APPARATUS DRIVER / OPERATOR HYDRAULIC CALCULATION & MEASUREMENT STANDARDS
UPDATED 2018

KNOW THE FLOW!

Determining GPM from Smooth Bore Nozzles;

1. GPM = 29.7 x D^2 x $\sqrt{NP}$
2. Standard GPM for the common Smooth Bore Tips

SOLID STREAM / SMOOTH BORE TIPS			
HAND LINES	**GPM @50psi**	**MASTER STREAMS**	**GPM @ 80psi**
15/16"	180	1 1/4"	400
1"	200	1 3/8"	500
1 1/8"	250	1 1/2"	600
1 1/4"	325	1 5/8"	700
		1 3/4"	800
		1 7/8"	900
		AERIAL 2"	1,000
		AERIAL 2 1/4"	1,350
		AERIAL 2 1/2"	1,670
		AERIAL 2 3/4"	2,000

Determining GPM from FOG Nozzles;

1. GPM Range Pre-Calculated by Manufacturer Based on Hose Diameter
2. Standard GPM for FOG Nozzles by Hose Diameter
   a. This is for TFT Red, Blue, Orange Nozzles
      i. TFT Mid-Matic Low PSI Red Automatic @ 75psi
      ii. TFT Mid-Matic Blue / Dual Flow Automatic @ 100psi / 50psi Emergency
      iii. TFT Metro 2 Orange Fixed GPM @ 75psi

AUTOMATIC AND FIXED GALLON FOG NOZZLES	
HOSE DIAMETER	**STANDARD GPM**
1 3/4"	150
2 1/2"	250
3"	300
Master Stream Minimum	350

ELKHART R.A.M. (RAPID ATTACK MONITOR) FOG NOZZLE		
HOSE DIAMETER	**NOZZLE PRESSURE**	**GPM**
2 1/2" / 3"	75	500
2 1/2" / 3"	50	400

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CALCULATING PUMP DISCHARGE PRESSURE

1. Net Pump Discharge Pressure
    a. From a Hydrant
        i. NPDPpps
            1. **NPDP = PDP – INTAKE**
                a. No work is being performed on the suction side of the pump
                b. This is the total work of the pump. Therefore, the incoming pressure must be subtracted from the discharge pressure.

2. Calculating Method for PDP
    a. PDP = Nozzle Pressure + Total Friction Loss
    b. Always start at the nozzle and work your way back to the pump.

Total Friction Loss:
- **F** – Friction Loss #1 from nozzle back to the 1st appliance
- **F** – Friction Loss #2 from 1st appliance back to the pump or next appliance
- **E** – Elevation Loss or Gain in the hose layout
- **A** – Appliance pressure loss in the hose layout

N – Nozzle Pressure

    c. **FL**
        i. CQ^2L
            1. Coefficient = C

HOSE DIAMETER	COEFICIENT
1"	150
1 3/4"	15.5
2 1/2"	2
3"	.8
5"	.08

            2. Quantity Squared = Q^2
                a. GPM / 100 = Q

            3. Length of Hose per 100' = L

ii. **1 ¾" Hose – Range 100-200 GPM - Drop 100 ÷ 2**
    1. Field Hydraulic Calculation Method.
        a. Subtract 100 from the given GPM.
        b. Divide the remainder by 2.
        c. **150 – 100 = 50, 50 ÷ 2 = 25, 25psi / 100' Hose**

iii. **2 ½" Hose – Range 100-500 GPM – Drop 10** (GPM Flowing)
    1. Field Hydraulic Calculation Method.
        a. 100-300 GPM
            i. Subtract 10 from the first two digits of GPM
                1. 250; 25 – 10 = 15psi / 100' Hose
        b. 301-500 GPM
            i. Subtract 10 from the 1st two digits of GPM
            ii. Add back the first digit of the GPM
                1. 350; 35 – 10 = 25 + 3 = 28psi / 100'

iv. **3" Hose – Range 300 +, Q^2** (Condensed Q)
    1. Field Hydraulic Calculation Method
        a. 300 or more GPM
        b. GPM ÷ 100 = Q, Square the Q = PSI / 100' Hose
            i. 300; 300 ÷ 100 = 3, 3 x 3 = 9psi / 100' Hose

v. **5" Hose – Range 500 +, $Q^2 \div 10$** (Condensed Q)
    1. Field Hydraulic Calculation Method
        a. 500 or more GPM
        b. GPM ÷ 100 = Q, Square the Q = PSI / 100' Hose
            i. 1,000; 1,000 ÷ 100 = 10, 10 x 10 = 100 ÷ 10 = 10
            ii. 10psi / 100' Hose

FRICTION LOSS STANDARD PER 100' HOSE			
HOSE SIZE	**GPM**	**FIELD FL**	**CQ^2L**
1 3/4"	150	25	27
2 1/2"	250	15	12.5
3"	300	9	7.2
5"	1,000	10	8

HANDLINE PUMP DISCHARGE PRESSURE STANDARD					
HOSE SIZE	**GPM**	**PRE-CONNECT**	**PDP @ 50psi**	**PDP @ 75psi**	**PDP @ 100psi**
1 3/4"	150	200'	100	125	150
2 1/2"	250	150'	70	100	120
2 1/2"	250	200'	80	105	130
3"	300	150'	65	90	115
3"	300	200'	70	95	120

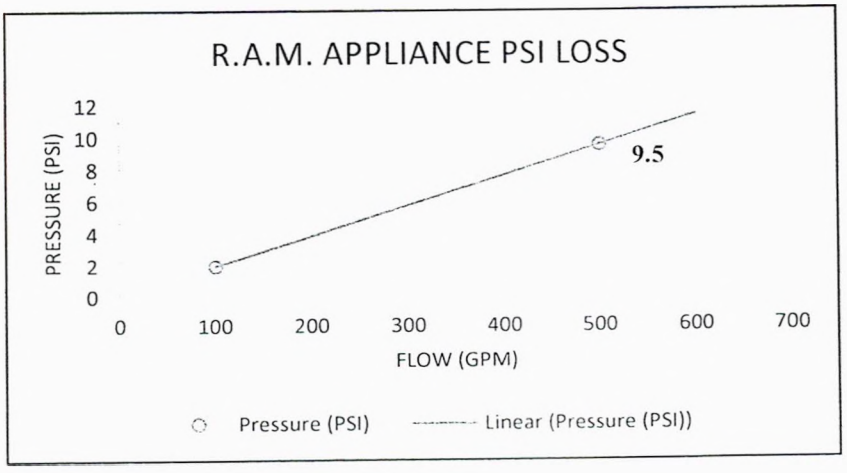
d. EL

i. Field Hydraulic Calculation
   1. Geographical: .5psi / Ft.
   2. Structural: 5psi / Floor – 1st Floor
   3. Sub-Level is a Gain that is subtracted from the PDP.

e. **AL**

i. Small Appliances
   1. Wyes, Gated Wyes, Siamese, Reducer, Increaser.
      a. 10 psi if the combined flow exceeds 350 GPM
      b. 0 psi for less than 350 GPM.

ii. Large Appliances
   1. Deck Gun, Ground Monitor
      a. 25 psi
   2. Aerial Master Stream
      a. 25 psi +/- Elevation
   3. Standpipe
      a. 25 psi Regardless of Flow
         i. Standpipe with a known pressure reducing valve, EL is based on total height of the standpipe.
   4. Rapid Attack Monitor (R.A.M.)
      a. 10 psi



f. NP

i. 50 psi Hand-line Smoothbore and TFT Blue Low-Psi Dual Flow.
ii. 75 psi Fog for TFT Red and Orange
iii. 100 psi Fog and Specialty Nozzles for TFT Blue, Piercing and Chimney.

3. Net Pump Discharge Pressure
   a. NPDPpps
      i. This is the net pump pressure from a positive pressure water supply (hydrant).
      ii. NPDP = PDP – INTAKE PSI
         1. PDP of 150 psi – Intake of 90 psi = Net of 60 psi
            a. This is how much work the pump is actually doing.

4. Calculating Like Volumes
   a. 1st Digit Method with 90 Intake Pressure
      i. 90 x 1 = 9: R-Difference 1-9 psi = 3 Like Volumes
      90 x 2 = 18: R-Difference 10-18 = 2 Like Volumes
      90 x 3 = 27: R-Difference 19-27 = 1 Like Volume
      R-Difference 28+ = 0 Like Volumes

5. Nozzle Reaction
   a. Smoothbore Nozzle
      i. 1.57 x Nozzle Diameter Squared x Nozzle Pressure ($NR = 1.57 \times d^2 \times NP$)
      ii. 1.57 is constant; d is nozzle diameter in inches; NP is nozzle psi
      iii. Field Method, 1/3 the Flow

   b. Fog (Straight Stream)
      i. .0505 x GPM x √ Nozzle Pressure ($NR = .0505 \times GPM \times \sqrt{NP}$)
      ii. .0505 is the constant; GPM is the total flow; NP is the nozzle psi
      iii. Field Method, 1/2 Flow

6. Volume and Area
   a. 1 cubic foot = 1728 cubic inches
   b. Volume of a Cylinder: 3.14 x radius^2 ($\pi r^2 \times H \times 7.5$)
   c. Volume of a Rectangular Tank: Length x Width x Height x 7.5
   d. Volume in a Stream or River: A x V x 7.5
      i. A = w x d
      ii. V = feet / minute
      iii. 7.5 = cubic gallons

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FOAM OPERATIONS

1. Calculating Foam
    a. ***Area x Critical Application Rate (CAR) x Eduction Rate (ER) x 15 Minutes = Amount of Foam Concentrate Needed***
        i. Area: Square footage; length x width
            1. Circle; 3.14 x r^2
        ii. Critical Application Rate; minimum flow of finished foam per square foot.
            1. Hydrocarbon fuels; 0.1gpm/sqft
            2. Polars/Alcohols; 0.2gpm/sqft
        iii. Eduction Rate; minimum metering valve settings
            1. Hydrocarbons; 3% (.03)
            2. Polars/Alcohols; 6% (.06)
        iv. 15 Minutes; NFPA 11 standard for amount of foam concentrate on hand to operate for 15 minutes.
    b. Aeration
        i. TFT foam jet nozzle attachment for foam expansion that increases the expansion ratio of Class B foam from 4:1 to 8:1.
    c. **Simplified Foam Calculation**
        i. ***Hydrocarbons: Area ÷ 20***
        ii. ***Polars/Alcohols: Area ÷ 5***
    d. Example
        i. Area x CAR x ER x 15 = Foam Concentrate Needed
        ii. 10' x 10' or 100 sqft Gasoline Spill
            1. 100 x .1gpm/sqft x .03 x 15 = 4.5 gallons of concentrate.
                a. Or; Area ÷ 20
                    i. 100 ÷ 20 = 5 gallons of concentrate.
    e. Remember, we are limited by how much foam we have on hand and how fast we can get more. It may be that if we only have 20 gallons (4 pails) we are limited to a 60' x 60' hydrocarbon or 30' x 30' polar solvent spill.

Sprinkler Systems

1. 150 with or without smoke showing.

Relay Pumping Operations

1. Maximum Distance and Constant Pressure
    a. Refer to the tables on the next page.

Maximum Distance Relay

Implementing a Maximum Distance Relay operation

Step 1, Determine relay distance
Step 2, Determine required flow
Step 3, Determine maximum distance between pumpers
Step 4, Divide relay distance by maximum distance from table 1, round result up and add one additional pumper
Step 5, Position Attack Pumper
Step 6, Position Source at "Key" hydrant
Step 7, Lay out hose and place Relay Pumpers at intervals determined by Table 1
Step 8, All pumpers except source pumper open a discharge to exhaust air from the lines
Step 9, Source pumper throttles up to proper PDP
Step 10, 1st Relay pumper closes unused discharge once a steady stream of water flows through it, then throttles up to proper PDP
- *All successive Relay pumpers follow the same procedure*
Step 11, All Driver/Operators set their intake relief valves
Step 12, Attack pumper adjusts PDP to supply attack lines.
- *Maintain water flow during temporary shutdowns by using one or more discharges as waste or dump lines*

Example: (1,000 gpm relay over 10,000 feet using 5" LDH) 10000÷2050=4.87(5)+1=6 Pumpers total

Table 1 - Maximum distance relay lengths in feet

Flow in gpm	One 2 1/2	One 3	One 4	One 5	Two 2 1/2's	One 2 1/2 & one 3	Two 3's
250	1,440	3,600	13,200	33,000	5,760	9,600	14,400
500	360	900	3,300	8,250	1,440	2,400	3,600
750	160	400	1,450	3670	640	1050	1,600
1000	90	225	825	2,050	360	600	900
1250*	50	140	525	1,320	200	375	500

Maximum distance relay pump discharge pressure

Formula: PSI + or – Elevation ÷ CQ2 x 100 = Distance Between Pumpers

2 1/2 & 3 inch - Maintain 200psi PDP [200-20] = 180psi PDP
4 & 5 inch - Maintain 185 psi PDP [185-20] = 165psi PDP

**1,250 gpm requires a 1,750 gpm pump to achieve. * PDP accounts for 20 psi residual pressure for the next pumper in the relay*

Key positions in a relay operation

Source Pumper – Largest Capacity Pumper Positioned at the "Key" hydrant
Relay Pumper/Pumpers - Spaced evenly throughout the relay at intervals determined from Table 1
Attack Pumper - Placed at a forward "Key" attack position

1 mile = 5280 Feet

Constant Pressure Relay (Maximum Volume)

Implementing a constant pressure relay operation

Step 1, Position Attack Pumper
Step 2, Position Source Pumper at "Key" hydrant
Step 3, Lay out hose and place Relay Pumpers at 750 foot intervals
Step 4, All pumpers except source pumper open a discharge to exhaust air from the lines
Step 5, Source pumper throttles up to 175 psi
Step 6, 1st Relay pumper closes unused discharge once a steady stream of water flows through it, then throttles up to 175 psi.
- *All successive Relay pumpers follow the same procedure*

Step 7, All Driver/Operators set their intake relief valves
Step 8, Attack pumper adjusts PDP to supply attack lines.
- *Maintain water flow during temporary shutdowns by using one or more discharges as waste or dump lines*

Maximum volume at 750 feet by hose layout

	One 2 1/2	One 3	One 4	One 5	Two 2 1/2's	One 2 1/2 & one 3	Two 3's
Max flow	321 gpm	508 gpm	1017 gpm	1607 gpm	643 gpm	830 gpm	1017 gpm

Maximum volume relay pump pressure

Source and Relay pumpers - Maintain 175 psi PDP
Attack Pumper - adjust PDP as needed making sure to dump excess pressure
** PDP accounts for 20 psi residual pressure for the next pumper in the relay*

Key positions in a relay operation

Source Pumper - Positioned at the "Key" hydrant
Relay Pumper/Pumpers - Spaced evenly throughout the relay at intervals of 750 feet
Attack Pumper - Placed at a forward "Key" attack position

1 mile = 5280 Feet