Engineer Exam Guide 25-1

Included in this packet:

If you have questions regarding recruitment or hiring processes, please email recruitment@sanmiguelfire.org, or call our Human Resources Specialist at (619) 942-2062.

ENGINEER PROMOTIONAL
ORIENTATION & STUDY GUIDE – 2025

Study Material Guide:

- IFSTA Pumping and Aerial Apparatus Driver/Operator (Third Edition 2017)
- California Commercial Driver's License Handbook 2019-2021 (DL 650)
  https://www.dmv.ca.gov/portal/file/california-commercial-driver-handbook-pdf/
- California Commercial Driver's License Handbook-Supplement of Modernized Version January 2023
  https://www.dmv.ca.gov/portal/file/commercial-driver-license-manual-modernization-supplement-pdf/
- California's Driver's Handbook – 2024 (DL 600)
  https://www.dmv.ca.gov/portal/handbook/california-driver-handbook/
- Central Zone Operational Policies and Procedures
  https://www.heartlandfire.net/central-zone-policies-and-procedures
- San Diego County Operational Area Policies and Procedures
  http://sdoparea.org/county-op-area-policies
- San Miguel Fire & Rescue Strategic Plan (2021-2023)
  https://www.sanmiguelfire.gov/
- General use knowledge of the Incident Response Pocket Guide "IRPG" – January 2022
  https://www.dnr.wa.gov/publications/rp_cb_incident_response_pocket_guide.pdf
- General use knowledge of the Field Operations Guide ICS 420-1, 2022
  https://firescope.caloes.ca.gov/fog-manual
- San Miguel Fire & Rescue Procedural Exam Guide- Engineer
- San Miguel Hydraulics Manual and Field Hydraulics Guide

All candidates should be prepared to operate all District fire apparatus, with the exception of our Aerial Apparatus. Additionally, candidates should be prepared to perform a DMV road test and DMV Basic Control Skills Test as part of the manipulative portion of the exam.

Procedural Exam Guide for the Position of Engineer

Introduction

San Miguel Fire & Rescue (hereafter referred to as the District) has made a concerted effort to provide you with as much information as possible regarding the Engineer promotional process. The District reserves the right to modify the testing process and information in this guide as this guide serves informational purposes only.

This guide has been developed to inform you about, and assist you with, preparation for future promotional exams with San Miguel Fire & Rescue. In this guide you will learn about the examination process, the individual sections you may encounter while participating in the exam, and instructions and suggestions that will help you perform at your best on the day of the exam.

Candidates should remember that the exam process is governed by the official job announcement and the accompanying study guide documents and publications.

Overview of the Examination Process

Examination Schedule

The District attempts to adhere to an examination schedule that maintains eligible candidates for move-up opportunities, out-of-class assignments, and promotions. The normal exam schedule for Engineer creates an eligibility list that is certified for two years from list creation. The Fire Chief has the right to extend eligibility lists if the need arises.

Every effort will be made to notify internal candidates 6 months prior to the anticipated test dates. Once the testing timelines have been established, they will be published on the announcement.

Orientation

Orientation will be provided for the assessment center prior to the dates of the exam. This will take place in person and will be recorded. The recording will be posted on Vector Solutions for the duration of the exam period. Specific questions answered during the Orientation will be at the discretion of the Training Division to protect the integrity of the exam. After the Orientation, any formal questions must be submitted via email to the Training Battalion Chief. All correspondence will be shared with all exam candidates concerning any answers or clarification points. An orientation agenda will be provided by Human Resources.

Exam Sections and Sub-sections for Engineer Classification

The District's Training Division strives to properly assess candidates with exam sections relevant to the Engineer positions. The intent is to identify which candidates possess the knowledge, skills, and abilities necessary to assume this position, which requires new levels of mechanical aptitude, leadership, managerial, and administrative responsibilities.

Many factors are considered when selecting how many, and which sections each exam will include. The district reserves the right to adjust the length and diversity of the examination process to fulfill financial, logistical, and time constraint needs. The District will also consider current "best practices" within the Operational Area when creating an appropriate exam. The following is a list of potential exam sections (●) and sub-sections (□) that may appear in the examination process:

- Written Exam
- Manipulative Exam
    - Apparatus Pre-Trip Inspection
    - Apparatus Mechanical / Pump Component Identification
    - Apparatus Driving Evolution
    - Type 1 Pumping Evolution
    - Type 3 Pumping/Drafting Evolution
- Oral Interview
- Appointing Interview

Written Exam

Written tests allow the District to assess a candidate's knowledge of the classification they are aspiring to, including but not limited to, hydraulic calculations, requisite skills, ICS, District policy and procedures, and concepts/information found in the study guide material.

Apparatus Pre-Trip Inspection

This section ensures the candidate is compliant with current California DMV laws regarding the proper inspection of commercial vehicles before their operation.

Apparatus Mechanical / Pump Component Identification

This section requires the candidate to identify and discuss the use of various mechanical and/or pump components on a given apparatus.

Driving Evolution

Operating a commercial vehicle is vastly different from a passenger vehicle or light truck/SUV. This section validates a candidate's ability to safely maneuver an apparatus, taking into consideration stopping distances, turning radius', clearances, laws about commercial vehicles, and handling characteristics, among other things.

Type 1 Pumping Evolution

Essential to the Engineer position is the ability to effectively provide adequate nozzle pressure to a firefighter attacking a fire and a sound understanding of the principals of fireground hydraulics. This includes securing a water supply and delivering it through multiple hose lines, relay pumping, drafting, and supplying other apparatus with water at sufficient pressures.

Type 3 Pumping/Drafting Evolution

The District maintains multiple type 3 apparatus that routinely respond throughout the state as part of the Master Mutual Aid agreement. Their operating and handling characteristics are sufficiently different from a type 1 apparatus. A sound understanding of driving, operating, and pumping this apparatus is key to the growth and development of the Engineer position.

Oral Interview

The oral interview phase of the exam allows candidates to answer job-related questions which are evaluated by a panel that scores the candidate's responses in several critical dimensions. At times Oral Interview questions may be asked during a specific component or throughout the Assessment Center, quantifying this portion of an Assessment Center. The five dimensions are listed in the chart in the grading section.

Appointing Interview

When the time comes to fill a vacancy with a promotion, candidate(s) will be scheduled for an appointing interview with identified evaluators, according to the Districts Exam Evaluator Matrix. At that time, the evaluators will select which candidate(s) best fit the position.

Grading

When developing a study guide for the Engineer exams, the District understands and accepts that justification for correct responses to questions may be drawn from materials and practices that are not found in the materials listed in the exam study guide. Justification may also be based on the experience of fire service subject matter experts. When justification is based on experience, San Miguel Fire & Rescue will take steps to ensure that the correct answer does not conflict with the material found in the study guide.

Below is a description of the grading rubric for the Engineer Exam Manipulative Sections:

DIMENSIONS	SCORING				
	Fail	**Minimally Qualified**	**Qualified**	**Well Qualified**	**Excellent**
	0-69	**70-79**	**80-89**	**90-94**	**95-100**
Efficiency The candidate performs tasks without wasting time or movement. Completes objectives promptly.					
Safety Candidate follows accepted safe work practices for themselves, proctors, and assisting firefighters. Cones placed? Water hammer? Communications?					
Accuracy The candidate correctly calculates hose line pressures. Correctly communicates information to firefighters and proctors.					
Completeness Tasks are completed to an acceptable level. Tools/hose are stowed appropriately, hose kinks mitigated, and gauges marked.					

Below is a description of the grading rubric for the Engineer Exam Oral Interview section:

Fail	**Minimally Qualified**	**Qualified**	**Well Qualified**	**Excellent**
0-69	**70-79**	**80-89**	**90-94**	**95-100**
Shows no understanding of the topic. A candidate did not cover this topic in their preparation.	Demonstrates superficial awareness of the topic or inaccurate answers requiring follow-up questions and prompts	Has some understanding of the topic but is limited to basic comprehension that does not give insight.	Understands the intent of the topic to a higher level than average but does not show deep or robust insight. Articulates information well.	Shows deep/robust insight into the topic without follow-up questions or prompts. Articulates information exceptionally

Evaluators

When possible, candidate performance will be evaluated by a panel that consists of a combination of evaluators from agencies within San Diego County, District personnel, and/or retired fire personnel who are considered subject matter experts. Selection of qualified raters will follow the Districts Exam Evaluator Matrix. Selected evaluators will receive instructions regarding the exercise, District SOG/SOP, scoring procedures, and nuances of the exercise before rating candidates during the examination process.

Section Weights

Subsections are components of a section. As an example, a type 3 drafting evolution and a pre-trip inspection are subsections of the manipulative section of the exam. Candidates will receive a score for each section and sub-section which is weighted to calculate the overall score for the exam. Candidates must receive a minimum of 70% in each section and subsection, with an overall exam score (all sections) of 80% or greater to be placed on the eligibility list.

Confidentiality

The District takes exam confidentiality seriously and will take necessary steps to keep the examination content and nature confidential before, and during the examination process. Each evaluator, role player, candidate, and member of logistical support will be required to complete the District's confidentiality form. There will be no exceptions to this requirement. Also, candidates may not take any of their notes or exercise instructions with them when they leave the exam area. The intent is to preserve the integrity of the process and ingrain confidence in each candidate that they participated in a professional and fair process.

Prohibited Items

Certain items are prohibited during the examination process, including, but not limited to all electronic communication devices (this includes cell phones, iPods/MP3 devices, smart watches, recording devices, iPads/tablets, electronic notebooks, etc.), backpacks, briefcases, policy manuals, previously prepared notes, etc. All necessary testing items will be provided such as electronic devices and manuals.

Dress Code

Unless otherwise noted, candidates shall be in their fire department class B uniform upon arrival to all sections of the exam. When participating in the manipulative sections, candidates must bring, and wear proper PPE for that particular evolution (structural or wildland). In the event of an open or lateral test, an outside candidate may be provided the necessary PPE to safely participate. If the outside candidate is not permitted to wear their class B uniform, a professional business-like suit & tie ensemble will substitute for a class B uniform.

Exam Preparation

Informal Study Group Method

When preparing for the Engineer exam, some candidates may wish to combine their efforts with other candidates by participating in mutually beneficial pumping evolutions in which each member rotates through the engineer position and hose handler positions. This allows candidates to practice their ability to deliver water through multiple lines in simulated emergency incidents.

Study groups also allow Candidates to collectively review and interpret publications and documents that are listed on the exam study guide; quizzing each other to assist with content comprehension and memorization. This is also an opportunity for group members to gain the perspective of the others in the group by discussing, debating, and sharing their experiences and knowledge.

Individual Study Method

Some candidates prefer to prepare for the examination process by studying individually and not in a group setting. If you choose this method, we suggest brainstorming scenarios, using the internet to research publications relevant to the classification you are pursuing, reaching out to crew members for information, etc.

While some candidates may feel as if they will be benefiting other candidates by networking in the group setting, it is important to note that reviewing study guides, participating in group simulations, and reviewing notes prepared by others, can allow you to explore perspectives that one might not consider when preparing for the exam alone. The study group may also have participants who have previously experienced the exam process and be able to share strategies and insight into the testing process.

"We suggest a combination of both methods to best prepare you for the exam"

General Strategies

Understand Classification Expectations – review job classifications and discuss job roles with the immediate supervisor or engineer who currently fills the position; complete tasks and reports when allowed; trade seats with your Engineer on permissible calls-to-service.

Complete Relevant Training – utilize your education reimbursement to further your education that is relevant to the position you pursue. Don't just acquire the minimum education/training required for the position; gain more insight by expanding your knowledge in areas such as leadership, management, and administrative skills.

Reach Out – Seek advice and information from other Engineers, Captains, and BCs in the Central Zone or surrounding areas. Many retired fire department personnel are welcoming to individuals who aspire to promote - sharing their ideas and experiences.

Practice – Research sample interview questions online and consider appropriate answers; give presentations to family members; practice simulations with your crew; conduct pumping evolutions whenever possible, on and off-duty. The constant practice raises your skill level and thus raises confidence in your ability to perform the position you seek. Confident, knowledgeable candidates are usually successful with exam assessments.

Maintain your well-being – Committing to the promotional process requires a sacrifice that can place family life on a temporary holding pattern. Establish a balanced approach and ensure life's priorities are appropriately placed. It is important to inform family and close friends of your desire to promote and seek their support while preparing. Begin and/or continue your physical fitness routine to relieve excess stress accumulated because of exam preparation. This includes quality nutrition that supports your mental and physical health. If you are scheduled to work the day before, or the day of the exam, begin securing time off well in advance.

Exam Day Tips

Give yourself enough time to travel to the test site in a non-stressed manner, arriving early enough to stay relaxed before your assessment. Anticipate and plan for traffic delays. It would be disappointing to miss the exam due to an accident or traffic violation because you felt the need to rush.

It is critical that you understand and follow all the instructions for each section of the exam. While we attempt to provide a realistic exercise, it is impossible to replicate what occurs at the scene of a real-life incident. Therefore, it is necessary to adjust procedures and tasks to accommodate the examination process.

Being nervous is a natural response experienced by most people on test day. Many candidates experience anxiety because of stress and pressure to perform well. Understanding and acknowledging these feelings may help you to relax and put you in a better mindset to take the exam. As much as possible, you need to have a positive attitude when taking the exam.

It's a fact, mistakes will be made by almost everyone on the day of the exam. Accept that as part of the examination process. What is notable is how many, how severe, and how well you recover from those mistakes. Do not let one mistake frustrate you, and thus, manifest into numerous, more critical mistakes. As mentioned before, preparation is the key to success, and it will assist you in keeping the number of mistakes to a minimum.

Field Hydraulics Sheet rev. 11/23/2020

PUMP PRESSURES

1 ¾	Bundle @ 125	113
1 ¾”	150’ @ 95	111
1 ¾”	150’ @ 125	120
1 ¾”	200’ @ 95	115
1 ¾”	200’ @ 125	126
1 ¾”	200’ @ 200	165
2 ½	PRE @ 250	120
HARDLINE		150
SPRINKLER SYS		150

APPLIANCE LOSSES

STANDPIPE SYS	25
MSTR STRM	15
Water Thief	15
Aerial Device	80

RELAY PUMPING

PP = FL + GL – GG + 10 (intake)

NO OF PUMPS = $\frac{TFL + GL - GG}{240}$

IMMEDIATE PUMP PRESSURES

RELAY PUMPING 200
STANDPIPES 150
UNKNOWN LAYS USE:
PP = NP + 20 + GL – GG +AL + SL

NOZZLE PRESS

SB HAND 50 psi
SB MSTR STRM 80 psi
ALL FOG 100 psi

SB GPM- FLR

¼	13 -3
3/8	30 -2
½	50- 6
5/8	80
¾	120
7/8	160
1	210- 9
1 1/8	270- 15
1 ¼	330- 22

SB MS- FLR

1 ¼	400 - 2
1 3/8	500 - 3
1 ½	600 - 5
1 ¾	800 - 8
2	1100 - 15
2 ¼	1400 - 25

MSTR STRM LIMITS ON GROUND BASE

FOG	100 PSI	1000 GPM MAX
2”	75 PSI MAX	850 GPM
1 3/4	100 PSI MAX	800 GPM
1 1/2	100 PSI MAX	700 GPM
1 3/8	100 PSI MAX	550 GPM

EST HYDRANT CAPACITY

Note static pressure
Flow fixed GPM
Note drop
For estimated total flow, a drop of
10% 3 more like GPMs
15% 2 more like GPMs
25% 1 more like GPMs

Conversion Factors

1”	9
1 ½	3.6
1 ¾	2
2 ½	1
3”	.67
4”	.25

GRAVITY GAIN/LOSS

1/2 # PER FOOT
5 # PER FLOOR

TANK CAPACITIES

REC TANK L x W x H x 7.5
CYL TANK $6D^2$ x H – 2 %

GPMs and FLR TABLE

1”	1 ½	1 ¾	2 ½	3”	4”	FLR
11	28	50	**100**	150	400	**2**
12	**30**	55	110	160	**440**	**2**
13	34	60	120	180	480	**3**
14	36	65	130	200	520	3
15	39	70	140	210	560	4
17	42	75	150	230	600	5
18	45	80	160	240	640	5
19	48	85	170	250	680	6
20	**50**	90	180	270	720	**6**
21	53	**95**	**190**	280	760	**7**
22	56	100	200	300	800	8
23	59	105	**210**	310	840	**9**
24	62	110	220	330	880	10
25	64	115	230	340	920	11
26	67	120	240	360	960	12
28	70	**125**	**250**	370	1000	**13**
29	73	130	260	390	1040	14
30	76	135	**270**	400	1080	**15**
31	78	140	280	420	1120	16
32	81	145	290	430	1160	17
33	84	150	300	450	1200	18
34	87	155	310	460	1240	19
35	90	160	320	480	1280	20
36	92	165	**330**	490	1320	**22**
37	**95**	170	340	510	1360	**23**
39	98	175	350	520	1400	25
40	101	180	360	540	1440	26
41	104	185	370	550	1480	27
42	106	190	**380**	570	1520	**29**
43	109	195	390	580	1560	30
44	112	**200**	400	600	1600	**32**
45	115	205	410	610	1640	33
46	118	210	420	630	1680	35
47	120	215	430	640	1720	37
50	**125**	225	450	680	1800	**41**
51	129	230	460	690	1840	42
52	132	235	470	710	1880	44
53	134	240	480	720	1920	46
54	137	245	490	740	1960	48
55	140	250	500	750	2000	50
56	143	225	510	770	2040	52
57	146	260	520	780	2080	54
58	148	265	530	800	2120	56
59	151	270	540	810	2160	58

HYDRAULICS

San Miguel Fire & Rescue

Service Beyond Expectations

Introduction
The primary objective of the pump operator on the fire ground is to provide fire suppression crews with the water flow and pressure needed to achieve efficient fire control and extinguishment. To meet this objective, operators must understand the theoretical aspects of fire stream development. They must then be able to convert these theories into practice during fire ground operations in order to produce effective fire streams.

In this section, the reader will learn; methods of calculating pressure loss in a variety of hose lays and fire ground situations, the effects of friction within hose, appliances, and systems as well as the effect that changes in elevation have on supplying hose lines. Lastly, the reader will learn to use the figures derived from pressure loss calculations to determine the pump discharge pressure required to adequately supply fire streams.

Pump operators rarely perform the calculations contained in this section while on the fire ground. On the fire ground they are more likely to use the methods on pump charts which have pre-done hydraulic answers for determined hose lays. However, it is important that the operator be able to calculate friction loss for a variety of other reasons. It gives a better understanding of fire ground methods. It allows operators to predetermine accurate pump discharge pressures for pre-connected lines and common hose lays used on the apparatus. It serves as a tool for pre-incident planning at locations that require hose deployment that is out of the ordinary from the standard hose lays.

Objectives
This section provides information pertaining to fire ground hydraulics that will assist the reader in the ability to:

- State the factors that determine pump pressure.
- Define pump pressure and friction loss.
- Describe sources of friction loss which include:
    - Hose Friction loss
    - Gravity Loss and Gravity gain
    - Appliance loss
    - System loss
- Describe the correlation between the weight of water and elevation pressure loss.
- State the friction loss rate formula and describe its parts.
- Describe these facts as they relate to determining pump pressure:
    - Nozzle pressure
    - Size of the nozzle tips and/or fog nozzle settings
    - Size of the hose
    - Amount of hose in the evolution
    - Elevation differential between pump and nozzle
    - Appliance loss and system loss
- State the initial pressures when a request is made for water before hydraulic calculations can be made for the following instances:
    - Hand lines
    - Aerial systems
    - Standpipe systems
- Calculate pump pressure for a variety of hand lines including:
    - Straight lays
    - Lays with elevation changes
- Identify the conversion factors to 2½" hose when using different diameters of hose.

- Calculate equivalent flow conversions when converting from 2½" hose to all other diameters of hose used by the San Miguel Fire and Rescue.
- Calculate pump pressures for specific instances of:
    - Siamese lines
    - Wye lines
    - Multiple lines from different discharges
    - Use of appliances
    - Heavy and multiple streams
    - Standpipes and sprinkler systems
- Describe the specific information needed to set up a relay pumping operation.
- Describe the considerations observed before and during relay pumping operations.
- Describe considerations that should be made concerning nozzle reaction.
- Estimate the water available from a given hydrant, through supply hose, to the pump.
- Estimate hydrant discharge capacity.
- State measurements which are specific to determining hydraulic pressure which include:
    - Atmospheric pressures
    - The weight and size of one gallon of water
    - The weight of water in one cubic foot
- Describe considerations regarding the amount of water delivered into buildings.
- Estimate the water capacity for a container (tank, room, etc.).
- Calculate pump discharge maximums given the rated capacity, rated pressure, and given pressure.
- Describe operations necessary to prepare a pumper for a service test, and when the test should occur.
- Describe each portion of the service test including:
    - Dry Vacuum
    - Quick lift
    - 100% Capacity
    - 10% Capacity
    - 70% Capacity
    - 50% Capacity
    - Relief Valve

Determining Pump Pressure

Pump Pressure

In order to deliver the necessary water flow rate, the pump must be able to develop enough pressure to overcome the sum of all the pressure losses and gains. These constant factors include; nozzle pressure (NP), total friction loss (TFL), gravity loss (GL), gravity gain (GG), appliance loss (AL), and system loss (SL).

These factors are then placed into the pump pressure (PP) formula shown below:

PP = NP + TFL + AL + SL + GL - GG

Pump pressure is the amount of pressure in pounds per square inch (PSI), indicated on the pump discharge gauge, that the pump is developing. This pressure will decrease due to friction loss, as it travels through piping, and hose, and if calculated properly, have enough left to properly operate the nozzle at its required pressure and gallons per minute (GPM) selected. The pressure on the pump discharge gauge may be different than on individual discharge gauges due to friction loss within the pump plumbing or systems

The pressure on the pump discharge gauge may also be different than on individual discharge gauges because of different GPM and pressure losses associated with different hose lines being pumped by those discharges. The PP is the highest pressure being generated by the pump and usually matches the discharge with the highest required pressure.

Because most of the fire ground hydraulic calculation examples in this section are being pumped through one discharge, with a few exceptions, PP will be the same as the discharge pressure.

To determine pump pressure, these six factors are needed:

- Nozzle pressure
- Size of the nozzle tips and/or fog nozzle settings (GPM flowing)
- Size of hose
- Amount of hose in a lay
- Elevation differential between pump and nozzle
- Appliance and system losses

Nozzle Pressure

The first step in fire ground hydraulics is to establish nozzle pressures for all fire streams.

The San Miguel Fire and rescue has established the following standard nozzle pressures:

- 50 psi NP on hand held lines with smooth bore tips
- 80 psi NP on master streams with smooth bore tips
- 100 psi NP on all fog nozzles

Size of Nozzle Tip and GPM

The size of the smooth bore tip (SB) and pressure determines the nozzle's GPM. The GPM is the major factor that causes friction loss in fire hose. The larger the GPM, the more friction loss involved. For any size SB, where d = tip diameter and $\sqrt{NP}$ = square root of the nozzle pressure, the GPM for fresh water can be approximated by this SMG recognized formula:

$GPM = 30 d^2 \sqrt{NP}$

**Rounding for master stream smooth bore tips, round to the nearest 100 GPM*

Rounding
Rounding is performed at several points during hydraulic calculations.

Below are the points at which rounding up or down should be performed:

- In normal math, work to the thousandth decimal place and round to the hundredth place.
- After computing a nozzle's GPM (Smooth Bore) round to the hose size it is attached to:
    - ¾" and 1" hose to the nearest 1 GPM
    - 1 ½" and 1 ¾" hose to the nearest 5 GPM
    - 2 ½", 3", and 4" to the nearest 10 GPM
- 2 ½" hose and Equivalent flow to the nearest 10 GPM.
- Friction loss rate to the nearest whole number.
- Total friction loss to the nearest whole number
- Volume of water in a container to the nearest whole number.
- Pounds of water to the nearest whole number.
- Gravity gains/losses to the nearest whole number.

Friction Loss
One of the physical properties of water is that it is practically incompressible. This means that the same volume of water put into a hose under pressure at one end will be discharged at the other end.

Friction loss is that part of the total pressure lost while forcing water through pipe, fittings, fire hose and adapters. In hose, this is caused by the turbulent movement of water molecules against each other and against the lining of the hose itself. How much pressure needed to overcome this loss is called the friction loss rate (FLR).

The pump is performing work to develop pressure. The FLR formula represents the work needed to provide the pressure to overcome the friction of the water flowing through 2 ½" hose.

The smaller the hose diameter, with a given flow, the more friction loss is involved.

This is because a greater percentage of the water pushed through the hose contacts the interior surface than in larger hose. Large diameter hose allows a greater percentage of the water to pass without contacting the interior surface thus needing less pressure to push the water through the hose.

In fire hose the friction loss rate is measured by the total gallons per minute (GPM) divided by 100, then squared and then doubled. The result is the FLR per 100 feet of hose. This formula has been found to be sufficient on the fire ground for computing the friction loss rate:

$FLR = 2Q^2$

Where $Q = GPM/100$

Equivalent Flow and size of hose
All the formulas are based on water flowing through 2 ½" hose. When water flows through any other size hose, the flow must be converted to a 2 ½" equivalent flow so the pump creates pressure as though it is through a 2 ½" hose. The conversion factors are derived from comparison tables in the NFPA Booklet "Nozzle Pressures on the Fire Ground", as well as actual flow tests. After converting the new GPM is rounded to the nearest ten as the final step in converting the flow. Below are the conversion factors for all hose used at San Miguel Fire and Rescue and the equivalent flow formula where EF = equivalent flow and F = conversion factor:

EF = F x GPM

Conversion Factors to 2½" Hose

Conversion Factors to 2 ½" Hose	
Diameter of Hose	Conversion Factor
¾"	25
1"	9
1 ½ "	3.6
1 ¾"	2
3"	.67
4"	.25

Amount of hose in Lay
In order to solve the amount of friction loss in a hose lay you must know the entire length of the hose lay. The hose lay is then divided by 100 as shown below:

Lay / 100 = L

Total friction loss
Because the friction loss rate is based on 100 feet of hose it must be applied to the amount of hose used between the pump discharge and the nozzle (lay) before it can be placed into the PP formula as the total friction loss (TFL). When the friction loss rate is multiplied by the lay the result is the total friction loss (TFL) for the hose lay as shown below:

FLR x L = TFL

Elevation Differentials or Gravity Loss and Gain
Fire ground operations often require the use of hose lines with the nozzle at elevations different from the pump. Any elevation differences must be considered when determining PP.

Head pressure or head, refers to the height of a water supply above the discharge orifice. A column of water, one square inch and one foot high, weighs .434 pounds and pushes downward with the same force or head pressure. When a nozzle is flowing at an elevation higher than the pump, this head pressure is exerted back against the pump. To compensate for this loss in pressure, or gravity loss (GL), pressure must be added to the PP. Operating a nozzle at an elevation lower than the pump results in head pressure pushing against the nozzle. This gain in pressure, or gravity gain (GG), is compensated for by subtracting the pressure from the PP.

For ease of calculations in fire ground hydraulics the .434 is rounded to .5 pounds and multiplied by the number of feet above or below the pump. The resultant pressure is then placed into the PP formula as gravity loss (GL) or gravity gain (GG).

Appliance loss
Fire ground operations often require hardware that is used in conjunction with fire hose for delivering water and are considered appliances. They include reducers, wyes, tri-ways, master streams, etc. The amount of friction loss created varies in all appliances. That loss is called appliance loss (AL) and is the amount of energy used up in the turbulence of the water flowing through the appliance. Any appliances flowing greater than 350 GPM you will need to add 15 psi.

Multiply 15 by the number of appliances to get the total AL as shown below:

AL = 15 x # of appliances

System Loss
Most buildings with two or more stories have some sort of built-in fire protection standpipe system. Turbulence or friction is caused when water flows through wet or dry standpipe systems and must be considered in the overall PP. Known as system loss (SL), San Miguel adds 25 pounds for any standpipe system which is added to the PP formula as shown below.

PP = NP + TFL + SL

Initial Pressures
Pump operators often need to flow water before accurate hydraulic calculations can be completed. The standard operating procedure will be to pump initial pressures as shown below:

- For 2 ½” hand lines with fog nozzles set at 250 GPM:
  - Lines up to 400’: 125 psi
  - Lines 400-800’ : 175 psi
  - Lines exceeding 800’: 200 psi
- Standpipe systems: 150 psi
- Aerial Device: 180 psi
- Wildland lays: 100 psi
- Unknown lays use: NP+20+AL+SL+GL-GG

Pre-Established Pressures
Some operations have pre-determined or fixed GPM, length and size of hose. For efficiency on the fire ground their final pressures have been pre-calculated and provided as established pressures. This is a partial list of SMG pre-calculated pressures:

- 100 ft 1 ¾”pre-conn. @ 95 GPM — 107 psi
- 150 ft 1 ¾”pre-conn. @ 95 GPM — 111 psi
- 200 ft 1¾” pre-conn. @ 125 GPM — 126 psi
- 150 ft 1¾” pre-conn. @ 125 GPM — 120 psi
- 200 ft 1¾” pre-conn. @ 200 GPM — 164 psi
- 150 ft 2½” pre-conn. @ 250 GPM — 120 psi
- 100 ft 1¾” bundle @ 125 GPM — 113 psi
- 100 ft 1 ¾” bundle @ 200 GPM — 132 psi
- Sprinkler System (regardless of # of heads) — 150 psi
- Hardline ¾” or 1” — 150 psi

Rule of “Twelve’s”
Another quick way to help remember the friction loss rates for the majority of GPM flows that we may encounter is informally referred to as the “Rule of ‘Twelve’s”. For 2½" equivalent flows between 180 and 320 GPM, then can be calculated by subtracting 12 from the first two digits of the GPM flow. For example, the friction loss rate for 250 GPM is (25 - 12) = 13 psi/100’ of 2 ½”

Fire Ground Hydraulic Calculation Examples
This part contains example problems designed to familiarize the reader with the concepts used in performing hydraulic calculations. The example problems serve as a guide and show the proper way to solve a particular problem. They are worked out step by step to show the entire problem-solving process. The examples start with basic hose lays and progressively become more complex so that when followed in sequence the reader will have a good working knowledge of fire ground hydraulics:

Example 1
650' of 2½" hose, with a 1" SB. What is the PP?

In fire ground hydraulics the basic pump pressure formula for a lay is:

PP = NP + TFL + AL + SL + GL - GG

The standard nozzle pressure for hand held smooth bore tips is 50 psi. It is the total friction loss that needs to be determined in this problem. This can be done by finding the GPM. Then using the FLR and L formulas to find the TFL.

These are the formulas needed for this problem:

NP = SB hand held pressure
$GPM = 30d^2\sqrt{NP}$
Q = GPM/100

$FLR = 2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR x

Start by finding the GPM:
$GPM = 30d^2\sqrt{NP}$
$GPM = 30 \times 1^2 \times \sqrt{50}$
GPM = 30 x 1 x 7.07
GPM = 212 *round to nearest 10*
GPM = 210

Now find the FLR:
$FLR = 2Q^2$
$FLR = 2 \times 2.1^2$
FLR = 2 x 4.41
FLR = 8.82 *round to nearest whole number*
FLR = 9

Q = GPM / 100
Q = 210 / 100
Q = 2.1

*Rule of 12's (GPM 180-320) - **GPM 210** - Subtract 12 from the front 2 numbers (21) gives you a FLR of 9 per 100 ft*

TFL= FLR x L
TFL = 9 x 6.5
TFL = 58.5 *round to nearest whole number*
TFL = 59

L = Lay / 100
L = 650 / 100
L = 6.5

PP = NP + TFL +AL + SL + GL - GG
PP = 50 + 59
PP = 109

Example 2
450' of 2 ½" hose, with a 2 ½ fog nozzle set at 250 GPM. What is the PP?

Using the initial pressures procedure, the initial PP would be 175 psi.
2 ½" hand lines with fog nozzles set at 250 GPM with 400'-800' = 175 psi

PP = NP + TFL + AL + SL + GL – GG **GPM = 250** **450 ft of 2 ½" hose**

These are the formulas needed for this problem:

NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
Q = GPM/100
$FLR = 2Q^2$
L = LAY (total feet of hose lay)/ 100
TFL = FLR x L

TFL = FLR x L

$FLR = 2Q^2$
$FLR = 2 \times 2.5^2$
FLR = 2 x 6.25
FLR = 12.5 *round to nearest whole number*
FLR = 13

L = Lay / 100
L = 450 / 100
L = 4.5

TFL = 13 x 4.5
TFL = 58.5 *round to nearest whole number*
TFL = 59

*Rule of 12's (GPM 180-320) - **GPM 250** - Subtract 12 from the front 2 numbers 25 gives you a FLR of 13 per 100 ft*

Q = GPM / 100
Q= 250 / 100
Q = 2.5

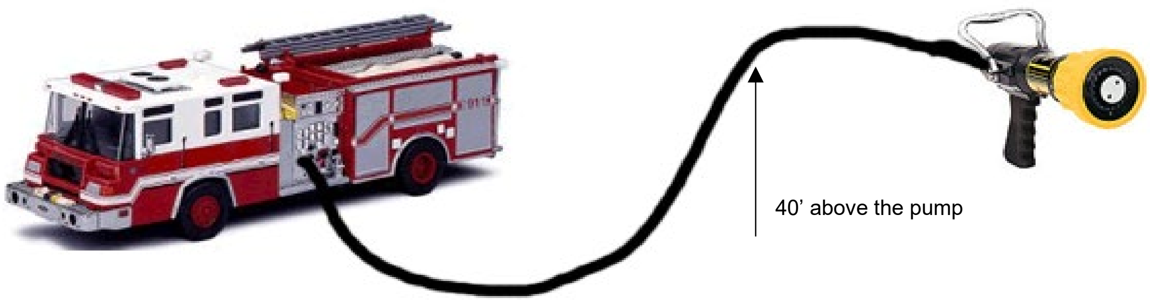
PP= NP+TFL + AL + SL + GL - GG
PP= 100 + 59
PP= 159

<u>Example 3</u>
300' 2 ½" hose, with a 2 ½ fog nozzle set at 250 GPM, 40' above the pump. What is the PP?

Using the initial pressures procedure, the initial PP would = 125 psi
2 ½" hand lines with fog nozzles set at 250 GPM with up to 400' = 125 psi

Then use the basic pump pressure formula for a level lay, plus to allow for GL or GG, allow .5 for each foot of elevation (**GL = .5 x H**)

<u>PP= NP + TFL + AL + SL + GL - GG</u> **<u>GPM= 250</u>** **300 Ft of 2 ½" hose**



<u>These are the formulas needed for this problem:</u>

NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
Q = GPM/100
FLR = $2Q^2$

L = LAY (total feet of hose lay)/100
TFL = FLR X L
GL = .5 x H

FLR = $2Q^2$
FLR = 2 x 2.5^2
FLR = 2 x 6.25
FLR = 12.5 *round to nearest whole number*
FLR = 13

Q = GPM / 100
Q = 250 / 100
Q = 2.5

*Rule of 12's (GPM 180-320) - **GPM 250** - Subtract 12 from the front 2 numbers 25 gives you a FLR of 13 per 100 ft*

L = Lay / 100
L = 300 / 100
L = 3

TFL = FLR x L
TFL = 13 x 3
TFL = 39

GL = .5 x H
GL = .5 x 40
GL = 20

PP = NP + TFL + AL + SL + GL – GG

PP = 100 + 39 + 20
<u>PP = 159</u>

<u>Example 4</u>
300' of 2 ½" hose, with a 2½" fog nozzle set at 250 GPM, 45' below the pump. What is the PP?

Let's add the initial pressure for unknowns: NP + 20 + AL + SL + GL – GG
Since the only givens are the NP and TFL the initial PP would = 120

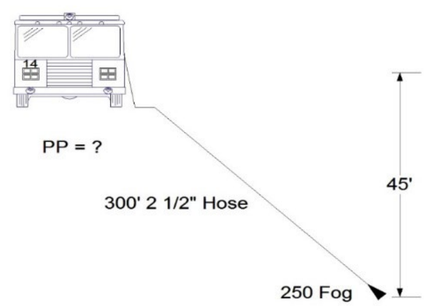
Then use the basic pump pressure formula for a level lay, plus to allow for GL or GG, allow .5 for each foot of elevation (**GG = .5 x H**)

<u>PP= NP + TFL + AL + SL + GL - GG</u> **<u>GPM= 250</u>** **300 of Ft 2 ½" hose**

<u>These are the formulas for this problem:</u>
NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
Q = GPM/100
FLR = $2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR X L
GG = .5 x H

FLR = $2Q^2$
FLR = 2 x 2.5^2
FLR = 2 x 6.25
FLR = 12.5 -round to nearest whole number
FLR = 13

L = 300 / 100
L = 3



L = Lay / 100

*Rule of 12's (GPM 180-320) - **GPM 250** - Subtract 12 from the front 2 numbers 25 gives you a FLR of 13 per 100 ft*

Q = GPM / 100
Q = 250 / 100
Q = 2.5

TFL = FLR x L
TFL = 13 x 3
TFL = 39

GG = .5 x H
GG = .5 x 45
GG = 22.5 *round to nearest whole number*
GG = 23

PP = NP + TFL + AL + SL + GL - GG
PP = 100 + 39 – 23
<u>PP = 116</u>

Equivalent Flows
The FLR formula is based on water flowing through 2 ½" hose. Using any other size hose must be converted to 2 ½" hose by using the equivalent flow conversion factors (F) below:

Conversion Factors to 2½" Hose

Conversion Factors to 2 ½" Hose	
Diameter of Hose	Conversion Factor
¾"	25
1"	9
1 ½ "	3.6
1 ¾"	2
3"	.67
4"	.25

For example, the pump is flowing 250 GPM through a 2 ½" hose. We know from the previous example above that the FLR was 13 pounds per 100' of hose. If the engine were to pump the same GPM through a 4" hose, the flow would have to be converted to the 2 ½" equivalent GPM first before the FLR formula could be applied correctly.

This is done by multiplying the GPM by the conversion factor of the hose size being used. After converting the new GPM, it is rounded to the nearest ten as the final step in converting the flow. The equivalent flow is now considered to be flowing through 2 ½" hose.

The equivalent flow formula is shown below:

EF = F x GPM

Using the example above, to convert 250 GPM flowing through 4" hose, multiply .25 by 250 or divide 250 by 4.

250 GPM x .25 = 62.5 GPM which is then rounded to the nearest 10 (2 ½ hose) or 60 GPM.
EF = F x GPM
EF = .25 x 250
EF = 62.5 –rounded to nearest 10 (2 ½" hose)
EF = 60 GPM

In another example, to convert 95 GPM flowing through 1 ½" hose, multiply 3.6 by 95.

95 GPM x 3.6 = 342 which is then rounded to the nearest 10 or 340 GPM.

EF = F x GPM
EF = 3.6 x 95
EF = 342 --round to nearest 10
EF = 340 GPM

<u>Example 5</u>
200'of 1 ¾" hose, with a 1 ½" fog nozzle set at 125 GPM. What is the PP?

PP = NP + TFL + AL + SL + GL - GG

Before the FLR formula can be solved the GPM must be converted to the 2 ½" hose equivalent flow. The formula for equivalent flow is written as follows:
EF = F x GPM

These are the formulas needed for this problem:
NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
EF = F x GPM
Q = <u>GPM/</u>100

FLR = $2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR x L

EF = F x GPM
200 of Feet of 1 ¾" Fog Nozzle 200 GPM

Equivalent Flow
GPM = 125
EF = F x GPM
EF = 2 x 125
EF = 250

*Rule of 12's (GPM 180-320) - **GPM 250** - Subtract 12 from the front 2 numbers 25 gives you a FLR of 13 per 100 ft*

FLR = $2Q^2$
FLR = 2×2.5^2
FLR = 2 x 6.25
FLR = 12.5 *(round to the nearest whole number)*
FLR = 13

Q = GPM / 100
Q = 250 / 100
Q = 2.5

L = Lay / 100
L = 200/100
L = 2

TFL = FLR x L
TFL = 13 x 2
TFL = 26

PP = NP + TFL + AL + SL + GL - GG
PP = 100 + 26
<u>PP = 126</u>

Multiple sized lines in the same lay

When using multiple size hoses in a lay, the TFL must be calculated in each of the hose sizes individually for the entire lay. Before the FLR formula can be solved, the GPM must be converted to the equivalent flow for all the hose in the lay other than 2 ½".
The flow through the 2 ½" hose is figured as the actual total GPM.

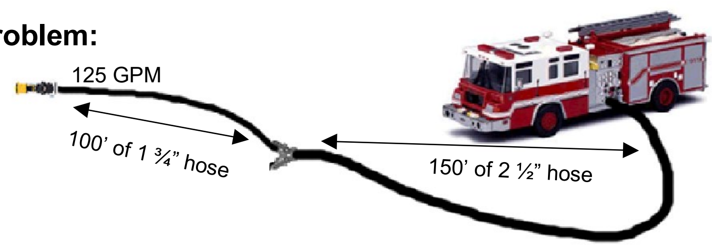
Example 6

150 ft of 2 ½" hose wye into 100 ft. of 1 ¾" hose flowing 125 GPM Fog. What is the PP?

PP = NP + TFL + AL + SL + GL - GG

These are the formulas needed for this problem:

NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
EF = F x GPM
Q = GPM/100
FLR = $2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR X L



Equivalent Flow

1 ¾" hose
125 GPM
EF = F x GPM
EF = 2 x 125
EF = 250
EF= 250 GPM

FLR = $2Q^2$
FLR = 2 x 2.5^2
FLR = 2 x 6.25
FLR = 12.5 *round to nearest whole number*
FLR = 13

Q = GPM / 100
Q = 250 / 100
Q = 2.5

L = Lay / 100
L = 300 / 100
L = 3

TFL = FLR x L
TFL = 13 x 1
TFL = 13

PP = NP + TFL
PP = 100 + 13 (1 ½" hose)
+ 5 (2 ½" hose)
PP = 100 + 18
PP = 118

2 ½" Hose
GPM = 125 *round to nearest 10 (2 ½ hose)*
GPM = 130

FLR = 2Q^2
FLR = 2 x 1.32

FLR = 2 x 1.69
FLR = 3.38 *round to the nearest whole number*
FLR= 3

Q = GPM / 100
Q = 130 / 100
Q = 1.3

TFL = FLR x L
TFL = 3 x 1.5
TFL = 4.5
TFL= 5

L = Lay / 100
L = 150 / 100
L = 1.5

Siamese lines

When pumping Siamese lines that are equal size and length, determine the GPM, divide by the number of lines, and calculate the TFL through one line. Figure the TFL for the single line for the entire GPM.

Siamese lines

GPM = 330

Divide flow by the number of lines

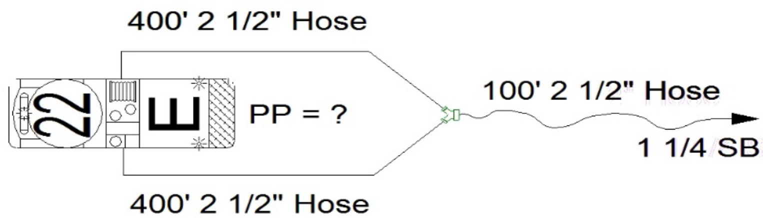
GPM = 330 / 2

GPM = 165 *round to nearest 10*

GPM = 170

Example 7
Two 400’ 2 ½” lines Siamese into 100’ 2 ½” hose, with a 1 ¼” SB. What is the PP?

PP = NP + TFL



These are the formulas for this problem:
NP = SB hand held pressure
GPM = $30d^2\sqrt{NP}$
Q = GPM/100
FLR = $2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR x L

GPM = 30d2√NP
GPM = 30 x $1¼^2$ x √50
GPM = 30 x 1.56 x 7.07
GPM = 331 *round to nearest 10 (2 ½ hose)*
GPM = 330

Siamese Lines
GPM = 330
Divide flow by the number of lines
GPM = 330 / 2
GPM = 165 *round to the nearest 10 (2 ½ hose)*
GPM = 170

FLR = 2Q2
FLR = 2 x 1.72
FLR = 2 x 2.89
FLR = 5.78 *round to nearest whole number*
FLR = 6

Q = GPM / 100
Q = 170 / 100
Q = 1.7

L = Lay / 100
L = 400 / 100
L = 4

TFL = FLR x L
TFL = 6 x 4
TFL = 24

Single 2 ½” line
FLR = $2Q^2$
FLR = 2 x 3.3^2
FLR = 2 x 10.89
FLR = 21.78
round to nearest whole number
FLR = 22

TFL = FLR x L
TFL = 22 x 1
TFL = 22

GPM = 330
Q = GPM / 100
Q = 330 / 100
Q = 3.3

L = Lay / 100
L = 100 / 100
L = 1

PP = NP + TFL
PP = 50 + 24 (Siamese 2 ½ lines)
PP =   + 22 (single 2 ½ line)
PP = 50 + 46
PP = 96

When Pumping Siamese and Wye lines with unequal nozzle types, flow, hose size, hose length, or elevation changes.

Safety and efficiency are vital on the fire ground to mitigate the emergency. With this in mind, pump to the highest pressure on Siamese and wye lines that have different:

Nozzle pressures
GPMs
Hose sizes
Hose lays
Elevation differences

With this practice of pumping to the highest pressure, each nozzle person will know they are receiving, at least, the proper GPMs and nozzle pressure to maintain the correct fire flow for the nozzle setting. Also, the pump operator will have fewer calculations to perform to get the final correct discharge pressure.

To calculate the Siamese or wye line with the highest pressure, determine the line that has the highest pressure and use that line in the PP formula. As you get better at figuring calculations, recognizing the line with the highest TFL due to nozzle type, hose size, etc. will be obvious and you can short cut the process by only calculating the higher TFL line.

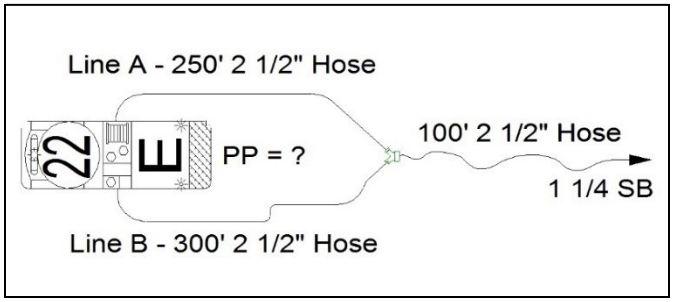
Siamese lines with unequal lengths

When pumping Siamese lines that are of different length, determine the GPM and use the TFL for the Siamese line with the highest pressure.

Figure the TFL for the single line for the entire GPM.

Example 8

Two 2 ½" lines: (line A) 250'of 2 ½", (line B) 300' of 2 ½" Siamese into 100' of 2 ½" hose, with a 1 ¼" SB.



What is the PP?

These are the formulas for this problem:

NP = SB hand held pressure

GPM = $30d^2\sqrt{NP}$

Q = GPM/100

FLR = $2Q^2$

L = LAY (total feet of hose lay)/100

TFL = FLR X L

PP = NP + TFL + AL + SL + GL - GG

GPM = $30d^2\sqrt{NP}$

GPM = 30 x 1 ¼ ^{2} x $\sqrt{50}$

GPM = 30 x 1.5625 x 7.07

GPM = 331 -round to nearest 10

GPM = 330

Siamese lines

Divide flow by the number of lines

GPM = 165 *round to nearest 10*

GPM = 330 / 2

GPM = 170

250' 2 ½"

FLR = 2Q2

FLR = 2 x 1.72

FLR = 2 x 2.89

FLR = 5.78 *nearest whole number*

FLR = 6

Q = GPM / 100

Q = 170 / 100

Q = 1.7

L = Lay / 100

L = 250 / 100

L = 2.5

TFL = FLR x L

TFL = 6 x 2.5

TFL = 15

300' 2 ½"

FLR = 2Q2

FLR = 2 x 1.72

FLR = 2 x 2.89

FLR = 5.78 *nearest whole number*

FLR = 6

Q = GPM / 100

Q = 170 / 100

Q = 1.7

L = Lay / 100

L = 300 / 100

L = 3

TFL = FLR x L

TFL = 6 x 3

TFL = 18

This is the line with the highest TFL

Single 2 ½" line

GPM = 330

FLR = $2Q^2$

FLR = 2 x 3.3^2

FLR = 2 x 10.89

FLR = 21.78 *nearest whole number*

FLR = 22

Q = GPM / 100

Q = 330 / 100

Q = 3.3

L = Lay / 100

L = 100 / 100

L = 1

TFL = FLR x L

TFL = 22 x 1

TFL = 22

PP=NP+TFL+AL+SL+GL-GG

PP = 50 + 18 (Siamese lines highest TFL)

PP = + 22 (single line)

PP = 50 + 40

PP = 90

Wye lines

When pumping wye lines with the same GPM, size and length of hose, determine the TFL needed to pump only for one line. Both nozzle GPM will be added when figuring at the wye point.

Example 9:
150' 2 ½" hose wye into two 100' 1 ¾" lines, with two fog nozzles set at 125 GPM. What is the PP?

PP = NP + TFL + AL + SL + GL - GG

Before the FLR formula can be solved the GPM must be converted to the equivalent flow for all the hose in the lay other than 2 ½". The flow through the 2 ½" hose is the figured as the actual total GPM.

These are the formulas needed for this problem:
NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
EF = F x GPM
Q = GPM/100
FLR = $2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR x L

*Rule of 12's (GPM 180-320) - **GPM 250** - Subtract 12 from the front 2 numbers 25 gives you a FLR of 13 per 100 ft*

<u>Single 2 ½" line</u>
GPM = 125 x 2
GPM = 250

FLR = 2Q2
FLR = 2 x 2.5²
FLR = 2 x 6.25
FLR = 12.5 *round to nearest whole number*
FLR = 13

Q = GPM / 100
Q = 250 / 100
Q = 2.5

L = Lay / 100
L = 150 / 100
L = 1.5

TFL = FLR x L
TFL = 13 x 1.5
TFL = 19.5 *round to nearest whole number*
TFL = 20

<u>Wye 1 ¾" lines</u>
GPM = 125
EF = F x GPM
EF = 2 x 125
EF = 250 *round to nearest 10*
EF = 250

FLR = 2Q2
FLR = 2 x 2.5²
FLR = 2 x 6.25
FLR = 12.5 -round to nearest whole number
FLR = 13

Q = GPM / 100
Q = 250/ 100
Q = 2.5

L = Lay / 100
L = 100 / 100
L = 1

TFL = FLR x L
TFL = 13 x 1
TFL = 13

PP = NP + TFL
PP = 100 + 13 (wye lines)
PP = + 20 (single line)
PP = 100 + 33
PP = 133

<u>Wye lines of unequal types</u>
San Miguel pumps to the highest pressure on Siamese and wye lines that have different:

- Nozzle pressures
- GPMs
- Hose sizes
- Hose lays
- Elevation differences

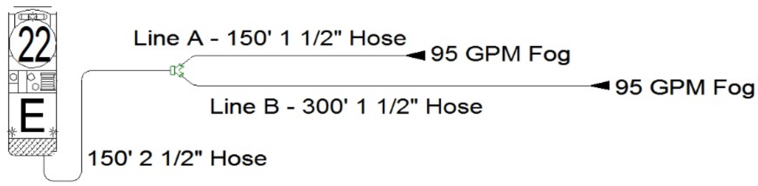
To calculate the wye line with the highest pressure, figure the TFL for each line and use the TFL for the line with the highest TFL.

The flow through the 2 ½" hose is the figured as the actual total GPM.

Example 10

150'of 2 ½" hose wye into two 1 ½" lines: line 'A' 150'of 1 ½", line 'B' 300'of 1 ½", with two fog nozzles set at 95 GPM. What is the PP?

Before the FLR formula can be solved the GPM must be converted to the equivalent flow for all the hose in the lay other than 2 ½".



PP= NP + TFL + AL + SL + GL - GG

These are the formulas needed for this problem:

NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
EF = F x GPM
Q = GPM/100

FLR = $2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR x L

Single 2 ½" line

GPM = 95 x 2
GPM = 190

FLR = $2Q^2$
FLR = 2 x 1.9^2
FLR = 2 x 3.61

FLR = 7.22 *round to nearest whole number*
FLR = 7

Q = GPM / 100
Q = 190 / 100
Q = 1.9

L = Lay / 100
L = 150 / 100
L = 1.5

TFL = FLR x L
TFL = 7 x 1.5
TFL = 10.5 *round to nearest whole number*
TFL = 11

PP = NP + TFL
PP = 100 + 11 (single line)
PP = + 69 (wye lines)
PP = 100 + 80
PP = 180

Wye 1 ½" lines

GPM = 95
EF = F x GPM
EF = 3.6 x 95
EF = 342 *round to nearest 10*
EF = 340

FLR = $2Q^2$
FLR = 2 x 3.4
FLR = 2 x 11.56

FLR = 23.12 *round to nearest whole number*
FLR = 23

Q = GPM / 100
Q = 340 / 100
Q = 3.4

L = Lay / 100
L = 150 / 100
L = 1.5

TFL = FLR x L
TFL = 7 x 1.5
TFL = 10.5 -round to nearest whole number
TFL = 11

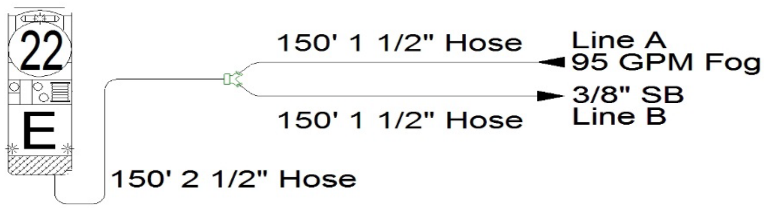
Wye lines with unequal nozzles and GPM

As mentioned above San Miguel now pumps to the highest pressure on Siamese and wyed lines that have different:
Nozzle pressures
GPM
Hose sizes
Hose lays
Elevation differences
For the next example problem, calculate the wye line with the highest pressure. Figure the PP (NP and TFL), for each wye line and use the PP (NP and TFL) for the line with the highest PP. Figure the TFL for the rest of the lay for the entire GPM.

<u>Example 11</u>

150'of 2 ½" hose wye into two 150'of 1 ½" lines: (line A) with a fog nozzle set at 95 GPM, (line B) with a 3/8" SB. What is the PP?

Before the FLR formula can be solved the GPM must be converted to the equivalent flow for all the hose in the lay other than 2½".



PP = NP + TFL + AL + SL + GL - GG

These are the formulas needed for this problem:

NP = SB handheld pressure
GPM = 30d²√NP
NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
EF = F x GPM
Q = GPM/100
FLR = 2Q²
L = LAY/100
TFL = FLR X L

3/8" SB
GPM = 30d²√NP
GPM = $30 \times \frac{3}{8}^2 \times \sqrt{NP}$
GPM = 30 x .14 x 7.07
GPM = 29.82
GPM = 30

<u>Single 2 ½" line</u>

GPM = 95 + 30
GPM = 125 -round to nearest 10
GPM = 130

FLR = $2Q^2$ Q = GPM / 100
FLR = $2 x 1.3^2$ Q = 130 / 100
FLR = 2 x 1.69 Q = 1.3
FLR = 3.38 -round to nearest whole number
FLR = 3

L = Lay / 100
L = 150 / 100
L = 1.5

TFL = FLR x L
TFL = 3 x 1.5
TFL = 4.5 -round to nearest whole number
TFL = 5

Wye 1 ½" lines 95 GPM Fog

NP = 100 psi.
GPM = 95

EF = F x GPM

EF = 3.6 x 95
EF = 342 –round to nearest 10

EF = 340

L = Lay / 100
L = 150 / 100
L = 1.5

FLR =$2Q^2$
FLR = $2 \: x \: 3.4^2$
FLR = 2 x 11.56
FLR = 23.12 -round to nearest whole number
FLR = 23

TFL = FLR x L
TFL = 23 x 1.5
TFL = 34.5
TFL = 35

Q = GPM / 100
Q = 340 / 100
Q = 3.4

This line has the highest nozzle pressure
This is the line with the highest TFL
3/8" SB

NP = 50 psi.

GPM = 30d²√NP
GPM =$30 \: x \frac{3}{8}^2 \: x \sqrt{50}$
GPM = 30 x .14 x 7.07
GPM = 29.82
GPM = 30

EF = F x GPM
EF = 3.6 x 30
EF = 108 –round to nearest 10
EF = 110

FLR =$2Q^2$
FLR = $2 \: x \: 1.1^2$
FLR = 2 x 1.21
FLR = 2.42 -round to nearest whole number
FLR = 2

Q = GPM / 100
Q = 110 / 100
Q = 1.1

L = Lay / 100
L = 300 / 100
L = 3

TFL = FLR x L
TFL = 2 x 3
TFL = 6

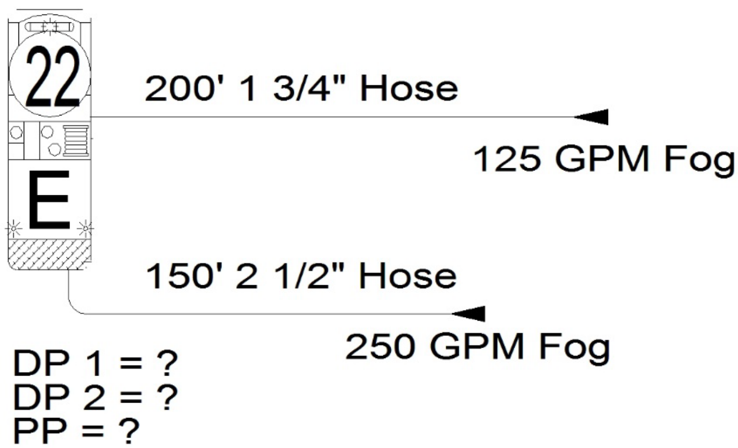
PP = NP + TFL
PP = 100 + 35 (wye lines)
PP = + 5 (single line)
PP = 100 + 40
PP = 140

Pumping multiple discharges
When pumping multiple discharges, the PP equals the discharge with the highest pressure or discharge pressure (DP). Gate down the other discharges to their respective DPs.

Example 12:
Discharge #1: 200'of 1 ¾" hose with a 1 ½" fog set at 125 GPM, and
Discharge #2: 150'of 2 ½" hose with a 2 ½" fog set at 250 GPM.
What is the PP?

DP = NP + TFL

PP = Highest DP



These are the formulas needed for this problem:

NP = 100 psi on all fog nozzles
EF = F x GPM

Discharge #1

GPM = 125
EF = F x GPM
EF = 2 x 125
EF = 250

$FLR = 2Q^2$ Q = GPM / 100
$FLR = 2 \times 2.5^2$ Q = 250 / 100
FLR = 2 x 6.25 Q = 2.5
FLR = 12.5 *round to nearest whole number*
FLR = 13

L = Lay / 100
L = 200 / 100
L = 2

TFL = FLR x L
TFL = 13 x 2
TFL = 26

Q = GPM/100
$FLR = 2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR X L

Rule of 12's

GPM 180-320
GPM 250

Subtract 12 from the first 2 numbers 25 gives you a FLR of 13 per 100 ft

Discharge #2

GPM = 250

$FLR = 2Q^2$	Q = GPM / 100
$FLR = 2 \times 2.5^2$	Q = 250 / 100
FLR = 2 x 6.25	Q = 2.5

FLR = 12.5 *round to nearest whole number*
FLR = 13

L = Lay / 100
L = 150 / 100
L = 1.5

TFL = FLR x L
TFL = 13 x 1.5
TFL = 19.5 *round to nearest whole number*
TFL = 20

DP 1 = NP + TFL
DP 1 = 100 + 26
DP 1 = 126

DP 2 = NP + TFL
DP 2 = 100 + 20
DP 2 = 120

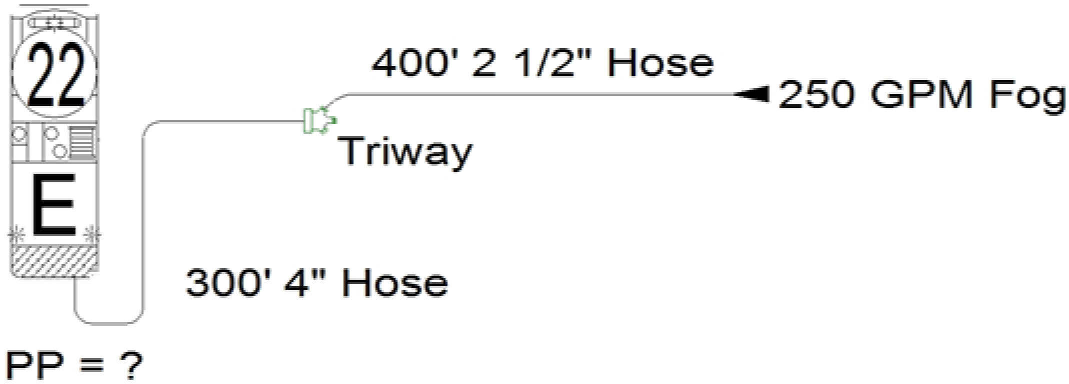
PP = Highest DP
PP = DP 1
PP = 126 **Gate down DP 2 to = 120**

Appliance loss
Hardware that is used in conjunction with fire hose for delivering water is considered appliances. They include reducers, wyes, tri-ways, master streams, etc. The friction created is called appliance loss (AL). Any appliances flowing greater than 350 GPM you will need to add 15 psi.

Multiply 15 by the number of appliances to get the total AL as shown below:

AL = 15 x # of appliances

Example 13:
300'of 4" hose into a Tri-way into 400'of 2 ½" hose with a 2 ½" fog nozzle set at 250 GPM. What is the PP?



PP = NP + TFL + AL + SL + GL - GG

GPM = 250

These are the formulas needed for this problem:

NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
EF = F x GPM
Q = GPM/100
FLR = 2Q²
L = LAY (total feet of hose lay)/100
TFL = FLR X L
AL = 15 x # of appliances

4" hose

GPM = 250
EF = F x GPM
EF = .25 x 250
EF = 62.5 –round to nearest 10
EF = 60

FLR = 2Q²	Q = GPM / 100
FLR = 2 x .6²	Q = 60 / 100
FLR = 2 x .36	Q = .6

FLR = .72 *round to nearest whole number*
FLR = 1

L = Lay / 100
L = 300 / 100
L = 3

TFL = FLR x L
TFL = 1 x 3
TFL = 3

2 ½" hose
GPM = 250

FLR = 2Q²	Q = GPM / 100
FLR = 2 x 2.5²	Q = 250 / 100
FLR = 2 x 6.25	Q = 2.5

FLR = 12.5 *round to nearest whole number*
FLR = 13

L = Lay / 100
L = 400 / 100
L = 4

TFL = FLR x L
TFL = 13 x 4
TFL = 52

AL = 15 x # of appliances
AL = 15 x 0 (not flowing 350 GPM)
AL = 0

PP = NP + TFL + AL
PP = 100 + 3 (4" hose)
PP = + 52 (2 ½" hose)
PP = 100 + 55 + AL
PP = 100 + 55 + 0
PP = 155

System Loss

There are two systems that San Miguel recognizes; standpipes, and sprinkler systems.

Standpipe systems: Most buildings with two or more stories have some sort of built in fire protection standpipe system. Turbulence or friction is caused when water flows through standpipe systems and must be considered in the overall PP. Known as system loss (SL), San Miguel adds 25 pounds for any standpipe system which is added to the PP formula as shown below:

PP = NP + TFL + SL +GL - GG

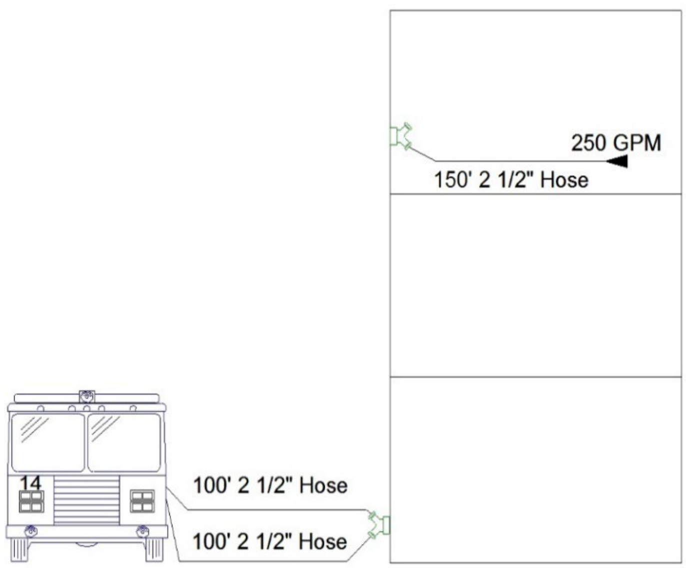
Sprinkler systems: San Miguel Fire recognizes maintaining 150 psi pump pressure as the correct pressure for all sprinkler systems, regardless of the number of heads flowing.

***Refer to IFSTA for specific types of sprinkler systems and their operation.*

Example 14:

Two 100'of 2 ½" hoses into a standpipe with 150'of 2 ½" hose with a 2 ½" fog nozzle set at 250 GPM on the 3rd floor. What is the PP?

Allow for SL at 25 psi regardless of the system size and for GL at 5 psi (per story -1 story).



These are the formulas needed for this problem:
NP = 100 psi on all fog nozzles
GPM = Fog nozzles have set GPM
Q = GPM/100
FLR = $2Q^2$
L = LAY (total feet of hose lay)/100
TFL = FLR X L
GL = 5 x (# of stories -1)
SL = 25

Siamese 2 ½" hose

Divide flow by number of lines
GPM = 250 / 2
GPM = 125 -round to nearest 10
GPM = 130

FLR = $2Q^2$
FLR = 2×1.3^2
FLR = 2 x 1.69
FLR = 3.38 *round to nearest whole number*
FLR = 3

Q = GPM / 100
Q = 130 / 100
Q = 1.3

L = Lay / 100
L = 100 / 100

TFL = FLR x L
TFL = 1 x 3
TFL= 3

<u>Single 2 ½" hose</u>

GPM = 250

FLR = $2Q^2$	Q = GPM / 100
FLR = 2 x 2.5^2	Q = 250 / 100
FLR = 2 x 6.25	Q = 2.5

FLR = 12.5 *round to nearest whole number*
FLR = 13

L = Lay / 100	TFL = FLR x L
L = 150 / 100	TFL = 13 x 1.5
L = 1.5	TFL = 19.5
	TFL = 20

SL = 25

GL = 5 x (# of stories -1)
GL = 5 x (3 -1)
GL = 5 x 2
GL = 10

PP = NP + TFL + GL + SL
PP = 100 + 3 (Two 2 ½" hoses)
PP = + 20 (2 ½" hose)
PP = 100 + 23 + GL +SL
PP = 100 + 23 + 10 + 25
<u>PP = 158</u>

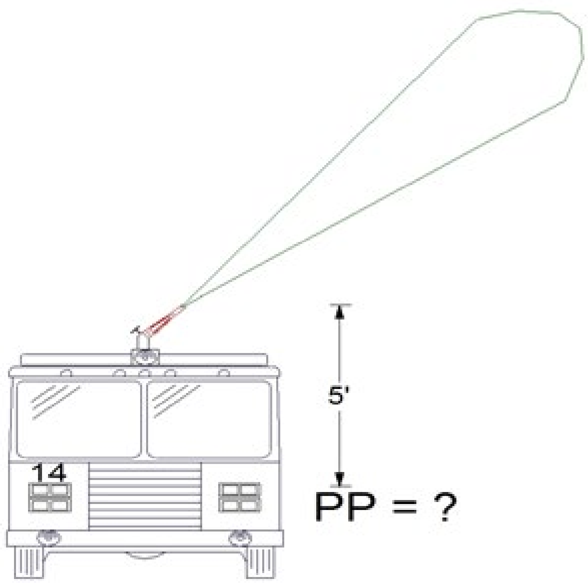
Rule of 12's
GPM 180-320

<u>GPM 250</u>
Subtract 12 from the first 2 numbers 25 gives you a FLR of 13 per 100 ft

Master streams

When pumping master streams mounted on the pump, there are no restrictions to the GPM or standard nozzle pressures. Allow for appliance loss and gravity loss as the appliance is above the pump.

Example 15:



PP= NP + GL + AL

GPM = 1000

GL = .5 x H
GL = .5 x 5
GL = 2.5 –round to nearest whole number
GL = 3
AL = 15 x # appliances
AL = 15 x 1
AL = 15

Master Stream Devices on the Ground

These are the formulas needed for this problem:
NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
AL = 15 x # of appliances
GL = .5 x H

PP = NP + GL + AL
PP = 100 + 3 + 15
PP = 118

Master stream devices used on the ground have GPM and NP restrictions due to nozzle reaction forces that must not be exceeded. The restrictions vary slightly with each base manufacturer and are found on a placard mounted on the master stream base. They are maximum GPM and NP that in some cases lower the GPM and the reach of the stream with an example shown below. *Check the base that is being used for the correct restrictions.*

When used in the portable base, the unit should not be operated at more than 1000 GPM. Therefore, do not exceed the following discharge pressures with straight tips unless the unit is secured in the direct connect flange base

Tip Size	Max PSI
1 3/8”	100 PSI
1 ½”	100 PSI
1 ¾”	100 PSI
2”	75 PSI

Also, do not exceed 1000 GPM when using a fog nozzle, unless the unit is secured in the direct connect flange base. Be sure the Storz or swivel is attached securely. For use with 4”, 4-1/2” or 5” hose only.

**** Based on 2005-2007 Pierce portable monitor*

Example 16

300’of 4” hose into a master stream with a fog nozzle set at 750 GPM. What is the PP?

Before the FLR formula can be solved the GPM must be converted to the equivalent flow for all the hose in the lay other than 2 ½”.

PP = NP + TFL + AL + SL + GL - GG
GPM = 750

GPM = 750
EF = F x GPM
EF = .25 x 750
EF = 187.5 *round to nearest 10*
EF = 190

FLR = $2Q^2$	Q = GPM / 100
FLR = 2 x 1.9^2	Q = 190 / 100
FLR = 2 x 3.61	Q = 1.9

FLR = 7.22 *round to whole number*
FLR = 7

L = Lay / 100
L = 300 / 100
L = 3

TFL = FLR x L
TFL = 7 x 3
TFL = 21

<u>Master streams with elevation (i.e. ladder pipe)</u>

Some operations include pumping master streams on trucks without pre-plumbed ladders. Consider them the same as pumping a master stream on the ground with GL. Ask the operator for any NP restriction with the ladder pipe.

These are the formulas needed for this problem:

NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
EF = F x GPM

$$Q = \frac{GPM}{100}$$

$FLR = 2Q^2$

$$L = \frac{LAY}{100} \text{ (total feet of hose lay)}$$

TFL = FLR X L
AL = 15 x # of appliances

AL = 15 x # of appliances
AL = 15 x 1
AL = 15

PP = NP + TFL + AL + SL + GL - GG
PP = 100 + 21 + 15
PP = 136

Example 17

100' of 4" hose into a Triway into 100' 3" hose into a ladder pipe with a 1 ¾" SB and 70' elevation. What is the PP?

PP = NP + TFL + GL +AL

These are the formulas needed for this problem:

NP = SB master stream pressure
GPM = 30d²√NP
EF = F x GPM
$Q = \frac{GPM}{100}$
FLR = 2Q²
$L = \frac{LAY}{100}$

AL = 15 x # of appliances
GL = .5 x H
TFL = FLR X L

GPM = $30x\ d^2 x\ \sqrt{NP}$

GPM = $30x\ 1\frac{3}{4}^2\ x\ \sqrt{80}$

GPM = 30 x 3.06 x 8.94

GPM = 820.69 -round to nearest 100

GPM = 800

3" hose

GPM = 800
EF = F x GPM
EF = .67 x 800
EF = 536 -round to nearest 10 (2 ½" hose)
EF = 540

FLR = $2Q^2$ Q = GPM / 100
FLR = $2\ x\ 5.4^2$ Q = 540 / 100
FLR = 2 x 29.16 Q = 5.4
FLR = 58.32 -round to whole number
FLR = 58

L = Lay / 100
L = 100 / 100
L = 1

TFL = FLR x L
TFL = 58 x 1
TFL = 58

AL = 15 x # of appliances
AL = 15 x 2
AL = 30

GL = .5 x H
GL = .5 x 70
GL = 35

4" hose

GPM = 800
EF = F x GPM
EF = .25 x 800
EF = 200

FLR = $2Q^2$ Q = GPM / 100
FLR = $2\ x\ 2^2$ Q = 200 / 100
FLR = 2 x 4 Q = 2
FLR = 8

L = Lay / 100
L = 100 / 100
L = 1

TFL = FLR x L
TFL = 8 x 1
TFL = 8

PP= NP+TFL+AL+SL+GG-GL

PP = 80 + 8 (4" hose)
PP = + 58 (3" hose)
PP = 80 + 66 + AL + GL
PP = 80 + 66 + 30 + 35

PP = 211

Pumping pre-plumbed aerial devices

There are many variables to consider when pumping to a pre-plumbed aerial device including:

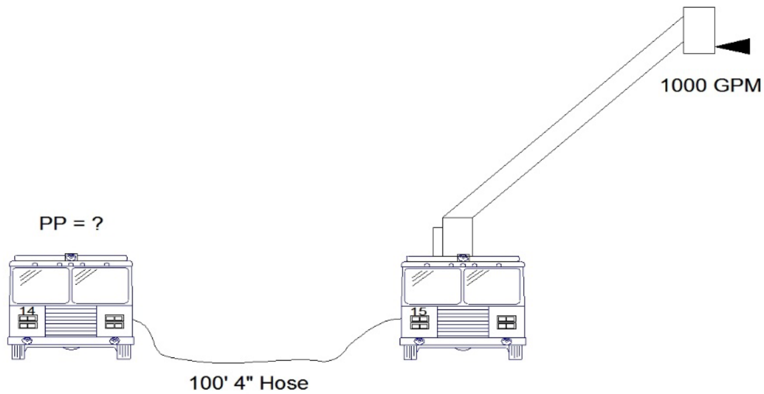
a. Different manufacturers with various system losses
b. Elevation and extension differences on scene
c. Nozzle pressure differences
d. Different Nozzle types

Because of these factors use the initial pump pressure of 80 + NP for aerial devices. The factor of 80 psi takes into consideration Elevation Loss, System Loss and Appliance Loss for the pre-plumbed waterway.

Then communicate with the apparatus operator for any adjustments in pressure using the flow meter on the pedestal.

Example 18:

100’of 4” hose into an elevated platform with a fog nozzle set at 1000 GPM. What is the PP?



PP = Initial Aerial Pressure +/- Adjustments
GPM = 1000

These are the formulas needed for this problem:
Initial PP for aerial devices PP = 80 + NP
NP= 80 for Smooth Bore **PP=160**
NP= 100 for Fog Nozzle **PP=180**

****Communicate with aerial operator for any adjustments in the PP*

Relay Pumping
Suppling water form a supply/source to a destination through hose. Utilizing multiple pumps (Engine Companies) to maintain a constant pressure and GPM required or needed

Relay pumping operations must take into consideration the following information:

- GPM needed.
- Size and length of available hose.
- Apparatus available for pumping purposes.
- Time required setting up the operation.
- Maximum distance one pumper can deliver the GPM.
- Topography over which relay is to be made.
- Capacity of the water source

The GPM needed to effectively handle the situation must be estimated, because every succeeding phase of the relay will be governed by this estimate.

More time will be needed to complete a relay than would be necessary to make a regular hose lay. This unavoidable delay should be considered in determining how large the need will be by the time relayed water is available.

It is logical to expect pumps of varying capacities may be used in each relay operation. It must be noted that the capacity of a pump diminishes as the pump pressure exceeds a certain pressure. Class A pumps will deliver about one half of capacity at 250 psi PP. Low discharge capacity compared to those of high discharge capacity should be taken into consideration. The largest capacity pumper should be placed at the source of supply.

Since friction loss in hose used for relays will be one of the factors determining the distance between pumps, the largest hose available should be used to minimize the number of pumps required in the relay.

The distance from the water supply to the location of need is secondary in estimating the amount of hose required for the relay. Primarily, it is the length of hose between individual pumps that must be determined.

Differences in elevation between water supply and the pump at the scene will have a decided effect on the placement of pumps in the relay, and also upon the total number required.

When calculating the pump pressure, a minimum intake pressure of 10 psi must be maintained by each pump in line. The maximum pump pressure is 250. This leaves 240 psi to overcome any friction and or gravity loss. Pumping the maximum pressure is not necessary when a lower pump pressure will provide a sufficient intake pressure to the final pump.

After the size and number of hose lines are decided upon, determine the friction loss rate, based on the GPM flow. Now the maximum amount of hose between pumps delivering water to the pump at the scene can be determined using the formula shown below:

$$\textbf{Number of pumps} = \frac{\textbf{TFL + GL – GG}}{\textbf{Maximum PP – IP}}$$

The hose lines from the pump at the scene do no effect relay operations; therefore, there is no need to enter them into relay calculations. The operator of this pump may assume it is connected to a water supply.

It is now evident several things must be considered to keep within the maximum allowable pump pressure:

Total friction loss developed by the water flowing, which has to be overcome by the pump.
Any gravity loss or gravity gain.
The intake pressure at the next pump in line.

After determining the number of pumps needed to supply the pump at the scene, two more steps are needed to calculate those pumps' PP.

First, assume the pumps are an equal distance apart and the rise in elevation between them is equal. The first pump is spotted at the source with the remaining divided equally along the lay. Dividing the lay by the number of pumps will give the number of feet between each pump. Each pump now has its own TFL.

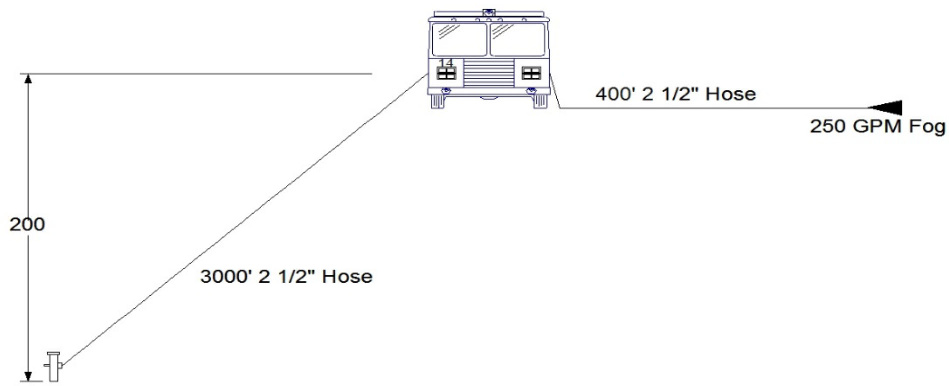
Second, divide the total change in elevation by the number of pumps. Each pump now has its own GL or GG.

Now each pump in the supply lay will have its own PP which usually is the same with all the pumps in the lay.

Example 19

400' of 2½" hose with a fog nozzle set at 250 GPM. What is the PP?

3000'of 2½" hose will be laid from the source to the pump at the scene which is 200' above the source. How many pumps will it require to complete this relay?



PP = NP + TFL+AL+SL+GG-GL

GPM = 250

These are the formulas needed for this problem:
NP = 100 psi on all fog nozzles

$FLR = 2Q^2$ $\quad Q = \frac{GPM}{100}$

$TFL = FLR \times L$ $\quad L = \frac{LAY}{100}$

$$\text{No. Pumps} = \frac{TFL + GL - GG}{\text{Maximum PP} - IP}$$

$$\text{Head} = \frac{\text{TTL Elevation}}{\text{No. Pumps}}$$

<u>3000'of 2 ½" supply hose</u>

GPM = 250
FLR = $2Q^2$
FLR = $2 \, x \, 2.5^2$
FLR = 2 x 6.25
FLR = 12.5 *round to whole number*
FLR = 13

Q = GPM / 100
Q = 250 / 100
Q = 2.5

TFL = FLR x L
TFL = 13 x 30
TFL = 390
L = Lay / 100
L = 3000 / 100
L = 30

GL = .5 x H
GL = .5 x 200
GL = 100

No. Pumps = <u>TFL + GL – GG</u>
Maximum PP – IP

No. Pumps = 390 + 100
250 – 10

No. Pumps = 490
240

No. Pumps = 2.04 or 3 pumps

GPM = 250

FLR = $2Q^2$
FLR = $2 \, x \, 2.5^2$
FLR = 2 x 6.25
FLR = 12.5 *round to a whole number*
FLR = 13

Q = GPM / 100
Q = 250 / 100
Q = 2.5

TFL = FLR x L
TFL = 13 x 10
TFL = 130

L = Lay / 100
L = 1000 / 100
L = 10

Using the above formulas, 3 pumps would be required for the supply hose relay and stay below the maximum pump pressure. Assume the pumps are an equal distance apart and the rise in elevation between them is equal. The distance between the pumps = 3000' / 3 = 1000'.
Each pump's PP =?

Head = <u>Total Elevation</u>
No. Pumps

Head = <u>200</u>
3

Head = 67'

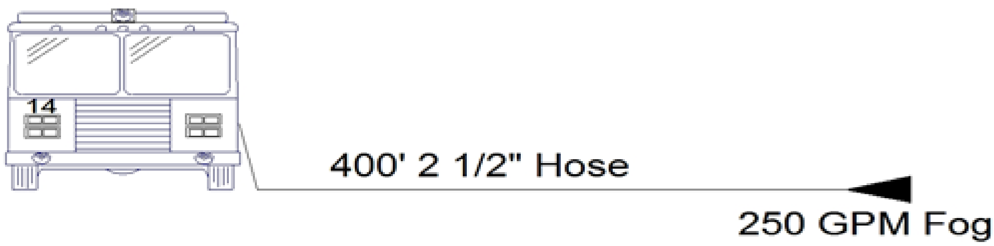
GL = .5 x H
GL = .5 x 67
GL = 34 psi

PP = TFL + GL + IP
PP = 130 + 34 +10
PP = 174

The PP would be 174 for each pump in the relay to furnish the pump at the scene.
The total number of pumps for this problem would be four. Three to supply the water and one to pump the lines.

Example 20

Restating the original example: 400’ of 2 ½” hose with a fog nozzle set at 250 GPM. What is the PP of the pump at the scene?



400’ of 2 ½” hose
GPM = 250

FLR = $2Q^2$	Q = GPM / 100
FLR = 2×2.5^2	Q = 250 / 100
FLR = 2 x 6.25	Q = 2.5
FLR = 12.5 -round to a whole number	
FLR = 13	

TFL = FLR x L	L = Lay / 100
TFL = 13 x 4	L = 400 / 100
TFL = 52	L = 4

These are the formulas needed for this problem:

NP = 100 psi on all fog nozzles
GPM = Fog nozzles have GPM settings
$Q = \frac{GPM}{100}$
FLR = $2Q^2$

$L = \frac{LA}{100}$
TFL = FLR X L

PP = NP + TFL+AL+SL+GG-GL
PP = 100 + 52
PP = 152

If the supply line was changed to parallel lines or one larger diameter line the number of pumps and their distance apart would adjust.

<u>Example 20 cont'd</u>
400' of 2 ½" hose with a fog nozzle set at 250 GPM.

3000' 4" hose will be laid from the source to the pump at the scene which is 200' above the source. How many pumps will it require to complete this relay?

PP = NP+TFL+AL+SL+GG-GL

GPM = 250

400' of 2½" hose

GPM = 250

FLR $=2Q^2$	Q = GPM / 100
FLR $=2 \, x \, 2.5^2$	Q = 250 / 100
FLR = 2 x 6.25	Q = 2.5

FLR = 12.5 -round to a whole number
FLR = 13

TFL = FLR x L	L = Lay / 100
TFL = 13 x 4	L = 400 / 100
TFL = 52	L = 4

These are the formulas needed for this problem:

NP = 100 psi on all fog nozzles

EF = F x GPM

TFL = FLR X L

$Q = \frac{GPM}{100}$

FLR = $2Q^2$

$L = \frac{LAY}{100}$

$\text{No. Pumps} = \frac{TFL + GL - GG}{\text{Maximum PP} - IP}$

$\text{Head} = \frac{\text{TTL Elevation}}{\text{No. Pumps}}$

PP = NP + TFL
PP = 100 + 52
PP = 152

ADDITIONAL INFORMATION

Critical Velocity

Pushing water through hose causes friction. Friction causes turbulence in the hose, which gets larger as the velocity increases. Due to turbulence, there is a limit to the velocity or speed that water can travel through hose. Critical velocity is reached when the turbulence is so great that no more water can be moved through the hose no matter how much pressure is applied.

Nozzle Reaction

Newton's 3rd law states that for every action, there is an equal and opposite reaction. As water is discharged from a nozzle, force pushes back in the opposite direction of the flow. Nozzle reaction (NR) is the amount of this force measured in pounds. Fog nozzles have less reaction force because of their internal design that diverts some of the force back and sideways before it leaves the nozzle. NR for fog nozzles varies with manufacture and there is no constant formula. The formula to compute NR in smooth bore nozzles is shown below:

$1.5 \times d^2 \times NP$

Example: 650' of 2½" hose, with a 1 ¼" SB. What is the nozzle reaction?

$NR = 1.5 \times d^2 \times NP$

$NR = 1.5 \times 1.25^2 \times 50$

$NR = 1.5 \times 1.56 \times 50$

NR = 117 pounds of force

Initial nozzle reaction

When a nozzle is suddenly opened or closed the momentary pressure is much greater than the PP for that line. For example, 650' of 2 ½" flowing a 1 ¼" SB, the PP = 193. If the nozzle were suddenly opened the momentary or initial nozzle reaction (INR) would be 542 pounds. This is why water controls are opened and closed slowly. This INR can also be referred to as water hammer and affects all the plumbing in the pump, hose, hydrant, etc.

If the PP were higher because other hose lines with higher discharge pressures are being pumped, the INR would be even greater! The formula for determining initial nozzle reaction is:

$INR = 1.8 \times d^2 \times PP$

Example: 650' of 2½" hose, with a 1 ¼" SB. What is the INR?

GPM = $30d^2\sqrt{NP}$
GPM = $30 \times 1\,¼^2 \times \sqrt{50}$
GPM = 30 x 1.56 x 7.07
GPM = 330

Q = GPM / 100
Q = 330 / 100
Q = 3.3
FLR = 2 x (3.3)2
FLR = 2 x 10.89
FLR = 21.78 -round to nearest 10 (2 ½ hose)
FLR = 22

TFL = FLR x L
TFL = 22 x 6.5
TFL = 143
L = Lay / 100
L = 650 / 100
L = 6.5
PP= NP + TFL
PP = 50 + 143
PP = 193

INR = $1.8 \times d^2 \times PP$
INR = $1.8 \times 1.25^2 \times 193$
INR = 1.8 x 1.56 x 193
INR = 542 pounds of force
Estimating available flow from a hydrant

To estimate the available flow from a hydrant through the supply hose and into a pump the operator must determine the percentage of drop between the static and residual pressures. This percentage of drop will indicate the remaining estimated GPM flow.

- **a. Up to a 10 percent drop = 3 more equal volumes**
- **b. From 11 to 15 percent drop = 2 more equal volumes**
- **c. From 16 to 25 percent drop = 1 more like volume.**

Adding this number to the original flow will give the total GPM available. Use the following steps to estimate the available GPM from hydrant to pump:

- a. Note the static pressure on the intake gauge after opening the intake and before opening any discharge.
- b. Open a discharge and flow water. Note the residual pressure on the intake gauge.
- c. Determine the percentage of drop between the two intake pressures.

Example 1: The pump's static pressure is 60. A 250 GPM nozzle is flowed, the residual pressure is 54. Estimate the available GPM flow.

Subtract the residual from the static to find the drop. Static - Residual = Drop

60 – 54 = 6

Divide the drop by the static to find the drop percentage.

Drop / Static = Percent   6/60 = 10%

10% = 3 more equal volumes or 3 x original GPM

3 x 250 = 750

750 + original GPM = total GPM available from hydrant to pump

750 + 250 = 1000 GPM

Example 2: The pump's static pressure is 120. A 250 GPM nozzle is flowed, the residual pressure is 95. Estimate the available GPM flow.

Static – Residual = Drop

120 – 95 = 25

Drop / Static = Percent

25 / 120 = 21%

21% is more than 15% but less than 25% so use 25%.

25% = 1 more equal volume or 1 x original GPM

1 x 250 = 250

250 + original GPM = total GPM available from hydrant to pump

250 + 250 = 500 GPM

Estimating Static Pressure

Use this procedure to estimate the static pressure if the pump was flowing water before the static pressure was noted:

1. Note the residual pressure on the intake gauge with the current GPM flow.
2. Flow the same GPM and note the drop in residual pressure.
3. Divide the drop by 2 and add it to the first noted residual pressure.
   This is the estimated static pressure.

Example 1: The pump is flowing 190 GPM and the residual pressure is 68.

Estimate the available GPM flow.

Flow the same GPM and note the new residual pressure. Assume it is 44.

Subtract the second residual from the first residual. 1st res. – 2nd res. = Drop.
68 – 44 = 24

Divide the drop by 2.
24 / 2 = 12

Add the answer to the original residual pressure to equal the static pressure.
Answer + first residual pressure = Static pressure
12 + 68 = 80

Static pressure = 80
The static pressure is 80 and 12 is the amount of drop from the static to the residual.

Divide the drop by the static to find the drop percentage.
12 / 80 = 15%

15% = 2 more equal volumes or 3 x original GPM
2 x 190 = 380

380 + original GPM = total GPM available from hydrant to pump
380 + 190 = 570 GPM

Residual pressure minimum
Whenever possible keep a minimum intake pressure of 10 psi. This way if there is a fluctuation of incoming pressure the residual pressure won't drop below 10 to zero causing suction and collapsing the supply hose which then could cavitate the pump.

Net pump pressure
Centrifugal pumps take advantage of incoming pressure and volume due to their construction. Net pump pressure is the actual pressure that the pump is producing. When the water supplied to the pump is from a positive pressure source, i.e. a hydrant, the net PP is the difference between the incoming pressure (IP) and the PP as shown below:
Net PP = PP – IP

Example 1: A pump connected to a hydrant has a PP of 150 and an IP of 80.

What is the net pump pressure?

Net PP = PP – IP
Net PP = 150 – 80
Net PP = 70

When the water supplied to the pump is from a draft, i.e. a pond, the net PP is the sum of the incoming pressure and the PP. This is because the pump is producing work to lift the water into, and then through the pump.

Example 2: A pump is drafting from a pool has a PP of 150 and an intake vacuum pressure of 10.

What is the net pump pressure?

Net PP = PP + IP
Net PP = 150 + 10
Net PP = 160

Estimating capacity from an open discharge

To estimate the amount of water able to be flown from any non-restricted opening such as a hydrant port or the end of a hose, where P = the pressure at the opening, use the following formula:

$GPM = 27 \times d^2 \times \sqrt{P}$

Example 1: The 2 ½" port on a hydrant is flowing at a pressure of 100.

Estimate the available GPM flow.

$GPM = 27 \times d^2 \times \sqrt{P}$

$GPM = 27 \times 2\frac{1}{2}^2 \times \sqrt{100}$

$GPM = 27 \times 6.25 \times 10$

GPM = 1687.5 –round to nearest whole number

GPM = 1688

Example 2: A 4" hose is flowing at a pressure of 50.

Estimate the available GPM flow.

$GPM = 27 \times d^2 \times \sqrt{P}$

$GPM = 27 \times 4^2 \times \sqrt{50}$

$GPM = 27 \times 16 \times 7.07$

GPM = 3054.24 –round to nearest whole number

GPM = 3054

Water and pressure weights and measurements

Below are the San Miguel recognized weights and measurements for pressure and water.

a. Atmospheric pressure at sea level at 70 degrees = 14.7 psi.
b. 14.7 = 30 inches of mercury.
c. 1 inch of mercury = 1.13 feet of water.
d. A 1 square inch column of water 2.304 ft. high = 1 psi.
e. A 1 square inch column of water 1 ft. high = .434 psi.
f. Atmospheric pressure x 2.304 = maximum theoretical lift.
   14.7 x 2.304 = 33.9 feet of water.
g. Atmosphere pressure decreases .5 #s for every 1000' in elevation
h. One gallon of water weighs 8.33 pounds.
i. One gallon of water = 231 cubic inches.
j. One cubic foot = 7.5 gallons.
k. 1 Cubic foot = 1728 cubic inches.
l. 1 gallon x 7.5 = weight of 1 cubic foot of water
   8.33 x 7.5 = 62.5 pounds.

Weight of water delivered

At 250 GPM, a fire stream represents approximately one ton of water delivered per minute. Operators should be cognizant of the time that water has been pumped into enclosed spaces not on ground level. Consideration should be given to the water weight because of the possibility of structural collapse. Provisions for the release of water from an enclosed building should also be considered.

Shown below are the weights of water delivered over one minute for specific GPM.

NOZZLE	PSI	GPM	WEIGHT PER MINUTE
Fog	100	95	791 #s
Fog	100	125	1041 #s
Fog	100	250	2082 #s
1⅛"	50	270	1¼ ton
1¼"	80	400	1½ ton
1½"	80	600	2½ ton
1¾"	80	800	3⅓ ton
2"	80	1100	4½ ton

Amount of water Fire Hose holds

Length	Hose size	Gallons
50 Feet	**1 inch**	**2 gallons**
50 Feet	**1 ½ inch**	**4.5 gallons**
50 Feet	**1 ¾ inch**	**6.25 gallons**
50 Feet	**2 ½ inch**	**12.75 gallons**
50 Feet	**4 inch**	**33 gallons**

Estimate quantities of water in containers

To determine the water capacity in an enclosed space, use the following formulas:

For rectangular spaces: $C = L \times W \times H \times 7.5$

For cylindrical spaces: $C = 6d^2 \times H – 2\%$

C = Capacity in gallons

L = Length in feet

W = Width in feet

H = Height in feet

7.5 = Gallons per cubic foot

d = Diameter

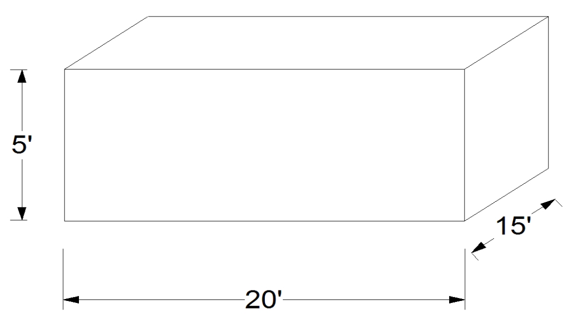
Example 1: A rectangular tank measures 20’ x 15’ x 5’.

What is the capacity?

$C = L \times W \times H \times 7.5$

$C = 20 \times 15 \times 5 \times 7.5$

C = 11,250 gallons



Example 2: A cylindrical tank measures 20’ x 5’.

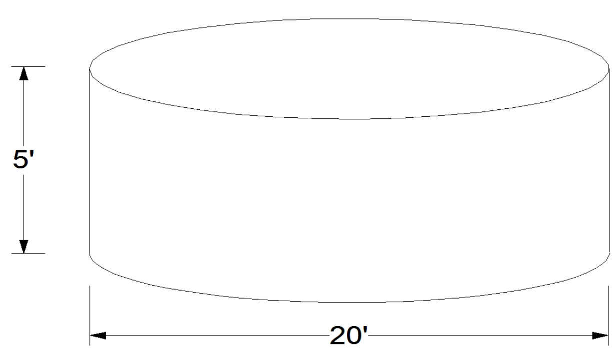
What is the capacity?

$C = 6d^2 \times H – 2\%$

$C = 6 \times 20^2 \times 5 – 2\%$

$C = 6 \times 400 \times 5 – 2\%$

C = 11,760 gallons



Weight of a volume of water

To determine the weight of a volume of water, multiply the number of gallons by 8.33.
Or, multiply the number of cubic feet by 62.5 pounds.

Example 1: A cylindrical tank 30' in diameter and 2' deep is full of water.

What is the weight of the water in the tank?

$C = 6d^2 \times H - 2\%$
$C = 6 \times 30^2 \times 2 - 2\%$
$C = 6 \times 900 \times 2 - 2\%$
$C = 10{,}584$

Weight = Gallons x weight of 1 gallon
Weight = 10,584 x 8.33
Weight = 88,164 pounds

Fire pump capacity at a given pressure
Most Type 1 fire pumps are of the centrifugal type. ISO rates centrifugal fire pumps from 500 to 1500 GPM of discharge capacity. Modern pumps can deliver their discharge capacity at 150 psi pump pressure from a draft of 10' at sea level. Knowing what a pump's maximum capacity at pressures above 150 psi is useful to figure the reduction in GPM at the higher pressures. Theoretical discharge capacity at a different given pressure can be computed by using the following formula:

$$PD = \frac{RC \times RP}{GP}$$

PD = Pump discharge maximum
RC = Rated capacity
RP = Rated pressure
GP = Given pressure

Example 1: A pump has a 1500 GPM at 150 psi rating.

What is the theoretical rating at 200 psi?

$$PD = \frac{RC \times RP}{GP}$$

$$PD = \frac{1500 \times 150}{200}$$

PD = 1125 GPM

Annual pump service test

Fire Department pumps are tested annually and after any extensive engine, transmission or pump repairs. Services tests are based on the capacity of the apparatus based on its specifications.

The service test for a Class “A” fire pump consists of the following:

a. Dry Vacuum
b. Quick lift
c. 100% Capacity
d. 10% Overload
e. 70% Capacity
f. 50% Capacity
g. Relief Valve

Test Procedures

a. Dry Vacuum – Drain the pump. Remove the discharge caps ensure the valves are closed. Engage the priming pump and draw at least 22 inches of mercury. After disengaging the priming pump a loss of no more than 10 inches of mercury in 5 minutes is passing. Priming pumps should not be run longer than 30 seconds for pumps with a capacity less than 1,250 GPM and 45 seconds for pumps greater than 1,250 GPM.

b. Quick Lift Test – Place pump shift lever in pump position, engage the primary pump at idle speed and advance The RPM, to proper priming RPM. (See individual apparatus manual.) Engage the primer. Water should be lifted into the pump in a maximum of 30 seconds for pumps with a capacity less than 1,250 GPM and 45 seconds for pumps greater than 1,250 GPM.

c. 100% Capacity – When a constant lift of water is obtained, slowly open a discharge, disengage priming pump, advance throttle, and open correct discharge valves for remaining hose lines. Adjust engine rpm and choke discharge valve(s) to obtain desired nozzle and pump pressure (see Pump Test Chart). Hold for 20 minutes.

d. 10% Overload – After completion of the 100% capacity test, a 10% overload test will be conducted. The test is 150 psi. Plus 10% at 100% GPM. This is 165 psi.

e. 70% Capacity – The procedure is the same as the 100% test, with a change of PP. The PP = 200 and the GPM will change (see Pump Test Chart). Hold for 10 minutes.

f. 50% Capacity – The procedure is the same as the 100% test, with a change of PP. The PP = 250 and the GPM will change (see Pump Test Chart). Hold for 10 minutes.

g. Relief Valve – The relief valve is tested at 150 psi at 100% capacity, 90 psi at 100% capacity and 250 psi at 50% capacity. At a draft, the pump pressure should not increase more than 30 psi each time when all lines are shut down.

Pump Test Chart

PUMP SIZE	GPM	FLOW	NOZZLE SIZE	PITOT DISTANCE	DURATION	NOZZLE PRESSURE	PUMP PRESSURE
1000 GPM	100%	1008	2	1”	20 MIN	72	150
	70%	704	1¾	⅞”	10 MIN	60	200
	50%	508	1½	¾”	10 MIN	58	250
1250 GPM	100%	1260	2¼	1⅛”	20 MIN	70	150
	70%	875	1⅞	15/16”	10 MIN	70	200
	50%	627	1⅝	13/16”	10 MIN	64	250
1500 GPM	100%	1500	2½”	1¼”	20 MIN	66	150
	70%	1050	2”	1”	10 MIN	78	200
	50%	750	1¾”	⅞”	10 MIN	68	250