GOLDER RANCH FIRE DISTRICT

Engineer Practical Check Sheets

Calculating Hydraulics (Theoretical)

Standards:
NFPA 1010 Section 1002: 5.2.4, 5.2.4(B)

Task/Performance Outcome:
The candidate shall be given the objective of completing a theoretical hydraulics test. This will verify the Candidate's abilities to determine common hydraulic questions that commonly pertain to the position of a driver operator with in the fire service.

Required Personal Protective Equipment (PPE):
Test with be administered through professional development.

Required Equipment:

Theoretical Equations	
Nozzle Reaction Smooth-Bore Nozzle	$NR = 1.57 \times d^2 \times NP$
Nozzle Reaction for Fog Nozzle	$NR = 0.0505 \times gpm \times \sqrt{NP}$
GPM Flow of Smooth Bore Nozzles	$gpm = 29.7 \times d^2 \times \sqrt{NP}$
Friction Loss	$FL = C\,Q^2\,L$
Elevation Pressure	EP = 5 psi × (number of stories – 1) or EP = 0.5 × Height

Friction Loss Coefficients	
Hose Diameter (inch)	Coefficient
1 ¾	15.5
2 ½	2
3 with 2 ½ couplings	0.8
5	0.08

Appliance Losses for High-Flow Devices (flows greater than 350 gpm)	
Device	Appliance Loss (psi)
Wye and Siamese	10
Ram XD	10
Standpipe and FDC	10
Elevated master stream and deck gun monitors	25
Dead Pump	25

Smooth Bore Tips GPM Flow Rates		
Size (inches)	GPM Handline/Master	
	50 psi	**80 psi**
1"	200	250
1 1/8"	250	350
1 1/4"	325	400
1 3/8"		500
1 1/2"		600
1 5/8"		700
1 3/4"		800
1 7/8"		900
2		1000

Smooth Bore Tips Decimal conversions	
Size (inches)	Decimal
1"	1
1 1/8"	1.125
1 1/4"	1.25
1 3/8"	1.375
1 1/2"	1.5
1 5/8"	1.625
1 3/4"	1.75
1 7/8"	1.875
2	2

Calculating Hydraulics (Theoretical)

Critical Fail Criteria:
Failure consists of the following:

- Glaring, gross errors, as documented by the evaluator
- An apparent lack of efficiency and comfort with the activity, as documented by the evaluator
- Less than 80% of available points scored

Evolution Details:
The will candidate will be administered a theoretical hydraulics test via paper or electronic form. The individual will have a set amount of time to complete the test (time allotment will be notified prior to test being administered).

Calculating Hydraulics (Theoretical)

Tasks
Calculate Nozzle Reaction of a Smooth-Bore Nozzle **Example 1**: Calculate the nozzle reaction for a 1-inch tip operating at 50-psi nozzle pressure. $NR = 1.57 \times d^2 \times NP$ $NR = 1.57 \times 1^2 \times 50$ $NR = 1.57 \times 1 \times 50$ NR = 78.5 pounds Where NR is nozzle reaction, *d* is the diameter of the nozzle, and NP is the nozzle pressure.
Calculate Nozzle Reaction for Fog Nozzle **Example 1:** Calculate the nozzle reaction for a fog nozzle flowing 200 gpm operating at 100-psi nozzle pressure. $NR = 0.0505 \times gpm \times \sqrt{NP}$ $NR = 0.0505 \times 200 \times \sqrt{100}$ $NR = 0.0505 \times 200 \times 10$ NR = 101 pounds Where NR is nozzle reaction and $\sqrt{NP}$ is the square root of the nozzle pressure.
Determine the gpm Flow of Smooth Bore Nozzles To calculate the flow (gpm) from smooth-bore nozzles, follow these steps: 1. Determine the diameter of the nozzle tip (it is usually stamped into the side of the nozzle). Convert the diameter fraction to a decimal and square it. 2. Find the square root of the desired nozzle pressure ($\sqrt{NP}$). 3. Multiply the diameter squared (d^2) by the square root of the nozzle pressure ($\sqrt{NP}$), and then multiply the result by the constant 29.7 to find the gpm flow rate of the nozzle. **Example 1:** Calculate the flow rate for a 1¼-inch tip used on a 2½-inch handline. $gpm = 29.7 \times d^2 \times \sqrt{NP}$ $gpm = 29.7 \times (1\frac{1}{4})^2 \times \sqrt{50}$ $gpm = 29.7 \times (1.25)^2 \times \sqrt{50}$ $gpm = 29.7 \times 1.56 \times 7.07$ gpm = 327.567 (round to 300 gpm) **Example 2:** Calculate the flow rate for a 1½-inch smooth-bore master stream nozzle. $gpm = 29.7 \times d^2 \times \sqrt{NP}$ $gpm = 29.7 \times (1.5)^2 \times \sqrt{80}$ $gpm = 29.7 \times 2.25 \times 8.94$ gpm = 597.415 (round to 600 gpm)

Determine FL of 1-3/4" and 2-1/2" hoses with differing nozzles and gpm's (single hoseline)

To determine the FL in a hose lay, follow these steps:

1. Write the FL formula: FL = C Q^2 L.
2. Select the coefficient (C) that matches the hose in the given scenario.
3. The coefficient for 2½-inch hose is 2. Therefore C = 2.
4. Determine the flow rate (quantity) of water through the hoseline and divide the amount by 100 to find Q. Next, square Q.
5. The flow is determined by knowing the flow of each nozzle. We know that a 1¼-inch handline nozzle tip will flow 328 gpm. On paper you may use 328, but on the fireground you may round this value off to 300 gpm. If you are flowing 300 gpm, then 300/100 = 3.
6. Because Q = 3, $Q^2 = 3^2 = 9$.
7. Determine the length of the hose you are calculating and then divide by 100 to find L. How long is the hoseline? If it is 200 ft long, then 200/100 = 2. Therefore L = 2.
8. Multiply the results from steps 1, 2, and 3 to determine FL:
   FL = C × Q^2 × L
   FL = 2 × 9 × 2
   FL = 36

Example 1: What is the PDP for 300 ft of 2½-inch hose with a 11/8-inch smooth-bore nozzle?
In this problem, we see a smooth-bore nozzle on a handline, so we know to assign it a NP of 50 psi:
PDP = NP + FL
PDP = 50 + FL

Now we must calculate FL:

- For a 2½-inch hose, the coefficient is 2 (C = 2).
- The nozzle has a 11/8-inch tip, which we know will flow 250 gpm (rounded).
- We know the nozzle flow from Table 7-1; alternatively, using the formula, gpm = 29.7 $d^2 \sqrt{NP}$.
- The flow is 250 gpm, so 250/100 = 2.5 and Q = 2.5.

Insert these values into the formulas:
FL = C Q^2 L
FL = 2 × $(2.5)^2$ × 300/100
FL = 2 × 6.25 × 3
FL = 37.5 psi

Now we return to our PDP formula and insert the FL:
PDP = NP + FL
PDP = 50 + 37.5
PDP = 87.5 psi

Example 2: Calculate the FL in 200 ft of 1¾-inch hose with a 7/8-inch smooth-bore nozzle. A smooth-bore handline has a NP of 50 psi, so NP = 50. A 7/8-inch tip flows 161 gpm, so Q = 1.6.

Insert these values into the formulas:
FL = C Q^2 L
FL = 15.5 × $(1.6)^2$ × 2
FL = 15.5 × 2.56 × 2
FL = 79.36 psi (round to 80 psi)

Now we return to our PDP formula and insert the FL:
PDP = NP + FL
PDP = 50 + 80
PDP = 130 psi

Calculating Friction Loss in Multiple Hoselines of Different Sizes and Lengths

To calculate the FL for multiple hoselines of different size and length, follow these steps:

1. Determine the correct PDP for each line in the scenario.
2. Use the pump discharge formula: PDP = NP + FL (nozzle pressure + friction loss). Also use the FL formula: FL = C Q^2 L, where C = coefficient for the line diameter, Q^2 = quantity of flow (gpm or L/min) divided by 100 and squared, and L = length divided by 100.
3. Determine which line requires the highest pressure. This pressure is the correct answer for a written problem.
4. On the fireground, pump to the highest pressure, and gate back any lines requiring lower discharge pressures.

Example 1: A pumper is supplying two attack lines. The first consists of 150 ft of 1¾-inch hose flowing 150 gpm with a fog nozzle. The second consists of 200 ft of 2½-inch hose flowing 250 gpm with a smooth-bore nozzle. What is the PDP?

In this scenario, the operator will calculate the pressure for each line and then set the pump to the highest pressure and gate the other discharge back to its required pressure. The answer to the written problem is the highest pressure.

The PDP for the first line is
$FL = C\ Q^2\ L$
$FL = 15.5\ (1.5)^2\ 1.5$
$FL = 15.5 \times 2.25 \times 1.5 = 52.3$

Insert the FL into the PDP formula:
PDP = 100 NP + 52.3 FL = 152.3 psi

The PDP for the second line is
$FL = C\ Q^2\ L = 2\ (2.5)^2\ 2$
$FL = 2 \times 6.25 \times 2 = 25$

Insert the FL into the PDP formula:
PDP = 50 NP + 25 FL = 75 psi

The answer for this scenario is the highest pressure, which is 152.3 psi (round to 152 psi). In this example, the operator will set the pump to 152 psi and then gate down the discharge for the 2½-inch hoseline until it reads 75 psi, while the line is flowing water at a flow rate of 250 gpm.

Now that you are acquainted with the PDP formula, begin writing it with just the values for NP and FL, such as PDP = 50 + 25, so PDP = 75 psi.

Example 2: A pumper is supplying three hoselines. The first attack line is 300 ft of 2½-inch hose flowing 300 gpm with a smooth-bore nozzle. The second line is 200 ft of 1¾-inch hose flowing 150 gpm with a fog nozzle. The third line is 200 ft of 1¾-inch hose flowing 161 gpm with a 7/8-inch smooth-bore tip. What is the PDP?

In this scenario, the operator will calculate the pressure for each line and then set the pump to the highest pressure and gate the other discharges back to their required pressures. The answer to the written problem is the highest pressure.

The PDP for the first line is
$FL = C\ Q^2\ L$
$FL = 2\ (3)^2\ 3 = 54$

Insert the FL into the PDP formula:
$PDP = 50 + 54 = 104$ psi

The PDP for the second line is
$FL = C\ Q^2\ L$
$FL = 15.5\ (1.5)^2\ 2$
$FL = 15.5 \times 2.25 \times 2 = 69.75$

Insert the FL into the PDP formula:
$PDP = 100 + 69.5 = 169.75$ psi

The PDP for the third line is
$FL = C\ Q^2\ L$
$FL = 15.5\ (1.61)^2\ 2$
$FL = 15.5 \times 2.59 \times 2 = 80$

Insert the FL into the PDP formula:
$PDP = 50 + 80 = 130$ psi

The answer for this scenario is the highest pressure, which is 169.75 psi (round to 170 psi).

Calculating the Elevation Pressure (Loss and Gain)

To calculate the EP loss or gain, follow these steps:

1. Determine the EP when operating in a multistory building.
2. Use the formula: EP = 5 psi × (number of stories – 1).
3. Count the number of stories to the nozzle.
4. Multiply 5 psi times the number of stories minus 1.

Example 1: Determine EP when the nozzle is on the 11th floor of a building.

EP = (11 – 1) × 5 psi
EP = 10 × 5 psi
EP = 50 psi

You can also determine the EP for a grade using the formula EP = 0.5H, where 0.5 is a constant and H = height:

1. Estimate the elevation gain or loss. When the nozzle is higher than the pump, the EP is a positive number, and you will compensate for this loss in pressure by increasing pressure output from the pump. When the nozzle is below the pump, the elevation is a negative number, and you will compensate for this gain by decreasing pressure output from the pump.
2. Multiply 0.5 × height, where the height will be a positive or negative number.

Example 2: Determine the EP when the nozzle is 30 ft below the pump.

EP = –30 × 0.5 EP = –15

Determining the Pump Discharge Pressure in a Wye Scenario With Equal Lines

For a wyed hose lay where all discharge lines are of equal size and length, follow these steps to determine the PDP:

1. Add the flow rate for all discharges from the wye together to obtain the quantity (Q) for the supply line to the wye device.
2. Calculate the FL for the supply line to the wye device using the Q value determined in Step 1.
3. Calculate the FL for one of the discharge lines from the wye device, and add the nozzle pressure.
4. If the scenario is flowing 350 gpm or greater, add 10 psi friction loss for the wye device.
5. Add the results of Steps 2 through 4 to determine the PDP.

Example 1: A pumper is supplying 100 ft of 2½-inch hose to a wye that has two 1¾-inch lines 200 ft long flowing 150 gpm each through fog nozzles. What is the PDP?

PDP = NP + FL
FL = C Q^2 L
FL for the 2½ inch = 2 $(3)^2$ 1 = 18 psi

FL for a 1¾-inch line:
FL = C Q^2 L = 15.5 $(1.5)^2$ 2
FL = 15.5 × 2.25 × 2 = 69.75 (round to 70 psi)

It takes 70 psi to flow the first 1¾-inch line. The second 1¾-inch line is identical, so both lines experience the same FL and have the same NP. Insert the values in the formula:

PDP = NP + FL
PDP = 100 (NP) + 18 (for the 2½-inch line) + 70 (for the 1¾-inch lines)
PDP = 100 + 18 + 70 = 188 psi

As the flow did not exceed 350 gpm, do not add 10 psi AL for the wye.

Example 2: A pumper is supplying 100 ft of 3-inch (with 2½-inch couplings) to a wye with two equal lines of 2½-inch hose, each 200 ft flowing 250 gpm through smooth-bore nozzles. What is the PDP?

PDP = NP + FL

FL for the 3-inch line:

FL = C Q^2 L = 0.8 $(5)^2$ 1
FL = 0.8 × 25 = 20

FL for the 2-inch lines:

FL = C Q^2 L = 2 $(2.5)^2$ 2
FL = 2 × 6.25 × 2 = 25
PDP = 50 NP + (20 for the 3-inch line) + 25 (for the 2½-inch lines) + 10 (AP)
PDP = 50 + 20 + 25 + 10 = 105 psi

Determining the Pump Discharge Pressure in a Wye Scenario with Unequal Lines

For a wyed hose lay where each discharge line from the device is different (unequal), follow these steps to determine the PDP:

1. Add the flow rate for all discharges from the wye together to obtain the quantity (Q) for the supply line to the wye device.
2. Calculate the FL for the supply line to the wye device using the Q value determined in Step 1.
3. Calculate the FL and NP for each of the discharge lines from the wye device. Add the NP to the FL for the hoseline requiring the greatest pressure.
4. If flowing 350 gpm or greater, add 10 psi FL for the wye device.
5. Add the results of Steps 2 through 4 to determine the PDP.

Example 1: A pumper is supplying 100 ft of 3-inch hose (with 2½-inch couplings) to a wye. The first attack line from the wye is 200 ft of 2½-inch hose with a 1¼-inch smooth-bore nozzle flowing 300 gpm. The second attack line is 150 ft of 2½-inch hose with a 1-inch smooth-bore nozzle flowing 200 gpm. What is the PDP? (Remember that when the flow is 350 gpm or greater in a wye, you must add 10 psi AL.)

FL for 3-inch hose (with 2½-inch couplings) = $C\,Q^2\,L$
FL= $0.8\,(5)^2\,1$
FL= $0.8 \times 25 \times 1$
FL= 20 psi

FL for first 2½-inch hose = $C\,Q^2\,L = 2\,(3)^2\,2 = 36$ psi
PDP = 50 (NP) + 20 (FL in 3-inch) + 36 (FL in first 2½-inch) + 10 (AL) = 116 psi

FL for second 2½-inch hose = $C\,Q^2\,L = 2\,(2)^2\,1.5 = 12$ psi
PDP = 50 (NP) + 20 (FL in 3-inch) + 12 (FL in second 2½-inch) + 10 (AL) = 92 psi

The second attack line requires less pressure; gate this line back to 92 psi. This step will need to be done at the actual gated wye and not at the pump panel. The gated wye may not have a pressure gauge, so you will need to estimate the amount to gate the valve on the gated wye. As the first attack line has a greater FL, pump to its pressure of 116 psi: PDP = 116 psi

Example 2: A pumper is supplying 100 ft of 3-inch hose to a wye. From the wye, the first attack line is 200 ft of 1¾-inch hose flowing 150 gpm through a fog nozzle. The second attack line is 200 ft of 2½-inch hose flowing 300 gpm through a fog nozzle. What is the PDP?

FL for the 3-inch hose = $C\,Q^2\,L$
FL= $0.67\,(4.5)^2\,1$
FL= $0.67 \times 20 \times 1$
FL= 13.5 (round to 14)

FL for first 1.75-inch attack line: FL = $C\,Q^2\,L$
FL= $15.5\,(1.5)^2\,2$
FL= $15.5 \times 2.25 \times 2$
FL= 69.75 (round to 70 psi)

PDP = 100 (NP) + 14 (FL in 3-inch hose) + 70 (FL in 1¾-inch hose) + 10 (AL) = 194 psi
FL for second attack line (2½-inch hose): FL = $C\,Q^2\,L$
FL= $2\,(3)^2\,2$
FL= $2 \times 9 \times 2$
FL= 36 psi

PDP = 100 (NP) + 14 (FL in 3-inch hose) + 36 (FL in 2½-inch hose) + 10 (AL) = 160 psi
The PDP for the 1¾-inch line is greater, so pump at 194 psi, and gate the 2½-inch valve down to 160 psi:
PDP = 194 psi

Calculating the Pump Discharge Pressure for a Prepiped Elevated Master Stream Device

To calculate the PDP for a prepiped elevated master stream device, follow these steps:

1. Determine the NP by observing which nozzle is on the tip. If it is a smooth-bore nozzle, the NP will be 80 psi unless the manufacturer's specifications differ. If it is a fog nozzle, is it an automatic appliance that delivers the standard pressure of 100 psi, or does it meet some other specification?
2. Determine the FL in the supply line(s) from the pumper to the aerial device. Use the split flow, Siamese coefficient **TABLE 7-4**, or percentage method to find the FL in the supply line.
3. Determine the FL of the prepiped master stream. Add 25 psi FL for any master stream device.
4. Calculate the EP.
5. Add the results of Steps 1 through 4 to obtain the PDP.

Example 1: A pumper supplying an elevated master stream is on the hydrant. This apparatus is supplying one 5-inch line that is 200 ft long to the inlet of the ladder truck, which the ladder has extended 80 ft vertically; it is equipped with a 1½-inch smooth-bore master stream tip (600 gpm). What is the PDP?

PDP = NP + FL
PDP = 80 + FL
FL = $(C \times Q^2 \times L) + AL + EP$
FL = $(0.08 \times 6^2 \times 2) + 25 + 40 = 71$
FL = 6 + 25 + 40
FL = 71 psi
PDP = 80 + 71
PDP = 151 psi

Calculating the Pump Discharge Pressure for a RAM XD Portable Master Stream Device

To calculate the PDP for a portable elevated master stream device, follow these steps:

6. Determine the NP by observing which nozzle is on the tip. If it is a smooth-bore nozzle, the NP will be 80 psi unless the manufacturer's specifications differ. If it is the RAN fog nozzle NP will be 75 psi. If outfitted with a different type of fog nozzle refer to manufactures recommendation.
7. Determine the FL in the supply line(s) from the pumper to the aerial device. Use the split flow, Siamese coefficient **TABLE 7-4**, or percentage method to find the FL in the supply line.
8. Determine the FL of the prepiped master stream. Add 10 psi FL for any master stream device.
9. Calculate the EP if applicable.
10. Add the results of Steps 1 through 4 to obtain the PDP.

Example 1: A pumper supplying a portable master stream is on the hydrant. This apparatus is supplying one 2 1/2-inch line that is 200 ft long to the inlet of the RAM XD, which is on level ground with no elevation gain or loss; it is equipped with a RAN fog nozzle tip (500 gpm). What is the PDP?

PDP = NP + FL
PDP = 75 + FL
FL = $(C \times Q^2 \times L) + AL + EP$
FL = $(2 \times 5^2 \times 2) + 10 + 0 = 110$
FL = 100 + 10 + 0
FL = 110 psi
PDP = 75 + 110
PDP = 185 psi

Calculating Pump Discharge Pressure for a Standpipe

To calculate the PDP for standpipe operations, follow these steps:

1. Determine how you will connect to the standpipe and the amount of hose needed.
2. Use the appropriate FL calculation given the size and amount of hose needed. An LDH fire department connection may require only a single line, whereas the more common 2½-inch FDC will require multiple hoses to be used. When using two 2½-inch lines, split the flow to determine the quantity value (Q) for the FL. For multiple 2½-inch hoselines, use the Siamese coefficient.
3. Calculate the FL in the riser using the applicable coefficient from Table 7-5. The height of the highest discharge used will be the value of L in the equation. Add 10 psi FL for the FDC if flowing 350 gpm or greater. If the amount of water flowing is less than 350 gpm, do not add the 10 psi. If the pump pressure has not been predetermined and the riser size and length are not known, add 25 psi FL for the FDC.
4. Calculate the amount of pressure lost due to the increase in elevation as described in the discussion of elevation loss/gain.
5. Calculate the FL in the attack hoselines, and then add the associated NP.
6. Add the results of Steps 1 through 5 to determine the PDP.

Example: You are supplying three 200-ft attack lines consisting of 2½-inch hose with 11/8-inch tips rated at 50 psi. The highest attack line is on the 15th floor. The other two lines are on the 14th floor. Using the split flow method for the two 2½-inch supply lines that are 200 ft long to the FDC, what is the PDP?

Friction Loss: Supply
Total flow = 266 gpm × 3 = 798 gpm (round to 800)
800 gpm/2 supply lines = 400 gpm each
FL (supply) = $2 \times (4)^2 \times 2$ = 64 psi

Friction Loss: Standpipe
The standpipe is made of 6-inch pipe, and the connection on the 15th floor is 180 ft in elevation (L).

$FL = C\,Q^2\,L$
FL (riser) = $0.052 \times (798/100)^2 \times 180\text{ ft}/100$ (round 798 to 800)
FL (riser) = $0.052 \times (8)^2 \times 1.8$ (round to 2)
FL (riser) = 6 psi
FDC = 10 psi
AL (FDC and standpipe) = 16 psi

Elevation Pressure
EP = (15 – 1) × 5 = 14 × 5 psi
EP = 70 psi

Friction Loss: Attack Line
FL (attack line) = $2 \times (266/100)^2 \times 200\text{ ft}/100$
FL (attack line) = $2 \times (2.66)^2 \times 2$
FL (attack line) = 2 × 7.08 × 2
FL (attack line) = 28 psi

Nozzle Pressure
NP = 50 psi

Pump Discharge Pressure
PDP = NP + FL (supply) +AL (FDC and standpipe) + EP + FL (attack line)
PDP = 50 + 64 + 16 + 70 + 28
PDP = 228 psi