BASIC HYDRAULICS

AN

INTRODUCTION TO FIRE STREAM PRACTICES

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INTRODUCTION

The fire service pump operator (engineer) must supply adequate hose streams with the correct amounts of water at precise pressures in order to insure an effective and safe stream at the nozzle. The engineer must rely upon experience and quick, effective guides to perform this vital function. The engineer is often not allowed sufficient time to perform long hydraulics formulas and exacting slide rule calculations.

The majority of pump operations are performed through a time consuming process of trial and error, which can result in increased fire size, increased radio traffic and equipment damage. As an engineer, you have a limited amount of time to react to the rapid changes that occur within the fire environment.

This workbook is designed to give you the knowledge necessary to adapt to these rapid changes and provide a safe and effective operating environment.

It should be emphasized that the method used for determining proper pump discharge pressure within this text is only one of many possible methods that may be used. The other methods are just as accurate for what they were designed. We feel that this method is more flexible and is better suited for the type of hoselays described in this text.

It is also important to remember that many times theories that work on paper do not always work during "in-field" situations.

The students will be allowed a plus or minus 5 psi error, as friction loss calculators from different manufacturers vary. This does not excuse the student from computing the problem and demonstrating an acceptable explanation as to why their answer is different from the textbook answer.

This text is designed to help you achieve the correct answer, step by step. It will be your responsibility to interpret all portions and perform rudimentary mathematics correctly. By the end of this text you should be able to determine pump discharge pressure (PDP) quickly and correctly.

DETERMINING PUMP DISCHARGE PRESSURE (PDP)

Pump discharge pressure is the amount of pressure in pounds per square inch (psi) indicated on the pressure gauge or any given orifice discharge gauge at the engine. Stream pattern remaining the same, pump discharge pressure is the major controlling factor that changes nozzle pressure and volume of discharge. Adjusting the pump throttle changes pump discharge pressure and volume output.

PUMP DISCHARGE PRESSURE:

PDP = NP +/- H + FL

Where:

PDP = Pump Discharge Pressure
Pressure at the discharge side of the pump

NP = Nozzle Pressure
Pressure at the nozzle

+/-H = Head (elevation differential)
.434psi will lift water vertically 1 foot; 43.4psi will lift water vertically 100 feet.

FL = Friction loss per every 100 feet of hose

We will use the standard for this text of 0.5psi will lift water vertically 1 foot or 1psi will lift water vertically 2 feet. This standard will be discussed in greater detail further on in the text.

PUMP DISCHARGE PRESSURE: (continued)

Elements that you must have as a fire engine operator in order to correctly calculate pump discharge pressure (PDP) are:

1. **Length of hose in the hoselay**
2. **Diameter of hose**
3. **Volume flow rate**
4. **Elevation differential (vertical rise or fall) between hoselay and pump**
5. **Working nozzle pressure**

The above five elements are used in all pumping operations to solve for pump discharge pressure. The relationship between these five elements can be expressed mathematically in the following formula:

$$PDP = NP +/- H + FL$$

The next section discusses each element of the formula and their relationship to determining PDP.

NOZZLE PRESSURE (NP): PDP = **NP** +/- H + FL

For our purposes, fire streams are divided into two categories:

1. Solid stream nozzles (tips)..50psi
2. Fog stream nozzles (combination)................................…...100psi

Tips and combination nozzles were designed to work most effectively at the above-designated pressures.

All fog streams in this workbook are considered to be combination nozzles with the exception of the "Forester" (R5) nozzle, which will always be computed as a straight stream nozzle at 50psi.

A straight stream nozzle is used to supply large concentrations of water in one specific location or in cases where a long reach is required.

Fog stream nozzles are designed to break up the water into small particles or droplets. This increases the surface area of the water increasing heat absorption relative to solid streams.

When computing pump discharge pressure, the proper nozzle pressure is the objective and must be established to calculate the correct pump discharge pressure.

- **Remember, all problems in this workbook are calculated with straight stream tips operating at 50psi and combination nozzles operating at 100psi.**

If a fire engine is pumping low volume (<80gpm) a short distance (<50') through a 1-1/2" hose to a small fire, with a combination nozzle, we really only need to consider the "NP" element of the pump discharge pressure formula. In this case, the formula would be PDP = NP. But, note that we must always consider the other four elements of the PDP formula. In this case we considered volume, distance, hose diameter and presumed elevation to be zero.

The desired pressure for a combination nozzle is 100psi. By replacing the NP element with 100psi, we have PDP = 100psi.

HEAD PRESSURE (ELEVATION DIFFERENTIAL):

PDP = NP +/-H + FL

Head is also known as lift, back pressure, gravity loss or gain.

By definition:

Head is the height of water that is necessary to create a given pressure at its base.

Head is measured in terms of vertical feet of water; one foot of head is equivalent to a column of water one foot high. One foot of head exerts a pressure of .434psi at the base. Two feet of head exerts a pressure of .868psi (2x.434) at the base and so on. Conversely, to raise water one foot you would have to create .434psi at its base. To raise water two feet you would have to create .868psi at its base.

The standard rule of thumb used to determine head pressure when solving problems in this workbook will be:

0.5 POUNDS PER SQUARE INCH WILL LIFT WATER 1 FOOT
1.0 POUND PER SQUARE INCH WILL LIFT WATER 2 FEET

The reverse is also true:

- **0.5 POUNDS PER SQUARE INCH WILL BE GAINED FOR EACH 1 FOOT VERTICAL LOSS (drop) IN ELEVATION.**
- **1.0 POUND PER SQUARE INCH WILL BE GAINED FOR EACH 2 FEET VERTICAL LOSS (drop) IN ELEVATION.**

Now, consider that we have a water tank filled to a level 2 feet higher than its base. The pressure exerted by the water at the base of the tank is 1psi. If we attached a pressure gauge to a water outlet at the base of the tank we could expect to have a water pressure of 1psi.

HEAD PRESSURE (continued)

This also means that if we had a water tank filled to a level of 50 feet higher than the base, we can presume that the pressure exerted by the water at the base of the tank will be 25psi (50ft/2psi per ft). If we attached a pressure gauge to a water outlet at the base of the tank we could expect to have a water pressure of 25psi.

Fire engine operators must consider the effects of changes in elevation to supply proper water pressure to the hoselay to provide a proper nozzle pressure.

For instance:

A fire engine is pumping a 300-foot hoselay up a hillside. The vertical change in elevation between the fire engine pump and the top of the hoselay is a 100 feet rise.

What is the required Pump Discharge Pressure to overcome head pressure (gravity) and force water to the end of the hoselay?

By using our rule of thumb, 0.5psi will lift water vertically 1 foot then 50psi will lift water vertically 100 feet (+H). If you engaged the pump on your fire engine and adjusted the pressure to 50psi, you can expect water to be forced to the top of the hoselay. (If no other factors influenced the flow of water.) We will discuss those other factors later.

In the previous example we have only solved the head pressure element (+/-H) in the Pump Discharge Pressure formula. If an R-5 nozzle were added to the end of the hoselay, pump discharge pressure would have to be increased to supply an effective water stream. Solving the formula; PDP = NP +/-H, the result is PDP = 50psi (desired NP) + 50psi (+H), PDP = 100psi.

- Remember, vertical changes in elevation are only considered when solving for head pressure. Head pressure is not a function of hoselay length, but rather the gain (+) or loss (-) in elevation relative to the pump.

If we had a downhill hoselay with a vertical drop of 100 feet, and a KK type (combination) nozzle attached to the end of the hoselay, what would the desired Pump Discharge Pressure be?

- NOTE: Only solve PDP = NP +/-H.

  PDP = 100psi (desired NP) - 50psi (downhill head pressure)
  PDP = 100psi - 50psi
  PDP = 50psi

  So, when the pressure is adjusted to read 50psi on the pump control panel, the pressure at the nozzle will be 100psi. (Presuming all other factors were negligible.)

Downhill hoselays with substantial changes in elevation can be a major problem. The accumulated high water pressure is a safety hazard to the nozzle person and/or any other person in the immediate area. Equipment damage can also be expected. How to overcome these problems will be discussed in greater detail in the classroom.

- **Remember, anytime the nozzle is above the pump add the head pressure to the PDP formula; and when the nozzle is below the pump, subtract head pressure from the PDP formula.**

FRICTION LOSS (FL): PDP = NP +/-H + **FL**

The next element in the PDP formula is friction loss (FL). When moving water comes in contact with the inner lining a hose, a loss of energy will occur due to friction. This energy loss is expressed in pounds per square inch loss. This friction results in an eddying of the water or turbulence within the hose. The "drag" that results consumes energy.

Eddying is caused by the difference in the flow rates of water at the center of the hose and at the outer edges against the lining. The water flowing along the outer edge of the hose is slowed down when it comes in contact with the lining due to friction. The water in the center of the hose flows faster because it is not in contact with any surface. These differences create eddies which retards total water flow. As gpm flow or volume is increased, turbulence is increased, increasing total resistance to flow. Eventually, a point is reached where flow reaches a maximum flow per given length for any given hose.

Maximum flow is that volume of water that can be passed through a given length and diameter hose where the psi required to overcome the FL at that flow does not exceed the limitations of any single part of the system (i.e. broken hose, plumbing or pump).

Since hoselays vary in length from fire to fire, it is easiest to consider friction loss (FL) in terms of a common unit. The calculator supplied with this workbook expresses FL per every one hundred feet of hose. This will be explained in greater detail later.

FACTS ABOUT FRICTION LOSS:

1. The smaller the diameter of the hose, the greater the friction loss.
2. Friction loss factors are computed on 100-foot sections of hose. For each 100-foot length of hose added, whether uphill or downhill, the friction loss of each length added must be determined.
3. The larger the diameter of hose, the less friction loss involved.
4. Friction loss increases 4 times, if the volume is doubled through a given size hose.

5. If the cross sectional area of a hose is doubled, FL decreases 4 times.

REDUCING FRICTION LOSS:

- REDUCE NOZZLE PRESSURE: If the nozzle pressure is reduced, the volume discharged (GPM output) will be less; therefore, the friction loss will be less. This may prevent the fire stream from performing the required task.

- REDUCE NOZZLE SIZE, MAINTAINING SAME NOZZLE PRESSURE: Reducing the nozzle size and maintaining the same nozzle pressure reduces gpm discharged.

CAUTION: The quantity of water being discharged may not be sufficient to cool and completely extinguish the fire.

- LAY PARALLEL HOSE LINES OR INCREASED HOSE DIAMETER: With all other factors remaining constant, two parallel lines will have 1/4 the friction loss of a single line of the same diameter and length, transporting the same quantity of water. Three lines will have 1/9 the friction loss of a single line, and four lines will have 1/16 the friction loss.

(Recently there have been claims and indications that water additives such as foam or wet water may also reduce friction loss.)

SAFETY WARNING!!

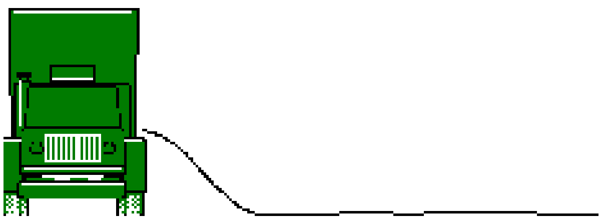
- **ANYTIME YOU MAKE CHANGES WHICH WILL AFFECT A HOSELAY, IMMEDIATELY NOTIFY ALL NOZZLE OPERATORS USING THE LAY PRIOR TO THE MODIFICATION!!**

The Pump Discharge Pressure formula is now complete:

$$\mathbf{PDP = NP +/- H + FL}$$

DETERMINING PDP USING THE FIRE STREAM/FRICTION LOSS CALCULATOR:

Included with the hydraulics workbook is a fire stream calculator. One side is for metric unit calculations and the other side is for English unit calculations. The upper portion of the calculator is used to determine the gallons per minute (gpm) flow through various straight stream nozzle diameters at a selected pressure (psi). The lower portion of the calculator is used to determine friction loss (measured in psi) in a 100-foot section of hose of various diameters. The following example will show you how to use this tool.



100 ft. of 1" line = 23psi loss

The illustration shows an engine pumping, on flat ground, a 100-foot section of one-inch diameter hose. Attached to the end of the hose is a Forester R-5 nozzle with a 3/8 tip. What would be the correct pump discharge pressure to supply 50 psi to the nozzle?

STEP #1 is to write down the PDP formula.

+NP =
+/-H =
+FL =

PDP

(Remember, R-5 nozzles are considered straight stream nozzles (tips) designed to operate at 50 psi).

DETERMINING PDP: (continued)

STEP #2 is to fill-in all known information in the PDP formula prior to using the calculator. We know NP = 50 psi, and +/-H = 0 (there is no rise or loss in elevation). Your PDP formula should now look like the one below.

+NP = 50
+/-H = 0 (flat land)
+FL = ??

PDP ??

The only element left to solve for is Friction Loss (FL).

STEP #3 is to take the “Cascade" calculator and flip to the English measurement side. Adjust the top window labeled “NOZZLE PRESSURE psi” to read 50 on the sliding scale under the upper most arrow.

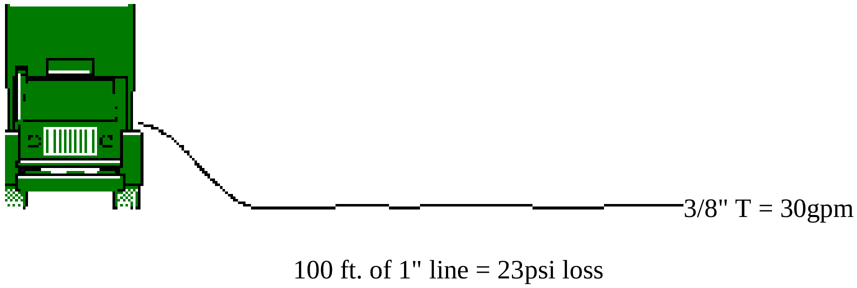
STEP #4 is to determine the amount of gpm flow for a particular size straight stream tip at 50 psi.

In this workbook we will use the top window labeled "NOZZLE DISCHARGE CALCULATOR". To the right of "NOZZLE BORE" are tip sizes ranging from 3/16" to 1-1/4”. Locate 3/8", the tip size for the problem we are solving. Directly above 3/8" is a scale, which reads between 29 gpm and 30 gpm "DISCHARGE US gal/min". The reading is closer to 30 than 29 so we will use 30 gpm.

We have determined that 30 gpm will be flowing through the 100-foot section of 1" hose.

STEP #5 will give the amount of friction loss (psi loss) per 100 feet in length that 30 gpm produces when flowing through a 1" hose.

Using the lower portion of the calculator labeled FRICTION LOSS CALCULATOR, adjust the window marked "FLOW US gal/min" to indicate 30 below the arrow. Refer to the columns on the left side of the calculator marked "psi LOSS PER 100 ft SINGLE LINE” and "SIZE OF HOSE". In the size of hose column, which ranges from 2-1/2" down to 3/4" locate 1". The scale directly above reads almost 23. It is closer to 23 than 22 so we will round up to 23 psi. This is the pressure lost in a 1" hose, for every 100 foot section, with a flow of 30 GPM.



As the above illustration shows, we now have all the elements needed to solve for PDP. It is recommended you label any problems you are solving in this method or a similar manner in order to keep track of all the necessary information. On any test this is how you show your work.

STEP #6 is to fill in FL and determine PDP.

+NP = 50
+/-H = 0
+FL = 23

PDP = 73 psi

The correct answer for our problem is PDP = 73 psi. When pump discharge pressure is adjusted to 73 psi on the pump panel water is forced through the hoselay. Eddy currents are formed creating a 23 psi loss within the 100-foot section of hose. 50 psi is the pressure remaining when the water reaches the nozzle. With a 3/8" tip, 30 gpm will exit the nozzle and supply the desired fire stream.

DETERMINING PDP FOR SIMPLE HOSELAYS:

Let's review the necessary steps to solve a problem:

STEP #1	Write down the PDP formula.
STEP #2	Fill-in all known information prior to using the calculator.
STEP #3	Enter the desired nozzle pressure in the “NOZZLE PRESSURE psi” window.
STEP #4	Determine "DISCHARGE US gal/min" above the desired tip size.
STEP #5	Set the "FLOW US gal/min" under the arrow in the middle window and determine friction loss per 100 foot section of hose using the “psi LOSS PER 100 ft SINGLE LINE” scale over the desired “SIZE OF HOSE” scale in the lowest window of the friction loss calculator.
STEP #6	Fill in the proper FL value, multiple by the number of 100-foot sections and complete the PDP problem.

DETERMINING PDP: (continued)

PROBLEM #2

You are pumping a 1-1/2” hoselay 500 feet long with a 5/16" tip on level ground. What is your pump discharge pressure??

STEP #1

Write out the PDP formula.

+NP =
+/-H =
+FL =

PDP =

STEP #2

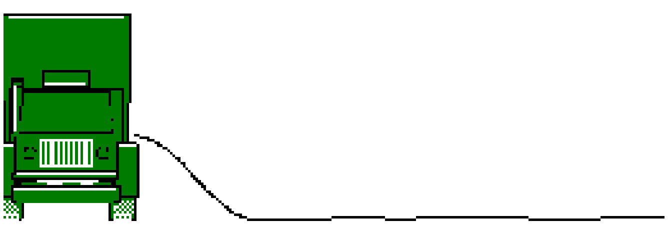
Fill in the known values.

+NP = 50
+/-H = 0
+FL = ??

PDP =

STEP #3 & #4 By setting the “NOZZLE PRESSURE psi” window to 50, the “DISCHARGE US gal/min” for a 5/16" tip is near 21 gpm.

STEP #5 By setting the “DISCHARGE US gal/min” to 21, a 1-1/2" hose will have friction loss of 2psi for each 100 foot section of hose. Remember to round down if your reading is less than ½ way to the next whole number on the scale and up if equal to or greater than ½ the way.



STEP #6

Fill in the FL value and solve the PDP problem.

+NP =50
+/-H = 0
+FL = 10 (five 100’ sections of hose x 2 psi)

PDP = 60 psi

DETERMINING PDP WITH HEAD (ELEVATION DIFFERENTIAL):

PROBLEM #3 You are pumping 800 feet of 1" hose 50 vertical feet above the pump with a 3/8" tip. What is the pump discharge pressure?

STEP **#1**

Write out the PDP formula.

+NP =
+/-H =
+FL =

PDP =

STEP #2

Fill in the known values.

+NP = 50
+/-H = 25 (50'/2 psi per foot)**
+FL = ??

PDP = ??

** **NOTE:** We now have a change in elevation requiring a value for +/-H. The vertical change is 50 feet above the pump so you must <u>add</u> pressure to the PDP formula. If 1 psi will raise water vertically 2 feet then 25 psi will raise water vertically 50 feet.

STEP #3 & #4 By setting the "NOZZLE PRESSURE psi" window to 50 the "DISCHARGE US gal/min" for a 3/8" tip is 30 gpm.

STEP #5 By setting the "FLOW US gal/min" to 30, a 1" hose will have a friction loss value of 23 psi for each 100 foot section of hose.

STEP #6 Multiply the FL per 100-foot section by the number of 100 ft sections

Fill in the FL value and solve the PDP problem.

+NP = 50
+/-H = 25
+FL = 184 (8 x 23 = 184 psi)

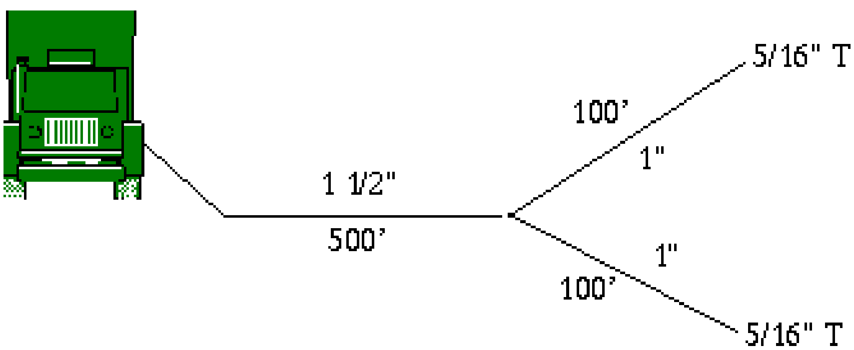
PDP = 259 psi

DETERMINING PDP: (continued)

Before proceeding to the next problem be sure you understand how to correctly complete the previous three. Most mistakes occur by misreading the calculator, using the wrong nozzle pressure, forgetting to properly add or subtract the head pressure or omitting the number of 100 foot sections of hose when determining FL in that hoselay.

NOTE: The graduated scale on the calculator varies. Care must be taken when reading the values. Round up to the nearest whole number when the value is 0.5 to 0.9; round down when the value is 0.1 to 0.4. For example, if you read a value of 2.3, round down to 2.0. If you read a value of 2.7, round up to 3.0. If it is so close you cannot tell, be safe and round up.

PROBLEM #4 You are pumping 500 feet of 1-1/2" hose through a gated wye to two sections of 1" hose each 100 feet long with 5/16" tips on flat ground. What is the pump discharge pressure?



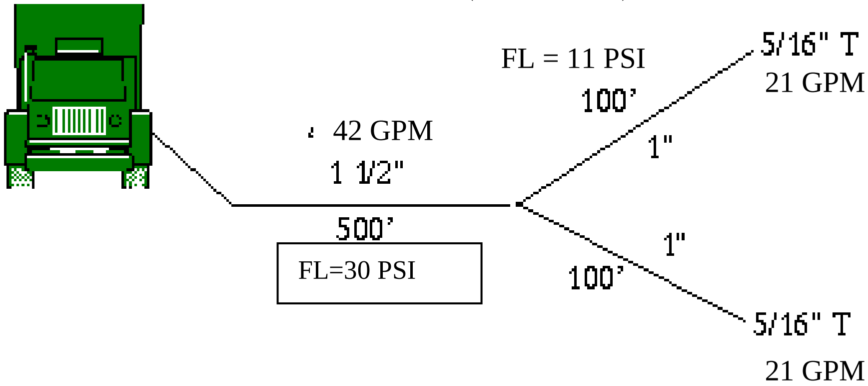
Visualize how the water will flow in problem #4. Pressurized water is forced out of the pump through the 500' section of 1-1/2" hose to the gated wye. An equal amount of water is then forced through each lateral. If the nozzle sizes differed the amounts out each line would differ also. The sum of the water flowing thru each nozzle will have to travel through the 1-1/2" line.

SOLVING PDP:+NP = 50
+/-H = 0
+FL = ??
+FL = ??

PDP

Note that the FL element is divided into 1" FL and 1-1/2" FL. Resistance to flow must be figured for both lengths of hose.

DETERMINING PDP: (continued)



Problem #4 now illustrates that the pump must discharge 42 gpm to supply fire streams to each nozzle.

SOLVING PDP:

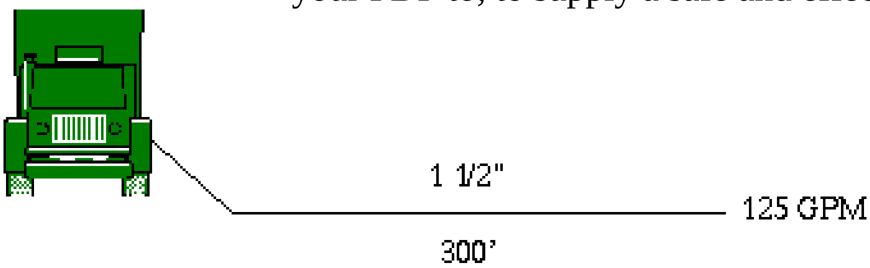
+NP = 50
+/-H = 0
+1" FL = 11 *
+1-1/2" FL = 30 (5 x 6 = 30 psi)

PDP = 91 psi

* **NOTE: RULE OF THUMB**! When solving FL for hoselays with more than one lateral, only use the FL of the lateral which will require **<u>the greatest PDP to achieve the desired working pressure.</u>** We only solve for one nozzle/lateral. If we solve for the nozzle requiring **<u>the greatest PDP to achieve the desired working pressure</u>** than all other nozzles will be supplied adequately if not in excess. In problem #4 the FL for each lateral is the same so a value of 11 psi is used. This will be discussed in greater detail during the classroom session.

DETERMINING PDP: (continued)

PROBLEM #5 You are filling the Engineer (FEO) position on a Model 61 Fire Engine and have been dispatched to a reported smoke in a rural area. Upon arrival you see flames impinging on an occupied structure. Your Captain decides to make an external attack on the structure by deploying 300' of 11/2" hose with a 125gpm combination nozzle. What should you set your PDP to, to supply a safe and effective fire stream??



STEP #1 +NP =
+/-H =
+FL =

Step #2 +NP = 100*
+/-H = 0
+FL = ??
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*REMEMBER: It is common for combination nozzles to operate at 100psi.

OMIT STEPS #3 & #4:

When using combination nozzles the gpm flow is calibrated by the manufacturer at 100 psi and normally marked either on the side or front of the nozzle. If the gpm flow is not indicated you must check the equipment catalogue or contact the manufacturer. This is something you should determine when filling in on an engine you're not accustomed to.

STEP #5:

By setting the "FLOW US gal/min" to 125 a 1-1/2" hose will have a friction loss of 55 psi per each 100 foot section of hose.

DETERMINING PDP: (continued)

STEP #6: Fill in the proper FL value and complete the PDP problem.

SOLVING PDP:

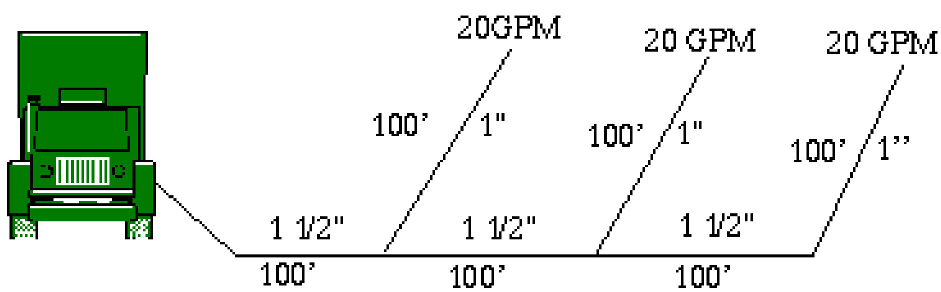
+NP = 100
+/-H = 0
+1-1/2"FL = 165 (3 x 55 = 165 psi)

PDP = 265 psi

DETERMINING PDP FOR PROGRESSIVE HOSELAYS:

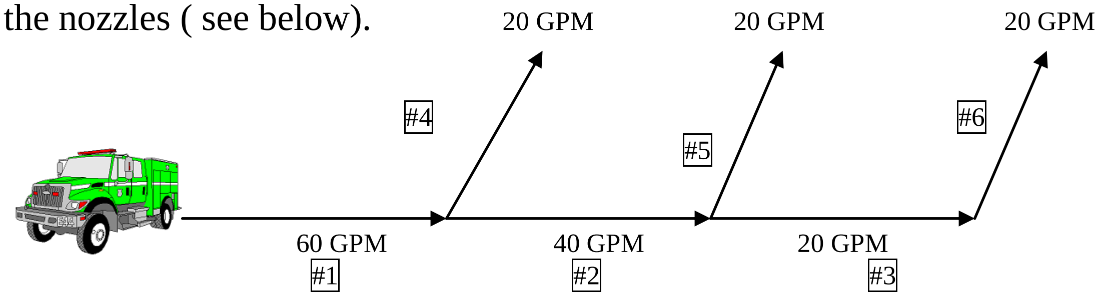
PROBLEM #6 Your Engine and a five-person support crew have been assigned to contain a flare-up in Division C. The Captain decides to deploy three Gansner packs using 20 gpm combination nozzles to suppress the flare-up and the many small spot fires starting on the unburned side of the line. As the Engineer, what is the correct pump discharge pressure?

(Note: Each gansner pack consists of: a 100' section of 1-1/2" hose; a 1-1/2" gated wye with a 1-1/2" to 1" reducer; a 100' section of 1" hose; and a 1" combination nozzle.)



DETERMINING PDP: (continued)

Before solving the problem, visualize how the water will flow through the hoselay and exit the nozzles (see below).



In order to supply each nozzle with 20 gpm, the pump must discharge 60 gpm which flows through the first 100' section of 1-1/2" hose (#1) to lateral (#4). 40 gpm flows through the second section of 1-1/2" hose (#2) to lateral #5. The remaining 20 gpm flows through the third section of 1-1/2" hose (#3) and exits through the lateral (#6).

The path requiring **the greatest PDP to achieve the desired working pressure** is from the pump through all three sections of 1-1/2" hose and through lateral #6. When solving for PDP you must compute the FL for each 100' section of 1-1/2" hose and lateral #6.

SOLVING PDP:

+NP =	100	+NP =	100
+/-H =	0	+/-H =	0
+1"FL (#6) =	?	+1"FL =	10
+1-1/2"FL (#1) =	?	+1-1/2"FL =	13 (@ 60 gpm)
+1-1/2"FL (#2) =	?	+1-1/2"FL =	6 (@ 40 gpm)
+1-1/2"FL (#3) =	?	+1-1/2"FL =	1 (@ 20 gpm)
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PDP =	???	PDP =	130 psi

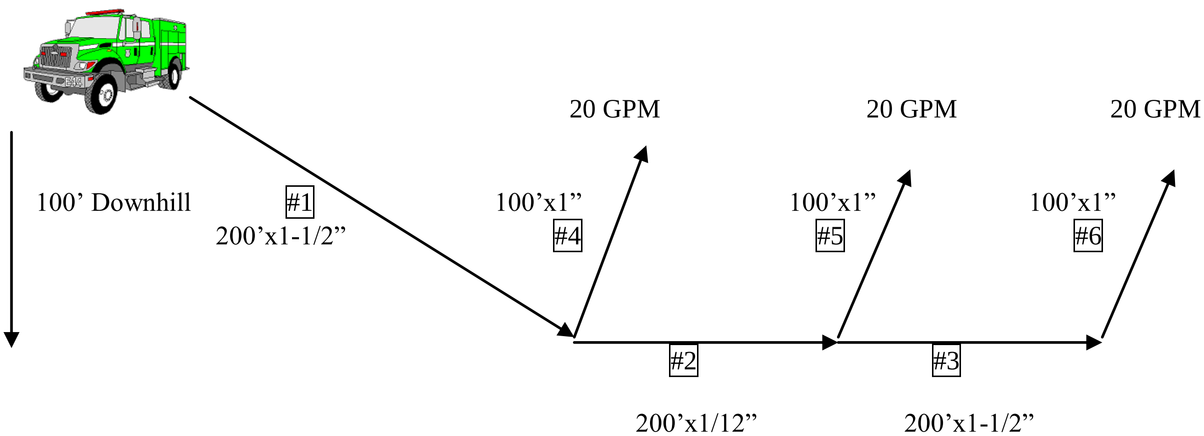
It is recommended you set up the PDP formula in the manner shown above. You will be less likely to make a mistake when computing PDP, especially when there are several sections of hose with various amounts of flow.

Remember to solve for FL for only one lateral: the lateral that will require the greatest PDP to achieve the desired working pressure. In problem #6 all the laterals are the same length (100') and diameter (1") and have identical nozzles.

When the water being discharged by the pump is pressurized to 120 psi each nozzle will deliver the desired fire stream for safe and effective application.

PROBLEM #7:

You have been assigned as a pump operator on a fire. A road on one flank and a handline that surrounds many fingers on the other flank contains the fire. The I.C. has decided to burn out the handline and begin mop-up prior to strong winds predicted for the next operational period. A type 3 engine is located at the top where the handline and road meet. The hoselay extends from the engine downhill along the handline to the road. The vertical drop between the pump and the bottom of the fire is 100 feet. What is the PDP needed to supply 100 psi to the bottom nozzle?



SOLVING PDP:

+NP = 100
- H = - 50
+1" FL (#6) = 10
+1-1/2" FL (#1) =26(@ 60 gpm, 2 x 13 = 26 psi)
+1-1/2" FL (#2) =12 (@ 40 gpm, 2 x 6 = 12 psi)
+1-1/2" FL (#3) =2 (@ 20 gpm, 2 x 1 = 2 psi)

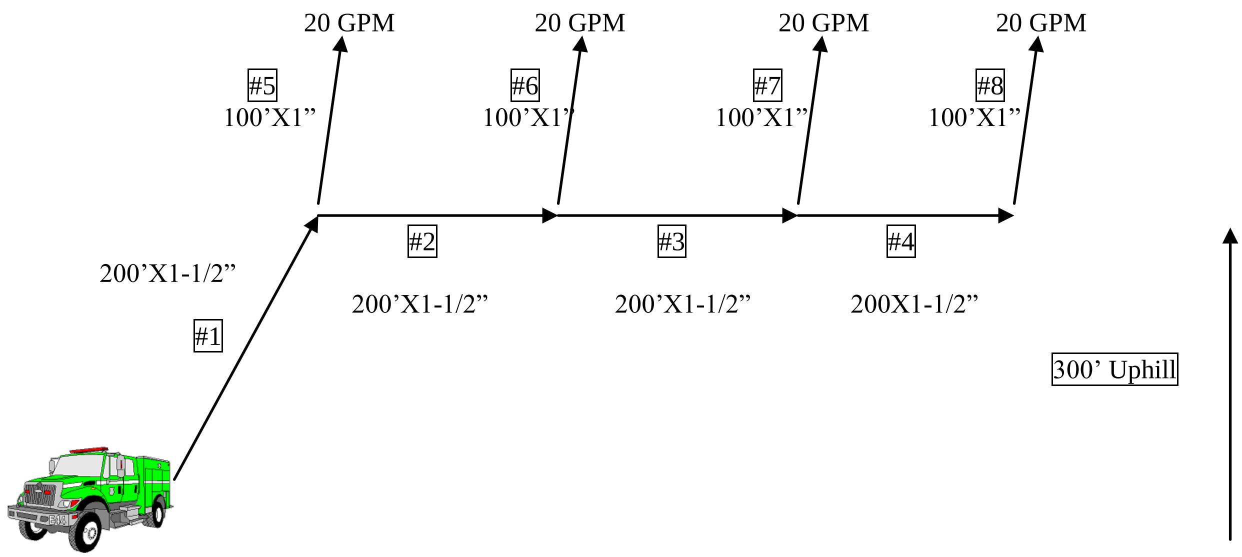
PDP = 100 psi

NOTE: Problem #6 & #7 used a 1-1/2" diameter hose to supply water to the 1" laterals. In the wildland fire environment you may hear the term supply line or trunk line describing the main water supply line for laterals.

If you have been assigned to pump a hoselay already in place, don't assume the main supply line or trunkline to be a 1-1/2" hose. (i.e. it could be a 1" line supplying 3/4" laterals.) Verify the hoselay!

PROBLEM #8:

You are the Engineer of a type 4 fire engine and part of a task force consisting of a dozer, 4,000-gallon water tender, and two type 3 fire engines assigned to a 50-acre brush fire. Upon arrival, the IC instructs your engine to initiate a hoselay up the right flank of the fire and hold and begin mop-up operations. The completed hoselay is shown below. What is the correct pump discharge pressure?



SOLVING PDP:

+NP = 100

+ H = 150

+1" FL(#8) = 10

+1-1/2" FL(#1) = 44 (@ 80 gpm, 2 x 22 = 44 psi)

+1-1/2" FL(#2) = 26 (@ 60 gpm, 2 x13 = 26 psi)

+1-1/2" FL(#3) = 12 (@ 40 gpm, 2 x 6 = 12 psi)

+1-1/2" FL(#4) = 2 (@ 20 gpm, 2 x 1 = 2 psi)

PDP = 344 psi

DETERMINING PDP: (continued)

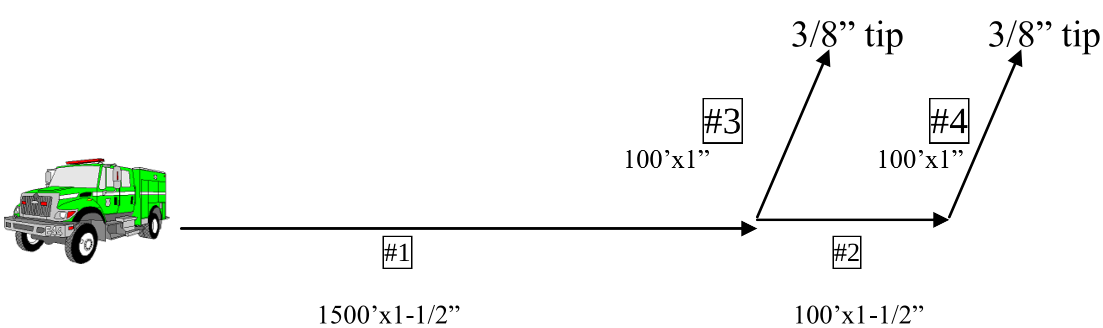
You may realize that the type 4 fire engine with a maximum pump discharge pressure of <300 psi is incapable of pumping the hoselay in Problem #8, as it is laid out. Alternatives to overcome this problem will be discussed in the classroom.

It was previously stated, one method to reduce excessive friction loss is the use of parallel hoselays. The following examples (Problem #9 & #10) show how FL is reduced when this parallel hoselays are used.

DETERMINING FL IN PARALLEL HOSELAYS

PROBLEM #9: You are pumping the hoselay shown below consisting of a 1500' 1-1/2" trunk line supplying two 3/8" tips. What is the PDP?

FIGURE #20:

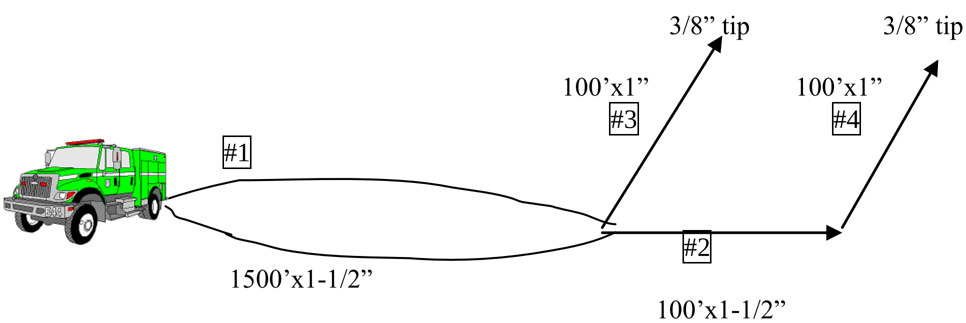


SOLVING PDP:

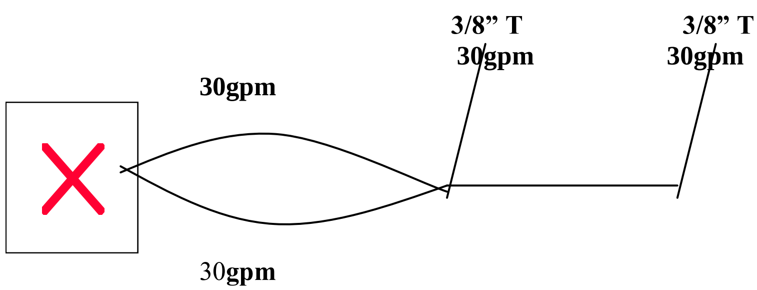
+NP = 50
+/-H = 0
+1" FL (#4) = 23
+1-1/2" FL (#1) = 195 @ 60 gpm, 15 x 13 = 195 psi)
+1-1/2" FL (#2) = 3 (@ 30 gpm, 1 x 3 = 3 psi)

PDP = 271 psi

The figure below illustrates the use of parallel lines to reduce FL. Two 1-1/2" trunk lines 1500' in length are supplying the laterals. A gated wye is used directly off the pump discharge and a Siamese and gated wye are coupled together at the first lateral.



This figure shows the flow rates and path the water will take in a parallel hoselay.



The pump must discharge 60 gpm in order to supply the proper flow for each nozzle in the top figure. The bottom figure shows the distribution that flow will take in a parallel hoselay. 30 gpm will flow through each parallel line merging at the siamese. 30 gpm is then discharged by the first lateral and the remaining 30 gpm continues through the last lateral.

- **When solving for FL in a parallel lay you only consider the loss in one side of the parallel lines. The pressure in each line will be the same so if your PDP overcomes the FL in one, your PDP will overcome the FL in both. Therefore the FL in only one line is of any concern.**

SOLVING PDP:

+NP = 50
+/-H = 0
+1" FL (#4) = 23 (@ 30 gpm, 1 x 23 = 23 psi)
+1-1/2” FL (#1) = 45 (@ 30 gpm, 15 x 3 = 45 psi)
+1-1/2” FL (#2) = 3 (@ 30 gpm, 1 x 3 = 3 psi)

PDP = 121 psi

When comparing the conventional hoselay in Problem #9 and the parallel hoselay in Problem #10 we find: There is a sizable difference in the required pump discharge pressure; the parallel lay required approximately twice the amount of hose as the single lay; having available resources and time to install a parallel lay could be a problem; the FL in the 1500' of 11/2” hose in the conventional lay has 4 times the FL as the parallel lay.

Try solving problem #8 (page 19) with 200 feet of parallel hose running off of the back of the model 71. Can the type 4 pump this lay now? Try 200 feet off of the engine being parallel and the 200 feet between the 1st and 2nd laterals being parallel.

SUMMARY

This text has shown the steps for calculating hydraulics problems you may encounter in the wildland fire environment. Following are sample problems with answers designed to increase your efficiency as an Engineer. The problems should be completed prior to attending the Academy. With practice, you should be able to complete these problems in a short period of time.

ACKNOWLEDGEMENTS

Andy Gay and Chuck Whitlock, Greenville Ranger District, Plumas National Forest, 1978, originally developed this text.

Revised 1983.

Revised 1992 by Mark Levitoff, Almanor Ranger District, Lassen National Forest.

Revised 1998 by Ralph C. Schurwanz, Doublehead Ranger District, Modoc National Forest.

Revised 2000 by Julie Zoppetti, Doublehead Ranger District, Modoc National Forest.

Revised 2004 by Phillip Shafer, Mt Hough Ranger District, Plumas National Forest.

Revised 2007 by Dave Haston, San Dimas Technology and Development Center.

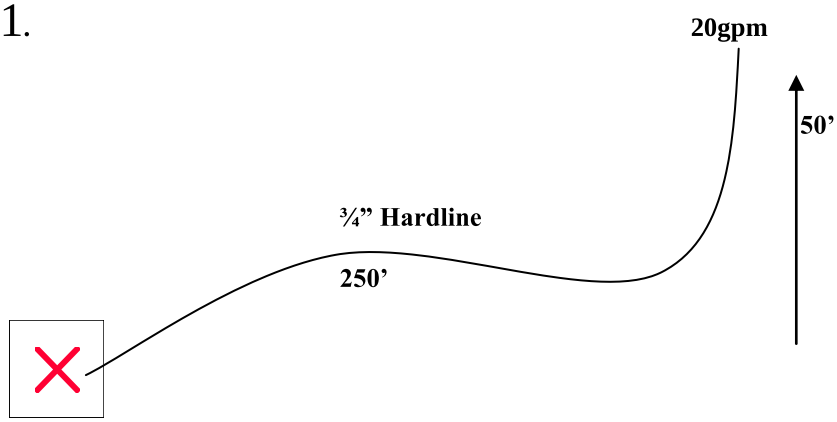
Revised 2011 by Roy Jones, Mike Cooper, Grindstone Ranger District, Mendocino National Forest.

IMPORTANT INSTRUCTIONS
FOR SAMPLE AND QUIZ PROBLEMS!!!!

- Although the FL for 1½" hose at 13gpm is zero per 100' on your calculator, since there is some friction loss we will assign a FL value of 1 psi/100' for a margin of safety.
- Sample Problem #1 shows 250' of 3/4" hardline. This is equivalent to 2½ 100' sections of hose when computing FL.
- It is recommended you solve the easiest problems first, then proceed to the others.
- Bring your workbook, FL calculator, sample problems, and quiz problems to the Academy.
- Only the sample problems include an answer sheet.
- **Show all your work for solving these problems**. Your work must be legible and your answers must be +/- 5psi of the correct answer to receive credit.
- There are minor variations between different manufactures of friction loss calculators and differences between printings of the same calculators. If your answer is +/-5psi and you have checked your work to identify the variance it may be no more than the calculator you're using. Ask your instructor in class if you have concerns.

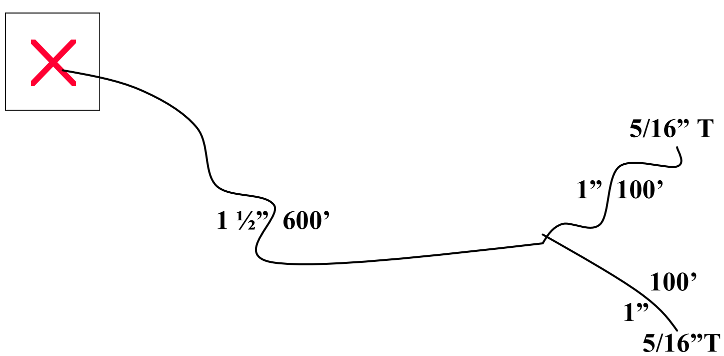
SAMPLE PROBLEMS (1-15)

1.



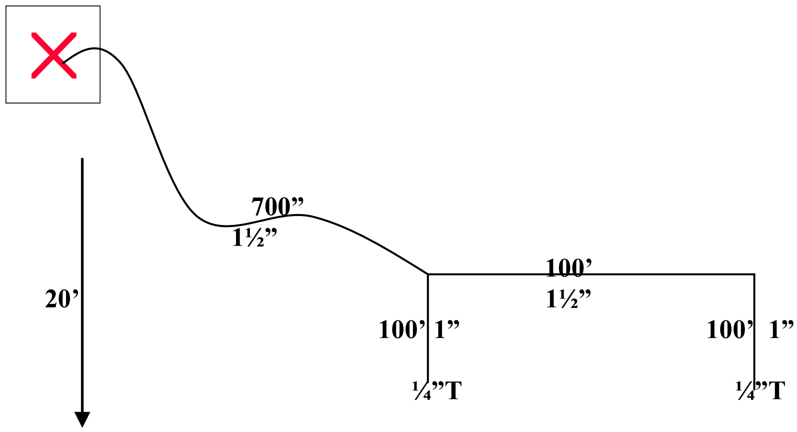
PDP = __________

2.



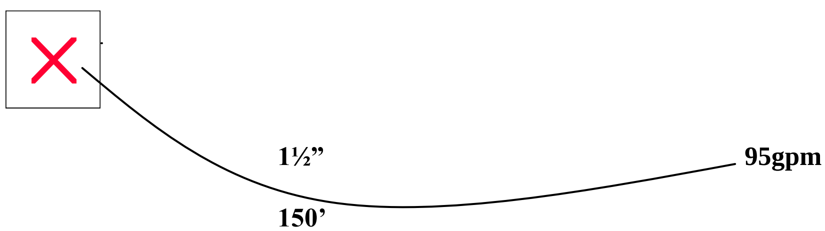
PDP = _____________

3.



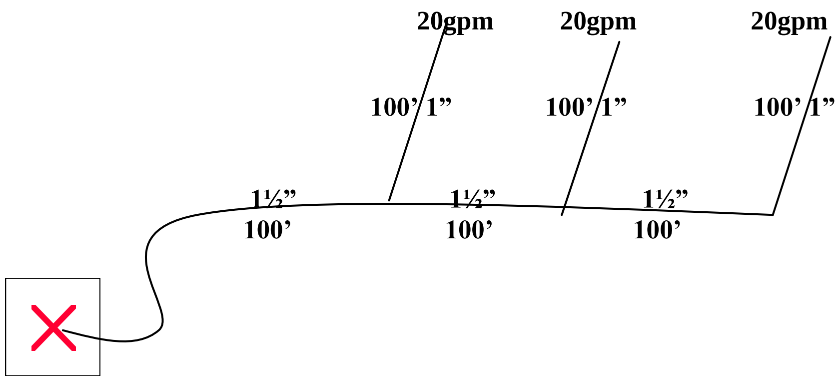
PDP = __________

4.



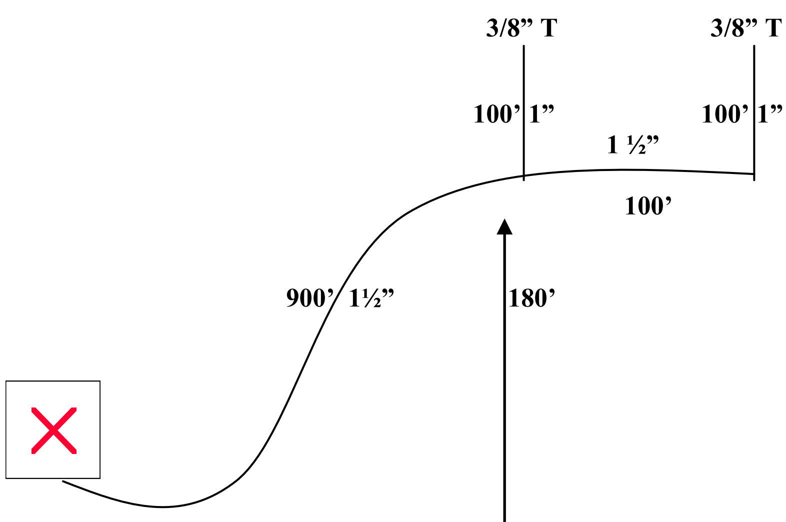
PDP = ____________

5.


20gpm
20gpm
20gpm
100’ 1”
100’ 1”
100’ 1”
1½”
100’
1½”
100’
1½”
100’

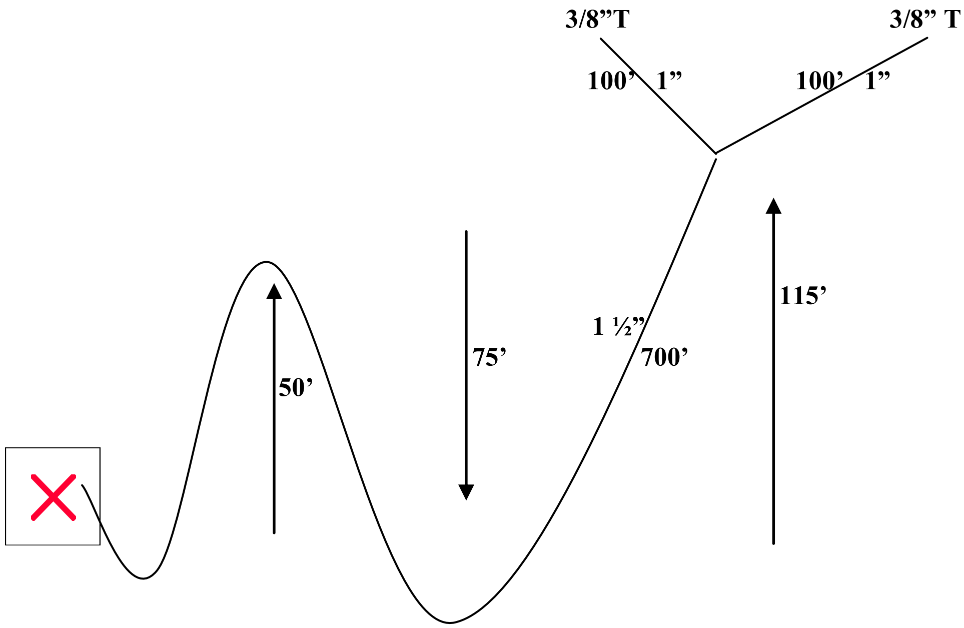
PDP = ___________

6.


3/8” T
3/8” T
100’ 1”
100’ 1”
1 ½”
100’
900’ 1½”
180’

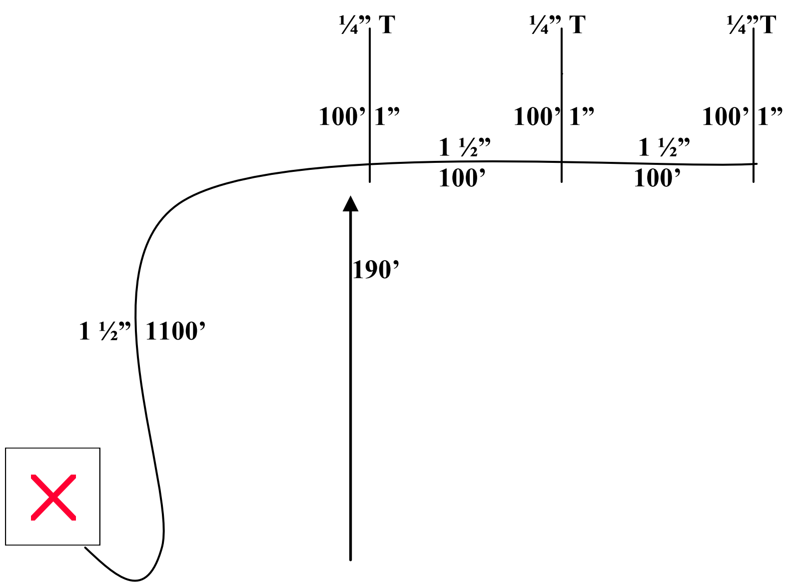
PDP = ___________

7.


3/8"T
3/8" T
100' 1"
100' 1"
115'
1 ½"
700'
75'
50'

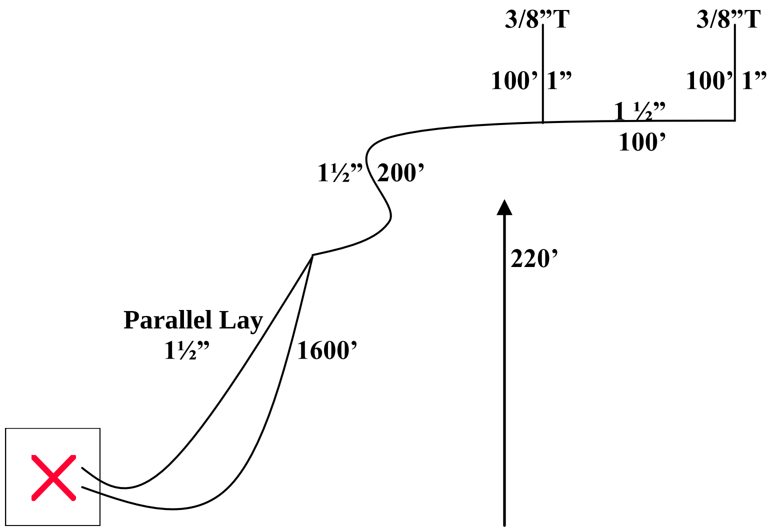
PDP = ___________

8.


¼" T
¼" T
¼"T
100' 1"
100' 1"
100' 1"
1 ½"
100'
1 ½"
100'
190'
1 ½" 1100'

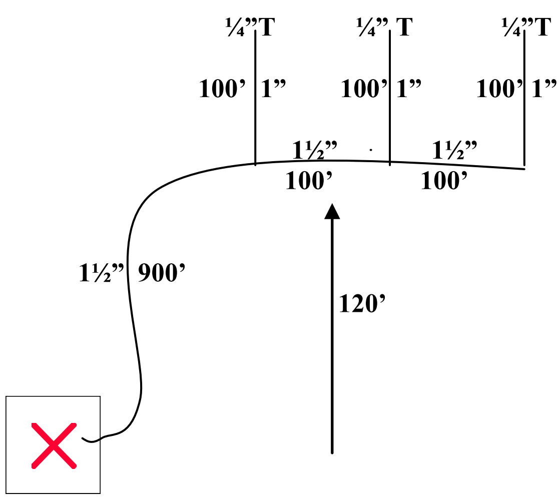
PDP = _____________

9.


3/8"T
3/8"T
100' 1"
100' 1"
1 ½"
100'
1½" 200'
220'
Parallel Lay
1½"
1600'

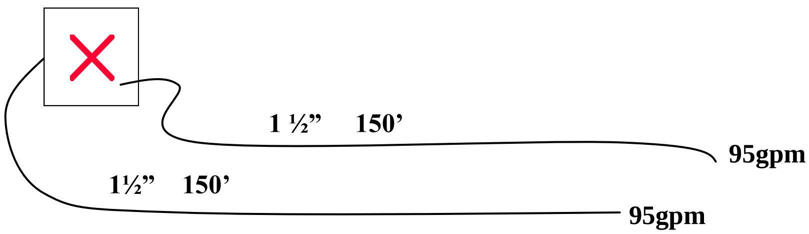
PDP = ______________

10.


¼"T
¼" T
¼"T
100' 1"
100' 1"
100' 1"
1½"
100'
1½"
100'
1½" 900'
120'

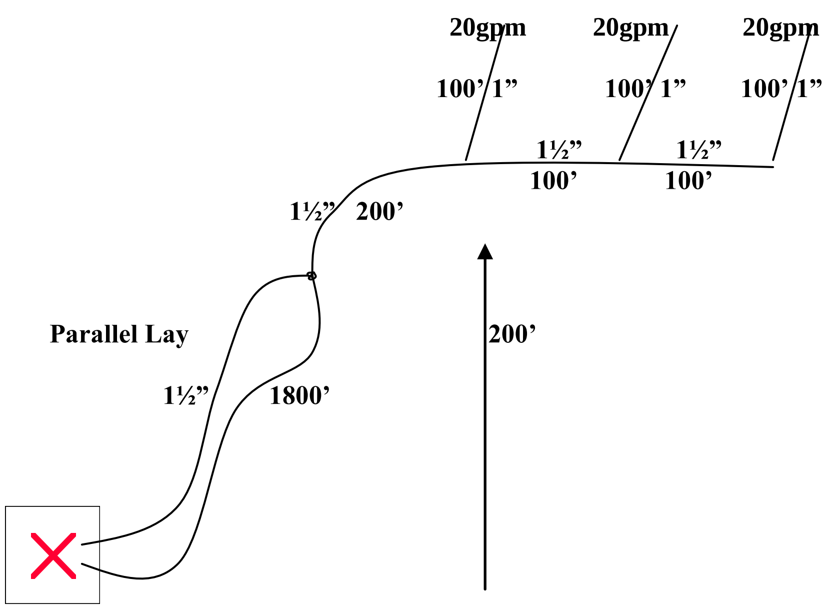
PDP = ______________

11.


1 ½”   150’
95gpm
1½”   150’
95gpm

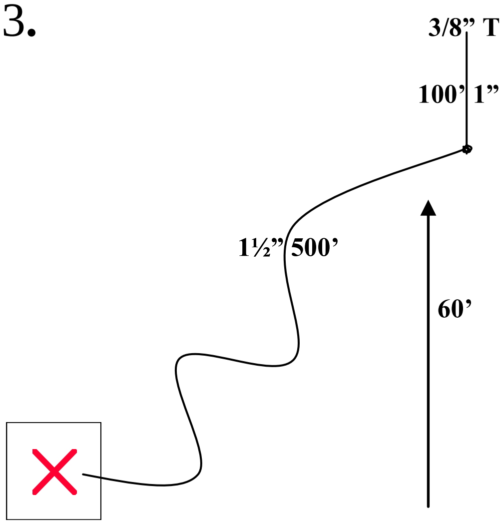
PDP = ______________

12.


20gpm
20gpm
20gpm
100’ 1”
100’ 1”
100’ 1”
1½”
100’
1½”
100’
1½”   200’
Parallel Lay
200’
1½”
1800’

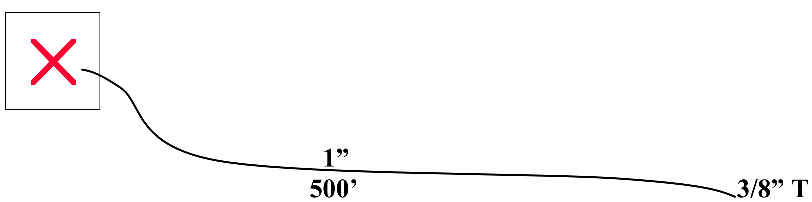
PDP = ____________

13.



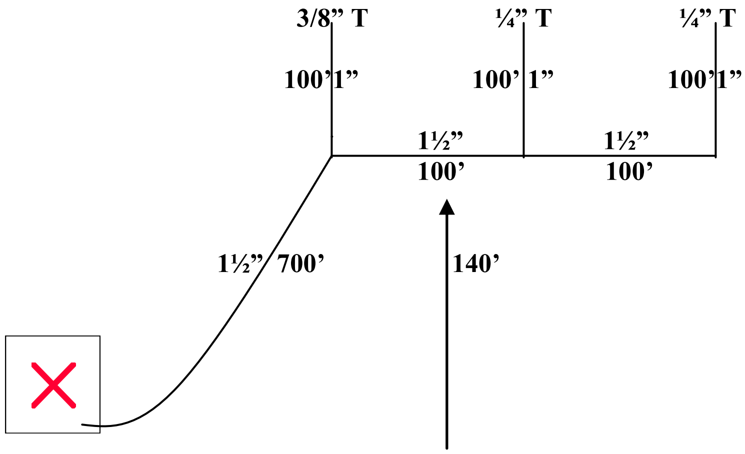
PDP = ____________

14.



PDP = __________________

15.



PDP = __________

ANSWERS TO SAMPLE QUESTIONS

1. PDP = 235 psi

GPM=20

			FL	GPM
NP= 100				
H= 25				
FL 3/4"= 110	(2.5x44)		44	20
PDP = 235 psi				

2. PDP = 97 psi

5/16" nozzle@50psi=21gpm

			FL	GPM
NP = 50				
H = 0				
FL 1" =	11	(1x11)	11	21
FL 1-1/2"=	36	(6x6)	6	42
PDP = 97 psi				

3. PDP = 59 psi

1/4" nozzle@50psi=13gpm

			FL	GPM
NP = 50				
H = -10				
FL 1" =	4	(1x4)	4	13
FL 1-1/2" =	1	(1x1)	1	13
FL 1-1/2" =	14	(7x2)	2	26
PDP = 59 psi				

4. PDP = 148 psi

95 GPM

			FL	GPM
NP = 100				
H = 0				
FL 1-1/2"=	48	(1.5x32)	48	95
PDP = 148 psi				

5. PDP = 130 psi

20 GPM

			FL	GPM
NP = 100				
H = 0				
FL 1" =	10	(1x10)	10	20
FL 1-1/2"=	1	(1x1)	1	20
FL 1-1/2"=	6	(1x6)	6	40
FL 1-1/2"=	13	(1x13)	13	60
PDP = 130 psi				

6. PDP = 283 psi

3/8" nozzle@50psi=30gpm

			FL	GPM
NP= 50				
H= 90				
FL 1"=	23	(1x23)	23	30
FL 1-1/2"=	3	(1x3)	3	30
FL 1-1/2"=	117	(9x13)	13	60
PDP = 283 psi				

7. PDP = 209 psi

3/8" nozzle@50psi=30gpm

			FL	GPM
NP= 50				
H= 45				
FL 1"=	23	(1x23)	23	30
FL 1-1/2"=	91	(7x13)	13	60
PDP = 209 psi				

8. PDP = 207 psi

1/4" nozzle@50psi=13gpm		
NP= 50		
H= 95	FL	GPM
FL 1"= 4 (1x4)	4	13
FL 1-1/2"= 1 (1x1)	1	13
FL 1-1/2"= 2 (1x2)	2	26
FL 1-1/2"= 55 (11x5)	5	39
PDP = 207 psi		

9. PDP = 260 psi

3/8" nozzle@50psi=23gpm		
NP= 50		
H=110	FL	GPM
FL 1"= 23 (1x23)	23	30
FL 1-1/2"= 3 (1x3)	3	30
FL 1-1/2"= 26 (2x13)	13	60
FL 1-1/2"= 48 (16x3)	3	30
PDP = 260 psi		

10. PDP = 162 psi

1/4" nozzle@50psi=13gpm		
NP= 50		
H= 60	FL	GPM
FL 1"= 4 (1x4)	4	13
FL 1-1/2"= 1 (1x1)	1	13
FL 1-1/2"= 2 (1x2)	2	26
FL 1-1/2"= 45 (9x5)	5	39
PDP = 162 psi		

11. PDP = 148 psi

95 GPM		
NP= 100		
H= 0	FL	GPM
FL 1-1/2"= 48 (1.5x32)	32	95
PDP = 148 psi		

12. PDP = 297 psi

20 GPM		
NP= 100		
H= 100	FL	GPM
FL 1" = 10 (1x10)	10	20
FL 1-1/2"= 1 (1x1)	1	20
FL 1-1/2"= 6 (1x6)	6	40
FL 1-1/2"= 26 (2x13)	13	60
FL 1-1/2"= 54 (18x3)	3	30
PDP = 297psi		

13. PDP = 118 psi

3/8" nozzle@50psi=30gpm		
NP= 50		
H= 30	FL	GPM
FL 1"= 23 (1x23)	23	30
FL 1-1/2"= 15 (5x3)	3	30
PDP = 118 psi		

14. PDP = 165 psi

3/8" nozzle@50psi=30gpm		
NP = 50		
H = 0	FL	GPM
FL 1" = 115 (5x23)	23	30
PDP = 165 psi		

15. PDP = 223 psi (Calculate FL in lateral with highest flow)

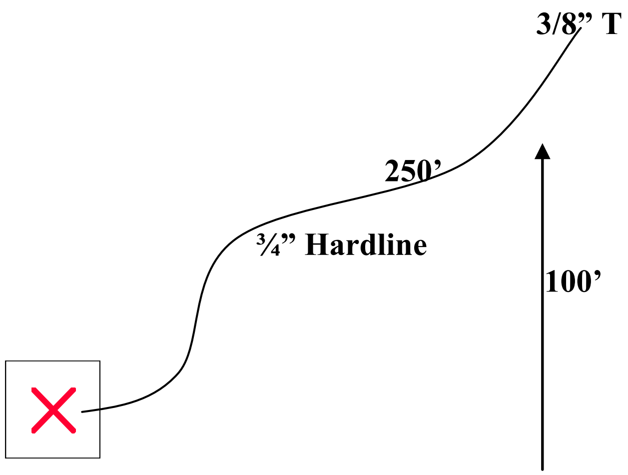
1/4" tip @50psi =13gpm
3/8" tip@50psi=30gpm

NP=	**50**		
H=	**70**	**FL**	**GPM**
FL 1"=	**23 (1x23)**	**23**	**30**
FL 1-1/2"=	**1 (1x1)**	**1**	**13**
FL 1-1/2"=	**2 (1x2)**	**2**	**26**
FL 1-1/2"=	**<u>77</u> (7x11)**	**11**	**56**
PDP =	**223 psi**		

QUIZ PROBLEMS (1-10)

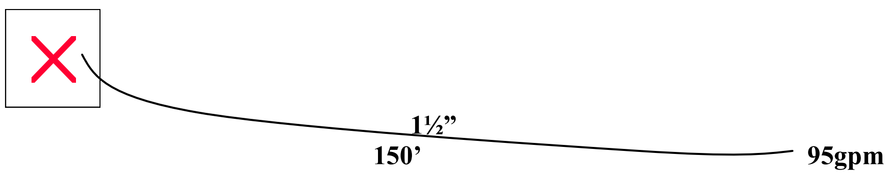
COMPLETE AHEAD OF TIME AND BRING TO ACADEMY

1.



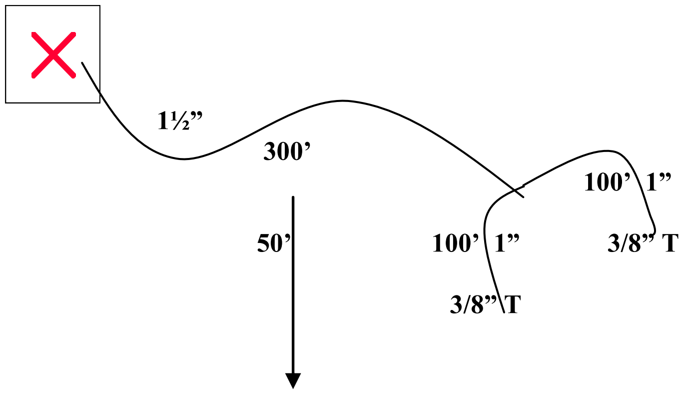
PDP = ______

2.



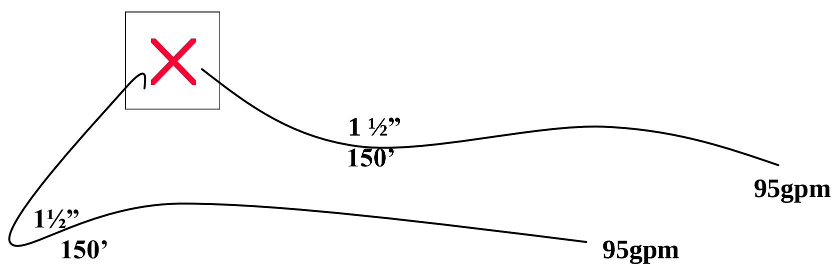
PDP = ______

3.



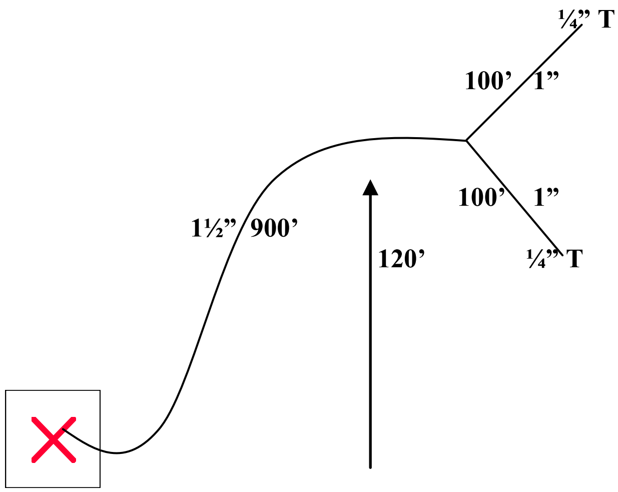
PDP = _______

4.



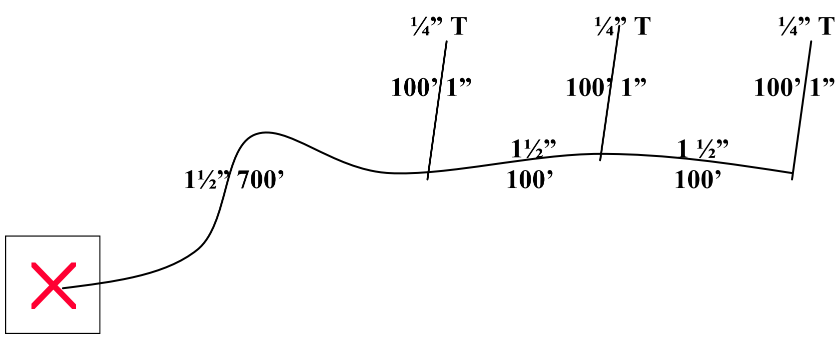
PDP = ______

5.


¼" T
100' 1"
100' 1"
1½" 900'
120'
¼" T

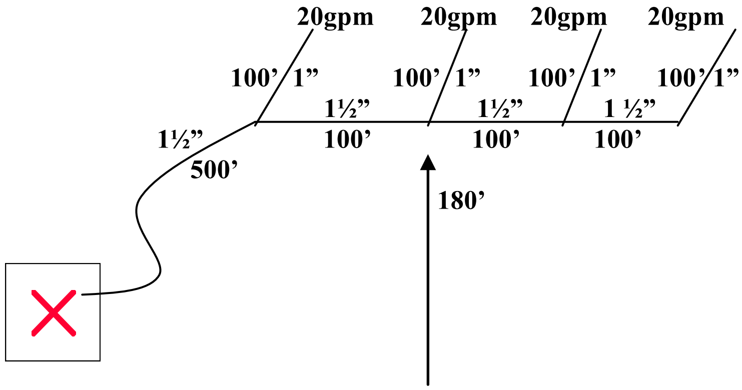
PDP = ______

6.


¼" T
¼" T
¼" T
100' 1"
100' 1"
100' 1"
1½"
1 ½"
1½" 700'
100'
100'

PDP = ______

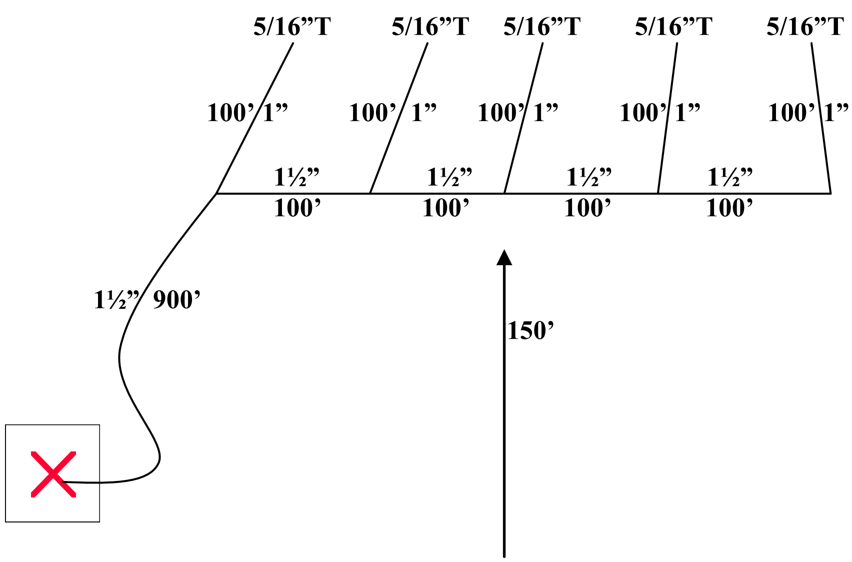
7.



20gpm
20gpm
20gpm
20gpm
100' 1"
100' 1"
100' 1"
100' 1"
1½"
100'
1½"
100'
1 ½"
100'
1½"
500'
180'

PDP = ______

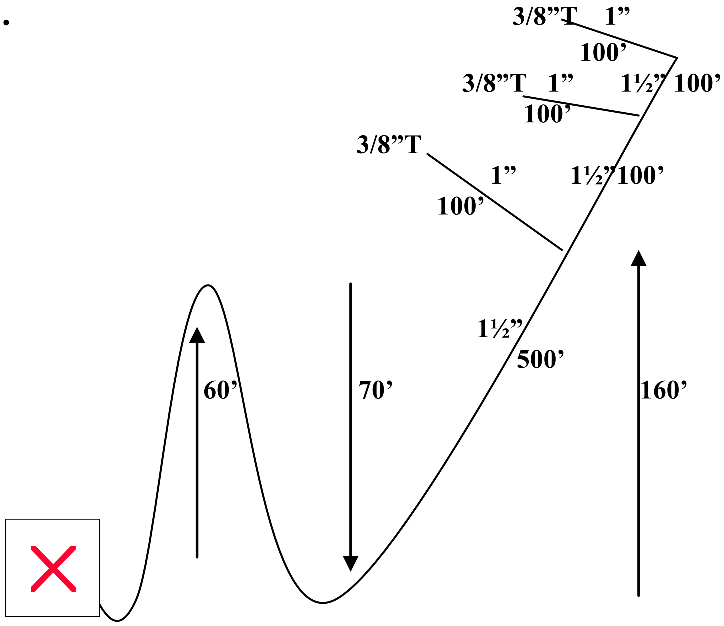
8.



5/16"T
5/16"T
5/16"T
5/16"T
5/16"T
100' 1"
100' 1"
100' 1"
100' 1"
100' 1"
1½"
100'
1½"
100'
1½"
100'
1½"
100'
1½" 900'
150'

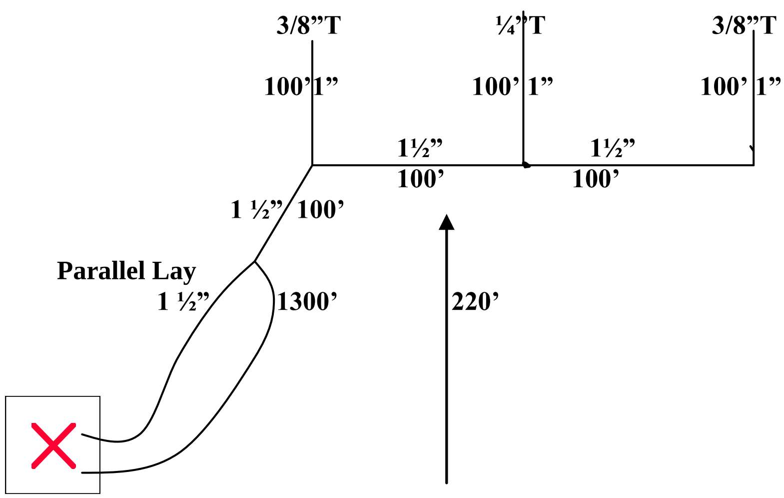
PDP = _______

9.


3/8"T 1"
100'
3/8"T 1"
1½" 100'
100'
3/8"T
1"
1½" 100'
100'
1½"
500'
60'
70'
160'

PDP = _______

10.


3/8"T
¼"T
3/8"T
100' 1"
100' 1"
100' 1"
1½"
100'
1½"
100'
1 ½" 100'
Parallel Lay
1 ½"
1300'
220'

PDP = _______