DFD PUMP CHART CURRICULUM

VERSION 2.2

UPDATED ON 02-17-2024

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Pump Chart Introduction

The purpose of a pump chart is to give pump operators a shortcut to the values they need to place into the variables to calculate the total Pump Discharge Pressure ***(PDP)***. The values that a pump chart provides are designed to get the pump operator within a range of an effective fire flow. Friction loss in a hoseline varies based on several factors, including (but not limited to) manufacturing processes, materials used, temperature, wear, age, etc. This curriculum for the DFD Pump Chart is intended to familiarize members with all the major components of the pump chart, some best practices noted in DFD SOGs, and to introduce basic hydraulic concepts.

The single most important skill to master to utilize the new DFD Pump Chart is to learn how to find your values by reading a table. This curriculum is intended to address this needed skillset by providing 14 examples, which are mirrored in the accompanying homework that has been uploaded onto Target Solutions (Example 4 of this curriculum document is shown as Problem 4 in the homework).

The driving changes for this revision of the pump chart include:

1) The replacement of the 2-1/2" smoothbore 1-1/8" and 1-1/4" tips with a new 1-3/16" tip that can flow the same rates as the 1-1/8" and 1-1/4" tips by varying the nozzle pressure (the ability to change the GPM by increasing or decreasing the nozzle pressure and the associated friction loss in the hoslines is not addressed in this version of the pump chart for simplicity, but is explained in ***Appendix I***)
2) The need to address multiple diameters in handlines (i.e., extending a 2-1/2" hoseline with a 2" nozzle section) without having to rely on CQ^2L to calculate the PDP
3) Advancements in hose manufacturing that are drastically lowering the coefficients of friction in our hoselines
4) The need for simplicity of use based on user feedback
5) A more comprehensive method for determining residual water to incorporate incidents where an engineer starts pumping off of tank water and does not get a static reading

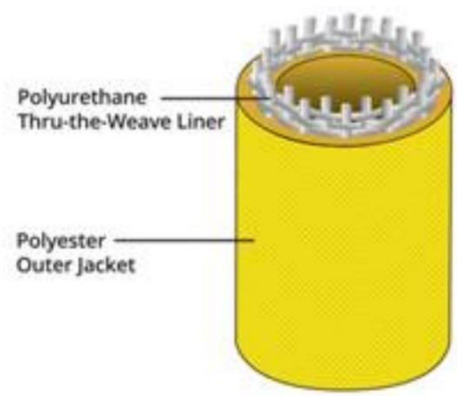


Figure 1: Manufacturing technology advancement example

Pump Discharge Pressure (PDP) Formula

The variables to calculate total Pump Discharge Pressure (PDP) are:

1) Nozzle Pressure ***(NP)***
2) Friction Loss in the hoseline ***(FL)***
3) Friction loss in the Appliances ***(APPL)***
4) The loss, or gain, due to Elevation ***(ELEV)***

The formula to calculate the total Pump Discharge Pressure is:

$$\textbf{PDP = NP + FL + APPL + ELEV}$$

Application

As with all perishable skillsets, it is recommended to review this curriculum on a periodic basis. Just like forcible entry or hose handling, working your way through pump problems is critical to being able to perform quickly, efficiently, and correctly on scene. **The Engineer position is unique in that they often work alone and without backup.** If an Engine Engineer cannot correct an error with the apparatus that is causing it to not go into pump gear, there is a high probability that there is no one nearby to walk them through the issue. Another example of having to think and act independently and outside of their skillset is when an Engine Engineer pulls up to a high-rise fire and sees the need for an immediate rescue from an elevated area and the Truck Company members are already inside the building; they may be the only person than can operate the aerial. Practicing all the skillsets of the Engineer position is critical to successful incident mitigation.

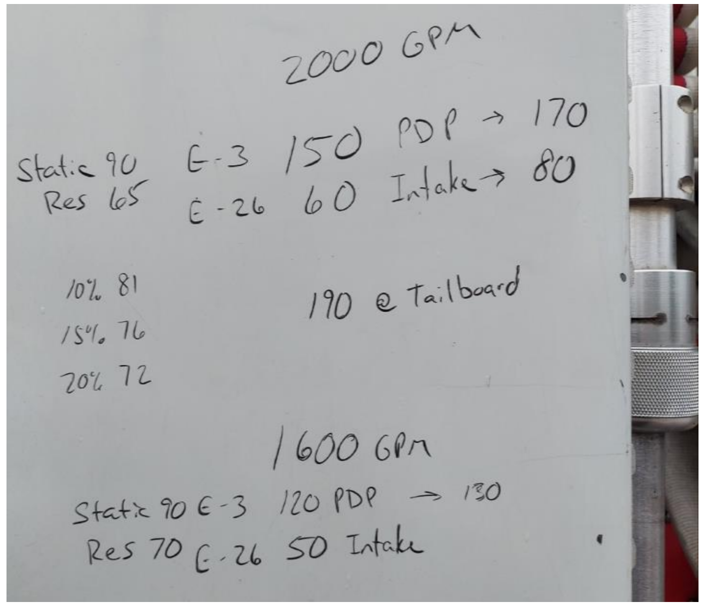


Figure 2: Calculating Residual Water with a grease pencil on the side of the rig can be useful

Friction Loss in a Hoseline Calculation

To find the friction loss in hoseline, manufactures provide fire service personnel with a Coefficient of Friction ***(C)***. This coefficient is utilized to determine how much friction loss is incurred when pumping water through a hoseline that the fire pump will have to overcome. The manufacture's *C* can become skewed over time due to issues including the age and wear of the interior jacket of hoseline. The DFD has refined our coefficient values based on extensive testing led by Captain Pavlich and supported by the work of the members of Engine 15. The *C* used to find the values of the variables in the PDP formula have been averaged across multiple flow tests and rounded to make flow estimation easier to calculate.

The variables to calculate the Friction Loss ***(FL)*** in a hoseline are:

1) Coefficient of Friction ***(C)***
2) Gallons per Minute (GPM) of flow through a hoseline divided by 100 ***(Q)***
3) Length of hoseline divided by 100 ***(L)***

The formula to calculate the Friction Loss in a hoseline is:

$$FL = CQ^2L$$

Example 1: Finding the PDP for a Handline Using CQ^2L

As an example, let's say that we wanted to find the pump discharge pressure needed to create an adequate fire flow in a two-hundred-foot section of 2" hoseline with a 1" tip that is flowing 210 gallons per minute.

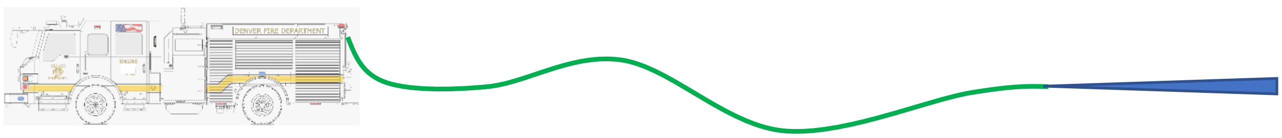


Figure 3: 200' of 2" Hoseline with a 1" Tip, Producing 210 GPM

Using our total Pump Discharge Pressure Formula (PDP = NP + FL + APPL + ELEV) we can fill in our variables in the following manner:

1) NP = 50 psi
2) FL = CQ^2L
3) APPL = 0
4) ELEV = 0

The variables needed to determine our Friction Loss for this example are:

1) C (coefficient of friction – this is a constant that is provided in Figure 4) = 6.8
2) Q (GPM divided by 100) = 210 GPM divided by 100 = 2.1
3) L (length of the hoseline divided by 100) = 200 feet divided by 100 = 2

HOSE	C	GPM
1-3/4"	7.3	180
2"	6.8	210
2-1/2"	1.7	300

Figure 4: Hoseline Coefficients

NOTE: *These are the general coefficients used for this pump chart. They were developed through a rigorous testing process by Captain Pavlich and Station 15 crew members. They are averaged over years and manufactures and are designed to get the engineer within the proper range of operating pressures.*

Using our friction loss formula, we can work our formula with the following steps:

1) FL = CQ^2L
2) FL = $6.8 \times 2.1^2 \times 2$
3) FL = 6.8 x 4.41 x 2
4) FL = 59.97 psi
5) Round to 60 psi for the Friction Loss in the hose

When we plug the answer from our Friction Loss formula back into our Pump Discharge Pressure formula, we get:

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + 60 psi + 0 psi + 0 psi
C. PDP = 110 psi

THERE IS AN EASIER WAY THAN USING CQ^2L!!!! We built a pump chart that does that math that determines the values for the PDP variables for you.

Old Pump Chart (For Reference)

DFD PUMP CHART - OFFENSIVE OPERATIONS

1-3/4" HOSE (*2018 AND NEWER - 25 psi/100') (**2017 AND OLDER - 35 psi/100')			
TIP SIZE	**GPM**	**NP**	**FL/100'**
15/16"	185	50	(*25) (**35)
COMBINATION FOG	175	50	(*25) (**35)
COMBINATION FOG	185	75	(*25) (**35)
1-1/2" BRESNAN	100	100	15
2" GREEN HOSE			
TIP SIZE	**GPM**	**NP**	**FL/100'**
1"	210	50	30
2-1/2" HOSE			
TIP SIZE	**GPM**	**NP**	**FL/100'**
1-1/8"	265	50	10
1-3/16"	300	50	15
1-1/4"	325	50	20
COMBINATION FOG	250	50 or 75	10
COMBINATION FOG	300	75	15
2-1/2" BRESNAN	300	100	15
RAM OR BLITZFIRE WITH 1-3/8" TIP			
2-1/2" HOSE	500	80	40
3" HOSE	500	80	25

APPLIANCES	
SIAMESE / WYE = 5 psi	STANDPIPE = 25 psi
ELEVATION	
PER FOOT = 0.5 psi	PER FLOOR = 5 psi

RESIDUAL WATER
0 - 10% STATIC TO RESIDUAL DROP = ADD **3** TIMES CURRENT GPM OUTPUT
11 - 15% STATIC TO RESIDUAL DROP = ADD **2** TIMES CURRENT GPM OUTPUT
16 - 20% STATIC TO RESIDUAL DROP = ADD **1** TIME CURRENT GPM OUTPUT

Revised – June 2021

DFD PUMP CHART - DEFENSIVE OPERATIONS

MASTER STREAMS						
TIP SIZE	**1 TIP GPM** *(2 TIP GPM)*	**FL/100' MULTIPLE LINES (TRUCK OR TOWERS WITH 1 TIP)** *(TOWERS WITH 2 TIPS)*				
	NP = 80 psi	**ONE - 3"**	**TWO - 3"**	**THREE - 3"**	**FOUR - 3"**	**ONE - 5"**
1-3/8"	**500** *(1000)*	**25** *(100)*	**6** *(25)*	**3** *(12)*	**2** *(8)*	**2** *(8)*
1-1/2"	**600** *(1200)*	**40** *(160)*	**10** *(40)*	**5** *(20)*	**3** *(12)*	**3** *(12)*
1-3/4"	**800** *(1600)*	**60** *(240)*	**15** *(60)*	**8** *(32)*	**5** *(20)*	**5** *(20)*
2"	**1000** *(2000)*	**100** *(400)*	**25** *(100)*	**13** *(50)*	**8** *(32)*	**8** *(32)*
FOG	**500** *(1000)*	**25** *(100)*	**6** *(25)*	**3** *(12)*	**2** *(8)*	**2** *(8)*
FOG	**1000** *(2000)*	**100** *(400)*	**25** *(100)*	**13** *(50)*	**8** *(32)*	**8** *(32)*

APPLIANCES	
SIAMESE / WYE = 5 psi	DECK GUN / GROUND MONITOR = 25 psi
SPRINKLER SYSTEMS = 150 psi	TRUCKS OR TOWERS AT TAILBOARD = 200 psi

RESIDUAL WATER
0 - 10% STATIC TO RESIDUAL DROP = ADD **3** TIMES CURRENT GPM OUTPUT
11 - 15% STATIC TO RESIDUAL DROP = ADD **2** TIMES CURRENT GPM OUTPUT
16 - 20% STATIC TO RESIDUAL DROP = ADD **1** TIME CURRENT GPM OUTPUT
MISCELLANEOUS
HIGH RISE: ENGINE AT THE FDC SHALL PUMP IN "PRESSURE" AND IN "PSI" MODE
RELAY PUMPING: SUPPLY ENGINES PUMP IN "VOLUME" AND IN "RPM" MODE, ATTACK ENGINES SHALL BE IN "PSI" MODE; MAINTAIN 20-80 psi INTAKE PRESSURE
SPRINKLER SYSTEMS: PUMP IN "VOLUME"
WHEN FLOWING MORE THAN 1000 GPM: PUMP IN "VOLUME"

WATER SUPPLY – THREE HYDRAULIC CONCEPTS

CONCEPT 1

Rule of 4's:
When you double the flow, you quadruple the friction loss; when you halve the flow, you quarter the friction loss (***NOTE:** Only for lines of equal length, size, and flow*).

Multiple Line Conversions:
2 lines equals ¼ of 1 line
3 lines equals ½ of 2 lines
4 lines equals ⅓ of 2 lines

CONCEPT 2

Maximum Length for Supply Lines:
Utilize the **Rule of 4's Concept** to calculate the maximum lengths of lines given the following:

Theoretical Max Length of Supply Hose:
2-½" hose flowing 500 GPM is 350'
3" hose flowing 500 GPM is 900'

Application Supplying Master Streams
Using 3 lines to pump into a Truck (1000 GPM); max distance is 800' (due to PDP limit).
Using 4 lines to pump into a Tower (2000 GPM); max distance is 300' (due to PDP limit).

CONCEPT 3

Volume of Water in a Hoseline:
Water is not compressible; therefore, volume can be defined by its weight.

Hose Diameter	Volume of Water
1-¾"	1 lb per foot
2"	1.5 lbs per foot
2-½"	2 lbs per foot
3"	3 lbs per foot
5"	8.3 lbs per foot

This version of the pump chart accounts for many of the issues that you will see on the fireground but there are two major issues with it identified by users:

1) There was no way to account for or figure out the flow rate for hoselines that do not match their recommended nozzle compliment (i.e., if you extend a line with a different diameter, you are unable to calculate the friction loss)
2) The hydraulic concepts needed to be included into the calculations, but not included in the chart

We incorporated this feedback into the new pump chart by including:

1) Putting the entire offensive operations page into a single table that mirrors the defensive operations of the chart
2) Incorporating the hydraulic concepts into the calculations for ease of use
3) Making the color scheme more user friendly (i.e., all items in green are the recommended tip/hose diameter pairing in the offensive table and the recommended tip to produce the highest volume with the longest reach in the Defensive Operations table)

DENVER FIRE DEPARTMENT PUMP CHART

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)

	FL/100'			
TIP	**15/16" TIP OR FOG**	**1" TIP**	**1-3/16" TIP OR FOG**	**RAM OR BLITZ**
FLOW RATE	**180 GPM**	**210 GPM**	**300 GPM**	**500 GPM**
NOZZLE PRESSURE	**50/75 PSI**	**50 PSI**	**50/75 PSI**	**80 PSI**
1-3/4"	**30**	35	60	NA
2"	20	**30**	50	NA
2-1/2"	5	10	**15**	40
3"	3	5	10	**25**

OFFENSIVE APPLIANCES AND ELEVATION

STANDPIPE AND SUPPLY HOSE TO FDC = 30 PSI | ELEV = 5 PSI PER FLOOR, 0.5 PSI PER FOOT

BRESNANS (1-1/2" OR 2-1/2") = 100 PSI NOZZLE PRESSURE, 15 PSI FL/100'

HIGH-RISE OPERATIONS

ENGINE AT FDC, PUMP IN "PRESSURE" AND "PSI" (FOR SPRINKLERS, START IN "VOLUME" AT 150 PSI)

BUILDINGS WITHOUT FIRE PUMPS: SLOWLY PUMP TO FIRE FLOOR

BUILDINGS WITH FIRE PUMP: IF FIRE PUMP IS RUNNING, GET WATER TO FDC WITH NO PRESSURE, IF FIRE PUMP IS ***NOT*** WORKING, PUMP TO FIRE FLOOR IF NO PRVS, PUMP TO ROOF IF PRVS

DEFENSIVE OPERATIONS (PDP = FL + APPL)

TIP SIZE	**1 TIP GPM** *(2 TIP GPM)* **FOGS = GPM**	**FRICTION LOSS PER 100' MASTER STREAMS WITH 1 TIP** *(TOWERS WITH 2 TIPS)*				
		ONE - 3"	**TWO - 3"**	**THREE - 3"**	**FOUR - 3"**	**ONE - 5"**
1-3/8"	**500** *(1000)*	**25** *(NA)*	**6** *(25)*	**3** *(12)*	**2** *(8)*	**2** *(8)*
1-1/2"	**600** *(1200)*	**40** *(NA)*	**10** *(40)*	**5** *(20)*	**3** *(12)*	**3** *(12)*
1-3/4"	**800** *(1600)*	**60** *(NA)*	**15** *(60)*	**8** *(32)*	**5** *(20)*	**5** *(20)*
2"	**1000** *(2000)*	**NA** *(NA)*	**25** *(NA)*	**13** *(50)*	**8** *(32)*	**8** *(32)*
2-1/4"	**1300** *(2600)*	**NA** *(NA)*	**40** *(NA)*	**20** *(80)*	**15** *(60)*	**15** *(60)*
2-1/2"	**1600** *(3200)*	**NA** *(NA)*	**60** *(NA)*	**30** *(NA)*	**20** *(80)*	**20** *(80)*

DEFENSIVE APPLIANCES

DECK GUN/GROUND MONITOR AT APPLIANCE = 100 PSI | RELAY ENGINES AT TAILBOARD = 50 PSI

TRUCKS OR TOWERS AT TAILBOARD = 200 PSI (ENGINE WITHIN 100' OF TAILBOARD)

RELAY OPERATIONS

RELAY PUMPING: ATTACK ENGINES SHALL BE IN "PSI" MODE, SUPPLY ENGINES IN "VOLUME" AND "RPM" MODE WHILE MAINTAINING AT LEAST 20 PSI MINIMUM INTAKE PRESSURE

RELAY MAX DISTANCES: WHEN PUMPING 5" AT 2000 GPM, MAX DIST 600' TO NEXT ENGINE

WHEN PUMPING 3 X 3" AT 2000 GPM, MAX DIST 400' TO NEXT ENGINE

PUMP IN "PRESSURE" WHEN PUMPING LESS THAN 1000 GPM INTO AN FDC

RESIDUAL WATER

0-10% DROP = **3** X GPM, **11-15%** DROP = **2** X GPM, **16-20%** DROP = **1** X GPM

New Denver Fire Department Pump Chart for the Cabinet Firefighter

An abridged pump chart and "cheat sheets" for 2-1/2" handlines and 2-1/2" with a 2" nozzle section combination handlines for the cabinet firefighter will also been included in the high-rise bags. Please note that the PDP calculation has been modified to omit the appliances, as these are not applicable to high-rise operations:

STANDPIPE OPERATIONS PDP = NP + FL + ELEV		
	FL/100'	
TIP SIZE	1" TIP	1-3/16"
FLOW RATE	210 GPM	300 GPM
NOZZLE PRESSURE	50 PSI	50 PSI
2"	30	50
2-1/2"	10	15
ELEV = 5 PSI PER FLOOR		

LENGTH	2.5" HOSE WITH A 2" NOZZLE SECTION	PSI
100'	1 SECTION 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	75
150'	2 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	80
200'	3 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	85
250'	4 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	90
300'	5 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	95
350'	6 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	100
400'	7 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	105
450'	8 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	110

LENGTH	2.5" HOSE ONLY	PSI
100'	2 SECTIONS 2.5", 1 FLOOR ELEVATION	70
150'	3 SECTIONS 2.5", 1 FLOOR ELEVATION	75
200'	4 SECTIONS 2.5", 1 FLOOR ELEVATION	85
250'	5 SECTIONS 2.5", 1 FLOOR ELEVATION	95
300'	6 SECTIONS 2.5", 1 FLOOR ELEVATION	100
350'	7 SECTIONS 2.5", 1 FLOOR ELEVATION	110
400'	8 SECTIONS 2.5", 1 FLOOR ELEVATION	115

DFD Pump Chart Offensive Operations Explained

The DFD Pump Chart Offensive Operations section contains four main parts:

1. An OFFENSIVE OPERATIONS section that details the friction loss per hundred feet for handlines and Ram XDs or Blitzfire. **This section is to be read as a COLUMN BASED TABLE, meaning, once your tip or GPM is determined, all the values for the variables needed to complete the Friction Loss section of the PDP formula will come from that column regardless of hose diameter.** For instance, if I'm flowing a 1" tip on a 50' section of 2" hose that was extended off of 200' of 2-1/2" hose, my values would come from the 1" tip column and would be located in the 2" and 2-1/2" rows (30 and 10 psi per 100', which results in 15 and 5 psi per 50' section respectively). This reduces the need to use the CQ^2L calculations for more complex problems.

   The columns increase in tip size from left to right and the rows increase in hose diameter from top to bottom.

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)				
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	**30**	35	60	NA
2"	20	**30**	50	NA
2-1/2"	5	10	**15**	40
3"	3	5	10	**25**

Figure 5: Friction Loss per 100' of Hoseline Used in Offensive Operations for Handlines and Ram XDs/Blitzfires

A few of items of note in this section:

A. The values annotated in green background with white lettering note the friction loss for hose with the recommended tips and resulting flow rates. For example, 2" hose is recommended to be paired with a 1" 210 GPM nozzle but can be extended with a 1-3/4" hoseline with a 15/16" tip, which reduces the friction loss by a third from 30 psi to 20 psi per hundred feet.

B. The flow rates increase from left to right, starting with the 15/16" smooth bore tip and 1-3/4" fog nozzle (roughly 180 GPM) and ending with the Ram XD or Blitzfire with an 1-3/8" nozzle (500 GPM); ***PLEASE NOTE*** - the Ram XD/ Blitzfire is **NOT** a defensive master stream and is intended to be used in offensive operations (i.e., in a hallway with a handline advancing underneath it).

2. An OFFENSIVE APPLIANCES AND ELEVATION section that includes the friction loss numbers associated with those items.

OFFENSIVE APPLIANCES AND ELEVATION	
STANDPIPE AND SUPPLY HOSE TO FDC = 30 PSI	ELEV = 5 PSI PER FLOOR, 0.5 PSI PER FOOT
BRESNANS (1-1/2" OR 2-1/2") = 100 PSI NOZZLE PRESSURE, 15 PSI FL/100'	

Figure 6: Miscellaneous appliances used on the fireground and two rules of thumb for determining discharge pressure changes needed to account for elevation loss or gain

Changes in this section are:

A. The Standpipe (typically incurring 25 psi of Friction Loss) includes the supply hose needed to get to the FDC (very rarely when tandem pumping to an FDC will you have to pump two 3” lines more than 5 psi).
B. Elevation includes both the head pressure loss/gain per floor and the 0.5 psi head pressure loss/gain per foot to account for head pressure issues within a building or in elevated terrain. Please note that counting of floors or feet is from the elevation of the fire pump. Meaning, we don’t typically account for the first floor – for example, if we are pumping to the 4th floor, we only have to account for three floors of head pressure loss above the pump. The elevation has also been included for feet when you’re having to deal with terrain (pumping up or down a hill, overpass, etc.).
C. The Bresnan section includes the nozzle pressure for both the 1-1/2” and 2-1/2” Bresnans and a standardized 15 psi friction loss per 100’ of either 1-3/4” or 2-1/2” hoselines.
D. Please note that we are no longer accounting for friction loss through wyes or siamese appliances; when tested, the friction loss in these appliances were small enough to be considered negligible.
E. There is a substantial difference on when to use clappered siamese and non-clappered Siamese
   i. Clappered siamese appliances are to be used when a pump will be taking over operations for another pump (i.e., when going to the clappered siamese on a standpipe as the third in engine). A clappered Siamese will only take water from one pump, it cannot augment a supply.
   ii. Non-clappered siamese are used to augment a water supply; water entering from both female fittings will go out through one fitting. A non-clappered siamese will augment water supplies, but can also backfill if one input is not hooked up or not pressurized.

3. A HIGH-RISE OPERATIONS section that includes an abridged set of rules for pumping into a FDC for standpipe equipped buildings based on the latest version of the high-rise policy.

HIGH-RISE OPERATIONS
ENGINE AT FDC, PUMP IN "PRESSURE" AND "PSI" (FOR SPRINKLERS, START IN "VOLUME" AT 150 PSI)
BUILDINGS WITHOUT FIRE PUMPS: SLOWLY PUMP TO FIRE FLOOR
BUILDINGS WITH FIRE PUMP: IF FIRE PUMP IS RUNNING, GET WATER TO FDC WITH NO PRESSURE, IF FIRE PUMP IS ***NOT*** WORKING, PUMP TO FIRE FLOOR IF NO PRVS, PUMP TO ROOF IF PRVS

Figure 7: The high-rise rules for pumping into a standpipe equipped building

4. The RESIDUAL WATER section is added to the bottom of the pump chart to prompt engineers to calculate their available residual water (the ability to provide "like flows" in terms of GPMs). This skillset is a crucial aspect of the Engineer's position, so that they can inform the Incident Commander of potential water supply issues as early in the incident as possible.

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Figure 8: Residual water is a critical aspect of the Engineer's position; any potential water supply issues need to be communicated immediately to the Incident Commander

The recommended technique to determine the available residual water is through the **Residual Drop Estimation Method**, which can be used when you have noted a static water pressure or when you have started flowing water from the tank and then introduced water from the hydrant (there is no initial static reading). To complete this process, use the following steps:

A. Start with creating a table for the Residual Drop Estimation that looks roughly like this:

TOTAL GPM	RESIDUAL DROP	STATIC OR FIRST RESIDUAL READING (S/R_1)	SECOND RESIDUAL READING (R_2)	THIRD RESIDUAL READING (R_3)
3	10%			
2	15%			
1	20%			

*Figure 9: 'Residual Drop Estimation' table – **note**: the grey text in the first row is for explanation only*

B. The first time you note your intake pressure (either static or when flowing), record that number and then determine your percentage drops (you can use the first number digit and round). For example, let's say that we started flowing a 2-1/2" handline at 300 GPM off of tank water and then introduced water from a hydrant. Our intake pressure from the hydrant, noted while already flowing the 2-1/2" handline, is 84 psi. Fill in the S/R_1 column of the table using the following steps:

a. Add the intake pressure value of 84 psi for the S/R_1 variable
b. Take 10% of 84 (think of it as a 10% tip or just use the first digit), which rounds to 8 and it in the 10% drop row
c. Take 15% of 84 (think of it as a 15% tip or divide the first result by 2 and add it back to the original number) and place the result in the 15% row
d. Take 20% of 84 (think of it as a 20% tip or double the first result) and place the result in the 20% row

TOTAL GPM	RESIDUAL DROP	S/R_1	R_2	R_3
		84		
3	10%	8		
2	15%	12		
1	20%	16		

C. The second time you note your intake pressure reading will be after you've started flowing water or have added a line. You will always subtract this reading, and all subsequent readings, from the first intake pressure reading. If the result is within 0% - 10% (0 – 8 for our example) than will have at least 3 times the total GPM flowing for available water. If the result is within 11% - 15% (9 – 12 for our example) than will have at least 2 times the total GPM flowing for available water. If the result is within 16% - 20% (13 – 16) than will have at least 1 times the total GPM flowing for available water. To continue with our example, let's say we add a second attack line which is a 1-3/4" line flowing 180 GPM and we note that our intake pressure is now at 74 psi. We add the 180 GPM to the original 300 GPM to get a total flow of 480 GPM and subtract second intake pressure reading of 74 psi from the original reading of 84 psi to get 10. 10 falls between 9 and 12 so we put our second residual reading in the 15% drop row, **which allows us 2 times the current flow of 480 GPM for 960 GPM of available water**.

TOTAL GPM	RESIDUAL DROP	S/R_1	R_2	R_3
		84	**74**	
3	10%	**8**		
2	15%	**12**	**R_2**	
1	20%	**16**		

D. The next time you note your intake pressure reading will be after you have added another line. You will always subtract this reading from the first intake pressure reading. If the result is within 0% - 10% (0 – 8 for our example) than will have at least 3 times the total GPM flowing for available water. If the result is within 11% - 15% (9 – 12 for our example) than will have at least 2 times the total GPM flowing for available water. If the result is within 16% - 20% (13 – 16) than will have at least 1 times the total GPM flowing for available water. If the drop more than 20%, the reading will be off the table, and you will not be able to supply another flow equal to the total GPM currently being pumped. To continue with our example, let's say we add a third attack line, which is a 2-1/2" line flowing 300 GPM and we note that our intake pressure is now at 67 psi. We add the 300 GPM to the previously flowing 480 GPM to get a total flow of 780 GPM and subtract third intake pressure reading of 67 psi from the original reading of 84 psi to get 17. 17 is greater than 16, **which means we cannot supply a current like flow of 780 GPM (although we may be able to flow a smaller handline)**. Remember to keep the intake pressure above 20 psi.

TOTAL GPM	RESIDUAL DROP	S/R_1	R_2	R_3
		84	**74**	**67**
3	10%	**8**		
2	15%	**12**	**R_2**	
1	20%	**16**		
				R_3

Please refer to ***Appendix II*** for the classical "Static to Residual Drop" method of calculating residual flow, which most DFD Engineers are familiar with.

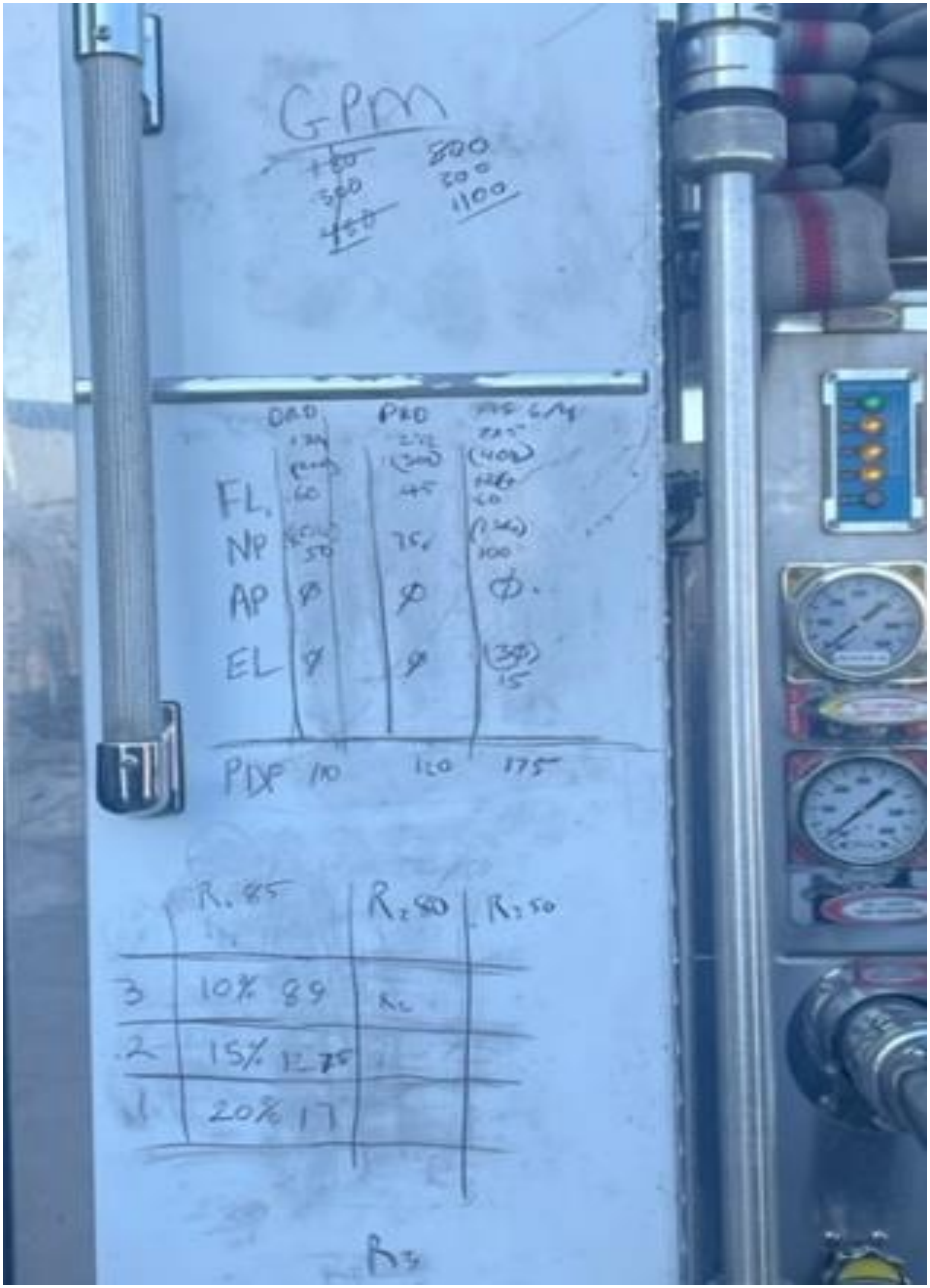


Figure 10: An example of using a grease pencil to keep track of calculations on the side of the rig next to the pump panel

Example 2: Finding the PDP for a Handline Using the Pump Chart (2” Handline)

Let’s tackle the same problem we looked at the last section that we solved using CQ^2L, but this time let’s use the pump chart. Find the total Pump Discharge Pressure needed to create an adequate fire flow in a two-hundred-foot section of 2” hoseline with a 1” tip that should be flowing 210 gallons per minute and note your residual water (your static pressure was 40 psi and your residual pressure was 30 psi).

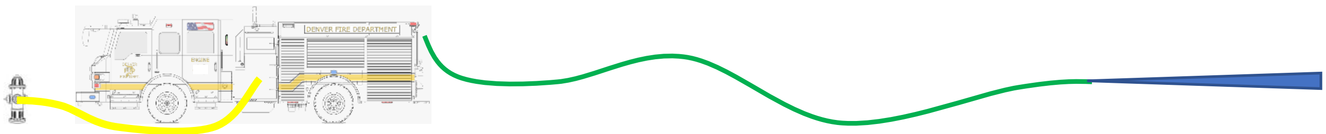


Figure 11: 200' of 2" Hoseline with a 1" Tip, Producing 210

First, find the values for the variables in the Pump Discharge Pressure Formula (PDP = NP + FL + APPL + ELEV):

A. NP = 50 psi
B. FL = Reference the pump chart to get 30 psi per 100’
C. APPL = 0
D. ELEV = 0

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)				
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	30	35	60	NA
2"	20	30	50	NA
2-1/2"	5	10	15	40
3"	3	5	10	25

When we plug the values into our Pump Discharge Pressure formula, we get:

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + (30 X 2) psi + 0 psi + 0 psi
C. PDP = 50 psi + 60 psi
D. PDP = 110 psi

Residual water – a 40 psi static pressure (S/R1) has been reduced to a 30 psi residual pressure (R_2) after water is flowing. This is a 10 psi reduction in intake pressure which is greater than a 20% residual drop, meaning we cannot pump any more like flows. The Engineer needs to notify the Incident Commander of this water supply issue immediately.

TOTAL GPM	RESIDUAL DROP	S/R_1 40	R_2 30
3	10%	4	
2	15%	6	
1	20%	8	
			R_2

40 - 30 = 10

RESIDUAL WATER		
0-10% DROP = 3 X GPM,	11-15% DROP = 2 X GPM,	16-20% DROP = 1 X GPM

Example 3: Finding the PDP for Two Handlines Using the Pump Chart (1-3/4” and 2-1/2” Handlines)

Find the total Pump Discharge Pressure needed to create an adequate fire flow in a three-hundred-foot section of 2-1/2” hoseline with a 1-3/16” smooth bore nozzle flowing 300 gallons per minute and a 200’ 1-3/4” hoseline with a 15/16” tip. Note your residual water (your static pressure was 40 psi, and your residual was 36 psi).

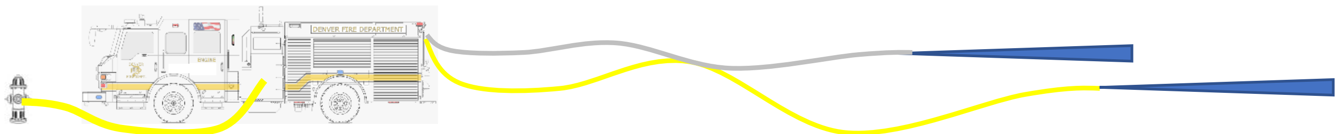


Figure 12: 300' of 2-1/2" Hoseline with a 1-3/16 Smooth Bore Nozzle with a Target Flow of 300 GPM and a 200’ 1-3/4” Hoseline with a 15/16” Smooth Bore Nozzle with a Target Flow of 180 GPM

First, find the values for the variables in the Pump Discharge Pressure Formula (PDP = NP + FL + APPL + ELEV) for both hoselines:

The values for the 1-3/4” hoseline would be:

A. NP = 50 psi
B. FL = Reference the pump chart to get 30 psi per 100’
C. APPL = 0
D. ELEV = 0

The values for the 2-1/2” hoseline would be:

A. NP = 50 psi
B. FL = Reference the pump chart to get 15 psi per 100’
C. APPL = 0
D. ELEV = 0

OFFENSIVE OPERATIONS	(PDP = NP + FL + APPL + ELEV)			
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	30	35	60	NA
2"	20	30	50	NA
2-1/2"	5	10	15	40
3"	3	5	10	25

When we plug the values into the Pump Discharge Pressure formula for the 200' 1-3/4" hoseline, we get:

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + (30 X 2) psi + 0 psi + 0 psi
C. PDP = 50 psi + 60 psi
D. PDP = 110 psi

When we plug the values into the Pump Discharge Pressure formula for the 300' 2-1/2" hoseline, we get:

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + (15 X 3) psi + 0 psi + 0 psi
C. PDP = 50 psi + 45 psi
D. PDP = 95 psi

Our Total PDP will be set to the highest pressure, which is the 1-3/4" hoseline at 110 psi. We will have to gate down the 2-1/2" hoseline to 95 psi.

Residual water – a 40 psi static pressure (S/R_1) has been reduced to a 36 psi residual pressure (R_2) after water is flowing. This is a 4 psi reduction in intake pressure which is within a 0-10% residual drop, meaning we can pump at least three more like flows (480 GPM x 3 = 1,440 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 **40**	R_2 **36**
3	10%	**4**	**R_2**
2	15%	**6**	
1	20%	**8**	

40 - 36 = 4

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 4: Finding the PDP when Extending a Hoseline (Larger Diameter Hoseline to Smaller)

Your Engine Company reverse lays out of an alley by disconnecting the 200’ 1-3/4” preconnect with a 180 GPM 75 psi fog nozzle from the rig, connecting it to the 2-1/2” static load with a reducer, and then laying out 600’ of the 2-1/2” hose to a hydrant and connecting to a water supply. Find the total Pump Discharge Pressure and note your residual water (your static pressure was 30 psi and your residual was 28 psi).

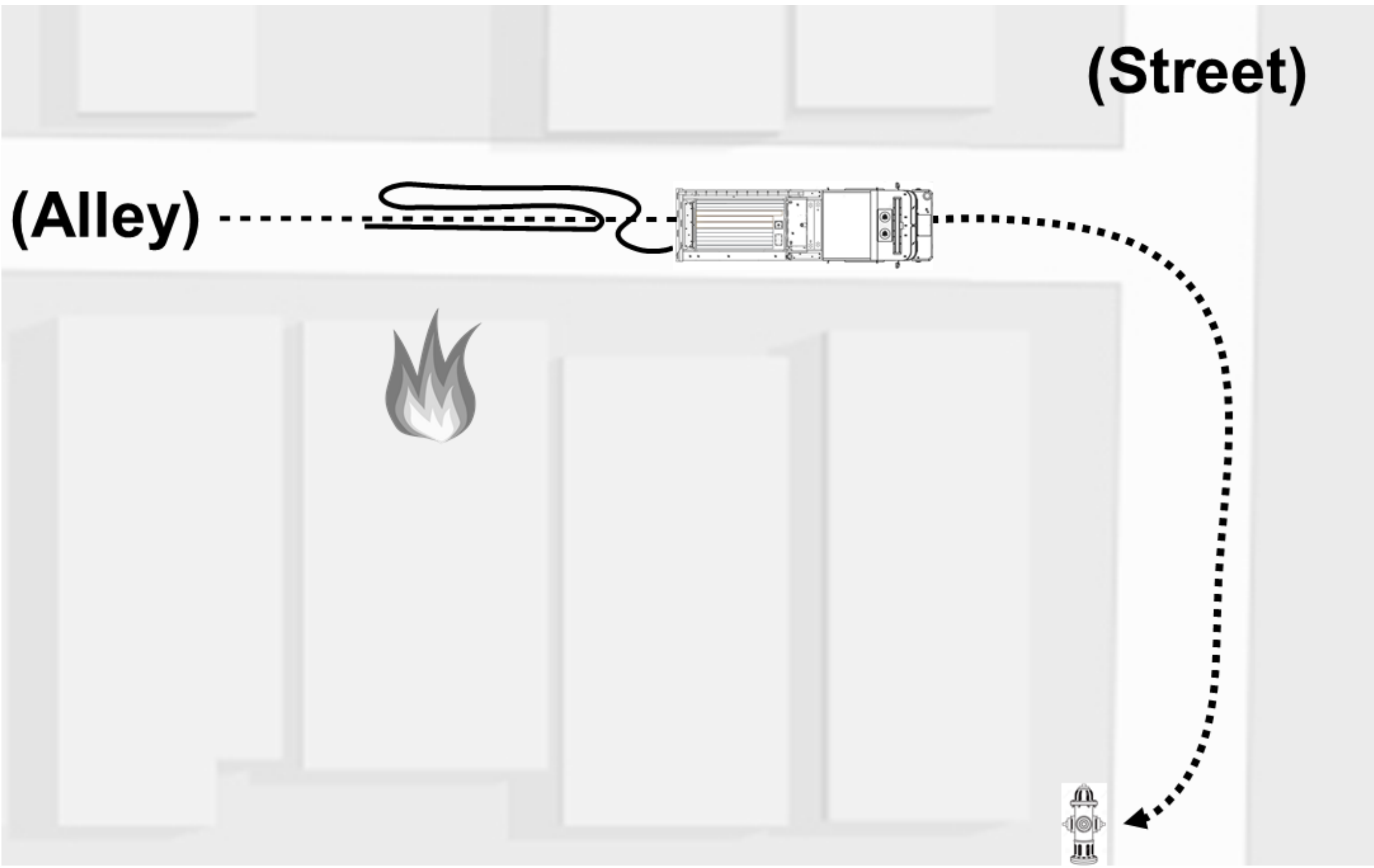


Figure 4: 600' of 2-1/2" Hoseline extended with a 200’ of 1-3/4" Hoseline with a 180 GPM 75 PSI Fog Nozzle

To find the PDP, we'll have to slightly modify our formula to account for two different diameters of handlines; we'll call these **FL_1** for the 1-3/4" line and **FL_2** for the 2-1/2" line.

Now, find the values for the variables in the Pump Discharge Pressure Formula:

A. NP = 75 psi
B. **FL_1** = Reference the pump chart to find the FL for the 1-3/4" line flowing 180 GPM from a fog nozzle
C. **FL_2** = Reference the pump chart to find the FL for the 2-1/2" line flowing 180 GPM (remember to use the same column)
D. APPL = 0
E. ELEV = 0

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)				
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	30	35	60	NA
2"	20	30	50	NA
2-1/2"	5	10	15	40
3"	3	5	10	25

When we plug the values into our modified Pump Discharge Pressure formula, we get:

A. PDP = NP + FL_1 + FL_2 + APPL + ELEV
B. PDP = 75 psi + (30 X 2) psi + (5 X 6) psi + 0 psi + 0 psi
C. PDP = 75 psi + 60 psi + 30 psi
D. PDP = **165 psi**

Residual water – a 30 psi static pressure (S/R_1) has been reduced to a 28 psi residual pressure (R_2) after water is flowing. This is a 2 psi reduction in intake pressure which is within a 0-10% residual drop, meaning we can pump at least three more like flows (180 GPM x 3 = 540 GPM)

TOTAL GPM	RESIDUAL DROP	S/R_1 30	R_2 28
3	10%	3	R_2
2	15%	4.5	
1	20%	9	

30 - 28 = 2

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 5: Finding the PDP when Extending a Hoseline (Smaller Diameter Hoseline to Larger)

Your engine crew attempted to stretch a 200’ 1-3/4” preconnect into an apartment building with a fire on the first floor and came up 50’ short. The probationary firefighter brought a 50’ section of 2-1/2” hoseline with a 1-3/16” nozzle and the high-rise bag, which includes an increaser. The DFD typically does not flow lines from a smaller diameter line to a larger diameter line, however, this is a feasible tactic and hydraulically acceptable. Find the total Pump Discharge Pressure needed to extend a 50’ section of 2-1/2” line with a 1-3/16” nozzle flowing 300 GPM connected to 200’ of 1-3/4” hose and note your residual water (your static pressure was 60 psi and your residual was 52 psi).

Figure 5: 200' of 1-3/4" Hoseline Extended with a 50’ Section of 2-1/2” High Rise Hose with a 1-3/16” Nozzle Flowing 300 GPM

Like the previous example, to find the PDP, we’ll have to slightly modify our formula to account for two different diameters of handlines; we’ll call these **FL_1** for the 2-1/2” nozzle section and **FL_2** for the 1-3/4” line.

Now, find the values for the variables in the Pump Discharge Pressure Formula:

A. NP = 50 psi
B. **FL_1** = Reference the pump chart to find the FL for the 2-1/2” 50’ nozzle section flowing 300 GPM from a 1-3/16” tip
C. **FL_2** = Reference the pump chart to find the FL for the 1.75” preconnect line flowing 300 GPM
D. APPL = 0
E. ELEV = 0

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)				
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	30	35	60	NA
2"	20	30	50	NA
2-1/2"	5	10	15	40
3"	3	5	10	25

When we plug the values into our modified Pump Discharge Pressure formula, we get:

A. PDP = NP + FL_1 + FL_2 + APPL + ELEV
B. PDP = 50 psi + (60 X 2) psi + (15 ÷ 2) psi + 0 psi + 0 psi
C. PDP = 50 psi + 120 psi + 7.5 psi
D. PDP = 177.5 psi, round up to 180 psi

Residual water – a 60 psi static pressure (S/ R_1) has been reduced to a 52 psi residual pressure (R_2) after water is flowing. This is an 8 psi reduction in intake pressure which is within an 11-15% residual drop, meaning we can pump at least tw0 more like flows (300 GPM x 2 = 600 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 **60**	R_2 **52**
3	10%	**6**	
2	15%	**9**	**R_2**
1	20%	**12**	

60 - 52 = 8

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 6: Finding the PDP for a Handline with an Increase in Elevation

Your engine crew responded to a structure fire in a four-story apartment building. Upon arrival your Company Officer notes fire through one window on the 3rd floor. From an inspection, you know that this building was built in the 1930s or 1940s and has an old standpipe that is something your entire crew looked at and stated, “we’ll never hook up to this”. Your Company Officer calls for the 300’ 1-3/4” preconnect off the rear of the apparatus, which you know has the 15/16” tip. Find the total Pump Discharge Pressure needed to make this fire attack and note your residual water (your static pressure was 80 psi and your residual was 70 psi).

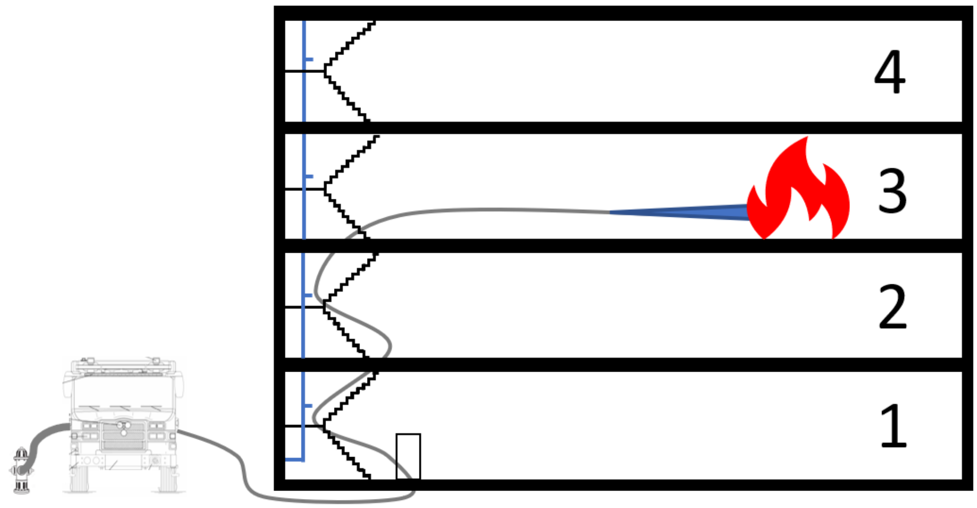


Figure 6: 300' of 1-3/4" Hoseline 15/16” Tip Flowing 180 GPM on the 3rd Floor

First, find the values for the variables in the Pump Discharge Pressure Formula:

A. NP = 50 psi
B. FL = Reference the pump chart to find the FL for the 1-3/4” hoseline flowing 180 GPM from a 15/16” tip
C. APPL = 0
D. ELEV = 3 floors minus 1 to account for the engine pump elevation = 2 floors x 5 psi = 10 psi

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)				
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	30	35	60	NA
2"	20	30	50	NA
2-1/2"	5	10	15	40
3"	3	5	10	25
OFFENSIVE APPLIANCES AND ELEVATION				
STANDPIPE AND SUPPLY HOSE TO FDC = 30 PSI	ELEV = 5 PSI PER FLOOR, 0.5 PSI PER FOOT			
BRESNANS (1-1/2" OR 2-1/2") = 100 PSI NOZZLE PRESSURE, 15 PSI FL/100'				

When we plug the values into the Pump Discharge Pressure formula, we get:

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + (30 X 3) psi + 0 psi + 10 psi
C. PDP = 50 psi + 90 psi + 0 psi + 10 psi
D. PDP = 150 psi

Residual water – a 80 psi static pressure (S/R_1) has been reduced to a 70 psi residual pressure (R_2) after water is flowing. This is a 10 psi reduction in intake pressure which is within an 11-15% residual drop, meaning we can pump at least two more like flows (180 GPM x 2 = 360 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 **80**	R_2 **70**
3	10%	**8**	
2	15%	**12**	**R_2**
1	20%	**16**	

80 - 70 = 10

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 7: Finding the PDP for a Handline with a Decrease in Elevation

Your company responds to a vehicle fire on an underpass – the only water supply is 250 away from the overpass. You have to park near the overpass with the pump panel approximately 35 feet above the vehicle on fire. Find the total Pump Discharge Pressure needed to create an adequate fire flow in a 300' 1-3/4" hoseline with a 50-psi fog nozzle that should be flowing 180 gallons per minute. You noted your static pressure at 50 psi and your residual pressure was 48 psi.

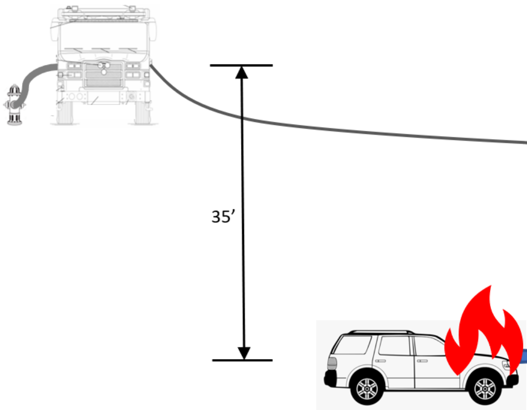


Figure 7: 300' of 1-3/4" Hoseline extended 35' Below the Pump with a 180 GPM 50 psi Fog Nozzle

First, find the values for the variables in the Pump Discharge Pressure Formula:

A. NP = 50 psi
B. FL = Reference the pump chart to find the FL for the 1-3/4" hoseline flowing 180 GPM from a 1-3/4" fog
C. APPL = 0
D. ELEV = the nozzle is 35' below the engine pump = 35' x 0.5 psi = 17.5 psi, round to 20 psi

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)				
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	30	35	60	NA
2"	20	30	50	NA
2-1/2"	5	10	15	40
3"	3	5	10	25
OFFENSIVE APPLIANCES AND ELEVATION				
STANDPIPE AND SUPPLY HOSE TO FDC = 30 PSI	ELEV = 5 PSI PER FLOOR	0.5 PSI PER FOOT		
BRESNANS (1-1/2" OR 2-1/2") = 100 PSI NOZZLE PRESSURE, 15 PSI FL/100'				

When we plug the answers from our Pump Chart back into our Pump Discharge Pressure formula, we get:

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + (30 x 3) psi + 0 psi **– 20 psi**
C. PDP = 50 psi + 90 psi + 0 psi **– 20 psi**
D. PDP = 120 psi

Residual water – a 50 psi static pressure (S/ R_1) has been reduced to a 48 psi residual pressure (R_2) after water is flowing. This is a 2 psi reduction in intake pressure which is within an 0-10% residual drop, meaning we can pump at least three more like flows (180 GPM x 3 = 540 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 **50**	R_2 **48**
3	10%	**5**	**R_2**
2	15%	**7.5**	
1	20%	**10**	

50 - 48 = 2

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 8: Finding the PDP for a Handline in a Standpipe Equipped Building without a Fire Pump

Find the total Pump Discharge Pressure needed to create an adequate fire flow at a seven-story standpipe equipped building with no fire pumps or PRVs with a fire reported on the 5th floor (if you don't have time to find out if there's a fire pump, you'll have to default to pumping to the roof). Your engine crew entered the building with four sections of 2-1/2" hose and one section of 2" hose. Your engine is located 100' from the standpipe connection. What pressure are you going to pump to the standpipe? What pressure is the control firefighter going to set the cabinet to? You noted your static pressure at 60 psi and your residual pressure was 48 psi, what is your available water? How should the engineer pump to the standpipe (knowing that we try to pump to the lowest flow rate, which is 210 GPM, to protect the standpipe, and increase pressure if requested by the control firefighter or company officer)?

Figure 4: Pump to a 7- Story Standpipe Equipped Building with a Fire on the Fifth Floor
Copyright https://history.denverlibrary.org/news/albany-hotel-fire

How will you determine the pressure that you will pump to the standpipe?

First, find the values for the variables in the Pump Discharge Pressure Formula (PDP = NP + FL + APPL + ELEV):

A. NP = 50 psi
B. FL = for the handlines; reference the pump chart column for the tip that will be used on the nozzle section to find the total friction loss for the mixed hose compliment (200' of 2-1/2" at 10 psi per 100', 50' of 2" at 30 psi per 100') = (2 x 10) + (30 ÷ 2) = 20 + 15 = 35 psi
C. APPL = Standpipe = 30 psi
D. ELEV = 5 floors minus 1 to account for the engine pump elevation = 4 floors x 5 psi = 20 psi

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)				
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	30	35	60	NA
2"	20	30	50	NA
2-1/2"	5	10	15	40
3"	3	5	10	25
OFFENSIVE APPLIANCES AND ELEVATION				
STANDPIPE AND SUPPLY HOSE TO FDC = 30 PSI		ELEV = 5 PSI PER FLOOR, 0.5 PSI PER FOOT		
BRESNANS (1-1/2" OR 2-1/2") = 100 PSI NOZZLE PRESSURE, 15 PSI FL/100'				

What is the control firefighter going to set the cabinet pressure to?

The cabinet firefighter witnessed the crew set up four sections of 2-1/2" hoseline with one section of 2" hose in the lead with a 1" 210 GPM smooth bore nozzle one floor above the cabinet. At this point, the control firefighter "becomes the engineer" and needs to set the pressure according to the abridged pump chart.

First, find the values for the variables in the Standpipe Pump Discharge Pressure Formula (PDP = NP + FL + ELEV):

A. NP = 50 psi
B. FL = for the handlines; reference the pump chart column for the tip that will be used on the nozzle section to find the total friction loss for the mixed hose compliment (200' of 2-1/2" at 10 psi per 100', 50' of 2" at 30 psi per 100') = (2 x 10) + (30 ÷ 2) = 20 + 15 = 35 psi
C. ELEV = 1 floor = 5 psi

STANDPIPE OPERATIONS PDP = NP + FL + ELEV		
	FL/100'	
TIP SIZE	1" TIP	1-3/16" TIP
FLOW RATE	210 GPM	300 GPM
NOZZLE PRES	50 PSI	50 PSI
2"	30	50
2-1/2"	10	15
ELEV = 5 PSI PER FLOOR		

Table 1: Abridged Pump Chart for the Control Firefighter

Then replace the variables with the values in the Standpipe Pump Discharge Pressure formula to get the PDP for the cabinet:

A. PDP = NP + FL + ELEV
B. PDP = 50 psi + 35 psi + 5 psi
C. PDP = 90 psi

LENGTH	2.5" HOSE WITH A 2" NOZZLE SECTION	PSI
100'	1 SECTION 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	75
150'	2 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	80
200'	3 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	85
250'	4 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	90
300'	5 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	95
350'	6 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	100
400'	7 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	105
450'	8 SECTIONS 2.5", 1 NOZZLE SECTION 2", 1 FLOOR ELEVATION	110

Figure 13: "Cheat Sheet" for the Control Firefighter

Alternatively, the cabinet firefighter could get the same answer of 90 psi from the "cheat sheet" located in the high-rise bag.

Residual water – a 60 psi static pressure (S/ R_1) has been reduced to a 48 psi residual pressure (R_2) after water is flowing. This is a 12 psi reduction in intake pressure which is within an 16-20% residual drop, meaning we can pump at least one more like flows (210 GPM x 1 = 210 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 60	R_2 48
3	10%	6	
2	15%	9	
1	20%	12	R_2

60 - 48 = 12

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

How should the Engineer pump to the standpipe?

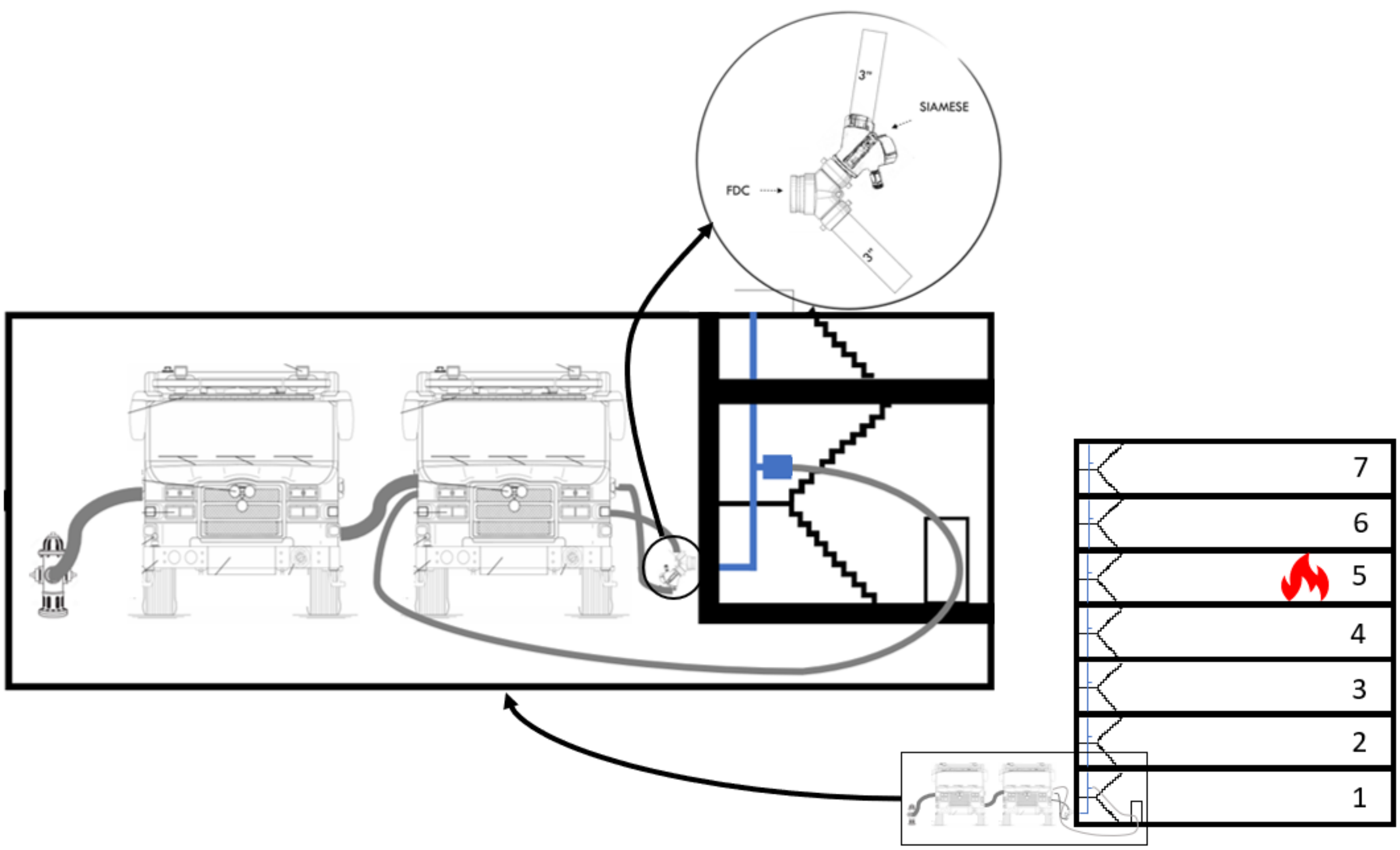


Figure 14: Setting up water delivery and supply for a standpipe equipped building without a fire pump

The 1st and 2nd Engine Engineers would set up the water supply with the following considerations (from High-Rise Exterior Operations, SOG 2114.03):

1) The 1st in Engine Engineer should spot the engine as close as possible to the building's Fire Department Connection (FDC) and would check to see if there is a fire pump (there is not), which means:

a. Hook up two 3" supply lines to the building's FDC. If the building has a two-inlet FDC, the Engineer should attach a clappered siamese to one of the inlets on the FDC. This will establish a third inlet for the water supply which can be used by the 3rd arriving Engine to establish an initial secondary supply.
b. The Engineer would hook up a supply line to the interior FDC because the building is not PRV equipped.
c. Supply lines to the building's system should be slowly charged as soon as it becomes apparent that a working fire is present.
d. The first in Engine should pump in PSI mode and in the PRESSURE setting.
e. The Engineer would then prepare to receive supply lines from the Engineer of the second-arriving engine company.

2) The 2nd in Engine Engineer (assisted by their crew if necessary) should:
   a. Reverse lay/hand stretch the appropriate supply lines to the first in engine at the FDC and go to work at a hydrant which will include:
      i. a minimum of two 3" supply lines from engine-to-engine
      ii. a 35' 5-inch supply connected to a hydrant
   b. All supply lines should be charged with water up to the first-arriving engine company at the FDC once it is confirmed that the first engine is prepared to receive water.
   c. When pressure is needed or requested, it should be brought up slowly to the correct setting; both Engineers should communicate with each other to achieve the desired result.
   d. The engine located at the hydrant should be in RPM mode (to remove the possibility of the computer attempting to overcorrect for fluctuations in the first in Engine's PSI setting) and start in the volume setting but be prepared to changeover to the pressure setting if needed.

Ensure that the pump is in the PRESSURE setting and the PSI mode because the apparatus will be pumping directly into the FDC. Due to condensation collecting in standpipes and falling to the lowest level (the FDC connection) causing rust, the Engineer needs to pump to the standpipe in up to three phases to reduce the risk of rupture. First, slowly get water to the FDC, then gradually increase the pressure to reach the fire floor, and if extension is noted or if the control firefighter asks for more pressure, pump to the roof (subtract one floor to account for the pump elevation):

HIGH-RISE OPERATIONS
ENGINE AT FDC, PUMP IN "PRESSURE" AND "PSI" (FOR SPRINKLERS, START IN "VOLUME" AT 150 PSI)
BUILDINGS WITHOUT FIRE PUMPS: SLOWLY PUMP TO FIRE FLOOR
BUILDINGS WITH FIRE PUMP: IF FIRE PUMP IS RUNNING, GET WATER TO FDC WITH NO PRESSURE, IF FIRE PUMP IS ***NOT*** WORKING, PUMP TO FIRE FLOOR IF NO PRVS, PUMP TO ROOF IF PRVS

Phase 1: Fill the lines going to the FDC by gating down the valves so the standpipe connection from the FDC to the riser is not under pressure.

Phase 2: Slowly pump to the fire floor (the floor minus one floor to account for the elevation of the engine pump), then find Pump Discharge Pressure (PDP = NP + FL + APPL + ELEV) by plugging in the values for the variables:

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + ((2 x 10) + (30 ÷ 2)) psi + 30 psi + 20 psi
C. PDP = 50 psi + (20 + 15) psi + 30 psi + 20 psi
D. PDP = 50 psi + 35 psi + 30 psi + 20 psi
E. PDP = 135 psi

Phase 3: When the cabinet firefighter requests more pressure or there is extension reported on another floor, the Engineer will pump to the highest standpipe connection (the roof of a 7-story building would be the 8th floor, minus one floor to account for the elevation of the engine pump, so 7-stories total times 5 psi friction loss per floor, equals 35 psi):

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + 35 psi + 30 psi + 35 psi
C. PDP = 150 psi

There are a couple important points to this order of operations:

1) The first in engine should go to the FDC, connect to the FDC with two 3" supply lines using a clappered Siamese on one connection so the third in engine can use a secondary supply should the need arise (see SOG 2114.02)
2) The first in engine needs to supply the FDC with tank water in PSI MODE, keeping the initial pump pressure under 270 psi until the second in engine has supplied the first in engine to protect the interior hose team in case there is any water spikes, then consider switching into RPM mode

Note that some engines have thrown an error code and automatically reduce their engine RPMs to idle when the psi is at or above 300 psi for more than 5 seconds to avoid cavitation. We recommend considering "turning the computer off" by switching to RPM mode when your PDP is at 270 psi or above. A momentary exception to this recommendation is when pumping to a non-PRV equipped building and the second engine is getting ready to supply the first engine, ensure that the first engine's pump is in PSI mode (the computer's pressure governor engaged) so any pressure spike won't be transmitted to the fire attack team.

Example 9: Finding the PDP for a Handline in a High-Rise with a Working Fire Pump and PRVs

Find the total Pump Discharge Pressure needed to create an adequate fire flow at a forty-two-story standpipe equipped building with PRVs and a fire pump that is operating when you check it in the pump room. The fire has been reported on the 5th floor. Your engine crew entered the building with four sections of 2-1/2" hose. Your engine is 100' from the standpipe connection. What pressure are you going to pump to the standpipe and how? How would you have the Engineers place their rigs? The control firefighter should set the cabinet to what pressure? You noted your static pressure at 40 psi and your residual pressure was 37 psi.

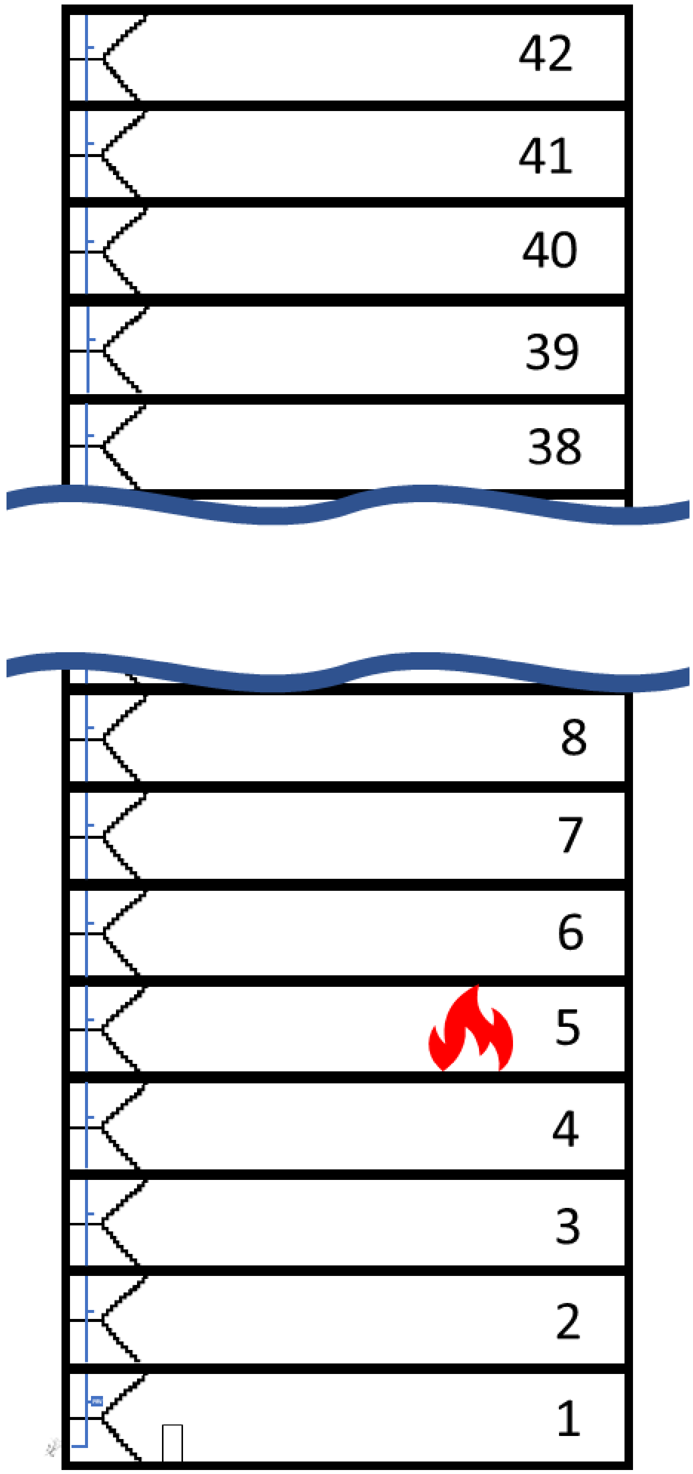


Figure 4: Pump to a forty-two-story standpipe equipped building with PRVs and a working fire pump.

How should the Engineer pump to the standpipe?

Using the HIGH-RISE OPERATIONS section of the DFD Pump Chart, and knowing that the building's fire pump is working, we are not going to try to overcome the building's fire pump but instead are going to pump to the building's FDC at idle to be ready to supply water in case the building's fire pump fails.

HIGH-RISE OPERATIONS
ENGINE AT FDC, PUMP IN "PRESSURE" AND "PSI" (FOR SPRINKLERS, START IN "VOLUME" AT 150 PSI)
BUILDINGS WITHOUT FIRE PUMPS: SLOWLY PUMP TO FIRE FLOOR
BUILDINGS WITH FIRE PUMP: IF FIRE PUMP IS RUNNING, GET WATER TO FDC WITH NO PRESSURE,
IF FIRE PUMP IS ***NOT*** WORKING, PUMP TO FIRE FLOOR IF NO PRVS, PUMP TO ROOF IF PRVS

The 1st in Engine Engineers would set up the water delivery system with the following considerations (abridged from High-Rise Exterior Operations, SOG 2114.03):

The 1st Engine Engineer should spot the engine as close as possible to the building's fire department connection (FDC) would check to see if the fire pump is running (in this exercise, it is) and if the building has PRVs (in this exercise, it does), which means:

A. Hook up two 3" supply lines to the building's FDC. If the building has a two-inlet FDC, the Engineer should attach a clappered siamese to one of the inlets on the FDC. This will establish a third inlet for the water supply which can be used by the 3rd arriving Engine to establish an initial secondary supply.
B. The Engineer would not attempt to overcome the building's fire pump; instead, the Engineer would get water to the building's FDC with no pressure, shut down the outlet gates, and be ready to take over the fire pump in case of failure.
C. The Engineer would not hook up a supply line to the interior FDC because the standpipe is PRV equipped. The PRV is essentially a check valve which will not allow water to be supplied through its outlet.
D. Supply lines to the building's system should be slowly charged and then the outlet gates shut down as soon as it becomes apparent that a working fire is present.
E. The first in Engine should pump in PSI mode and in the PRESSURE setting.
F. Prepare to receive supply lines from the Engineer of the second-arriving engine company.

The 2nd in Engine Engineer (assisted by their crew if necessary) should:

A. Reverse lay/hand stretch the appropriate supply lines to the first in engine at the FDC and go to work at a hydrant which will include:
B. a minimum of two 3" supply lines from engine-to-engine
C. a 35' 5-inch supply connected to a hydrant
D. All supply lines should be charged with water up to the first-arriving engine company at the FDC once it is confirmed that the first engine is prepared to receive water.
E. When pressure is needed or requested, it should be brought up slowly to the correct setting; both Engineers should communicate with each other to achieve the desired result.
F. The engine located at the hydrant should be in RPM mode (to remove the possibility of the computer attempting to overcorrect for fluctuations in the first in Engine's PSI setting) and start in the volume setting but be prepared to changeover to the pressure setting if needed.

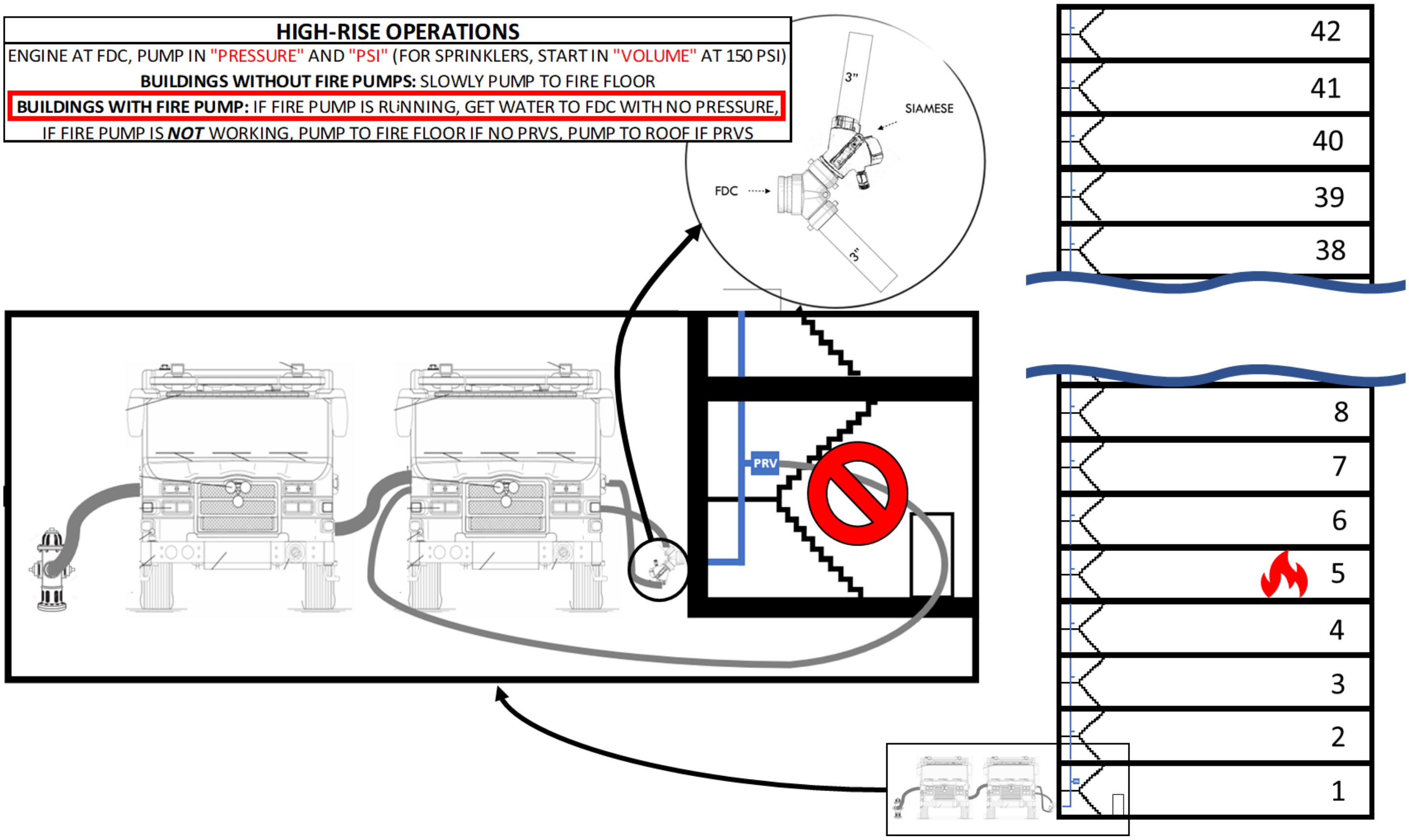


Figure 15: Water supply and delivery setup to a 42-story building with a working fire pump and a PRV equipped standpipe

Rig placement at a standpipe equipped building:

When placing engines a standpipe equipped building, ***after ensuring that there is no hampering of truck/tower placement for imminent rescue,*** it is important to set up in such a way as to allow for access to the FDC and possibly the location of the standpipe (to pull a supply line to if it does not have PRVs) and to allow access for the next in Engine Company to go to work on the nearest hydrant.

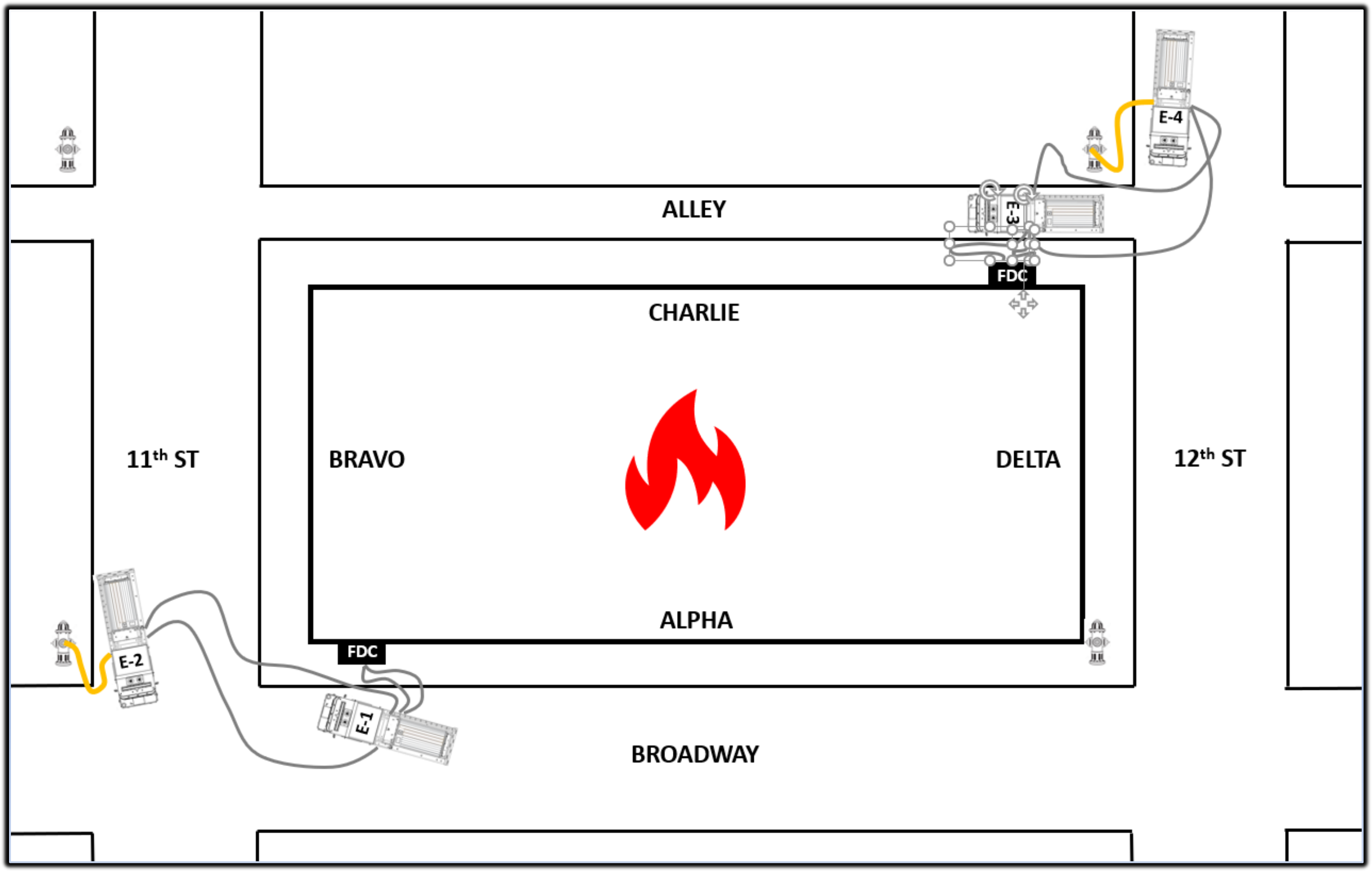


Figure 16: Possible rig placement at a high-rise structure fire

There are many variations for rig placement at a high-rise structure fire. Keep in mind the three strategic priorities for the fireground (LIP):

1) Life safety
2) Incident stabilization
3) Property conservation

In the picture above, E-3 blocked the alley to set up at the FDC; if there are multiple overhead obstructions, this may be a great placement to be out of the way. As stated above, although it is a good common practice for the first engine to park as close to the FDC as possible, it may be necessary to park farther away if there is an imminent rescue nearby. In this example, E-2 has set up on the plug at 11th and Broadway, which is close to E-1; however, the hose stretch has effectively blocked 11th Street. Although this still might be the best positioning based on next in companies, E-2 may also want to consider reversing from E-1 to the plug at Broadway and 12th to leave all access points open.

Conversely, it is typical for a truck/tower company to set up on the corner of the building to be able to sweep two sides, however, depending on the footprint of the building, this may or may not be the best option. In the pictures on the next page, T-8 was on the scene of a working structure fire and Engineer Ditolla placed the aerial within the courtyard of a at a "C-Shaped" building, allowing for multiple egress avenues instead of being focused on the corner of a building.

Figure 17: Courtyard placement of an aerial (T8)

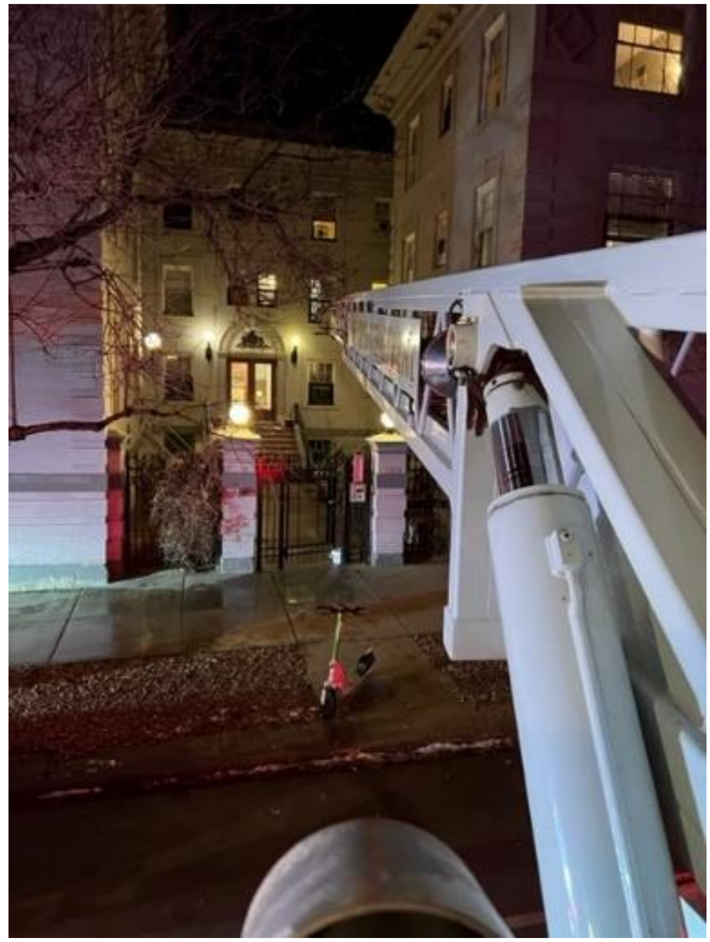


Figure 18: Turntable placement to a courtyard (T8)

Rig placement is rarely a black and white issue, but is instead the ability to quickly size up the building from multiple perspectives (as an Engine Engineer, you need to set up near an FDC, but also need to be considering the best spot for the truck company) while anticipating fire behavior and firefighting operations. The adage that you can stretch a hoseline but you can't stretch a ladder applies to nearly every fire incident.

What is the control firefighter going to set the cabinet pressure to?

At this point, the control firefighter becomes the engineer and needs to set the pressure according to the abridged pump chart:

STANDPIPE OPERATIONS		
	FL/100'	
TIP SIZE	1" TIP	1-3/16"
FLOW RATE	210 GPM	300 GPM
NOZZLE PRES	50 PSI	50 PSI
2"	30	50
2-1/2"	10	15
ELEV = 5 PSI PER FLOOR		

Table 2: Abridged Pump Chart for the Control Firefighter

The cabinet firefighter witnessed the crew set up four sections of 2-1/2" hoseline with a 1-3/16" smooth bore nozzle one floor above the cabinet. The Company Officer requested 300 GPM per minute. The cabinet firefighter finds the Friction Loss from their Standpipe Operations Pump Chart and works it into our Pump Discharge Pressure formula and get:

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + 30 psi + 0 psi + 5 psi
C. PDP = 85 psi

LENGTH	2.5" HOSE ONLY	PSI
100'	2 SECTIONS 2.5", 1 FLOOR ELEVATION	70
150'	3 SECTIONS 2.5", 1 FLOOR ELEVATION	75
200'	4 SECTIONS 2.5", 1 FLOOR ELEVATION	85
250'	5 SECTIONS 2.5", 1 FLOOR ELEVATION	95
300'	6 SECTIONS 2.5", 1 FLOOR ELEVATION	100
350'	7 SECTIONS 2.5", 1 FLOOR ELEVATION	110
400'	8 SECTIONS 2.5", 1 FLOOR ELEVATION	115

Figure 19: "Cheat Sheet" for the Control Firefighter

Alternatively, the cabinet firefighter could get the same answer of 85 psi from the "cheat sheet" located in the high-rise bag.

Residual water – a 40 psi static pressure (S/ R_1) has been reduced to a 37 psi residual pressure (R_2) after water is flowing. This is a 3 psi reduction in intake pressure which is within an 0-10% residual drop, meaning we can pump at least three more like flows (300 GPM x 3 = 900 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 40	R_2 37
3	10%	4	R_2
2	15%	6	
1	20%	8	

40 - 37 = 3

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 10: Finding the PDP for a Handline in a High-Rise with PRVs and a Failed Fire Pump

You are at the problem noted in the previous example, and suddenly hear radio traffic about water pressure loss. A building manager runs up to you and says that the fire pump has just stopped working and that they are unable to get it up and running again. As a reminder, this is a 42-story building with a PRV equipped standpipe and the fire has been reported on the 5th floor; your crew entered the building with four sections of 2-1/2" hose. What PDP are you going to pump to the standpipe? Your Engine is equipped with a single stage pump, how can you attain the required PDP? You noted your static pressure at 70 psi and your residual pressure was 65 psi.

How will you determine the pressure that you will pump to the FDC?

Using the total Pump Discharge Pressure Formula (PDP = NP + FL + APPL + ELEV):

A. NP = 50 psi
B. FL = for the handlines; reference the pump chart column for the tip that will be used on the nozzle section to find the total friction loss for the mixed hose compliment 200' of 2-1/2" at 15 psi per 100' = 2 x 15 = 30 psi
C. APPL = Standpipe = 30 psi
D. ELEV = 43 floors to the roof minus 1 to account for the engine pump elevation = 42 x 5 psi = 210 psi

OFFENSIVE OPERATIONS (PDP = NP + FL + APPL + ELEV)				
	FL/100'			
TIP	15/16" TIP OR FOG	1" TIP	1-3/16" TIP OR FOG	RAM OR BLITZ
FLOW RATE	180 GPM	210 GPM	300 GPM	500 GPM
NOZZLE PRESSURE	50/75 PSI	50 PSI	50/75 PSI	80 PSI
1-3/4"	30	35	60	NA
2"	20	30	50	NA
2-1/2"	5	10	15	40
3"	3	5	10	25
OFFENSIVE APPLIANCES AND ELEVATION				
STANDPIPE AND SUPPLY HOSE TO FDC = 30 PSI		ELEV = 5 PSI PER FLOOR, .5 PSI PER FOOT		
BRESNANS (1-1/2" OR 2-1/2") = 100 PSI NOZZLE PRESSURE, 15 PSI FL/100'				

How Should the Engineer Pump to the FDC?

Note that the Engineer should still pump in the PRESSURE setting and the PSI mode because the apparatus will be pumping directly into the FDC. To protect the standpipe, the Engineer needs to pump in two phases; first pump to the FDC at idle, then gradually increasing pressure required to reach the roof minus one floor to account for the engine pump elevation to ensure that the PRVs are working correctly, or when the control firefighter states that they have enough pressure, (outlined in the HIGH-RISE OPERATIONS section of the pump chart):

HIGH-RISE OPERATIONS
ENGINE AT FDC, PUMP IN "PRESSURE" AND "PSI" (FOR SPRINKLERS, START IN "VOLUME" AT 150 PSI)
BUILDINGS WITHOUT FIRE PUMPS: SLOWLY PUMP TO FIRE FLOOR
BUILDINGS WITH FIRE PUMP: IF FIRE PUMP IS RUNNING, GET WATER TO FDC WITH NO PRESSURE, IF FIRE PUMP IS ***NOT*** WORKING, PUMP TO FIRE FLOOR IF NO PRVS, PUMP TO ROOF IF PRVS

Phase 1: Fill the lines going to the FDC with water and then pump at idle.

Phase 2: Slowly pump to the roof (the floor minus one floor to account for the elevation of the engine pump):

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + 30 psi + 30 psi + 210 psi
C. PDP = 320 psi

Your Engine is equipped with a single stage pump, how can you attain the required PDP?

By ensuring that your supply engine is pumping into your inlets at a higher pressure than the minimum 20 psi. In essence, you are turning the two engines into a single dual stage pump that is in the pressure setting, so that the supply engine at the hydrant is boosting the pressure to the attack engine at the FDC. To complete this process, the supply engine will be in the RPM mode (to remove the computer from the process and make sure it doesn't conflict with the attack engine's computer) and start in the VOLUME setting, but most likely will have to switch to the PRESSURE setting if it is equipped with a dual stage pump. The attack engine at the FDC will be in PSI mode and will coordinate with the supply engine to adequately boost the pressure.

When the attack engine in receiving flow (GPM) and pressure (psi) from the supply engine, the attack engine may need to adjust their Intake Relief Valve if they need to achieve high total PDP pressures. Most engines have their Intake Relief Valves set to 150 psi. The access for the Intake Relief Valve on most engines is located on the Officer's side pump panel as shown below.

Figure 20: The intake relief valve is typically located on the Officer's side pump panel

The engineer can increase the amount of intake GPMs manually by rotating the valve in a clockwise motion.

Figure 21: Rotate the intake relief valve in a clockwise motion to increase intake GPMs

The shop recommends flushing the intake relief valve after hooking up to hydrants to remove any debris caught in the system and at least once a week, possibly on rig days.

Residual water – a 70 psi static pressure (S/R1) has been reduced to a 65 psi residual pressure (R_2) after water is flowing. This is a 5 psi reduction in intake pressure which is within an 0-10% residual drop, meaning we can pump at least one more like flows (300 GPM x 3 = 900 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 **70**	R_2 **65**
3	10%	**7**	**R_2**
2	15%	**10.5**	
1	20%	**14**	

70 - 65 = 5

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

DFD Pump Chart Defensive Operations Explained

The DFD Pump Chart Defensive Operations section contains four main parts:

1. The friction loss per hundred feet for trucks/towers/master streams based on nozzle type/flow and number of 3" supply lines (also includes a single 5" supply line)

DEFENSIVE OPERATIONS (PDP = FL + APPL)						
TIP SIZE	1 TIP GPM *(2 TIP GPM)* FOGS = GPM	FRICTION LOSS PER 100' MASTER STREAMS WITH 1 TIP *(TOWERS WITH 2 TIPS)*				
		ONE - 3"	TWO - 3"	THREE - 3"	FOUR - 3"	ONE - 5"
1-3/8"	**500** *(1000)*	**25** *(NA)*	**6** *(25)*	**3** *(12)*	**2** *(8)*	**2** *(8)*
1-1/2"	**600** *(1200)*	**40** *(NA)*	**10** *(40)*	**5** *(20)*	**3** *(12)*	**3** *(12)*
1-3/4"	**800** *(1600)*	**60** *(NA)*	**15** *(60)*	**8** *(32)*	**5** *(20)*	**5** *(20)*
2"	**1000** *(2000)*	**NA** *(NA)*	**25** *(NA)*	**13** *(50)*	**8** *(32)*	**8** *(32)*
2-1/4"	**1300** *(2600)*	**NA** *(NA)*	**40** *(NA)*	**20** *(80)*	**15** *(60)*	**15** *(60)*
2-1/2"	**1600** *(3200)*	**NA** *(NA)*	**60** *(NA)*	**30** *(NA)*	**20** *(80)*	**20** *(80)*

Table 3: Defensive Operations Matrix

A few of items of note in this section:

A. The values annotated in green background with white lettering note the friction loss using the recommended nozzle (1-3/4") to get the best distance/volume/penetration stream due to the diameter of the waterways on trucks and towers

B. Flows with one tip (trucks and master streams) are annotated in bold, flows with two tips (towers) are annotated with italics, underlined, and within parathesis

C. Please note that because master streams have incorporated the friction loss for the nozzle and aerial elevation, the **total PDP calculation has been simplified to PDP = FL + APPL**.

2. The Defensive Appliances section includes the friction numbers for deck guns, master streams, and trucks/towers at the appliance.

DEFENSIVE APPLIANCES	
DECK GUN/GROUND MONITOR AT APPLIANCE = 100 PSI	RELAY ENGINES AT TAILBOARD = 50 PSI
TRUCKS OR TOWERS AT TAILBOARD = 200 PSI (ENGINE WITHIN 100' OF TAILBOARD)	

Table 4: Friction Numbers for Nozzles, Appliances, and Elevation

A note about the 200 psi at the tailboard for trucks/towers:

This is an average pressure to deliver at the tailboard gauge on a Truck/Tower and includes the nozzle pressure, loss in the aerial waterway, appliance (Siamese or Triamese), and 50' of elevation.

This number was produced by averaging flows through:

- Several Trucks/Towers
- Various elevation changes
- All Tip sizes

This is a starting point and shouldn't take away what each Truck/Tower requests, the ability to change based on stream quality, or the intake pressure available at the water source.

The same concept applies to calculating for the deck gun or ground monitor, which we have simplified to 100 psi regardless of nozzle type or elevation – ***this is a starting point, be willing to adjust pressure based on conditions.***

3. A 'RELAY OPERATIONS' section that includes "rules of thumb" for pumping in high volume and extended distance scenarios.

RELAY OPERATIONS
RELAY PUMPING: ATTACK ENGINES SHALL BE IN "PSI" MODE, SUPPLY ENGINES IN "VOLUME" AND "RPM" MODE WHILE MAINTAINING AT LEAST 20 PSI MINIMUM INTAKE PRESSURE
RELAY MAX DISTANCES: WHEN PUMPING 5" AT 2000 GPM, MAX DIST 600' TO NEXT ENGINE WHEN PUMPING 3 X 3" AT 2000 GPM, MAX DIST 400' TO NEXT ENGINE
PUMP IN "PRESSURE" WHEN PUMPING LESS THAN 1000 GPM INTO AN FDC

5. To determine your residual water (the ability to provide "like flows" in terms of GPMs), note your static and residual pressures if you're initially going off a hydrant, or note your residual water pressures if you initially went off the tank and then introduced a water supply. Remember to maintain at least 20 psi intake pressure.

   Please refer to the Offensive Operations portion of this document (starting on page 11) for a detailed description of how to calculate residual water.

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 11: Finding the PDP for a Deck Gun

You arrive at a large rubbish fire on the edge of a field with a hydrant nearby. You hook up to the hydrant to supply your deck gun which has a 2" smooth bore nozzle flowing 1000 GPM. What is your PDP? You noted your static pressure at 50 psi and your residual pressure was 30 psi.

First, find the values for the variables in the Pump Discharge Pressure Formula (PDP = FL + APPL):

1) FL = 0 psi, there is no hose is this system
2) APPL = 100 psi

DEFENSIVE APPLIANCES	
DECK GUN/GROUND MONITOR AT APPLIANCE = 100 PSI	RELAY ENGINES AT TAILBOARD = 50 PSI
TRUCKS OR TOWERS AT TAILBOARD = 200 PSI (ENGINE WITHIN 100' OF TAILBOARD)	

When we replace the variables with our values determined by our Pump Chart back into our Pump Discharge Pressure formula, we get:

A. PDP = FL + APPL
B. PDP = 0 psi + 100 psi
C. PDP = 100 psi

Residual water – a 50 psi static pressure (S/R1) has been reduced to a 30 psi residual pressure (R_2) after water is flowing. This is a 20 psi reduction in intake pressure which is greater than our 20% residual drop, meaning we cannot pump any more like flows. The Engineer needs to notify the Incident Commander of this water supply issue immediately.

TOTAL GPM	RESIDUAL DROP	S/R_1 50	R_2 30
3	10%	5	
2	15%	7.5	
1	20%	10	
			R_2

50 - 30 = 20

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 12: Finding the PDP for a Ground Monitor

You arrive at another large rubbish fire in the same field, but sadly the nearest hydrant is 500’ away. The crew drops the ground monitor with a 2” smooth bore nozzle and you reverse lay two 3” supply lines to the hydrant. What is your PDP? You noted your static pressure at 60 psi and your residual pressure was 25 psi.

First, find the values for the variables in the Pump Discharge Pressure Formula (PDP = FL + APPL):

A. FL = 25 psi per 100’ for two 3” lines
B. APPL = 100 psi

DEFENSIVE OPERATIONS (PDP = FL + APPL)						
TIP SIZE	1 TIP GPM (2 TIP GPM) FOGS = GPM	FRICTION LOSS PER 100' MASTER STREAMS WITH 1 TIP (TOWERS WITH 2 TIPS)				
		ONE - 3"	TWO - 3"	THREE - 3"	FOUR - 3"	ONE - 5"
1-3/8"	500 (1000)	25 (NA)	6 (25)	3 (12)	2 (8)	2 (8)
1-1/2"	600 (1200)	40 (NA)	10 (40)	5 (20)	3 (12)	3 (12)
1-3/4"	800 (1600)	60 (NA)	15 (60)	8 (32)	5 (20)	5 (20)
2"	1000 (2000)	NA (NA)	25 (NA)	13 (50)	8 (32)	8 (32)
2-1/4"	1300 (2600)	NA (NA)	40 (NA)	20 (80)	15 (60)	15 (60)
2-1/2"	1600 (3200)	NA (NA)	60 (NA)	30 (NA)	20 (80)	20 (80)

DEFENSIVE APPLIANCES	
DECK GUN/GROUND MONITOR AT APPLIANCE = 100 PSI	RELAY ENGINES AT TAILBOARD = 50 PSI
TRUCKS OR TOWERS AT TAILBOARD = 200 PSI (ENGINE WITHIN 100' OF TAILBOARD)	

When we plug the answers from our Pump Chart back into our Pump Discharge Pressure formula, we get:

A. PDP = FL + APPL
B. PDP = (25 x 5) psi + 100 psi
C. PDP = 125 + 100 psi
D. PDP = 225 psi

Residual water – a 60 psi static pressure (S/R1) has been reduced to a 25 psi residual pressure (R_2) after water is flowing. This is a 35 psi reduction in intake pressure which is greater than our 20% residual drop, meaning we cannot pump any more like flows. The Engineer needs to notify the Incident Commander of this water supply issue immediately.

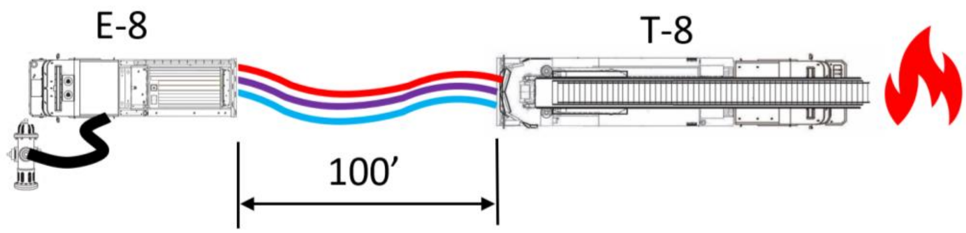
TOTAL GPM	RESIDUAL DROP	S/R_1 60	R_2 25
3	10%	6	
2	15%	9	
1	20%	12	
			R_2

60 - 25 = 35

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 13: Engineering the Most Efficient PDP for Supplying a Truck's Master Stream

You are assigned to Engine 8 and have been dispatched to an outside rubbish fire. When you arrive, you find a fire in a concrete vault under a railway bridge with no easy access, but fortunately, is located only about 200' from a hydrant, well within reach of an aerial. Your Company Officer calls for Truck 8 to respond to use their aerial to put out the confined space fire remotely. You go to work at the hydrant, and when T8 arrives with the 2" nozzle on their water way, you stretch one 3' line 100' to their tailboard and send them water. What do you set your PDP to? Your static pressure was 80 psi, and your residual is 64 psi, what is your residual water?



First, find the values for the variables in the Pump Discharge Pressure Formula (PDP = FL + APPL):

A. FL = **NOT APPLICABLE** (NA) for one 3" line
B. APPL = 200 psi

DEFENSIVE OPERATIONS (PDP = FL + APPL)						
TIP SIZE	1 TIP GPM (*2 TIP GPM*) FOGS = GPM	FRICTION LOSS PER 100' MASTER STREAMS WITH 1 TIP (*TOWERS WITH 2 TIPS*)				
		ONE - 3"	TWO - 3"	THREE - 3"	FOUR - 3"	ONE - 5"
1-3/8"	**500** (*1000*)	**25** (*NA*)	**6** (*25*)	**3** (*12*)	**2** (*8*)	**2** (*8*)
1-1/2"	**600** (*1200*)	**40** (*NA*)	**10** (*40*)	**5** (*20*)	**3** (*12*)	**3** (*12*)
1-3/4"	**800** (*1600*)	**60** (*NA*)	**15** (*60*)	**8** (*32*)	**5** (*20*)	**5** (*20*)
2"	**1000** (*2000*)	**NA** (*NA*)	**25** (*NA*)	**13** (*50*)	**8** (*32*)	**8** (*32*)
2-1/4"	**1300** (*2600*)	**NA** (*NA*)	**40** (*NA*)	**20** (*80*)	**15** (*60*)	**15** (*60*)
2-1/2"	**1600** (*3200*)	**NA** (*NA*)	**60** (*NA*)	**30** (*NA*)	**20** (*80*)	**20** (*80*)
DEFENSIVE APPLIANCES						
DECK GUN/GROUND MONITOR AT APPLIANCE = 100 PSI				RELAY ENGINES AT TAILBOARD = 50 PSI		
TRUCKS OR TOWERS AT TAILBOARD = 200 PSI (ENGINE WITHIN 100' OF TAILBOARD)						

When we plug the answers from our Pump Chart back into our Pump Discharge Pressure formula, we get:

A. PDP = FL + APPL
B. PDP = **NA** + 200 psi
C. PDP = **NA**

You are unable to pump to a Truck with a 2" tip flowing 1000 GPM. The Truck Engineer is calling for "more pressure". You realize that this is not a pressure problem, but is instead a volume problem. You can ask them to tip down to an 1-3/4" nozzle or adding a second and third supply lines. What would the PDP be for adding a second 3" supply lines and then a third 3" supply line?

The friction loss for two 3" lines is 25 psi per 100', which when added to 200 psi appliance friction loss results in a **PDP of 225 psi**.

The friction loss for three 3" lines is 13 psi per 100', which when added to 200 psi appliance friction loss results in a **PDP of 213 psi**.

Residual water – a 80 psi static pressure (S/R1) has been reduced to a 64 psi residual pressure (R_2) after water is flowing. This is a 16 psi reduction in intake pressure which is within an 16-20% residual drop, meaning we can pump at least one more like flows (1000 GPM x 1 = 1000 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 80	R_2 64
3	10%	8	
2	15%	12	
1	20%	16	R_2

80 - 64 = 16

RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

Example 14: Engineering the Most Efficient PDP for Supplying a Tower's Master Stream

You are the Acting Engineer assigned to Engine 1. You respond to a large, abandoned building fire off Seminole Road with Tower 1 and Chief 2 and are ordered to supply Tower 1 by Command. You know that water supply is an issue here and your Company Officer says the only hydrant he can find on the MDT is 1600' from the building and tells you to park 800' away at the entry to the complex and pump to the Tower. You respectfully remind your Company Officer of your amazing hydraulics class, specifically the Defensive Appliances section of the DFD Pump Chart, and ask them if you can position Engine 1 withing 100' from the tailboard of Tower 1.

DEFENSIVE APPLIANCES		
DECK GUN/GROUND MONITOR AT APPLIANCE = 100 PSI		RELAY ENGINES AT TAILBOARD = 50 PSI
TRUCKS OR TOWERS AT TAILBOARD = 200 PSI (ENGINE WITHIN 100' OF TAILBOARD)		
RELAY OPERATIONS		
RELAY PUMPING: ATTACK ENGINES SHALL BE IN "PSI" MODE, SUPPLY ENGINES IN "VOLUME" AND "RPM" MODE WHILE MAINTAINING AT LEAST 20 PSI MINIMUM INTAKE PRESSURE		
RELAY MAX DISTANCES: WHEN PUMPING 5" AT 2000 GPM, MAX DIST 600' TO NEXT ENGINE WHEN PUMPING 3 X 3" AT 2000 GPM, MAX DIST 400' TO NEXT ENGINE		
PUMP IN "PRESSURE" WHEN PUMPING LESS THAN 1000 GPM INTO AN FDC		
RESIDUAL WATER		
0-10% DROP = **3** X GPM,	**11-15%** DROP = **2** X GPM,	**16-20%** DROP = **1** X GPM

You also ask them to call Command to set up a relay operation with Engine 6 (a 3" Engine Company) 400' from you (E-1) and supplying you with three 3" supply lines, and Engine 11 (a 3" Engine Company) to be 400' from Engine 6 and supplying Engine 6 with three 3" lines, and Engine 3 (a 5" Engine Company) to supply Engine 11 for the remaining 600' to the hydrant, which Engine 3 fully taps to get the largest volume of water. Your officer looks at you in awe as you position engine 100' away from Tower 1 which has two 2" nozzles ready to flow and is positioned approximately 100' from the burning structure. The Tower crew sets up their aerial device far enough away from the fire as to not burn up while the engine companies get the relay operation up and running. Your crew stretches one 100' section of 3" supply line to the tailboard and then disappears. What is your total Pump Discharge Pressure?

Using our total Pump Discharge Pressure Formula for Defensive Operations (PDP = FL + APPL) we can attempt to fill in our variables in the following manner:

A. FL = Reference the pump chart to find the FL for one 3" line flowing 2,000 GPM (anything that is 100 psi and above is titled **Not Applicable – NA** – due to not being able to pump at excessive pressures. **It is important to note that we could consider "tipping down" to ONE 1-3/4" tip for 60 psi FL/100' if we need water immediately while setting up more lines for more volume.**
B. APPL = 200 psi

DEFENSIVE OPERATIONS (PDP = FL + APPL)						
TIP SIZE	1 TIP GPM (*2 TIP GPM*) FOGS = GPM	FRICTION LOSS PER 100' MASTER STREAMS WITH 1 TIP (*TOWERS WITH 2 TIPS*)				
		ONE - 3"	TWO - 3"	THREE - 3"	FOUR - 3"	ONE - 5"
1-3/8"	500 (*1000*)	25 (*NA*)	6 (*25*)	3 (*12*)	2 (*8*)	2 (*8*)
1-1/2"	600 (*1200*)	40 (*NA*)	10 (*40*)	5 (*20*)	3 (*12*)	3 (*12*)
1-3/4"	800 (*1600*)	60 (*NA*)	15 (*60*)	8 (*32*)	5 (*20*)	5 (*20*)
2"	1000 (*2000*)	NA (*NA*)	25 (*NA*)	13 (*50*)	8 (*32*)	8 (*32*)
2-1/4"	1300 (*2600*)	NA (*NA*)	40 (*NA*)	20 (*80*)	15 (*60*)	15 (*60*)
2-1/2"	1600 (*3200*)	NA (*NA*)	60 (*NA*)	30 (*NA*)	20 (*80*)	20 (*80*)

DEFENSIVE APPLIANCES	
DECK GUN/GROUND MONITOR AT APPLIANCE = 100 PSI	RELAY ENGINES AT TAILBOARD = 50 PSI
TRUCKS OR TOWERS AT TAILBOARD = 200 PSI (ENGINE WITHIN 100' OF TAILBOARD)	

We cannot pump at excessive pressures (generally more than 275 psi when pumping large volumes of water, and definitely not more than 300 psi), requiring us to get more volume by adding line(s).

You decide to add a second 3" supply line and move over one column to the TWO – 3" column on the pump chart, **which gives us a value of 100 psi per 100' in Friction Loss per 100 feet of hose**, which we can plug back into the PDP calculation to get:

A. FL = **NA**
B. APPL = 200 psi
C. PDP = NA

As a good general rule for defensive firefighting, we want to try to keep our PDP at 250 psi or less; it's difficult to supply water at volume at high pressures. Although we can get some water to the tower with two lines, we are still in the midst of a volume problem when our pressures are in excess of 250 psi, and we will need to add a line. When adding a third 3" supply line, we will move over yet another column on the pump chart to the THREE – 3" column, **which gives us a value of 50 psi in Friction Loss per 100 feet of hose**, which we can plug back into the PDP calculation to get:

A. FL = 50 psi
B. APPL = 200 psi
C. PDP = 250 psi

RELAY OPERATIONS

RELAY PUMPING: ATTACK ENGINES SHALL BE IN "PSI" MODE, SUPPLY ENGINES IN "VOLUME" AND "RPM" MODE WHILE MAINTAINING AT LEAST 20 PSI MINIMUM INTAKE PRESSURE

RELAY MAX DISTANCES: WHEN PUMPING 5" AT 2000 GPM, MAX DIST 600' TO NEXT ENGINE

WHEN PUMPING 3 X 3" AT 2000 GPM, MAX DIST 400' TO NEXT ENGINE

PUMP IN "PRESSURE" WHEN PUMPING LESS THAN 1000 GPM INTO AN FDC

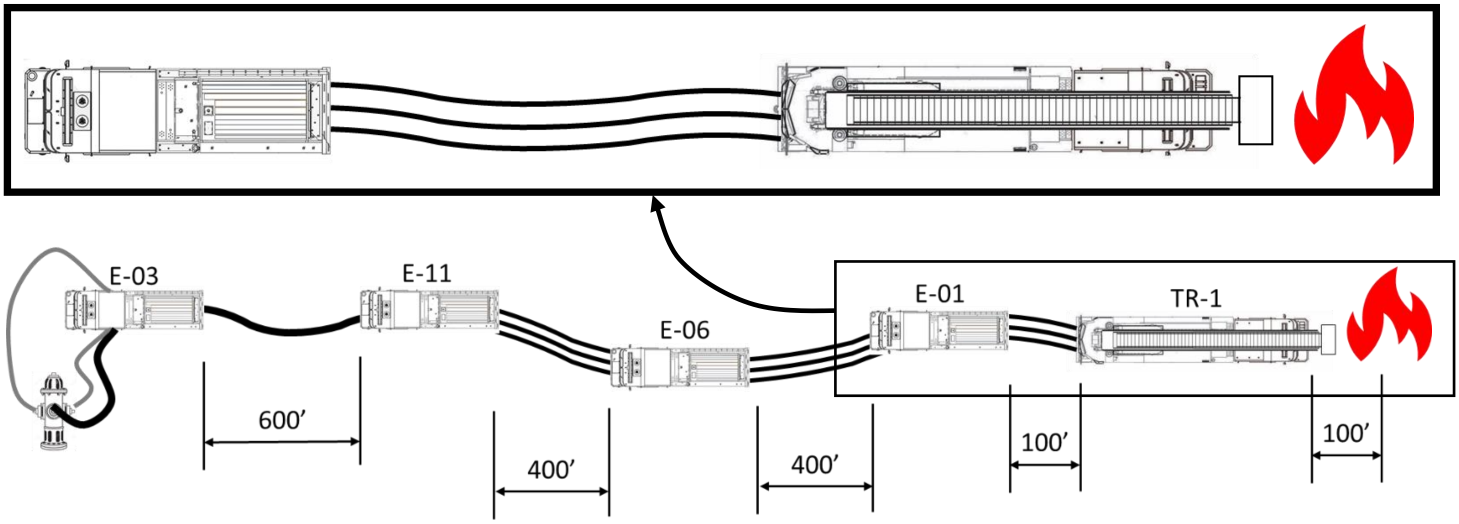


Figure 22: Applying the Pump Chart Relay Operations

If we want to reduce the friction loss even more, we can move over one more column to use four 3” supply lines (32 psi per 100’) to get a total PDP of:

A. FL = 32 psi
B. APPL = 200 psi
C. PDP = 232 psi

Residual water – Engine 3 noted a static pressure of 30 psi (S/R_1) to 22 psi (R_2) at the hydrant. This is a 8 psi reduction in intake pressure which is greater than our 20% residual drop, meaning we cannot pump any more like flows. The Engine 3 Engineer needs to notify the Incident Commander of this water supply issue immediately.

When Engine 3 “fully tapped the hydrant” they noted that the residual pressure increased 2 psi to 24 psi (R_3). This is a 6 psi reduction from the original intake pressure which is within an 16-20% residual drop, meaning we can pump at least one more like flows (2000 GPM x 1 = 2000 GPM).

TOTAL GPM	RESIDUAL DROP	S/R_1 **30**	R_2 **22**	R_2 **24**
3	10%	**3**		
2	15%	**4.5**		
1	20%	**6**		R_3
			R_2	

30 - 22 = 8

30 - 24 = 6

RESIDUAL WATER

0-10% DROP = **3** X GPM, **11-15%** DROP = **2** X GPM, **16-20%** DROP = **1** X GPM

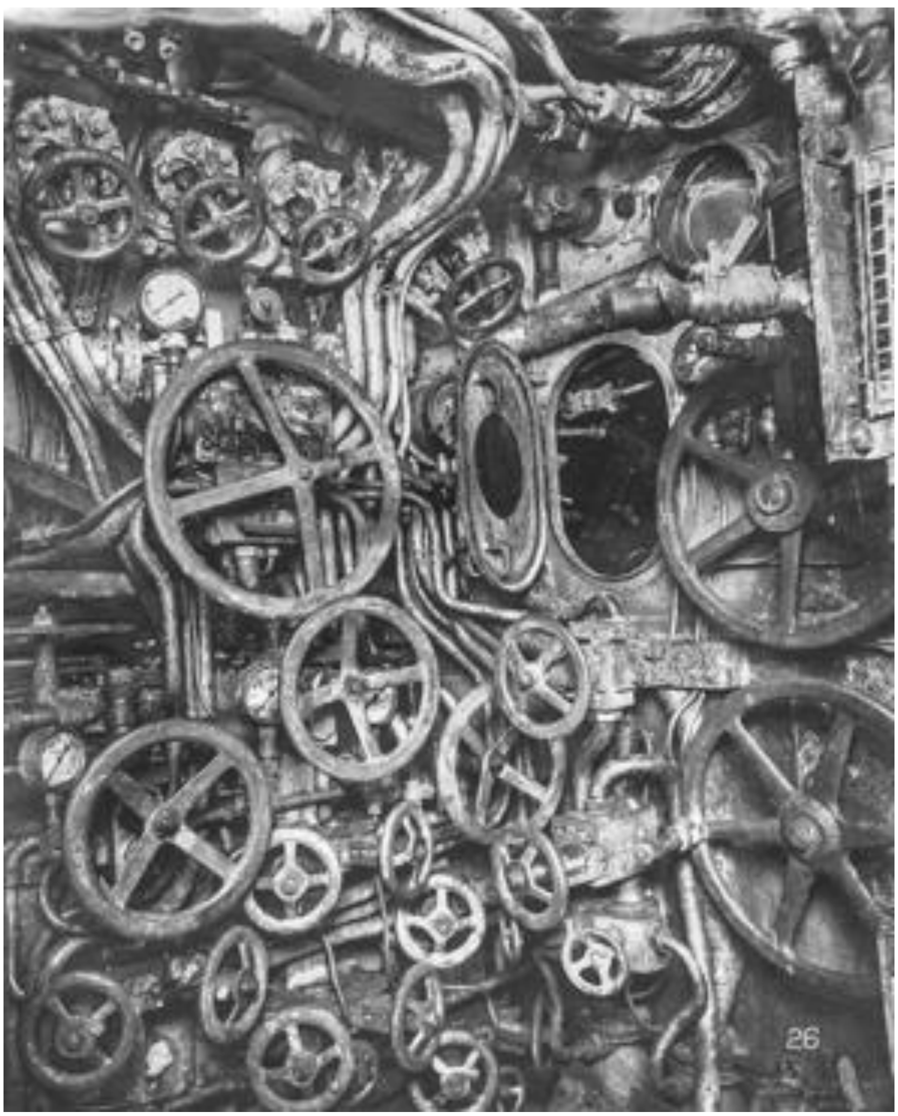
Conclusion

As stated in the introduction and hopefully reinforced throughout this document, **the single most important skill to master to utilize the new DFD Pump Chart is to learn how to find your values by reading a table.**

The issues addressed through this revision of the pump chart include:

1) The replacement of the 2-1/2" smoothbore 1-1/8" and 1-1/4" tips with a new 1-3/16" tip that can flow the same rates as the 1-1/8" and 1-1/4" tips by varying the nozzle pressure (the ability to change the GPM by increasing or decreasing the nozzle pressure and the associated friction loss in the hoselines is addressed in ***Appendix I***)
2) Reducing the need to utilize CQ^2L to calculate the PDP
3) Changes in Friction Loss due to manufacturing advancements
4) The need for simplicity of use based on user feedback
5) A more comprehensive method for determining residual water

Please consider revisiting and sharpening your skills by completing the accompanying homework (which can be found on Target Solutions) on a periodic basis. Learning and applying hydraulic concepts to the real world is a perishable skill which can be mastered and forgotten – keep yourself sharp by revisiting this document and training.



Appendix I: How to use the 2-1/2” Smoothbore with the 1-3/16” Tip

The new 2-1/2” smoothbore with the 1-3/16” tip can reach all the flow the previous stack tips could by varying the nozzle pressure. The old 1-1/8” tip flowed 265 GPM and the 1-1/4” tip flowed 325 GPM. By reducing the nozzle pressure to 40 psi, you will pump 265 GPM, and by increasing the nozzle pressure to 60 psi you will pump 325 GPM. The supporting friction loss values for DFD hose per 100’ are included in the pump chart below. Please not that this chart includes the C values for DFD hoselines.

FL/100' FOR 1-3/16" TIP			
	265 GPM	300 GPM	325 GPM
	40 PSI	50/75 PSI	60 PSI
1-3/4"	50	60	70
2"	45	50	60
2-1/2"	**10**	**15**	**20**
3"	7	10	12

Figure 23: Friction Loss numbers for the 1-3/16" tip

The associated nozzle reactions for the nozzle pressures are:

- 40 psi nozzle pressure = 90 pounds of nozzle reaction
- 50 psi nozzle pressure = 110 pounds of nozzle reaction
- 60 psi nozzle pressure = 130 pounds of nozzle reaction

To determine the PDP for the 2-1/2” hoseline with the 1-3/16” nozzle at 265 GPM, 300 GPM, and 325 GPM at ground level, we will need to determine three different PDPs:

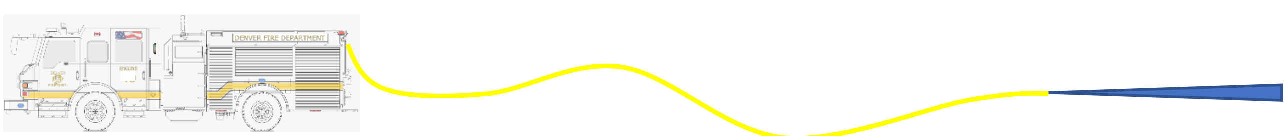


Figure 24: 200' of 2-1/2" Hoseline with a 1-3/16" Tip, producing 265 GPM, 300 GPM, and 325 GPM using PDP

To get 265 GPM we will use a Nozzle Pressure of 40 and a Friction Loss of 10 psi per 100’

A. PDP = NP + FL + APPL + ELEV
B. PDP = 40 psi + (10 X 2) psi + 0 psi + 10 psi
C. PDP = 40 psi + 20 psi + 0 psi + 10 psi
D. PDP = **60 psi**

To get 300 GPM we will use a Nozzle Pressure of 50 and a Friction Loss of 15 psi per 100’

A. PDP = NP + FL + APPL + ELEV
B. PDP = 50 psi + (15 X 2) psi + 0 psi + 10 psi
C. PDP = 50 psi + 30 psi + 0 psi + 10 psi
D. PDP = **80 psi**

To get 325 GPM we will use a Nozzle Pressure of 60 and a Friction Loss of 20 psi per 100’

A. PDP = NP + FL + APPL + ELEV
B. PDP = 60 psi + (20 X 2) psi + 0 psi + 10 psi
C. PDP = 60 psi + 40 psi + 0 psi + 10 psi
D. PDP = **100 psi**

Appendix II: Static to Residual Drop Method for Determining Residual Water

The **Static to Residual Drop Method** is used when you have connected to a hydrant, introduced water into the pump, and are not yet flowing water:

A. When you have connected to a static water supply (a hydrant that is not flowing water yet), and you introduce water into the pump, you will get an initial "Static" intake pressure reading – make a note of this reading.
B. When you start moving water through the pump by flowing water through a nozzle, you will get a drop in your intake pressure reading which is the "Residual" reading.
C. Take 10% of your "Static" reading (think of a 10% tip), and then ***subtract*** from the initial number. For example, if your "Static" reading is 90 psi, then you would find 10% of 90 psi, which is 9 psi, and subtract the 9 psi from the initial "Static" reading (90 psi – 9 psi) which is 81 psi; "10% Drop" number. Any "Residual" reading between 90 psi and 81 psi will result in being able to supply at least **three** more like GPM flows (i.e., if you're flowing 300 GPM, you will be able to flow at least 900 more GPM).
D. Take 15% of your "Static" reading (think of a 15% tip), and then ***subtract*** from the initial number. For example, if your "Static" reading is 90 psi, then you would find 15% of 90 psi, which is 13.5 psi, which you round up to 14 psi, and subtract the 14 psi from the initial "Static" reading (90 psi – 14 psi) which is 76 psi; this is the "15% Drop" number. Any "Residual" reading between 80 psi and 76 psi will result in being able to supply at least **two** more like GPM flows (i.e., if you're flowing 300 GPM, you will be able to flow at least 600 more GPM).
E. Take 20% of your "Static" reading (think of a 20% tip), and then ***subtract*** from the initial number. For example, if your "Static" reading is 90 psi, then you would find 20% of 90 psi, which is 18 psi, and subtract the 18 psi from the initial "Static" reading (90 psi – 18 psi) which is 72 psi; this is the "20% Drop" number. Any "Residual" reading between 75 psi and 72 psi will result in being able to supply at least **one** more like GPM flows (i.e., if you're flowing 300 GPM, you will be able to flow at least 300 more GPM).
F. If you're "Residual" reading is that is more than a 20% drop means that you cannot flow the same GPM as is currently flowing, although it may be possible that a line flowing fewer GPM could be added.

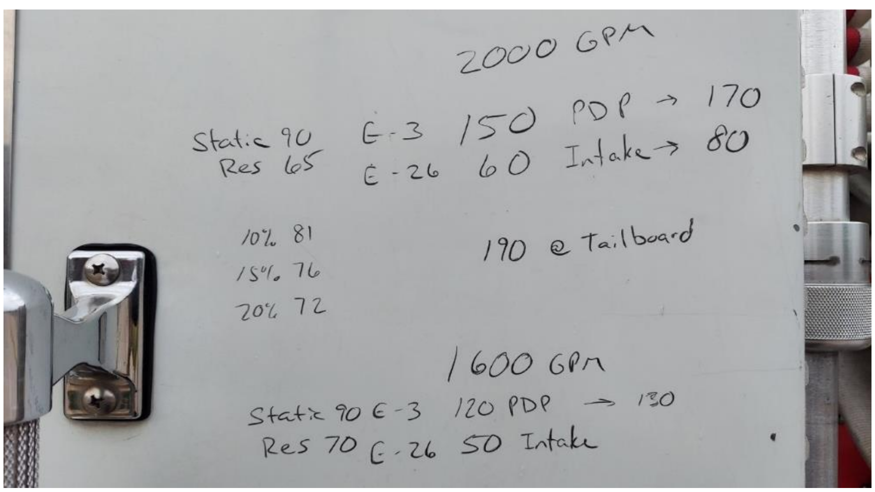


Figure 25: Having a grease pencil to keep track of numbers on the side of the rig next to the pump panel can be helpful

Remember to maintain at least 20 psi intake pressure. Keep in mind that the residual water calculations are theoretical in nature, meaning, that when pumping large volumes of water when you're connected to a high-volume hydrant, you're likely to reach the pump capacity before you run out of water. Even though the math says the water is there, the Engine might not be able to move it.

Appendix III: Using the Building's Test Header in the Case of a FDC Failure

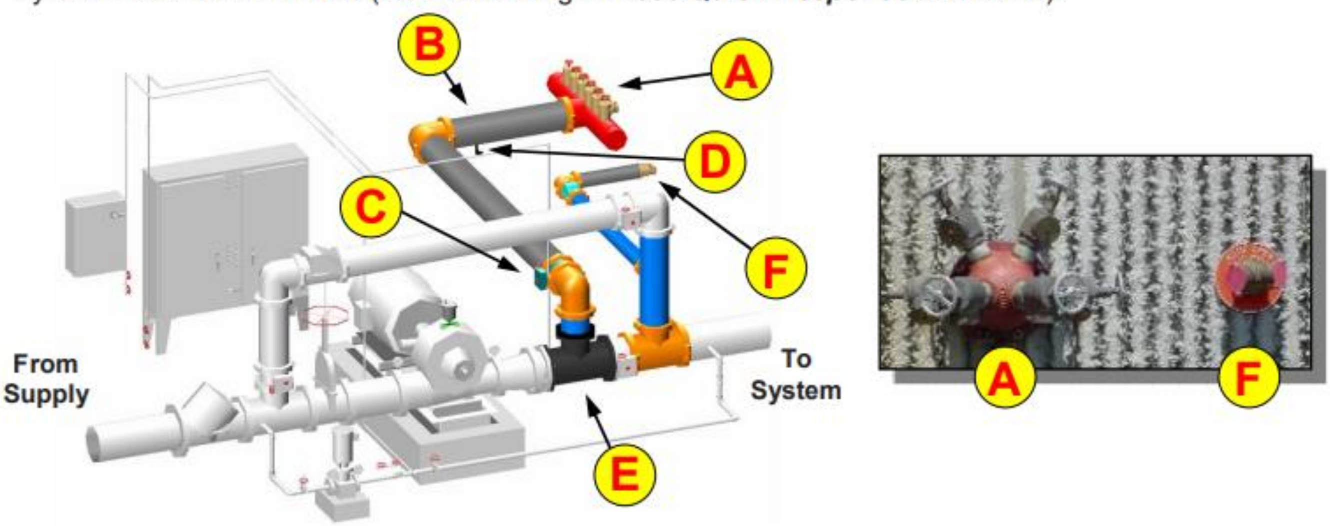
In the case of a FDC failure, it is possible to pump through the test headers of a buildings standpipe system if the test header control valve is manually opened. The test header control valve should be located in the building's pump room and should be labeled "TEST HEADER". For more information on the test header, please see the information provided by the Minnesota State Fire Marshal's Office below:

Figure 26: FDC Piping Failure from the Empower Field Fire, Courtesy of FPM Tony Caro

FIRE PUMPS – TEST HEADER AND FIRE DEPARTMENT CONNECTION

Every fire pump needs a method of testing to verify it is functioning properly. One of the more common methods is the use of a **test header** arrangement. A **test header** allows for the flowing of large quantities of water through multiple hoses.

The fire department connection (FDC) allows the fire department to supplement the fire protection system in the event of a fire (refer to the August 2006 ***Quick Response*** newsletter).



A = **Test Header –** This manifold includes hose valves to which hose is attached to when testing. The required number of hose valves and the minimum size of the hose valves are based on the rating of the fire pump and are indicated on **Table 5.25** of **NFPA 20 (2003 edition)**.

B = **Test Header Supply Pipe –** The minimum pipe size is indicated on **Table 5.25** of **NFPA 20 (2003 edition)**. Unless sized hydraulically, if the length of pipe between the **test header** and the connection to the discharge side of the pump exceeds 15 feet the next larger nominal pipe size must be used (**NFPA 20, Section 5.19.3.4**).

C = **Control Valve –** This control valve must be installed if the location of the **test header** is subject to freezing. This valve may be OS&Y or butterfly type. **NFPA 20, Section 5.16.2** requires this valve to be supervised closed. A drain valve or ball drip (**D**) shall also be installed.

E = **Test Header Connection –** The connection for the **test header** should be between the discharge check valve and the discharge control valve. This allows the fire pump to be tested with the discharge control valve closed, isolating the pump from the rest of the system.

F = **Fire Department Connection (FDC) –** It is important that the FDC be tied into the discharge side of the fire pump on the system side of the discharge control valve.

Figure 27: FDC/Test Header Schematic from https://dps.mn.gov/divisions/sfm/programs-services/Documents/Quick%20Response%20Newleter/QR0908FirePumpsTestHdrFDC.pdf

Appendix IV: Hydraulic Concepts

The following hydraulic concepts were utilized to build the DFD Pump Chart.

Rule of 4's

The Friction Loss in psi through a hoseline follows an exponential growth and decay path in relation to the flow of water in GPM through the hoseline, meaning:

- When the flow of water (GPM) through a hoseline is **doubled**, the Friction Loss (psi) is **quadrupled**
- When the flow of water (GPM) through a hoseline is **halved**, the Friction Loss (psi) is **quartered**

Multiple Line Conversions

This principle of exponential growth leads to the concept of "Multiple Lines Conversion" when applied to our Defensing Operations table in the DFD Pump Chart:

- 2 lines is ¼ of 1 line
- 3 lines is ½ of 2 lines
- 4 lines is ⅓ of 2 lines

You can see this hydraulics principle at work in the Defensive Operations table of the DFD Pump Chart:

DEFENSIVE OPERATIONS (PDP = FL + APPL)						
TIP SIZE	1 TIP GPM (*2 TIP GPM*) FOGS = GPM	FRICTION LOSS PER 100' MASTER STREAMS WITH 1 TIP (*TOWERS WITH 2 TIPS*)				
		ONE - 3"	TWO - 3"	THREE - 3"	FOUR - 3"	ONE - 5"
1-3/8"	500 (*1000*)	25 (*NA*)	6 (*25*)	3 (*12*)	2 (*8*)	2 (*8*)
1-1/2"	600 (*1200*)	40 (*NA*)	10 (*40*)	5 (*20*)	3 (*12*)	3 (*12*)
1-3/4"	800 (*1600*)	60 (*NA*)	15 (*60*)	8 (*32*)	5 (*20*)	5 (*20*)
2"	1000 (*2000*)	NA (*NA*)	25 (*NA*)	13 (*50*)	8 (*32*)	8 (*32*)
2-1/4"	1300 (*2600*)	NA (*NA*)	40 (*NA*)	20 (*80*)	15 (*60*)	15 (*60*)
2-1/2"	1600 (*3200*)	NA (*NA*)	60 (*NA*)	30 (*NA*)	20 (*80*)	20 (*80*)

Figure 28: How the "Rule of Fours" works within the Defenseive Operations table

When we look at one 3" line supplying a 600 GPM flow (a ground monitor or truck/tower flowing one 1-1/2" nozzle), it creates 40 psi of Friction Loss per 100' of 3" hose.

When we add a second 3" line (shown with the red arrow), we halve the amount of water in each line. We're still flowing 600 GPM through the nozzle, but with two lines, we are only flowing 300 GPM though each supply line. Going back to the Rule of 4's, by halving the amount of water flowing, we quarter the friction loss, which results in a friction loss of 10 psi per 100' feet of two 3" lines. Conversely, when we add a second nozzle, by flowing through a tower, we double the amount of water flowing through the line which quadruples the Friction Loss. This can be seen with the yellow arrow boing from 40 psi to 160 psi through the same length of hoseline when it's moving 1200 GPM.

You can see this same pattern repeating throughout the chart with three lines being half of two lines (going from 10 psi to 5 psi of Friction Loss of hoseline) and how four lines is one third of two lines (going from 10 psi to 3 psi of Friction Loss per 100’ of hoseline).

Maximum Length of Supply Lines

This principle of exponential growth that gives us the Rule of 4’s and Multiple Line Conversions can also be applied to the maximum length of supply lines. Knowing that the pump is engineered to pump the most amount of water at 150 psi, we are attempting to maintain a total PDP of around 250 psi; when pumping at a defensive fire, pumping large volumes of water at greater than 280 is difficult to maintain. This is why it is recommended to have a supply engine no more than 100’ from the tailboard of a truck or tower knowing that the Friction Loss for the apparatus is roughly 200 psi at the tailboard. When flowing 2000 GPM (two 2” nozzles on a tower) with three 3” lines, the maximum distance between rigs is 400’ (which is 200 psi PDP for the supply engine). If you reduce this to one 2” nozzle, using the Rule of 4’s as it relates to distance, we could now go 1600’ before getting 200 psi of friction loss (instead of 50 psi per hundred feet of hose for three hoses, we are now reduced to 13 psi of friction loss per hundred feet of hose for three hoses), which is more hose than we have on the rig. Therefore, the only limitation we have between relay pumpers before running out of hose, is a tower using two 2” tips flowing 200 GPM.

Volume as Water as a Unit of Weight

The volume of water in a hoseline can be defined by its weight as shown in the following table:

Hose Diameter	Volume of Water per Foot
1.75"	1 lb per foot
2"	1.5 lb per foot
2.5"	2 lb per foot
3"	3 lb per foot
5"	8.5 lb per foot (~1 Gallon)

Figure 29: Volume of water in hoselines as measured by weight

This can be useful in terms of understanding how much weight members are trying to move (a typical 50’ section of handline hose weighs approximately 20 pounds). For instance, a 300’ 1-3/4” preconnect will have 120 pounds of hoseline and, when charged, have 300 pounds of water in it. Using a quick approximation of a gallon weighing 10 pounds (instead of 8.3), dividing the 300 pounds of water volume by 10 gives me roughly 30 gallons of water, about 5% of my tank. Using this same principle, I cannot fill 600 feet of 5” hose with all the water in my tank.