 1/2" hose

i. C = 24

(b) Q = GPM ÷ 100

i. Q = 100 ÷ 100

ii. Q = 1

(c) L = hose length ÷ 100

i. L = 100 ÷ 100

ii. L = 1

(d) $FL = CQ^2L$

i. $FL = (24)(1)^2(1)$

ii. FL = 24 X 1 X 1

iii. FL = 24 X 1

iv. FL = 24 PSI

(2) Hose #2

(a) C = friction loss coefficient for 1 1/2" hose

i. C = 24

(b) Q = GPM ÷ 100

i. Q = 100 ÷ 100

ii. Q = 1

(c) L = hose length ÷ 100

i. L = 150 ÷ 100

ii. L = 1.5

(d) $FL = CQ^2L$

i. $FL = (24)(1)^2(1.5)$

ii. FL = 24 X 1 X 1.5

iii. FL = 24 X 1.5

iv. FL = 36 PSI

(3) PDP = NP + FL

(a) PDP = 100 + 36

(b) PDP = 136 PSI

c. Find pump discharge pressure required to supply four 2 1/2" handlines equipped with fog nozzles, two 200' in length flowing 250 gpm and two 300' in length flowing 200 gpm

(1) Hoses #1 & #2

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 250 ÷ 100

ii. Q = 2.5

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(2)$

ii. FL = 2 X 6.25 X 2

iii. FL = 12.5 X 2

iv. FL = 25 PSI

(2) Hoses #3 & #4

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 300 ÷ 100

ii. L = 3

(d) $FL = CQ^2L$

i. $FL = (2)(2)^2(3)$

ii. FL = 2 X 4 X 3

iii. FL = 8 X 3

iv. FL = 24 PSI

(3) PDP = NP + FL

(a) PDP = 100 + 25

(b) PDP = 125 PSI

3. Lines of unequal diameter and equal length

a. Find pump discharge pressure required to supply two handlines 150' in length, one 1 3/4" and one 1 1/2" hose, equipped with fog nozzles flowing 100 gpm each (student manual example)

(1) hose #1

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

SM Pg. 15

(b) Q = GPM ÷ 100

i. Q = 100 ÷ 100

ii. Q = 1

(c) L = hose length ÷ 100

i. L = 150 ÷ 100

ii. L = 1.5

(d) $FL = CQ^2L$

i. $FL = (15.5)(1)^2(1.5)$

ii. FL = 15.5 X 1 X 1.5

iii. FL = 15.5 X 1.5

iv. FL = 23.25 PSI

(2) hose #2

(a) C = friction loss coefficient for 1 1/2" hose

i. C = 24

(b) Q = GPM ÷ 100

i. Q = 100 ÷ 100

ii. Q = 1

(c) L = hose length ÷ 100

i. L = 150 ÷ 100

ii. L = 1.5

(d) $FL = CQ^2L$

i. $FL = (24)(1)^2(1.5)$

ii. FL = 24 X 1 X 1.5

iii. FL = 24 X 1.5

iv. FL = 36 PSI

(3) PDP = NP + FL

(a) PDP = 100 + 36

SM Pg. 16

(b) PDP = 136 PSI

b. Find pump discharge pressure required to supply three handlines, two 1 1/2" hoses 200' in length flowing 100 gpm through automatic fog nozzles and one 2 1/2" hose 200' in length flowing 250 gpm through fog nozzle.

(1) Hoses #1 & #2

(a) C = friction loss coefficient for 1 1/2" hose

i. C = 24

(b) Q = GPM ÷ 100

i. Q = 100 ÷ 100

ii. Q = 1

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) $FL = CQ^2L$

i. $FL = (24)(1)^2(2)$

ii. FL = 24 X 1 X 2

iii. FL = 24 X 2

iv. FL = 48 PSI

(2) Hose #3

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 250 ÷ 100

ii. Q = 2.5

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(2)$

ii. FL = 2 X 6.25 X 2

iii. FL = 12.5 X 2

iv. FL = 25 PSI

(3) PDP = NP + FL

(a) PDP = 100 + 48

(b) PDP = 148 PSI

c. Find pump discharge pressure required to supply four fog nozzle equipped handlines 200' in length, one 1 1/2" hose flowing 60 gpm, two 1 3/4" hoses flowing 100 gpm and one 2 1/2" hose flowing 250 gpm

(1) Hose #1

(a) C = friction loss coefficient for 1 1/2" hose

i. C = 24

(b) Q = GPM ÷ 100

i. Q = 60 ÷ 100

ii. Q = .6

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) $FL = CQ^2L$

i. $FL = (24)(.6)^2(2)$

ii. FL = 24 X .36 X 2

iii. FL = 8.64 X 2

iv. FL = 17.28 PSI

(2) Hoses #2 & #3

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 100 ÷ 100

ii. Q = 1

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) $FL = CQ^2L$

i. $FL = (15.5)(1)^2(2)$

ii. FL = 15.5 X 1 X 2

iii. FL = 15.5 X 2

iv. FL = 31 PSI

(3) Hose #4

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 250 ÷ 100

ii. Q = 2.5

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(2)$

ii. FL = 2 X 6.25 X 2

iii. FL = 12.5 X 2

iv. FL = 25 PSI

(4) PDP = NP + FL

(a) PDP = 100 + 31

(b) PDP = 131 PSI

4. Lines of unequal diameter and length

a. Find pump discharge pressure required to supply two handlines, one 1 3/4" hose 250' in length flowing 200 gpm through an automatic fog nozzle and one 2 1/2" hose 400' long equipped with fog nozzle flowing 250 gpm (student manual example)

(1) hose #1

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 250 ÷ 100

ii. L = 2.5

(d) $FL = CQ^2L$

i. $FL = (15.5)(2)^2(2.5)$

SM Pg. 17

ii. FL = 15.5 X 4 X 2.5

iii. FL = 62 X 2.5

iv. FL = 155 PSI

(2) hose #2

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. $Q = 250 \div 100$

ii. $Q = 2.5$

(c) L = hose length ÷ 100

i. $L = 400 \div 100$

ii. $L = 4$

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(4)$

ii. $FL = 2 \text{ X } 6.25 \text{ X } 4$

iii. $FL = 12.5 \text{ X } 4$

iv. FL = 50 PSI

(3) PDP = NP + FL

(a) PDP = 100 + 155

(b) PDP = 255 PSI

b. Find pump discharge pressure required to supply three handlines equipped with automatic fog nozzles, one 1 1/2" hose 150' in length flowing 125 gpm, one 1 3/4" hose 200' long flowing 150 gpm and one 2 1/2" hose 350' in length flowing 250 gpm

(1) Hose #1

(a) C = friction loss coefficient for 1 1/2" hose

i. $C = 24$

(b) Q = GPM ÷ 100

i. $Q = 125 \div 100$

ii. Q = 1.25

(c) L = hose length ÷ 100

i. L = 150 ÷ 100

ii. L = 1.5

(d) $FL = CQ^2L$

i. $FL = (24)(1.25)^2(1.5)$

ii. FL = 24 X 1.5625 X 1.5

iii. FL = 37.5 X 1.5

iv. FL = 56.25 PSI

(2) Hose #2

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 150 ÷ 100

ii. Q = 1.5

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) $FL = CQ^2L$

i. $FL = (15.5)(1.5)^2(2)$

ii. FL = 15.5 X 2.25 X 2

iii. FL = 34.875 X 2

iv. FL = 69.75 PSI

(3) Hose #3

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 250 ÷ 100

ii. Q = 2.5

(c) L = hose length ÷ 100

i. L = 350 ÷ 100

ii. L = 3.5

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(3.5)$

ii. FL = 2 X 6.25 X 3.5

iii. FL = 12.5 X 3.5

iv. FL = 43.75 PSI

(4) PDP = NP + FL

(a) PDP = 100 + 69.75

(b) PDP = 169.75 PSI

SM Pg. 18

c. Find pump discharge pressure required to supply four fog nozzle equipped handlines, one 1 1/2" hose 100' long flowing 200 gpm, one 1 3/4" hose 300' in length flowing 150 gpm, one 2 1/2" hose 500' long flowing 250 gpm and one 2 1/2" hose 700' long flowing 200 gpm

(1) Hose #1

(a) C = friction loss coefficient for 1 1/2" hose

i. C = 24

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 100 ÷ 100

ii. L = 1

(d) $FL = CQ^2L$

i. $FL = (24)(2)^2(1)$

ii. FL = 24 X 4 X 1

iii. FL = 96 X 1

iv. FL = 96 PSI

(2) Hose #2

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 150 ÷ 100

ii. Q = 1.5

(c) L = hose length ÷ 100

i. L = 300 ÷ 100

ii. L = 3

(d) FL = CQ²L

i. FL = (15.5)(1.5)²(3)

ii. FL = 15.5 X 2.25 X 3

iii. FL = 34.875 X 3

iv. FL = 104.625 PSI

(3) Hose #3

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 250 ÷ 100

ii. Q = 2.5

(c) L = hose length ÷ 100

i. L = 500 ÷ 100

ii. L = 5

(d) FL = CQ²L

i. FL = (2)(2.5)²(5)

ii. FL = 2 X 6.25 X 5

iii. FL = 12.5 X 5

iv. FL = 62.5 PSI

(4) Hose #4

(a) C = friction loss coefficient for 2 1/2" hose

i. $C = 2$

(b) $Q = GPM \div 100$

i. $Q = 200 \div 100$

ii. $Q = 2$

(c) $L = \text{hose length} \div 100$

i. $L = 700 \div 100$

ii. $L = 7$

(d) $FL = CQ^2L$

i. $FL = (2)(2)^2(7)$

ii. $FL = 2 \times 4 \times 7$

iii. $FL = 8 \times 7$

iv. FL = 56 PSI

(5) PDP = NP + FL

(a) PDP = 100 + 104.625

(b) PDP = 204.625 PSI

C. Determining Friction Loss in Wyed Lines

NOTE

THE FRICTION LOSS THROUGH WYES AND SIAMESES WILL VARY WITH THE SIZE, FLOW, AND DESIGN OF THE APPLIANCE. AS WITH FIRE HOSE, THE ONLY TRUE AND ACCURATE WAY TO DETERMINE THE ACTUAL FRICTION LOSS IS TO TEST IT. THE RULE OF THUMB FRICTION LOSS THROUGH A WYE OR SIAMESE IS BASED ON FLOW. FOR FLOWS LESS THAN 350 GPM WE ASSUME A FRICTION LOSS OF 0 PSI, FOR FLOWS GREATER THAN 350 GPM WE ASSUME A FRICTION LOSS OF 10 PSI.

1. Equal length lines

a. Determine total friction loss in hose assembly consisting of 500' of 2 1/2" hose wyed out to two 150' long 1 1/2" handlines flowing 100 gpm each

(1) 2 1/2" line

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 500 ÷ 100

ii. L = 5

(d) $FL = CQ^2L$

i. $FL = (2)(2)^2(5)$

ii. FL = 2 X 4 X 5

iii. FL = 8 X 5

iv. FL = 40 PSI

(2) gated wye

(a) 200 gpm

i. 0 PSI

(3) 1 1/2" handlines

(a) C = friction loss coefficient for 1 1/2" hose

i. C = 24

(b) Q = GPM ÷ 100

i. Q = 100 ÷ 100

ii. Q = 1

(c) L = hose length ÷ 100

i. L = 150 ÷ 100

ii. L = 1.5

(d) $FL = CQ^2L$

i. $FL = (24)(1)^2(1.5)$

ii. FL = 24 X 1 X 1.5

iii. FL = 24 X 1.5

iv. FL = 36 PSI

(4) Total FL = 40 + 0 + 36

(d) Total FL = 76 PSI

b. Determine total friction loss in hose assembly consisting of 400' of 3" hose wyed out to two 300' long 2 1/2" handlines flowing 250 gpm each

(1) 3" line

(a) C = friction loss coefficient for 3" hose

i. C = .8

(b) Q = GPM ÷ 100

i. Q = 500 ÷ 100

ii. Q = 5

(c) L = hose length ÷ 100

i. $L = 400 \div 100$

ii. $L = 4$

(d) $FL = CQ^2L$

i. $FL = (.8)(5)^2(4)$

ii. FL = .8 X 25 X 4

iii. FL = 20 X 4

iv. FL = 80 PSI

(2) gated wye

(a) 500 gpm

i. 10 PSI

(3) 2 1/2" handlines

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) $Q = GPM \div 100$

i. $Q = 250 \div 100$

ii. Q = 2.5

(c) $L = \text{hose length} \div 100$

i. $L = 300 \div 100$

ii. L = 3

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(3)$

ii. FL = 2 X 6.25 X 3

iii. FL = 12.5 X 3

iv. FL = 37.5 PSI

(4) Total FL = 80 + 10 + 37.5

(d) Total FL = 127.5 PSI

c. Determine total friction loss in hose assembly consisting of 800' of 4" hose wyed out to two 300' long 2 1/2" handlines flowing 250 gpm each

(1) 4" line

(a) C = friction loss coefficient for 4" hose

i. C = .2

(b) Q = GPM ÷ 100

i. Q = 500 ÷ 100

ii. Q = 5

(c) L = hose length ÷ 100

i. L = 800 ÷ 100

ii. L = 8

(d) $FL = CQ^2L$

i. $FL = (.2)(5)^2(8)$

ii. FL = .2 X 25 X 8

iii. FL = 5 X 8

iv. FL = 40 PSI

(2) gated wye

(a) 500 gpm

i. 10 PSI

(3) 2 1/2" handlines

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 250 ÷ 100

ii. Q = 2.5

(c) L = hose length ÷ 100

i. L = 300 ÷ 100

ii. L = 3

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(3)$

ii. FL = 2 X 6.25 X 3

iii. FL = 12.5 X 3

iv. FL = 37.5 PSI

(4) Total FL = 40 + 10 + 37.5

(d) Total FL = 87.5 PSI

SM Pg. 19

2. Unequal length lines

a. Determine total friction loss in hose lay consisting of 600' of 2 1/2" hose wyed out to two 1 1/2" handlines, one 100' and one 200' in length, flowing 125 gpm each

(1) 2 1/2" line

(a) C = friction loss coefficient for 2 1/2" hose

i. $C = 2$

(b) $Q = GPM \div 100$

i. $Q = 250 \div 100$

ii. $Q = 2.5$

(c) $L = \text{hose length} \div 100$

i. $L = 600 \div 100$

ii. $L = 6$

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(6)$

ii. $FL = 2 \times 6.25 \times 6$

iii. $FL = 12.5 \times 6$

iv. $FL = 75$ PSI

(2) gated wye

(a) 250 gpm

i. 0 PSI

(3) 1 1/2" handline #1

(a) C = friction loss coefficient for 1 1/2" hose

i. $C = 24$

(b) $Q = GPM \div 100$

i. $Q = 125 \div 100$

ii. $Q = 1.25$

(c) $L = \text{hose length} \div 100$

i. L = 100 ÷ 100

ii. L = 1

(d) FL = CQ^2L

i. FL = $(24)(1.25)^2(1)$

ii. FL = 24 X 1.5625 X 1

iii. FL = 37.5 X 1

iv. FL = 37.5 PSI

(4) 1 1/2" handline #2

(a) C = friction loss coefficient for 1 1/2" hose

i. C = 24

(b) Q = GPM ÷ 100

i. Q = 125 ÷ 100

ii. Q = 1.25

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) FL = CQ^2L

i. FL = $(24)(1.25)^2(2)$

ii. FL = 24 X 1.5625 X 2

iii. FL = 37.5 X 2

iv. FL = 75 PSI

(5) Total FL = 75 + 0 + 75

(a) Total FL = 150 PSI

b. Determine total friction loss in hose assembly consisting of 500' of 3" hose wyed out to one 1 3/4" hose 150' in length flowing 200 gpm and one 300' long 2 1/2" handline flowing 250 gpm

(1) 3" line

(a) C = friction loss coefficient for 2 1/2" hose

i. C = .8

(b) Q = GPM ÷ 100

i. Q = 450 ÷ 100

ii. Q = 4.5

(c) L = hose length ÷ 100

i. L = 500 ÷ 100

ii. L = 5

(d) $FL = CQ^2L$

i. $FL = (.8)(4.5)^2(5)$

ii. FL = .8 X 20.25 X 5

iii. FL = 16.2 X 5

iv. FL = 81 PSI

(2) gated wye

(a) 450 gpm

i. 10 PSI

(3) 1 3/4" handline

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 150 ÷ 100

ii. L = 1.5

(d) $FL = CQ^2L$

i. $FL = (15.5)(2)^2(1.5)$

ii. FL = 15.5 X 4 X 1.5

iii. FL = 62 X 1.5

iv. FL = 93 PSI

(4) 2 1/2" handline

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 250 ÷ 100

ii. Q = 2.5

(c) L = hose length ÷ 100

i. L = 300 ÷ 100

ii. L = 3

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(3)$

ii. FL = 2 X 6.25 X 3

iii. FL = 12.5 X 3

iv. FL = 37.5 PSI

(5) Total FL = 81 + 10 + 93

(a) Total FL = 184 PSI

c. Determine total friction loss in hose assembly consisting of 600' of 4" hose wyed out to one 200' long 2 1/2" line to master stream flowing 350 gpm and one 3" hose 250' in length flowing 500 gpm through master stream

(1) 4" line

(a) C = friction loss coefficient for 2 1/2" hose

i. C = .2

(b) Q = GPM ÷ 100

i. Q = 850 ÷ 100

ii. Q = 8.5

(c) L = hose length ÷ 100

i. L = 600 ÷ 100

ii. L = 6

(d) $FL = CQ^2L$

i. $FL = (.2)(8.5)^2(6)$

ii. FL = .2 X 72.25 X 6

iii. FL = 14.45 X 6

iv. FL = 86.7 PSI

(2) gated wye

(a) 850 gpm

i. 10 PSI

(3) 2 1/2" line

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 350 ÷ 100

ii. Q = 3.5

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) $FL = CQ^2L$

i. $FL = (2)(3.5)^2(2)$

ii. FL = 2 X 12.25 X 2

iii. FL = 24.5 X 2

iv. FL = 49 PSI

(4) 3" line

(a) C = friction loss coefficient for 3" hose

i. C = .8

(b) Q = GPM ÷ 100

i. Q = 500 ÷ 100

ii. Q = 5

(c) L = hose length ÷ 100

i. L = 250 ÷ 100

ii. L = 2.5

(d) $FL = CQ^2L$

i. $FL = (.8)(5)^2(2.5)$

ii. FL = .8 X 25 X 2.5

iii. FL = 20 X 2.5

iv. FL = 50 PSI

(5) Total FL = 86.7 + 10 + 50

(a) Total FL = 146.7 PSI

III. CALCULATING AVAILABLE WATER

A. Static pressure registers on compound gauge when not flowing water

B. Residual pressure registers on compound gauge when water flowing

C. Difference between two pressures used to determine how much more water hydrant can supply

D. Two (2) methods:

1. Percentage method

2. First-digit method

E. Percentage method calculated using formula:

1. **PD = (S - R) 100 ÷ S**

SM Pg. 20

a. **PD** is percent drop

b. **S** is static (pressure)

c. **R** is residual (pressure)

2. Percentage of pressure loss then compared to chart to identify quantity of water still available (if any)

ADDITIONAL WATER AVAILABLE AT A HYDRANT	
Percent Decrease of Compound Gauge Pressure	**Additional Water Available**
0-10	3 times amount being delivered
11-15	2 times amount being delivered
16-25	Same amount as being delivered
25+	More water might be available, but not as much as is being delivered

F. Determine additional water remaining in system when an engine supplying 500 gpm had static pressure of 65 psi and residual of 50 psi (student manual example)

1. PD = (S - R) 100 ÷ S

a. PD = (65 - 50)(100) ÷ 65

b. PD = 15 X 100 ÷ 65

c. PD = 1500 ÷ 65

d. PD = 23%

2. Based on the percentage of pressure loss, use chart to determine how much water still available in system

a. 500 gpm

G. Determine additional water remaining in system when an engine supplying 750 gpm had static pressure of 110 psi and residual of 95 psi

1. PD = (S - R) 100 ÷ S

a. PD = (110 - 95)(100) ÷ 110

b. PD = 15 X 100 ÷ 110

c. PD = 1500 ÷ 110

d. PD = 13.64%

2. Based on the percentage of pressure loss, use chart to determine how much water still available in system

a. 1500 gpm

H. Determine additional water remaining in system when an engine supplying 600 gpm had static pressure of 80 psi and residual of 65 psi

1. PD = (S - R) 100 ÷ S

a. PD = (80 - 65)(100) ÷ 80

b. PD = 15 X 100 ÷ 80

c. PD = 1500 ÷ 80

d. PD = 18.75%

2. Based on the percentage of pressure loss, use chart to determine how much water still available in system

a. 600 gpm

SM Pg. 21

I. Determine additional water remaining in system when an engine supplying 250 gpm had static pressure of 65 psi and residual of 52 psi

1. PD = (S - R) 100 ÷ S

a. PD = (65 - 52)(100) ÷ 65

b. PD = 13 X 100 ÷ 65

c. PD = 1300 ÷ 65

d. PD = 20%

2. Based on the percentage of pressure loss, use chart to determine how much water still available in system

   a. 250 gpm

J. First-digit method

1. Find psi difference between static and residual pressures

2. Multiply first digit of static pressure by 1, 2, or 3 to determine how much additional flow left

3. If psi drop equal to or less than first digit of static pressure multiplied by one (1), three times amount being used still available

4. If psi drop equal to or less than first digit of static pressure multiplied by two (2), twice amount being used still available

5. If psi drop equal to or less than first digit of static pressure multiplied by three (3), same amount as being used still available

K. Determine additional water remaining in system when an engine supplying 250 gpm had static pressure of 65 psi and residual of 58 psi (student manual example)

1. **DP = S - R**

   a. **DP** = Difference in pressure

   b. **S** = Static pressure

   c. **R** = Residual pressure

2. DP = S - R

   a. DP = S - R

   b. DP = 65 - 58

   c. DP = 7 psi

3. First digit of static pressure X 1

a. 6 X 1 = 6

4. 7 not less than 6

SM Pg. 22

5. First digit of static pressure X 2

a. 6 X 2 = 12

6. 7 less than 12

7. 500 gpm still available in hydrant

L. Determine additional water remaining in system when an engine supplying 500 gpm had static pressure of 55 psi and residual of 50 psi

1. DP = S - R

a. DP = 55 - 50

b. DP = 5 psi

2. First digit of static pressure X 1

a. 5 X 1 = 5

3. 5 is equal to 5

4. 1500 gpm still available in hydrant

M. Determine additional water remaining in system when an engine supplying 1250 gpm had static pressure of 95 psi and residual of 72 psi

1. DP = S - R

a. DP = 95 - 72

b. DP = 23 psi

2. First digit of static pressure X 1

a. 9 X 1 = 9

3. 23 not less than 9

4. First digit of static pressure X 2
   a. 9 X 2 = 18
5. 23 not less than 18
6. First digit of static pressure X 3
   a. 9 X 3 = 27
7. 23 less than 27
8. 1250 gpm still available in hydrant

<u>APPLICATION:</u> Ask class to:

<u>SUMMARY:</u> Does anyone have any questions or comments?

<u>CONCLUSION: & ASSIGNMENT:</u> If there are no further questions, I will hand out a written test for you to complete. A minimum score of 70% is needed to pass the test and receive credit for the class.

DRILL GROUND PREPARATIONS
FOR PUMPER OPERATOR
HYDRAULICS (Part II)
PRACTICAL EXERCISES

Materials Needed:

1. One (1) engine with operator
2. Supply Lines (2 1/2" and/or 3")
3. Fire Hydrant (output should exceed capacity of pump)
4. Discharge Lines (hand lines and master stream lines)
5. Master Stream Device(s) with straight tips and adjustable fog nozzles
6. Flow Test Kit
7. In-lines Gauges (1 1/2" & 2 1/2" * 0# - 300#)

NAME:___________________________________ **DATE:**____________________

HYDRAULICS II EVALUATION

1. T F A centrifugal fire pump pulls water through a hard suction hose from a static water source to supply fire department hoselines.

2. T F Maximum lift for a centrifugal fire pump is generally assumed to be 25'.

3. T F Atmospheric pressure has no effect on the ability of a centrifugal fire pump to lift water from a static source.

4. T F Fire pumps are rated and tested at a maximum lift of 10'.

5. T F The fire service commonly refers to Pounds per Square Inch Absolute (PSIA) as Pounds per Square Inch (PSI).

6. T F Lift is defined as the difference in elevation between the strainer and the center of the pump.

7. T F As the altitude increases, the atmospheric pressure decreases, reducing the lifting ability of the centrifugal fire pump.

8. T F The hard suction should be at a 30° angle to the pump for maximum water flow.

9. List three (3) things which affect the lift distance of a centrifugal fire pump.

   1. ____

   2. ____

   3. ____

   $FL = CQ^2L$

10. Find the friction loss in two 250' handlines of 1 3/4" hose equipped with fog nozzles flowing 150 gpm each.

11. Find the friction loss in two 200' handlines of 1 1/2" hose equipped with fog nozzles flowing 100 gpm each.

12. Find the pump discharge pressure required to supply three 2 1/2" handlines, each 500' in length, equipped with fog nozzles flowing 250 gpm each.

13. Find the pump discharge pressure required to supply two handlines of 1 3/4" hose, one 150' long flowing 200 gpm and the other 200' long flowing 150 gpm. Each line is equipped with a fog nozzle.

14. Find the pump discharge pressure required to supply two handlines of 1 1/2" hose, one 150' in length and one 200' in length, equipped with fog nozzles flowing 100 gpm each.

15. Find the nozzle pressure required to supply four 2 1/2" handlines equipped with fog nozzles, two 200' in length flowing 250 gpm and two 300' in length flowing 200 gpm.

16. Find the pump discharge pressure required to supply four fog nozzle equipped handlines, one 1 1/2" hose 150' long flowing 150 gpm, one 1 3/4" hose 200' in length flowing 200 gpm, one 2 1/2" hose 600' long flowing 250 gpm and one 2 1/2" hose 800' long flowing 200 gpm.

17. Determine the additional water remaining in a system when an engine supplying 500 gpm had a static pressure of 90 psi and a residual pressure of 69 psi.

18. Determine the additional water remaining in a system when an engine supplying 750 gpm had a static pressure of 60 psi and a residual pressure of 53 psi.

FRICTION LOSS COEFFICIENTS - SINGLE LINE	
Hose Diameter (in inches)	**Coefficient (C)**
3/4" booster	1100.0
1" booster	150.0
1 1/2"	24.0
1 3/4"	15.5
2 1/2"	2.0
3"	0.8
4"	0.2
4 1/2"	0.1
5"	0.08
6"	0.05

FRICTION LOSS COEFFICIENTS - SIAMESED LINES OF EQUAL LENGTH	
Hose Diameter (in inches)	**Coefficient (C)**
Two 2 1/2"	0.5
One 3" & One 2 1/2"	0.3
Three 2 1/2"	0.22
Two 3"	0.2
Two 2 1/2" & One 3"	0.16
Two 3" & One 2 1/2"	0.12

ADDITIONAL WATER AVAILABLE AT A HYDRANT	
Percent Decrease of Compound Gauge Pressure	**Additional Water Available**
0-10	3 times amount being delivered
11-15	2 times amount being delivered
16-25	Same amount as being delivered
25+	More water might be available, but not as much as is being delivered

ANSWER KEY
HYDRAULICS II EVALUATION

1. T ***F*** A centrifugal fire pump pulls water through a hard suction hose from a static water source to supply fire department hoselines.

2. ***T*** F Maximum lift for a centrifugal fire pump is generally assumed to be 25'.

3. T ***F*** Atmospheric pressure has no effect on the ability of a centrifugal fire pump to lift water from a static source.

4. ***T*** F Fire pumps are rated and tested at a maximum lift of 10'.

5. T ***F*** The fire service commonly refers to Pounds per Square Inch Absolute (PSIA) as Pounds per Square Inch (PSI).

6. T ***F*** Lift is defined as the difference in elevation between the strainer and the center of the pump.

7. ***T*** F As the altitude increases, the atmospheric pressure decreases, reducing the lifting ability of the centrifugal fire pump.

8. T ***F*** The hard suction should be at a 30° angle to the pump for maximum water flow.

9. List three (3) things which affect the lift distance of a centrifugal fire pump.

   1. Altitude
   2. Weather
   3. Water Temperature
   4. Hydraulic Losses
   5. Condition of Equipment

10. Find the friction loss in two 250' handlines of 1 3/4" hose equipped with fog nozzles flowing 150 gpm each.

    $FL = CQ^2L$
    $FL = (15.5)(1.5)^2(2.5)$
    $FL = 15.5 \times 2.25 \times 2.5$
    $FL = 15.5 \times 5.625$
    FL = 87.1875 PSI

11. Find the friction loss in two 200' handlines of 1 1/2" hose equipped with fog nozzles flowing 100 gpm each.

$FL = CQ^2L$
$FL = (24)(1)^2(2)$
FL = 24 X 1 X 2
FL = 24 X 2
FL = 48 PSI

12. Find the pump discharge pressure required to supply three 2 1/2" handlines, each 500' in length, equipped with fog nozzles flowing 250 gpm each.

$FL = CQ^2L$	PDP = FL + NP
$FL = (2)(2.5)^2(5)$	PDP = 62.5 + 100
FL = 2 x 6.25 X 5	***PDP = 162.5 PSI***
FL = 2 X 31.25	
FL = 62.5 PSI	

13. Find the pump discharge pressure required to supply two handlines of 1 3/4" hose, one 150' long flowing 200 gpm and the other 200' long flowing 150 gpm. Each line is equipped with a fog nozzle.

$FL = CQ^2L$	$FL = CQ^2L$	PDP = FL + NP
$FL = (15.5)(2)^2(1.5)$	$FL = (15.5)(1.5)^2(2)$	PDP = 93 + 100
FL = 15.5 X 4 X 1.5	FL = 15.5 X 2.25 X 2	***PDP = 193 PSI***
FL = 15.5 X 6	FL = 15.5 X 4.5	
FL = 93 PSI (Hose #1)	FL = 69.75 PSI (Hose #2)	

14. Find the pump discharge pressure required to supply two handlines of 1 1/2" hose, one 150' in length and one 200' in length, equipped with fog nozzles flowing 100 gpm each.

$FL = CQ^2L$	$FL = CQ^2L$	PDP = FL + NP
$FL = (24)(1)^2(1.5)$	$FL = (24)(1)^2(2)$	PDP = 48 + 100
FL = 24 X 1 X 1.5	FL = 24 X 1 X 2	***PDP = 148 PSI***
FL = 24 X 1.5	FL = 24 X 2	
FL = 36 PSI (Hose #1)	FL = 48 PSI (Hose #2)	

15. Find the nozzle pressure required to supply four 2 1/2" handlines equipped with fog nozzles, two 200' in length flowing 250 gpm and two 300' in length flowing 200 gpm.

REQUIRED FOG NOZZLE PRESSURE = 100 PSI

16. Find the pump discharge pressure required to supply four fog nozzle equipped handlines, one 1 1/2" hose 150' long flowing 150 gpm, one 1 3/4" hose 200' in length flowing 200 gpm, one 2 1/2" hose 600' long flowing 250 gpm and one 2 1/2" hose 800' long flowing 200 gpm.

$FL = CQ^2L$	$FL = CQ^2L$	$FL = CQ^2L$
$FL = (24)(1.5)^2(1.5)$	$FL = (15.5)(2)^2(2)$	$FL = (2)(2.5)^2(6)$
FL = 24 X 2.25 X 1.5	FL = 15.5 X 4 X 2	FL = 2 X 6.25 X 6
FL = 24 X 3.375	FL = 15.5 X 8	FL = 2 X 37.5
FL = 81 PSI (Hose #1)	FL = 124 PSI (Hose #2)	FL = 75 PSI (Hose #3)

$FL = CQ^2L$	PDP = FL + NP
$FL = (2)(2)^2(8)$	PDP = 124 + 100
FL = 2 X 4 X 8	***PDP = 224 PSI***
FL = 2 X 32	
FL = 64 PSI (Hose #4)	

17. Determine the additional water remaining in a system when an engine supplying 500 gpm had a static pressure of 90 psi and a residual pressure of 69 psi.

DP = S - R	FIRST DIGIT OF STATIC PRESSURE X
DP = 90 - 69	9 X 1 = 9
DP = 21 PSI	9 X 2 = 18
	9 X 3 = 27

21 IS LESS THAN 27, SO THERE IS STILL 500 GPM AVAILABLE

18. Determine the additional water remaining in a system when an engine supplying 750 gpm had a static pressure of 60 psi and a residual pressure of 53 psi.

DP = S - R	FIRST DIGIT OF STATIC PRESSURE X
DP = 60 - 53	6 X 1 = 6
DP = 7 PSI	6 X 2 = 12
	6 X 3 = 18

7 IS LESS THAN 12, SO THERE IS STILL 1500 GPM AVAILABLE

STUDENT MANUAL
HYDRAULICS (Part II)

STANDARD: NFPA 1002 (1998 Edition)

REFERENCE:
IFSTA "Fire Stream Practices", 7th Edition
IFSTA "Water Supplies", 4th Edition
IFSTA "Pumping Apparatus", 7th Edition
Fire Service Hydraulics, 2nd Edition, Donnelley
Fire Apparatus Practices, 3rd Edition, Ervin
Engine Company Fireground Operations, 2nd Edition, Richman

OBJECTIVES: At the end of this class the apparatus operator shall be able to:

1. Using written formulas, determine the following:
   a. friction loss in wyed lines when size of hose and gpm flow are given
   b. friction loss in multiple lines when the size of the hose and gpm flow are given
   c. an estimated remaining available volume from a hydrant while pumping a given volume
2. Describe variables which affect the pumper's ability to lift water

I. FLUID AND PRESSURE

A. Theory of Pressure (Understanding Fluids)

1. Fluids have no shape
2. They can flow from place to place
3. Fluids have no adhesive quality
4. Fluids cannot be lifted
5. Fluids must be pushed
6. Fluids must be confined to have direction
7. Fluids are a liquid or gas
8. Physical states of water

B. Fluids at Rest (Static)

1. No physical action

2. Cannot be compressed

3. Will not store pressure

4. Is pumped easily

5. Flows to areas of less pressure

6. Water pressure (static)

C. Fluids in Motion

1. Controlled by Law of Inertia

a. Definition of:

(1) "a body at rest will remain at rest, and a body in motion will remain in uniform motion along a straight line, unless it is acted upon by an unbalanced force"

2. Have velocity

3. Create friction

4. Have elevation loss / gain

5. Have pressure loss due to movement (friction loss)

D. Water Pressure

1. Generated three ways

2. Types of pressure

a. Atmospheric

b. Head

c. Static

d. Normal operating

e. Residual

f. Flow (velocity)

3. Measurement

   a. Measured in pounds per square inch (psi) using gauge

   b. Gauges are usually zeroed at normal atmospheric pressures, thus pressures registered at gauge will not include atmospheric pressure

   c. Fire service commonly refers to Pounds per Square Inch Gauge (PSIG) as Pounds per Square Inch (PSI)

   d. Pounds per Square Inch Absolute (PSIA) is pressure above absolute zero or perfect vacuum

E. Lift

1. Definition of (for this class):

   a. "The difference in elevation between the water level and the center of the pump"

2. Principles of lift

3. Theoretical lift

   a. Defined as:

      (1) "the theoretical, scientific height that a column of water may be lifted by atmospheric pressure in a true vacuum"

4. Maximum lift

   a. Defined as:

      (1) "the maximum height to which any amount of water may be raised through a hard suction hose to a pump"

5. Dependable lift

   a. Defined as:

      (1) "the height a column of water may be lifted in sufficient quantity to provide a reliable fire flow"

6. Factors affecting lift distance:

   a. Altitude

   b. Weather

   c. Water temperature

   d. Hydraulic losses

   e. Condition of apparatus

II. DETERMINING FRICTION LOSS

A. Single Lines / Siamesed Lines of Equal Length

1. Formula to calculate friction loss in fire hose:

   a. $FL = CQ^2L$

      (1) **FL** is friction loss in psi

      (2) **C** is friction loss coefficient

      (3) **Q** is GPM flow divided by 100

(a) Q = GPM ÷ 100

(4) **L** is hose length divided by 100

(a) L = Hose Length ÷ 100

FRICTION LOSS COEFFICIENTS - SINGLE LINE	
Hose Diameter (in inches)	**Coefficient (C)**
3/4" booster	1100.0
1" booster	150.0
1 1/2"	24.0
1 3/4"	15.5
2 1/2"	2.0
3"	0.8
4"	0.2
4 1/2"	0.1
5"	0.08
6"	0.05

FRICTION LOSS COEFFICIENTS - SIAMESED LINES OF EQUAL LENGTH	
Hose Diameter (in inches)	**Coefficient (C)**
Two 2 1/2"	0.5
One 3" & One 2 1/2"	0.3
Three 2 1/2"	0.22
Two 3"	0.2
Two 2 1/2" & One 3"	0.16
Two 3" & One 2 1/2"	0.12

2. Find friction loss in 100' of 2 1/2" flowing 500 GPM

a. C = Friction Loss Coefficient for 2 1/2" hose

(1) C = 2

b. Q = GPM ÷ 100

(1) Q = 500 ÷ 100

(2) Q = 5

c. L = Hose Length ÷ 100

(1) L = 100 ÷ 100

(2) L = 1

d. $FL = CQ^2L$

(1) FL = $(2)(5)^2(1)$

(2) FL = 2 x 25 x 1

(3) FL = 50 x 1

(4) FL = 50 PSI

3. Find friction loss in 500' of 2 1/2" hose flowing 300 GPM

   a. C = Friction Loss Coefficient for 2 1/2" hose

      (1) C = 2

   b. Q = GPM ÷ 100

      (1) Q = 300 ÷ 100

      (2) Q = 3

   c. L = Hose Length ÷ 100

      (1) L = 500 ÷ 100

      (2) L = 5

   d. FL = CQ^2L

      (1) FL = $(2)(3)^2(5)$

      (2) FL = 2 x 9 x 5

      (3) FL = 18 x 5

      (4) FL = 90 PSI

4. Find friction loss in 100' of 1 3/4" hose flowing 200 GPM

   a. C = Friction Loss Coefficient for 1 3/4" hose

      (1) C = 15.5

   b. Q = GPM ÷ 100

      (1) Q = 200 ÷ 100

      (2) Q = 2

   c. L = Hose Length ÷ 100

(1) $L = 100 \div 100$

(2) $L = 1$

d. $FL = CQ^2L$

(1) $FL = (15.5)(2)^2(1)$

(2) $FL = 15.5 \times 4 \times 1$

(3) $FL = 62 \times 1$

(4) FL = 62 PSI

5. Find friction loss in 500' of 3" hose flowing 500 GPM

a. C = Friction Loss Coefficient for 3" hose

(1) $C = .8$

b. $Q = GPM \div 100$

(1) $Q = 500 \div 100$

(2) $Q = 5$

c. L = Hose Length ÷ 100

(1) $L = 500 \div 100$

(2) $L = 5$

d. $FL = CQ^2L$

(1) $FL = (.8)(5)^2(5)$

(2) $FL = .8 \times 25 \times 5$

(3) $FL = 20 \times 5$

(4) FL = 100 PSI

6. Find friction loss in 150' of 1 1/2" flowing 60 GPM

a. C = Friction Loss Coefficient for 1 1/2" hose

(2) $C = 24$

b. $Q = GPM \div 100$

(1) $Q = 60 \div 100$

(2) $Q = .6$

c. $L = \text{Hose Length} \div 100$

(1) $L = 150 \div 100$

(2) $L = 1.5$

d. $FL = CQ^2L$

(1) $FL = (24)(.6)^2(1.5)$

(2) $FL = 24 \times .36 \times 1.5$

(3) $FL = 8.64 \times 1.5$

(4) $FL = 12.96$ PSI

7. Find friction loss in 500' of two 3" hoses flowing 1000 GPM

a. C = Friction Loss Coefficient for double 3" lines

(1) $C = .2$

b. $Q = GPM \div 100$

(1) $Q = 1000 \div 100$

(2) $Q = 10$

c. $L = \text{Hose Length} \div 100$

(1) $L = 500 \div 100$

(2) $L = 5$

d. $FL = CQ^2L$

(1) $FL = (.2)(10)^2(5)$

(2) $FL = .2 \times 100 \times 5$

(3) $FL = 20 \times 5$

(4) $FL = 100$ PSI

8. Find friction loss in 1000' of 5" flowing 1000 GPM

9. Find friction loss in 150' of 1 1/2" flowing 125 GPM

10. Find friction loss in 750' of one 3" and one 2 1/2" hose flowing 750 GPM

11. Find friction loss in 200' of 3/4" booster hose flowing 20 GPM

12. Find friction loss in 1200' of one 3" and one 2 1/2" hose flowing 1000 GPM

13. Find friction loss in 700' of one 3" and one 2 1/2" hose flowing 1000 GPM

14. Find friction loss in 1000' of two 3" and one 2 1/2" hose flowing 1200 GPM

B. Pump Discharge Pressure (In PSI)

1. Formula for finding required Pump Discharge Pressure (PDP) is:

a. PDP = NP + FL

(1) **PDP** is pump discharge pressure

(2) **NP** is nozzle pressure

NOTE

MOST FOG NOZZLES ARE DESIGNED TO OPERATE AND DELIVER RATED GALLONAGES AT 100 PSI. FOR THIS CLASS, USE 100 PSI NOZZLE PRESSURE TO CALCULATE PUMP DISCHARGE PRESSURE WHEN UTILIZING FOG NOZZLES. WHEN YOU GO HOME, FLOW PRESSURES SHOULD BE DETERMINED FOR ALL FOG NOZZLES UTILIZED BY YOUR DEPARTMENT AND THESE PRESSURES SHOULD BE USED TO CALCULATE YOUR REQUIRED PUMP DISCHARGE PRESSURE.

(3) **FL** is friction loss

2. Find pump discharge pressure required for supplying 200' of 2 1/2" hose equipped with 200 GPM fog nozzle operating at 100 PSI nozzle pressure

a. C = Friction Loss Coefficient for 2 1/2" hose

(1) C = 2

b. Q = GPM ÷ 100

(1) Q = 200 ÷ 100

(2) Q = 2

c. L = Hose Length ÷ 100

(1) L = 200 ÷ 100

(2) L = 2

d. $FL = CQ^2L$

(1) $FL = (2)(2)^2(2)$

(2) FL = 2 x 4 x 2

(3) FL = 8 x 2

(4) FL = 16 PSI

e. PDP = NP + FL

(1) PDP = 100 + 16

(2) PDP = 116 PSI

3. Find pump discharge pressure required for supplying 200' of 1 3/4" hose equipped with 200 GPM automatic fog nozzle

a. C = Friction Loss Coefficient for 1 3/4" hose

(1) C = 15.5

b. Q = GPM ÷ 100

(1) Q = 200 ÷ 100

(2) Q = 2

c. L = Hose Length ÷ 100

(1) L = 200 ÷ 100

(2) L = 2

d. $FL = CQ^2L$

(1) $FL = (15.5)(2)^2(2)$

(2) FL = 15.5 x 4 x 2

(3) FL = 62 x 2

(4) FL = 124 PSI

e. PDP = NP + FL

(1) PDP = 100 + 124

(2) PDP = 224 PSI

4. Find pump discharge pressure required for supplying 200' of 2 1/2" hose equipped with 350 GPM fog nozzle operating at 100 PSI nozzle pressure

5. Find pump discharge pressure required for supplying 200' of 1 3/4" hose equipped with 350 GPM automatic fog nozzle

C. Determining Friction Loss in Multiple Lines

1. Lines of equal diameter and length

a. Find friction loss in two 200' handlines of 1 3/4" hose with equipped with fog nozzles flowing 200 gpm each

(1) C = friction loss coefficient for 1 3/4" hose

(a) C = 15.5

(2) Q = GPM ÷ 100

(a) Q = 200 ÷ 100

(b) Q = 2

(3) L = hose length ÷ 100

(a) L = 200 ÷ 100

(b) L = 2

(4) $FL = CQ^2L$

(a) $FL = (15.5)(2)^2(2)$

(b) FL = 15.5 X 4 X 2

(c) FL = 62 X 2

(d) FL = 124 PSI

b. Find friction loss in two 150' handlines of 1 1/2" hose equipped with fog nozzles flowing 100 gpm each

c. Find pump discharge pressure required to supply four 2 1/2" handlines, each 300' in length, equipped with fog nozzles flowing 250 gpm

2. Lines of equal diameter and unequal length

a. Find pump discharge pressure required to supply two handlines of 1 3/4" hose, one 150' and one 200' in length, equipped with fog nozzles flowing 200 gpm each

(1) hose #1

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 150 ÷ 100

ii. L = 1.5

(d) $FL = CQ^2L$

i. $FL = (15.5)(2)^2(1.5)$

ii. FL = 15.5 X 4 X 1.5

iii. FL = 62 X 1.5

iv. FL = 93 PSI

(2) hose #2

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 200 ÷ 100

ii. L = 2

(d) FL = CQ^2L

i. FL = $(15.5)(2)^2(2)$

ii. FL = 15.5 X 4 X 2

iii. FL = 62 X 2

iv. FL = 124 PSI

(3) PDP = NP + FL

(a) PDP = 100 + 124

(b) PDP = 224 PSI

b. Find pump discharge pressure required to supply two handlines of 1 1/2" hose, one 100' and one 150' in length, equipped with fog nozzles flowing 100 gpm each

c. Find pump discharge pressure required to supply four 2 1/2" handlines equipped with fog nozzles, two 200' in length flowing 250 gpm and two 300' in length flowing 200 gpm

3. Lines of unequal diameter and equal length

a. Find pump discharge pressure required to supply two handlines 150' in length, one 1 3/4" hose and one 1 1/2", equipped with fog nozzles flowing 100 gpm each

(1) hose #1

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 100 ÷ 100

ii. $Q = 1$

(c) L = hose length ÷ 100

i. $L = 150 \div 100$

ii. $L = 1.5$

(d) $FL = CQ^2L$

i. $FL = (15.5)(1)^2(1.5)$

ii. FL = 15.5 X 1 X 1.5

iii. FL = 15.5 X 1.5

iv. FL = 23.25 PSI

(2) hose #2

(a) C = friction loss coefficient for 1 1/2" hose

i. $C = 24$

(b) Q = GPM ÷ 100

i. $Q = 100 \div 100$

ii. $Q = 1$

(c) L = hose length ÷ 100

i. $L = 150 \div 100$

ii. $L = 1.5$

(d) $FL = CQ^2L$

i. $FL = (24)(1)^2(1.5)$

ii. FL = 24 X 1 X 1.5

iii. FL = 24 X 1.5

iv. FL = 36 PSI

(3) PDP = NP + FL

(a) PDP = 100 + 36

(b) PDP = 136 PSI

b. Find pump discharge pressure required to supply three handlines, two 1 1/2" hoses 200' in length flowing 100 gpm through automatic fog nozzles and one 2 1/2" hose 200' in length flowing 250 gpm through fog nozzle.

c. Find pump discharge pressure required to supply four fog nozzle equipped handlines 200' in length, one 1 1/2" flowing 60 gpm, two 1 3/4" hoses flowing 100 gpm and one 2 1/2" flowing 250 gpm

4. Lines of unequal diameter and length

a. Find pump discharge pressure required to supply two handlines, one 1 3/4" hose 250' in length flowing 200 gpm through an automatic fog nozzle and one 2 1/2" hose 400' long equipped with fog nozzle flowing 250 gpm

(1) hose #1

(a) C = friction loss coefficient for 1 3/4" hose

i. C = 15.5

(b) Q = GPM ÷ 100

i. Q = 200 ÷ 100

ii. Q = 2

(c) L = hose length ÷ 100

i. L = 250 ÷ 100

ii. L = 2.5

(d) $FL = CQ^2L$

i. $FL = (15.5)(2)^2(2.5)$

ii. FL = 15.5 X 4 X 2.5

iii. FL = 62 X 2.5

iv. FL = 155 PSI

(2) hose #2

(a) C = friction loss coefficient for 2 1/2" hose

i. C = 2

(b) Q = GPM ÷ 100

i. Q = 250 ÷ 100

ii. Q = 2.5

(c) L = hose length ÷ 100

i. L = 400 ÷ 100

ii. L = 4

(d) $FL = CQ^2L$

i. $FL = (2)(2.5)^2(4)$

ii. FL = 2 X 6.25 X 4

iii. FL = 12.5 X 4

iv. FL = 50 PSI

(3) PDP = NP + FL

(a) PDP = 100 + 155

(b) PDP = 255 PSI

b. Find pump discharge pressure required to supply three handlines equipped with automatic fog nozzles, one 1 1/2" hose 150' in length flowing 125 gpm, one 1 3/4" hose 200' long flowing 150 gpm and one 2 1/2" hose 350' in length flowing 250 gpm

c. Find pump discharge pressure required to supply four fog nozzle equipped handlines, one 1 1/2" hose 100' long flowing 200 gpm, one 1 3/4" hose 300' in length flowing 150 gpm, one 2 1/2" hose 500' long flowing 250 gpm and one 2 1/2" hose 700' long flowing 200 gpm

C. Determining Friction Loss in Wyed Lines

NOTE

THE FRICTION LOSS THROUGH WYES AND SIAMESES WILL VARY WITH THE SIZE, FLOW, AND DESIGN OF THE APPLIANCE. AS WITH FIRE HOSE, THE ONLY TRUE AND ACCURATE WAY TO DETERMINE THE ACTUAL FRICTION LOSS IS TO TEST IT. THE RULE OF THUMB FRICTION LOSS THROUGH A WYE OR SIAMESE IS BASED ON FLOW. FOR FLOWS LESS THAN 350 GPM WE ASSUME A FRICTION LOSS OF 0 PSI, FOR FLOWS GREATER THAN 350 GPM WE ASSUME A FRICTION LOSS OF 10 PSI.

1. Equal length lines

a. Determine total friction loss in hose assembly consisting of 500' of 2 1/2" hose wyed out to two 150' long 1 1/2" handlines flowing 100 gpm each

b. Determine total friction loss in hose assembly consisting of 400' of 3" hose wyed out to two 300' long 2 1/2" handlines flowing 250 gpm each

c. Determine total friction loss in hose assembly consisting of 800' of 4" hose wyed out to two 300' long 2 1/2" handlines flowing 250 gpm each

2. Unequal length lines

a. Determine total friction loss in hose lay consisting of 600' of 2 1/2" hose wyed out to two 1 1/2" handlines, one 100' and one 200' in length, flowing 125 gpm each

b. Determine total friction loss in hose assembly consisting of 500' of 3" hose wyed out to one 1 3/4" hose 150' in length flowing 200 gpm and one 300' long 2 1/2" handline flowing 250 gpm

c. Determine total friction loss in hose assembly consisting of 600' of 4" hose wyed out to one 200' long 2 1/2" line to master stream flowing 350 gpm and one 3" hose 250' in length flowing 500 gpm through master stream

III. CALCULATING AVAILABLE WATER

A. Static pressure registers on compound gauge when not flowing water

B. Residual pressure registers on compound gauge when water flowing

C. Difference between two pressures used to determine how much more water hydrant can supply

D. Two (2) methods:

E. Percentage method calculated using formula:

1. **PD = (S - R) 100 ÷ S**

a. **PD** is percent drop

b. **S** is static (pressure)

c. **R** is residual (pressure)

2. Percentage of pressure loss then compared to chart to identify quantity of water still available (if any)

ADDITIONAL WATER AVAILABLE AT A HYDRANT	
Percent Decrease of Compound Gauge Pressure	**Additional Water Available**
0-10	3 times amount being delivered
11-15	2 times amount being delivered
16-25	Same amount as being delivered
25+	More water might be available, but not as much as is being delivered

F. Determine additional water remaining in system when an engine supplying 500 gpm had static pressure of 65 psi and residual of 50 psi

1. PD = (S - R) 100 ÷ S

a. PD = (65 - 50)(100) ÷ 65

b. PD = 15 X 100 ÷ 65

c. PD = 1500 ÷ 65

d. PD = 23%

2. Based on the percentage of pressure loss, use chart to determine how much water still available in system

a. 500 gpm

G. Determine additional water remaining in system when an engine supplying 750 gpm had static pressure of 110 psi and residual of 95 psi

1. Based on the percentage of pressure loss, use chart to determine how much water still available in system

H. Determine additional water remaining in system when an engine supplying 600 gpm had static pressure of 80 psi and residual of 65 psi

1. Based on the percentage of pressure loss, use chart to determine how much water still available in system

I. Determine additional water remaining in system when an engine supplying 250 gpm had static pressure of 65 psi and residual of 52 psi

1. Based on the percentage of pressure loss, use chart to determine how much water still available in system

J. First-digit method

1. Find psi difference between static and residual pressures

2. Multiply first digit of static pressure by 1, 2, or 3 to determine how much additional flow left

3. If psi drop equal to or less than first digit of static pressure multiplied by one (1), three times amount being used still available

4. If psi drop equal to or less than first digit of static pressure multiplied by two (2), twice amount being used still available

5. If psi drop equal to or less than first digit of static pressure multiplied by three (3), same amount as being used still available

K. Determine additional water remaining in system when an engine supplying 250 gpm had static pressure of 65 psi and residual of 58 psi (student manual example)

1. **DP = S - R**

   a. **DP** = Difference in pressure

   b. **S** = Static pressure

   c. **R** = Residual pressure

2. DP = S - R

   a. DP = S - R

   b. DP = 65 - 58

   c. DP = 7 psi

3. First digit of static pressure X 1

a. 6 X 1 = 6 psi

4. 7 psi not less than 6 psi

5. First digit of static pressure X 2

   a. 6 X 2 = 12 psi

6. 7 psi less than 12 psi

7. 500 gpm still available in hydrant

L. Determine additional water remaining in system when an engine supplying 500 gpm had static pressure of 55 psi and residual of 50 psi

M. Determine additional water remaining in system when an engine supplying 1250 gpm had static pressure of 95 psi and residual of 72 psi