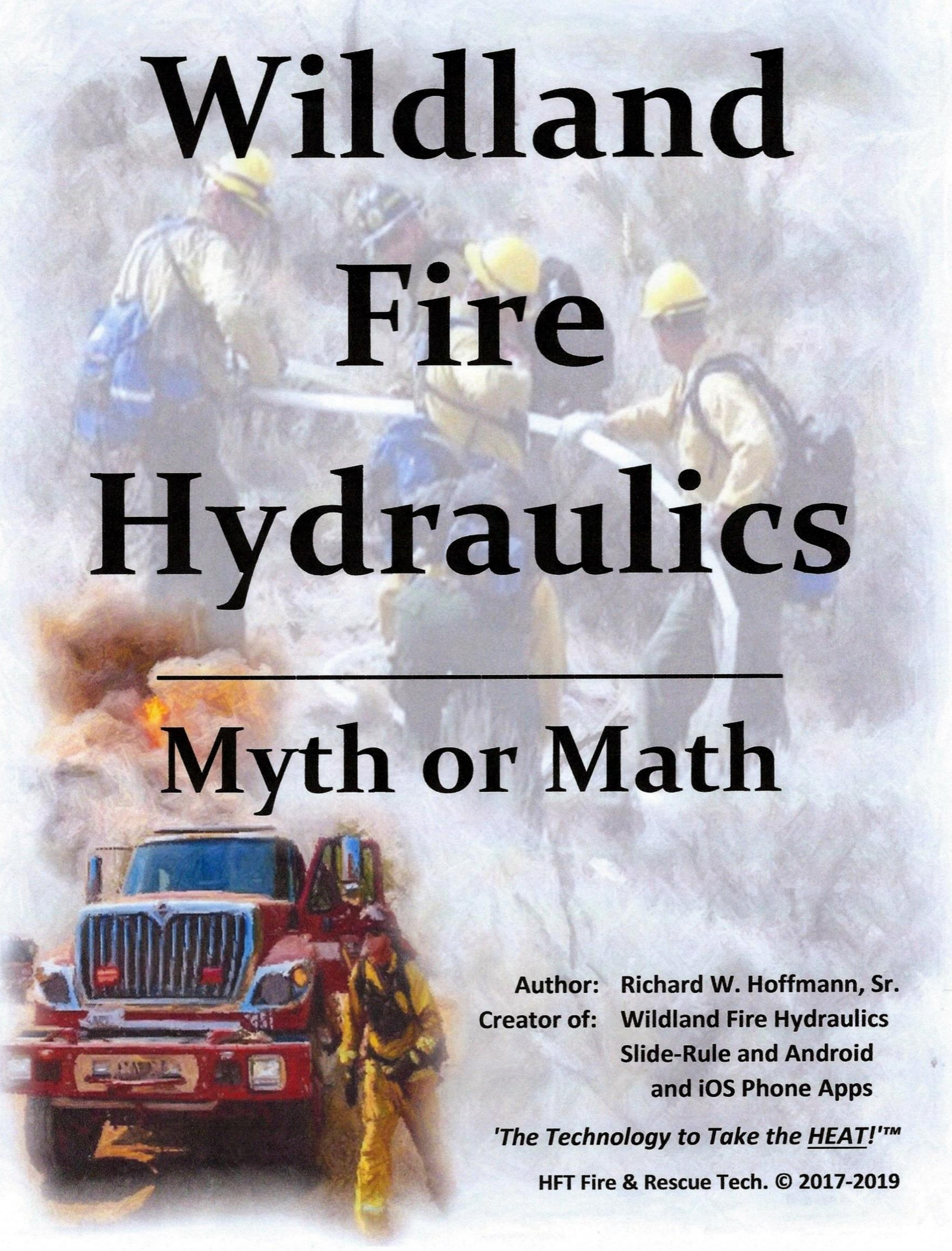
Wildland Fire Hydraulics

Myth or Math



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Creator of: Wildland Fire Hydraulics Slide-Rule and Android and iOS Phone Apps

'The Technology to Take the HEAT!'™

HFT Fire & Rescue Tech. © 2017-2019

...*for your* ***SAFETY!***

Dedicated to all those who have fallen before us.
May they all rest in eternal peace.

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Preface

After years of research and development, for the first time in Fire Service history, a complete wildland fire Engine Pressure (EP) hydraulics calculator is finally available. It not only accurately determines the most challenging variable of each affected section of a wildland hoselay, Friction Loss (FL), but also accurately includes Nozzle Pressure (NP), Appliance Loss (A), and (+) and (-) Head (H). This ensures the necessary Engine Pressure (EP) to create an effective fire stream is calculated in mere seconds to maintain firefighter safety at every step throughout the evolution of a wildland fire hoselay.

The development of both the Android and iOS phone apps and the mechanical Slide-Rule was inspired by the incredible need to provide every driver/operator of any fire apparatus engaged in wildland firefighting relief from the responsibility to accurately, yet quickly determine proper Engine Pressure (EP) when simultaneously balancing resource management and direction, incident mitigation, and crew supervision; but especially in **REAL-TIME** to keep up with the continuous progression of a hoselay as calculation data and results change with the addition of each 100' length of hose extended.

And now, upon the integration of the basic features of a U.S. Geographic Survey (USGS) phone app, downloadable to any firefighter's personal smartphone, and the Automatic Vehicle Location (AVL) technology with triple redundancy of the Global Positioning System (GPS), Cellular Site, and VHF radio triangulation to determine the 24/7 location of any fire apparatus in even the most remote areas of the North American continent, we can now meet the requirements of the ***"Holy Grail of Wildland Firefighting"*****; Section 5** of the ***"Wildfire Management Technology Advancement Act of 2018"*** within the ***"Natural Resources Management Act"*** that passed the Senate on February 12, 2019, with a vote of 92 to 8, and again passed the House on February 26, 2019, at 363 to 62:

- **"Develop and operate a tracking system to remotely locate the positions of fire resources**, including, at a minimum, any fire resources assigned to Federal Type 1 wildland fire incident management teams."

The integration of the Wildland Fire Engine Pressure Hydraulics Calculator not only ensures the once estimated (+) or (-) Head pressure to be accurately calculated to thus provide the proper yet SAFE Nozzle Pressure (NP) and water protection for every firefighter on the line, but the supporting phone app's ability to locate personnel upon communicated bearing and distance from any fire apparatus (as a ***BENCHMARK***) on any USGS map, our ability to meet these firefighter safety requirements is finally here!

"Wildland Fire Hydraulics – Myth or Math" – HFT Fire and Rescue Tech. and Equip., LLC © 2017-2019

Table of Contents

wild·land

noun

\ ˈwī(-ə)l(d)-ˌland \

Definition of *wildland*

: land that is uncultivated or unfit for cultivation

fire

/ˈfī(ə)r/

noun

1. 1.

combustion or burning, in which substances combine chemically with oxygen from the air and typically give out bright light, heat, and smoke.

hy·drau·lics

/hīˈdrôliks/

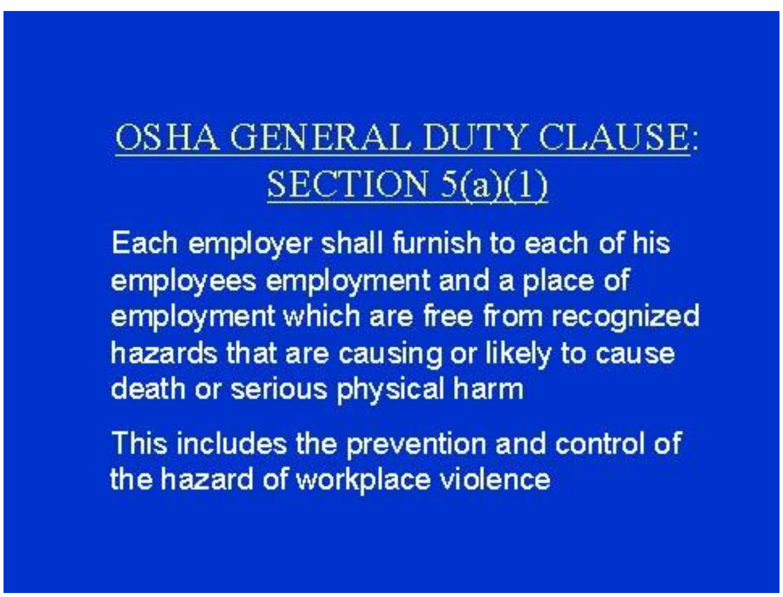
noun

noun: **hydraulics**; plural noun: **hydraulics**

1. 1.

the branch of science and technology concerned with the conveyance of liquids through pipes and channels, especially as a source of mechanical force or control.

Question*:** ***"How do these terms apply to OSHA's General Duty Clause to ensure the integrity of firefighter safety?"



NFPA 1002 – Standard for Fire Apparatus Driver/Operator Professional Qualifications

Chapter 8 Wildland Fire Apparatus

8.1 General:
The job performance requirements defined in Section 8.1 and 8.2 shall be met prior to qualifying as a driver/operator – wildland fire apparatus.

8.2 Operations:
8.2.1 Produce effective fire streams given the sources provided in the following list, so that the pump is engaged, all pressure-control and vehicle safety devices are set, the rated flow of the nozzle is achieved, and the apparatus is monitored for potential problems:

(1) Water tank
(2) Pressurized source
(3) Static Source

(A) Requisite Knowledge. Hydraulic calculations for friction loss and flow using both the written formulas and estimation methods, safe operations of the pump, correct apparatus placement, personal safety considerations, problems related to small diameter or dead-end mains and low-pressure and private water supply, hydrant coding systems, and reliability of static sources.

NFPA 1041 - Standard for Fire and Emergency Services Instructors Professional Qualifications

1.1 Scope:
The Standard identifies minimum Job Performance Requirements (JPR's) for all Fire and Emergency Services Instructors up to and including Live Fire Instructor in Charge.

1.2.2 Purpose:
The intent of the standard shall be to ensure that (all) personnel serving as Fire and Emergency Services Instructors up to and including Live Fire Instructor in Charge are qualified.

Occupational Safety and Health Administration Firefighter Training Standards

29 CFR 1910.156(c)(1)
The employer shall provide training and education for all fire brigade members **commensurate with those duties and functions that fire brigade members are expected to perform.** Such training and education shall be provided to fire brigade members **before they perform fire brigade emergency activities.** Fire brigade leaders and **training instructors shall be provided with training and education which is more comprehensive** than that provided to the general membership of the fire brigade.

29 CFR 1910.156(c)(2)
The employer shall assure that training and education are conducted frequently enough to assure that each member of the fire brigade is able to **perform the member's assigned duties and functions satisfactorily and in a safe manner so as not to endanger fire brigade members or other employees.**

One of the **goals of this recordkeeping rule** is to improve the completeness and accuracy of injury and illness data collected by employers and reported to OSHA. **When workers are discouraged** from reporting occupational injuries and illnesses, the **information gathered and reported is incomplete and inaccurate.**

The rule includes *three* provisions that are intended to address this issue:

(1) An employer's procedure for reporting work-related injuries and illnesses must be reasonable and **must not deter or discourage employees from reporting**

(2) Employers must inform employees of their **right to report work-related injuries and illnesses free from retaliation**

(3) An employer may not retaliate against employees for reporting work-related injuries or illnesses

Section 11(c) of the OSH Act already prohibits employers from retaliating against employees for reporting work-related injuries or illnesses This rule explicitly incorporates the prohibition against retaliation into **Section 1904.35** of the recordkeeping rule with respect to retaliation against employees for reporting work-related injuries or illnesses (at 29 CFR 1904.35(b)(1)(iv)). **The purpose of this provision is to improve the completeness and accuracy of injury and illness data by allowing OSHA to issue citations to employers who retaliate against their employees** for reporting an injury or illness and thereby discourage or deter accurate reporting of work-related injuries or illnesses.

Why does OSHA address retaliation in this rule? Isn't it already against the law to retaliate against an employee for reporting a workplace injury or illness?

Significant concerns were raised during the comment period that the new electronic reporting requirements in the final rule could lead to increased incentives to take retaliatory action that would discourage workers from reporting their work-related injuries or illnesses. OSHA acknowledges these concerns. Although section 11(c) of the **OSH Act already prohibits any person from DISCHARGING OR OTHERWISE DISCRIMINATING AGAINST AN EMPLOYEE who reports a fatality, injury, or illness,** OSHA may not act under section 11(c) unless an employee files a complaint with OSHA within 30 days of the retaliation. **In contrast, under the final rule, if OSHA finds evidence that an employee has been retaliated against for reporting an injury or illness, OSHA will be able to cite an employer for retaliation EVEN IF THE EMPLOYEE DID NOT FILE A TIMELY 11(C) COMPLAINT.** Often the point of retaliating against an employee who reports an injury or illness is to intimidate both the employee and other workers from reporting. This new rule gives OSHA an important new tool to ensure that employers maintain accurate injury and illness records because it **gives OSHA the ability to protect workers who have been subject to retaliation for reporting work-related injuries or illnesses, even when they cannot or will not speak up for themselves by filing an 11(c) complaint.**

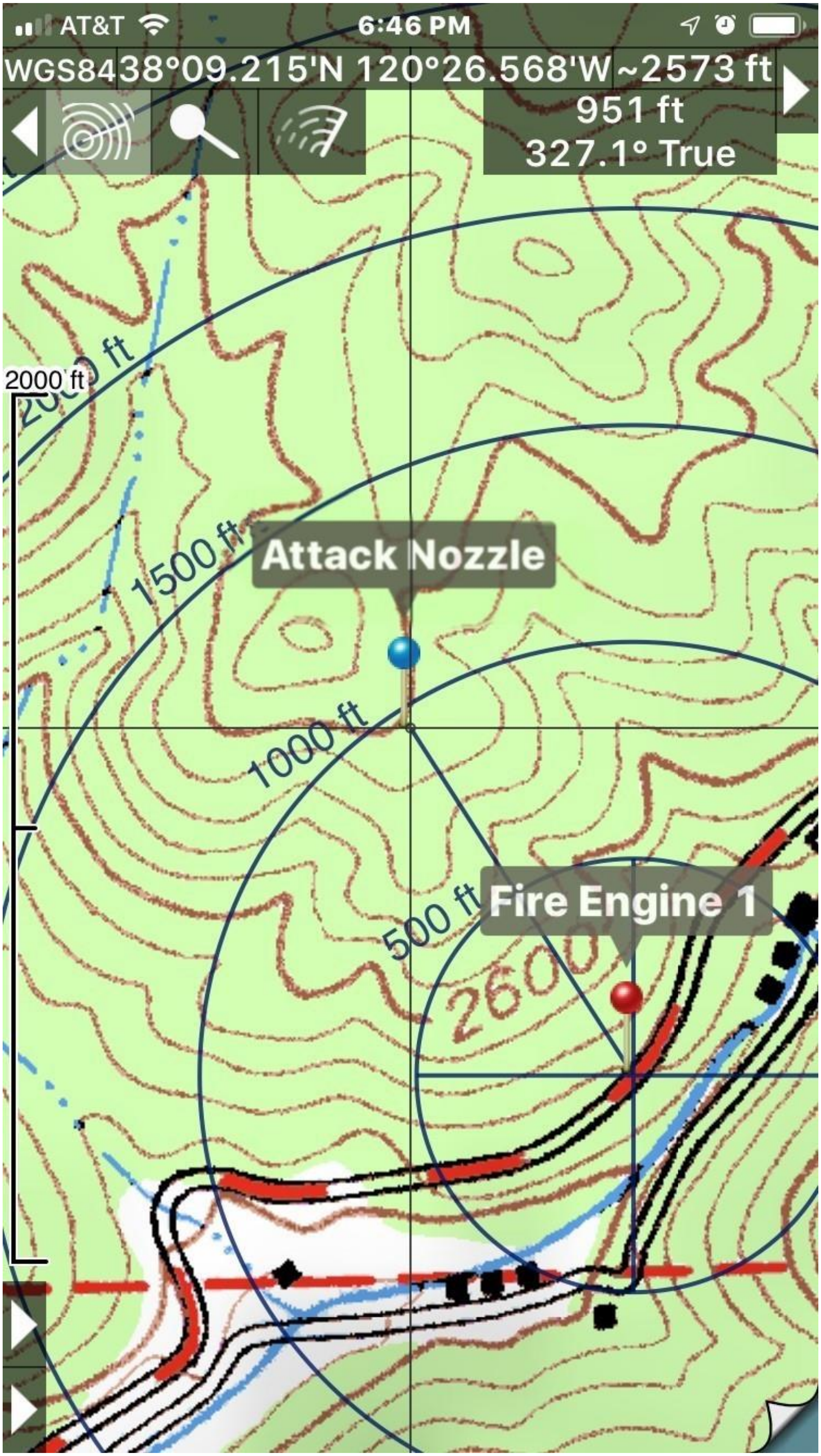
What forms of "retaliation" does this rule prohibit?

The rule prohibits employers from taking adverse action against employees for reporting work-related injuries or illnesses. **Adverse action is action taken by the employer that would discourage a reasonable employee from reporting a work-related illness or injury accurately**. Examples of adverse action include:

- **Discharge**, demotion, or denying a substantial bonus or another significant benefit
- Assigning the employee "points" that could lead to future consequences
- **Demeaning or embarrassing the employee** (for example, requiring an employee who reports an illness or injury to wear a fluorescent orange vest for a week)
- **Threatening to penalize or otherwise discipline an employee for reporting**

- Requiring employees to take a drug test for reporting without a legitimate business reason for doing so
- See Chapter 3 of the **Whistleblower Investigations Manual**, CPL 02-03-007 (01/28/2016), for additional examples of adverse action

Pass **ANY** Wildland Fire "Standard" method training and/or hiring Fire Academy course upon the use of this downloadable spreadsheet at **http://calculator.hydraulicsapp.com**


AT&T
6:46 PM
WGS8438°09.215'N 120°26.568'W~2573 ft
951 ft
327.1° True
2000 ft
2000 ft
1500 ft
Attack Nozzle
1000 ft
500 ft
Fire Engine 1
2600

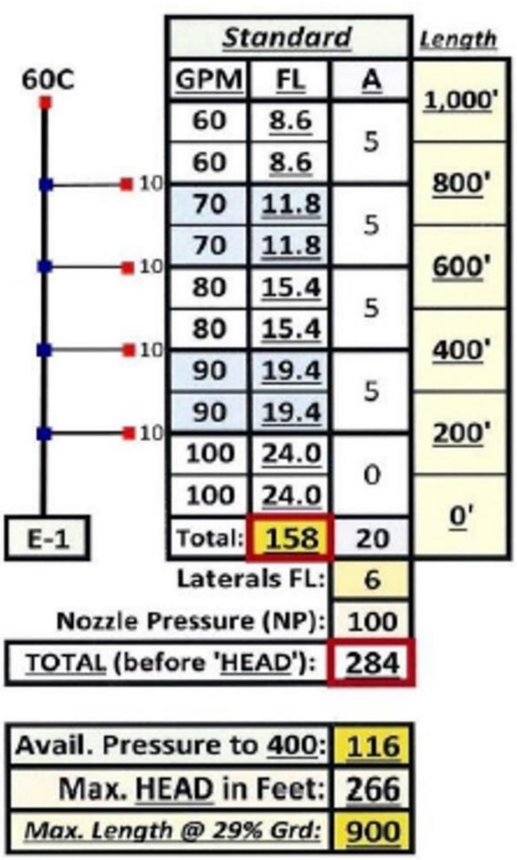
Chapter One: Purpose

When we consider the National Fire Protection Association (NFPA) and all of its OSHA mandated recommendations and guidelines upon these three (3) simple terms as they directly relate to minimum training and equipment standards to ensure personnel SAFETY…

…do we not realize if a driver/operator is not properly trained in the proper methodology and application to accurately calculate Engine Pressure (EP) to provide the minimum SAFE Nozzle Pressure (NP) to create an effective Fire Stream for his/her fireline personnel in the performance of their duties, we most certainly experience a SEVERE FIREFIGHTER SAFETY RISK that must be immediately addressed to establish and maintain the integrity of minimum SAFE fireline operations as mandated and exercised in the Fire Service even long before the OSH Act passed into law in 1971.

The purpose of this article is to describe in technical detail the very justification of the world's first-ever Wildland Fire Hydraulics Calculator [as both a mechanical Slide-Rule for the glove box and the Android and iOS format phone apps]. Not only can they accurately predetermine the most complex variable of this equation:

[Friction Loss (FL) = (GPM/100)^2 * Coefficient * Length/100']



…but both phone apps and the mechanical slide-rule, in fact, includes ALL four (4) variables **[Nozzle Pressure (<u>NP</u>), Friction Loss (<u>FL</u>), Appliance Loss (<u>A</u>), and (<u>+</u>) HEAD (<u>H</u>)]** to accurately calculate ***<u>TOTAL</u>*** Engine Pressure (EP) not in minutes while completing a Final Exam in the comfort of a classroom, but in mere seconds in the field! This allows every driver/operator, for the first time in Fire Service history, to keep up with the ***<u>REAL-TIME</u>*** adjustments in the field at any point of any recognized wildland fire progressive hoselay evolutions [**"<u>Standard</u>"** (above) and "Whaling" …and now the "HEN-WAY" methods] currently accepted and used today.

Now let's take a closer look at the proper methodology and application of the wildland fire hydraulics calculation process. A necessary evolution is much simpler to complete while seated at a desk yet extremely challenging to accomplish in the field. As many fire apparatus driver/operators suffer the complexity of this formula in the necessary time to execute can take so long to solve, that by the time Engine Pressure (EP) is finally calculated, personnel have many times already advanced the hoselay up to several more lengths. As a result, the now-expired data previously obtained to complete this calculation process produces an obsolete determination thus forcing the driver/operator to essentially start over from scratch left only to run out of time yet again and never catch up with the continual forward progression to ensure proper nozzle pressure is established and maintained at every stage of the hoselay progression to maintain minimum firefighter safety.

This leaves the driver/operator feeling fully resigned, left only to guess what he/she is able to pump is 'hopefully' enough to produce an effective fire stream, and thus, never truly know when the maximum 400 PSI a fire engine can produce [Engine Pressure (EP)] has been fully exhausted. Therefore, not knowing if the required Engine Pressure (EP) to produce the minimum Nozzle Pressure (NP) is even possible to maintain firefighter safety, regardless of the screams on the radio from crew members requesting more, fire personnel are then inadvertently placed in ***<u>DANGER</u>*** when these limits are unknowingly breached. Is it not, therefore, agreed that ignorance of the direct effect of these irrefutable laws of physics can never be an excuse for 100% preventable burn injuries or even death?

The mechanical Slide-Rule and both the Android and iOS phone apps are specifically created to immediately indicate the required Engine Pressure (EP) in ***<u>REAL-TIME</u>*** and at every stage of a hoselay evolution upon the addition of literally each and every length. **This includes up to and including the point in which <u>ALL FORWARD PROGRESSION SHALL IMMEDIATELY CEASE AND DESIST</u> when the maximum 400 PSI a fire engine has been governed to safely pump is reached.**

- To not do so immediately, it is then, therefore, evidence that any **Fire and Emergency Services Instructor(s)** as the authority having jurisdiction under **NFPA 1041 – 1.2.2** has trained his/her driver/operator in direct violation of **29 CFR 1910.156(c)(1) & (2)** mentioned above.

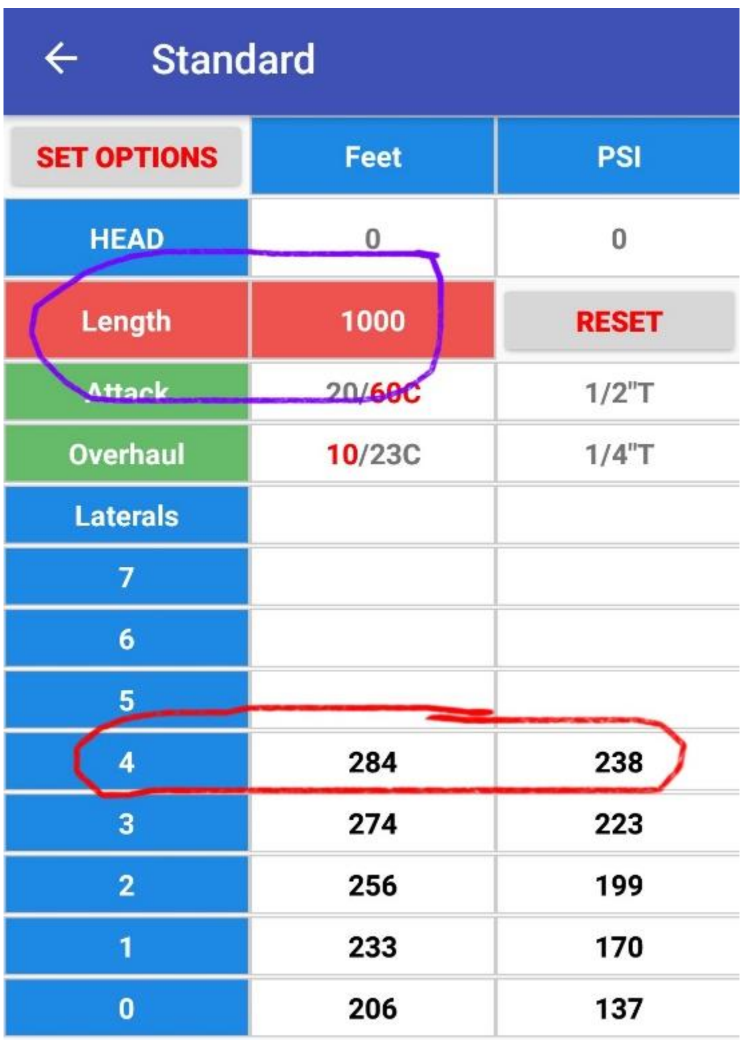
As literally every fire protection system worldwide [i.e. Hydrant, standpipe, and interior fire sprinkler systems, etc.] has been precalculated and established upon this internationally accepted formula…

[Friction Loss (FL) = (GPM/100)^2 * Coefficient * Length/100']

…based upon the viscosity of water at normal temperatures and pressures, the proper application/methodology, therefore, shall never be disregarded nor deviated from upon any (alleged) circumstance whatsoever. This is further evidenced going back well into the 1800s at the inception of this proper application as required upon the countless fire disasters of that era.

As a result, once the maximum Engine Pressure (EP) a fire apparatus maximum pressure has been exhausted to produce a precalculated, effective fire stream to ensure firefighter SAFETY, absolutely no further forward suppression efforts can be exercised unless other measures are implemented to again establish and maintain proper Nozzle Pressure (NP) within the limitations of the hoselay configuration in use. The only option(s) available are to either:

- Insert the necessary portable booster pump(s) in series at specific locations and maximum distances necessary to compensate for all four (4) pressure loss variables **[“<u>NP</u>,” “<u>FL</u>,” “<u>A</u>,” and (<u>+</u>) “<u>HEAD</u>”]** affecting this end result or...
- Wait until the total number of laterals for mop-up/overhaul procedures is reduced to the point in which the flow rates, and therefore the total Friction Loss (FL) within each affected section of hose is reduced, can a CALCULATED decision be made to proceed. Until then, a driver/operator is required (by law) to cease and desist all forward progression the moment the calculated maximum pump pressure is met, but especially when exceeded.



← Standard

SET OPTIONS	Feet	PSI
HEAD	0	0
Length	1000	RESET
Attack	20/60C	1/2"T
Overhaul	10/23C	1/4"T
Laterals		
7		
6		
5		
4	284	238
3	274	223
2	256	199
1	233	170
0	206	137

This is why both phone apps and mechanical slide-rule include the total number of laterals and each respective resulting minimum Engine Pressure, including a second list to indicate “OVERHAUL” operation Engine Pressures (EP). Upon reducing a 20/60 GPM nozzle from ‘ATTACK’ mode at 60 GPM to the ‘OVERHAUL’ operations at 20 GPM, because the gallons per minute is reduced to one-third (1/3rd), the Friction Loss (FL) component is reduced to 1/9th when considering the TOTAL Engine Pressure necessary to perform these duties.

A whole section of this transcript is dedicated to assisting the reader to fully understand the correct response to the inquiry,

“Is not friction loss a direct mathematical function of Gallons Per Minute (GPM)?”

Hence the need of both the Slide-Rule and both Phone Apps was the mother of invention to determine the accurate Engine Pressure (EP) for your fireline crew's SAFETY who are counting on you to meet and exceed **OSHA – 29 CFT 1910.156(c)(1) and (2)** upon the guidelines of **NFPA 1041** to execute this proper calculation methodology that has been established upon these unquestioned, irrefutable, Laws of Physics that have been instructed at literally every 'reputable' fire training/hiring academy, college, and university worldwide for more than a century.

To provide a first example, when utilizing the very popular "Standard" configuration with a 20/**60** GPM combination nozzle for ATTACK, and a **10**/23 GPM mop-up/overhaul nozzle every 200' of a 1,000 foot hoselay (**284 PSI** is precalculated upon "NP", "FL", & "A") ***PLUS*** the addition of the HEAD ("H") pressure loss upon a typical 26% grade (260 feet at 0.434 PSI/ft = 113 PSI HEAD) results in an Engine Pressure (EP) just under the maximum 400 PSI at **397 PSI (EP).**

← Standard

SET OPTIONS	Feet	PSI
HEAD	260	113
Length	1000	RESET
Attack	20/60C	1/2"T
Overhaul	10/23C	1/4"T
Laterals		
7		
6		
5		
4	397	351
3	387	336
2	369	312
1	346	283
0	319	250

If we add just one more length at 100', we must then calculate for another lateral at an additional 5 PSI for Appliance loss; which creates the addition of Friction Loss (FL) of 110 gallons per minute, at 29 PSI per 100' length, in TWO (2) affected sections of hose (+58 PSI), less the friction of loss of one (1) length at 60 GPM (-9 PSI), and the additional Friction Loss (FL) of a fifth (5^{th}) 1" lateral (+1.5 PSI) accordingly. The last consideration is HEAD at the same 26% Grade upon another 20 feet of elevation (+8 PSI), which requires a new adjusted **CALCULATED Engine Pressure (EP) at 462 PSI!**

← Standard

SET OPTIONS	Feet	PSI
HEAD	280	122
Length	1100	RESET
Attack	20/60C	1/2"T
Overhaul	10/23C	1/4"T
Laterals		
7		
6		
5	462	428
4	451	411
3	431	384
2	405	350
1	375	311
0	342	271

May I inquire, ***"If your fire engine is governed to produce a maximum of 400 PSI… and the irrefutable Laws of Physics upon the viscosity of water at normal temperature and pressures is 'constant,'*** (the Friction Loss component of this mathematical calculation that require the very hydrant system within your own township or city to be the size and dimensions it now is) upon the FACT you are ***<u>REQUIRED to pump 462 PSI</u> to maintain minimum/proper Nozzle Pressure (NP) for the <u>SAFETY</u> of your crew, would you not agree you are in direct violation of OSHA – 29 CFR 1910.156(c)(1) and (2) upon the standards of NFPA 1041?"***

Hence, this is the exact reason why the certified specifications of any "Type 3" Wildland Fire Engine has always only ever required twelve (12) 100-foot lengths of 1 ½" hose and only six (6) 100-foot lengths of 1" hose! 400 PSI can only support a typical 900 to 1,000-foot hoselay at a moderate slope/grade; with a few extra lengths of 1 ½" and 1" hose as spares onboard in the inevitable event that necessary replacement is required due to hose failure upon dragging every inch up steep, rough terrain.

Therefore, since this standard was established many decades ago at the inception that fire apparatus classifications for ISO purposes, there's never been a need to increase this financial investment to equip these fire apparatus with more hose than what the pump can SAFELY pressurize and therefore allow fireline personnel to SAFELY perform to accomplish an otherwise desired result.

To summarize, there are essentially only two (2) modes of operation that a wildland firefighter is engaged:

- **<u>Initial Attack</u>** - which applies to all previous references made herein so far.
- **<u>Mop-up/Overhaul operations</u>** and its effect on TOTAL Engine Pressure (EP) upon these reduced water flow rates.

An entire chapter is dedicated to addressing this need, but with full respect that even though less Engine Pressure is required to provide each nozzle with the minimum pressure to operate SAFELY, **the color-coding for each result is <u>NOT</u> changed from 'ATTACK' mode to emphasize the *<u>WARNING</u>*** to the operator that in the event of an unanticipated ESCAPE (slop-over) or severe BLOW-UP, communication to all personnel assigned on a given hoselay needs to be maintained to ensure all non-related overhaul nozzles can be temporarily suspended to ensure ALL nozzle(s) in the 'emergency' affected area to support those operations not only more effectively but much SAFER for all crew members as well.

Lastly, do please also read my article (attached) ***"Fire Hose Coil 'Bundle' Technology - Garden Hose Simplicity"*** for the most efficient hose deployment methodology that not only NEVER kinks under any circumstance EVER, but reduces the overall required effort to deploy any fire hose as much as 1/3 (per 100' <u>FULLY</u> deployed) to as much half and even more at deployment distances of less than 100'! Additionally, you can also learn the impossible! How to fully charge a 2 ½" X 200' 'Blitz Line' within 10' of the rear of your apparatus… and be fully deployed… around right-angle turns… and the nozzle person NEVER drags more than 25' of hose up to the full length of the hose! That's CRAZY!

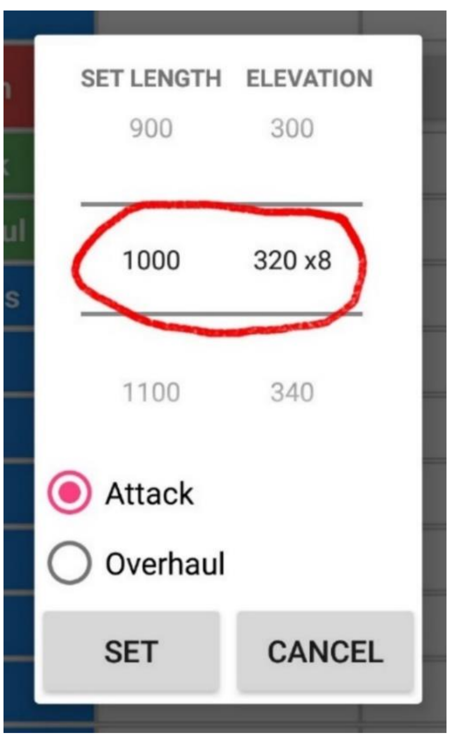
And now upon other incredible enhancements in technology such as the Automatic Vehicle Location (AVL) equipment to confirm resource situational awareness at all times, locations, when used in conjunction with the suggested Geographical Positioning System (GPS) features now available on any smartphone to immediately display personnel on any U.S.G.S. map (i.e. ***"Topo Maps"***) to assist a driver/operator to better determine accurate HEAD pressure loss or gain, to calculate accurate Engine Pressure (EP)… that upon the ***REAL-TIME*** radio-communicated location of all fire-line personnel who check-in with their supervisor regarding lateral/overhaul operation status…

…both phone apps therefore perform outstandingly as secondary back-up devices to ensure **Section 5** of the ***"Wildfire Management Technology Advancement Act of 2018"*** that mandates ALL fire resources, fire apparatus, and equipment, but especially personnel assigned to any Federal Type 1 incident shall be immediately and continuously monitored to determine exact location and status at all times is completely supported and therefore fulfilled as well!

Chapter Two: The Phone Apps

The ***'Topo Maps'*** phone app can be utilized to allow a user to pre-download literally any USGS map (especially those maps within the initial and potential response areas) across the entire North American continent for a one-time fee of approximately $12.99 for life. The "HEAD" pressure component of the calculation process is then determined by simply counting the number of contour lines at the given elevation change (either 20' interval isobars at lower, less steep areas… and 40' interval isobars at higher, and steeper terrain areas) that is measured between the fire engine and the last confirmed (communicated location) or expected peak elevation 'waypoint' of our personnel at the highest nozzle anywhere within the hoselay.

Upon activating the "***HFT-Fire***" **Wildland Fire Hydraulics Engine Pressure calculator** phone app, the "**SET OPTIONS**" button (at the upper left of the display page with red lettering on gray background) is then tapped to be transported to a second page to enter only the hoselay length and positive (+) or negative (-) elevation change accordingly. Simply scroll up to enter the current length of the hoselay indicated in 100' lengths (and verified by the approximate distance between the engine and last indicated waypoint as communicated by personnel) and do the same to calculate HEAD (H) by scrolling up or down to select the calculated elevation change per the contour lines found on the ***'Topo Maps'*** phone app display.



- It is critical to keep track of the actual number of lengths of 'Attack-Line/'Trunk-Line' to accurately calculate the TOTAL of all four (4) variables [(NP) + (FL) + (A) before adjusting for (+) or (-) Head (H)] to determine accurate Engine Pressure (EP) in ***REAL-TIME*** accordingly.

Next, the elevation is entered upon scrolling up (for uphill) upon the number of isobars counted up for positive (+) **HEAD** pressure ***(LOSS)*** and simply scrolling down (for downhill) for negative (-) **HEAD** pressure ***(GAIN)*** in increments of 20' intervals indicated as:

"0", then "(±) **20**", then "(±) **40 x1**" (to indicate one (1) contour line at (±) 40') then "(±) **60**", then "(±) **80 x2**" (to indicate two (2) contour lines at (±) 80') then "(±) **100**", then "(±) **120 x3**" (to indicate three (3) contour lines at (±) 120'), etc. …up to "(±) **520 x13**" (to indicate thirteen (13) contour lines

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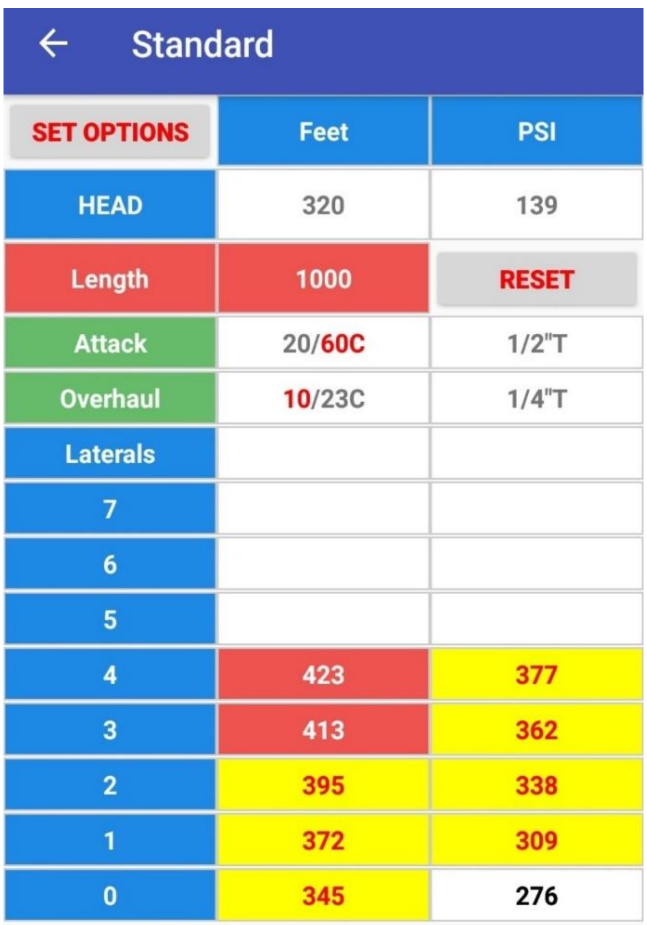
at (+) 520') in that the elevation change in feet is followed by "**x**" (times) the numeral portion"**Y**" that indicates the total number of **40' elevation intervals** in order to make this phone app a little more 'user-friendly' and therefore easier to accurately determine each Engine Pressure (EP) accordingly.

Upon selecting the **"ATTACK"** and **"SET"** keys, the phone app instantly calculates FULL Engine Pressure (EP), based on all four (4) variables listed above, that is presented on the first page that shows two (2) columns of Engine Pressure (EP) results per the nozzles selected in the field. The driver/operator then reads down the appropriate column by nozzle type ["20/**60C**" or **½"T**] and then reads across upon the current number of laterals (row) operating for mop-up/overhaul purposes in ***REAL-TIME*** at that particular phase of progression of the wildland hoselay accordingly.


← Standard

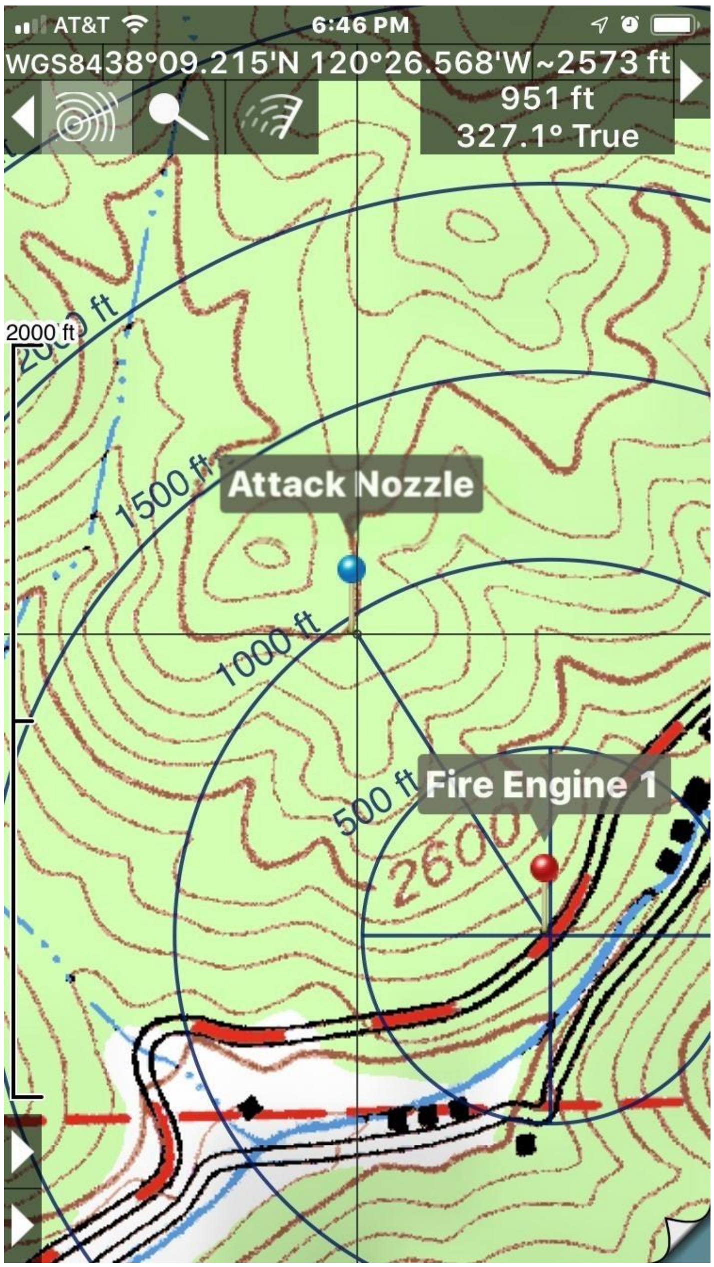
SET OPTIONS	Feet	PSI
HEAD	320	139
Length	1000	RESET
Attack	20/60C	1/2"T
Overhaul	10/23C	1/4"T
Laterals		
7		
6		
5		
4	423	377
3	413	362
2	395	338
1	372	309
0	345	276

TOTAL Engine Pressure (EP) is calculated in each respective column. Between 0 and 299 all numeric characters remain **bold black on a white background**. When the Engine Pressure (EP) reaches above 300 PSI and up to and including 400, the numeric characters become **bold red on a yellow background to indicate you are quickly approaching the maximum 400 PSI that your engine will produce**. But when the calculated Engine Pressure (EP) exceeds 400 PSI, the number characters become **bold white on a red background** to indicate ***OSHA's General Duty Clause 5(a)(1)*** to ensure firefighter safety has been violated upon the evidence that **required Nozzle Pressure (NP) is no longer possible.**

- For the first time in Fire Service history, it is now clear when the forward progression of a wildland fire hoselay must **CEASE and DESIST** until other critical measures are taken to ensure **OSHA's General Duty Clause 5(a)(1) to maintain Firefighter SAFETY!** [i.e., portable 'in-line' booster pump(s) or fire apparatus that can be safely driven upslope strategically placed in series within the hoselay to boost to the minimum necessary pressure; and/or wait for the number of laterals operating are reduced upon completion of mop-up/ overhaul operations to again recapture enough pressure before breaching the maximum pump pressure ratings yet again.

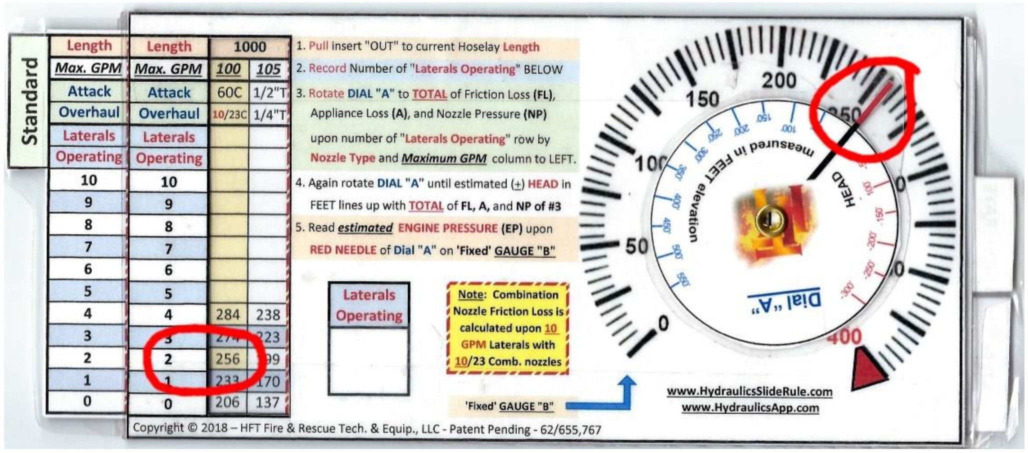
Please note, in order to "**RESET**" the Engine Pressure (EP) calculator to its default condition [all results to zero (0)], please select:

The examples within are based upon a typical scenario found at the 2,600' elevation in the central Sierra Nevada Mountain range foothills per the following USGS Topo Map image:



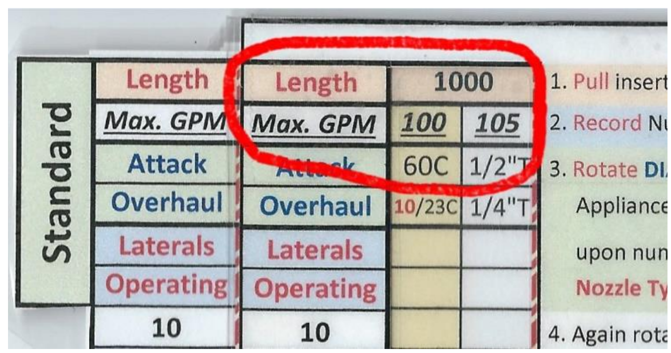
Chapter Three: The Slide-Rule

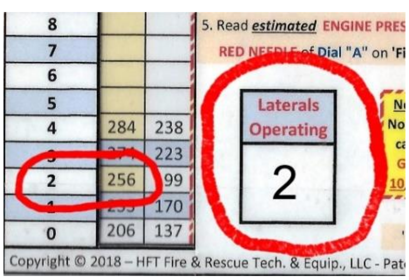
To demonstrate the process of the HFT Fire Hydraulics Slide-Rule, to calculate Engine Pressure in mere seconds as well, we will use the example on Page 6 and 15 upon a **1,000' "<u>Standard</u>" 1 ½" hoselay with a 20/<u>60</u> GPM 'Attack' combination nozzle; with <u>with ONLY two (2) of four (4) laterals operating</u> with <u>10</u>/23 GPM combination nozzles; upon eight (8) USGS map contour lines at 40' each to determine 320' of elevation and therefore 139 PSI "HEAD" pressure loss.**



It is recommended this tool shall be maintained within each fire apparatus, as a back-up to the phone app, but with its own set of instructions in that the driver/operator shall:

1. **<u>Pull insert "OUT" to current Hoselay Length</u>:** Pull out the appropriate insert [i.e., "Standard" or "Whaling" or "HEN-WAY"] to the actual hoselay length indicated in 100' intervals; both columns are listed by nozzle type ["20/<u>**60C**</u>" or **½"T**] and positioned to be visible within the laminated window.





2. **<u>Record number of "Laterals Operating" BELOW:</u>** Record (note) the current number of laterals operating, up to the maximum as indicated, at that point in the progression of the hoselay to read the first gauge setting as: [i.e. "2" laterals at 256 PSI for Nozzle Pressure (NP)

3. **<u>Rotate DIAL "A" to TOTAL of Nozzle Pressure (NP), Friction Loss (FL) and Appliance Loss (A) upon number of "Laterals" operating row by Nozzle Type (Combination or Tip) column to LEFT.</u>** The accurate calculated <u>SUBTOTAL</u> of (NP) + (FL) + (A) is then determined upon reading down the appropriate column by nozzle type and across by the current number of laterals operating at that particular phase of the hoselay evolution. "<u>**Dial 'A'**</u>", which represents a fire engine pump pressure gauge that reads from "0" to "400" PSI, is then manually <u>**rotated**</u> until the red/black pressure needle lines up with this calculated SUBTOTAL of (NP) + (FL) + (A) per the number of laterals in step #2. **[Example <u>256 PSI</u> for <u>two (2) laterals operating</u>]**

4. **Again rotate DIAL "A" until estimated (+) HEAD in FEET lines up with TOTAL of NP, FL, and A of #3**: Add (+) or subtract (-) calculated (or estimated) (±) HEAD Pressure at 0.434 PSI per foot elevation or 43.4 PSI per 100 feet of elevation change. Again, this is where the preloaded U.S.G.S. maps in **"*Topo Maps*"** is such a powerful and necessary tool in the field.

a. To the **LEFT** of the red/black pressure needle are the **"BLUE"** measured increments of approximately 22 PSI positive (+) **HEAD** pressure **(H)** per 50' in increased elevation.

b. To the **RIGHT** of the red/black pressure needle are the **"RED"** measured increments of approximately 22 PSI negative (-) **HEAD (H)** pressure in decreased elevation.

c. The final step to determine accurate Engine Pressure (EP) per the internationally recognized calculation methodology is to again **rotate "Dial 'A'"** until the estimated elevation [(+) **Blue** for upslope; (-) **Red** for downslope) lines up with the original result from item #2.

Thus **"NP" + "FL" + "A" [as one (1) result] + "H" = Engine Pressure (EP)**

5. **Read estimated ENGINE PRESSURE (EP) upon RED NEEDLE of Dial "A" on 'Fixed' GAUGE "B"**: Simply read the resulting accurately calculated Engine Pressure (EP) as indicated upon this final position of the red needle on the pressure gauge accordingly. **[Example 395 PSI Engine Pressure upon two (2) laterals operating]**

In other words, we just measured with a micrometer… marked it with chalk… and cut it with a chainsaw! We can now confirm this Engine Pressure (EP) upon verifying the same entries on the Phone App on page 14 above arrive at the result.

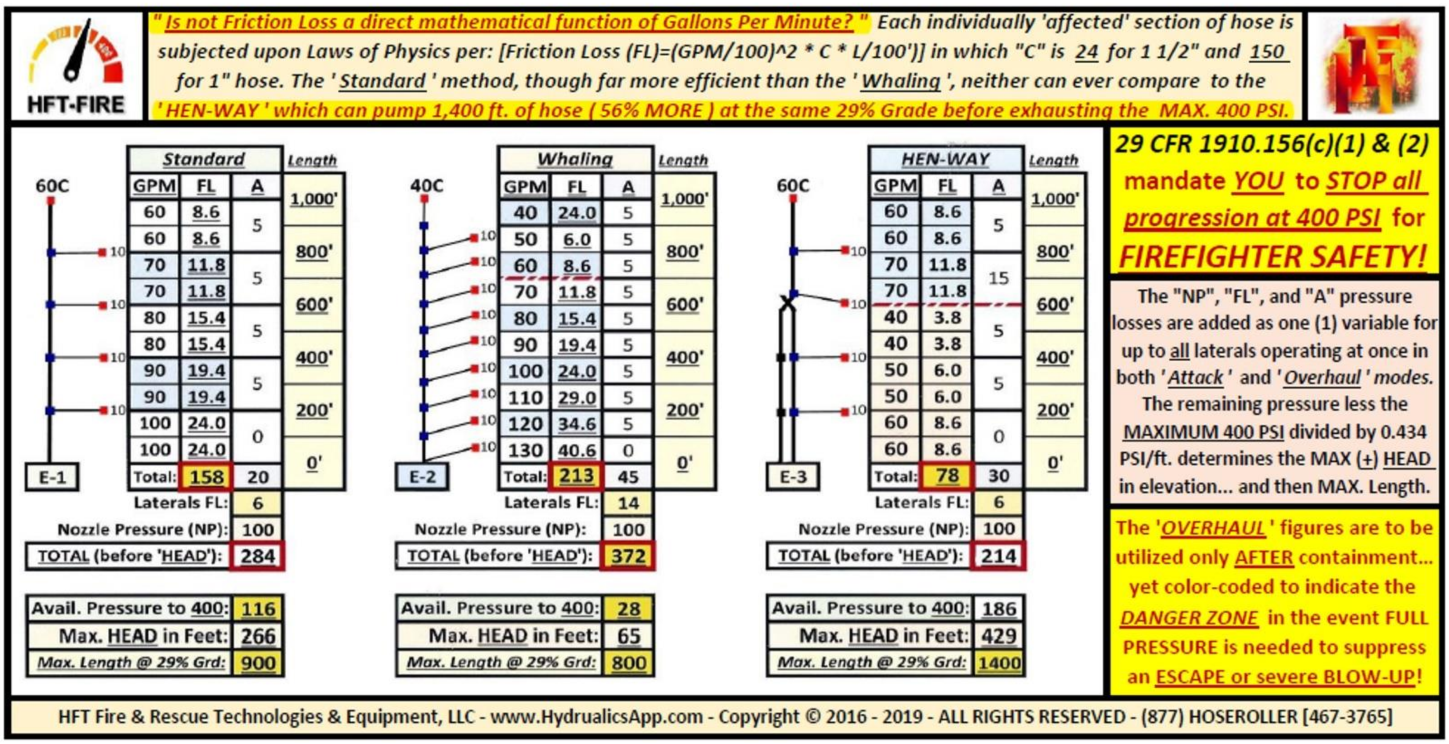
Never before has this technology been available to meet this SAFETY need… especially in mere seconds to maintain with every length of progression in ***REAL-TIME!***

Slide-Rule Reverse Side – "Standard", "Whaling", and "HEN-WAY" methods

The backside of the slide rule shows not only how each section of a hoselay is directly affected upon accurately measured and anticipated water-flow rates per the number of laterals operating, but it illustrates every dynamic of this mathematical process to further support a driver/operator's education of what he/she must respect and be accountable for, given the responsibility of each fireline crew member's safety as it applies to effective Engine Pressure (EP) and resulting SAFE Nozzle Pressure (NP) management accordingly.

Please take this opportunity to review each highlighted detail and directive to become fully aware of why we pump the pressures we pump… and why we must CEASE and DESIST all forward action when Laws of Physics PROVE we can proceed no more. It cannot be emphasized enough the liability each driver/operator is subjected to if he/she does not perform to these minimum written training standards and procedures as articulated herein.

The Second Edition will go into much more detail in this area as well as all others just briefly mentioned. Please become familiar with the following image and feel free to direct any and all inquiries you may have regarding this is and other products you may be interested in at your convenience.



HFT Fire and Rescue Technologies and Equipment, LLC.

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Chapter Four: Mop-Up/Overhaul mode

As an added benefit to both the iOS and Android Phone Apps and the mechanical Slide-Rule, the author has added the calculation process to determine Engine Pressure (EP) during **"Mop-Up"** or **"Overhaul"** procedures at which time **'Containment'** has for the most part been confidently achieved and established by Incident Command.

As a result, the 'Attack' nozzle can be flow rate can be reduced from 60 GPM to only 20 GPM, in that given this produces 1/3rd of the original water-flow, the end result is 1/9th the Friction Loss (FL) previously calculated. Upon this significant reduction in Friction Loss (FL), Engine Pressure (EP) can be greatly reduced AND/OR more laterals are able to be placed in service to assist with the efficient full extinguish of every smoldering ember that always has the potential of creating a 'slop-over' ('Escape' in older terminologies) that can significantly affect fireline safety if specific, proper measures are not exercised to prevent.

Please note the "Overhaul" Engine Pressures (EP) is greatly reduced, however, the color-coding to establish and indicate how close a driver/operator is to exhausting maximum Engine Pressure (EP) is NOT altered to keep him/her aware of the risk adequate Nozzle Pressure (NP) may not be readily or FULLY available in the event of an emergency incident that requires all related nozzles to resume FULL 'Attack' water-flow rates to suppress. Therefore, every effort shall be made to train all personnel and notify each via radio of the Emergency Action (contingency) Plan, prior to commencement and throughout all fireline operations, will include the potential temporary shut down of all NON-related/affected "Overhaul" nozzles in order to ensure the primary Engine Pump is able to provide the minimum Engine Pressure to produce the minimum Nozzle Pressure (NP) to effectively mitigate any potential incident most effectively.

Both the slide-rule and both Phone Apps can be utilized in each mode of operation, the **"Overhaul"** pressures, indicated in BOLD RED lettering with a yellow background, clearly marked above each indicated pressure result in order to effectively ***WARN*** the driver/operator these are NOT the Engine Pressure (EP) readings that will ever be adequate to produce the minimum Nozzle Pressure (NP) when engaging in ACTIVE and severe fire behavior incidents and situations.

The following photographs are images of the Slide-Rule inserts and Phone App pages upon selecting "Overhaul" vs. "Attack" that clearly indicate "OVERHAUL" above each pressure result calculated. Again, these significantly reduced Engine Pressure (EP) results shall **never** be utilized or exercised at any time during the risk of any extreme fire behavior and required emergency mitigation procedures and actions as deemed necessary accordingly.

Standard "OVERHAUL" Slide-Rule "overhaul" insert as:

	Length	100		200		300		400		500		600		700		800	
	Attack	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T
	Overhaul	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T
	Laterals																
	12																
	11																
	10																
	9																
	8																
Standard Overhaul	7																
	6																
	5													Overhaul		Overhaul	
	4									Overhaul		Overhaul					
	3					Overhaul		Overhaul						144	97	145	97
	2	Overhaul		Overhaul						126	76	127	76	139	88	140	89
	1					112	61	113	62	121	69	122	70	130	78	131	78
	0	101	50	102	51	108	56	109	57	115	62	116	62	122	68	123	68

	Length	900		1000		1100		1200		1300		1400		1500		1600	
	Attack	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T
	Overhaul	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T
	Laterals																
	12																
	11																
	10																
	9													Overhaul		Overhaul	
	8									Overhaul		Overhaul					
Standard Overhaul	7					Overhaul		Overhaul						281	268	282	268
	6	Overhaul		Overhaul						235	208	236	209	271	253	272	254
	5					198	161	199	161	227	195	228	196	255	229	256	230
	4	168	124	169	125	191	150	191	150	213	175	214	175	229	200	230	201
	3	161	115	162	115	178	132	179	133	195	150	196	151	212	168	213	169
	2	151	101	152	101	164	113	165	113	177	125	178	126	189	138	190	138
	1	140	86	141	86	149	94	150	95	158	102	159	103	168	111	169	111
	0	129	74	130	74	136	79	137	80	142	85	143	86	149	91	150	91

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Whaling "OVERHAUL" Slide-Rule "overhaul" insert as:

Whaling Overhaul

Length	100		200		300		400		500		600		700		800	
Attack	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)
Overhaul	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)
Laterals																
12																
11																
10													Overhaul		Overhaul	
9																
8									Overhaul		Overhaul				201	129
7													179	113	196	126
6					Overhaul		Overhaul				161	100	174	110	188	121
5									146	88	157	97	168	106	179	115
4	Overhaul		Overhaul				133	78	142	86	151	93	160	101	169	108
3					123	70	130	76	137	87	144	89	152	96	159	102
2			114	63	120	68	126	74	142	80	138	85	144	91	150	96
1	107	56	112	61	117	66	122	72	128	77	133	82	138	87	143	92
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Whaling Overhaul

Length	900		1000		1100		1200		1300		1400		1500		1600	
Attack	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)	10C	R5 (8)
Overhaul	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)	10/40C	R5 (8)
Laterals					Overhaul		Overhaul		381	253						
12	Overhaul		Overhaul				329	221	373	248						
11					293	193	322	217	361	240						
10			252	164	286	189	310	209	344	230						
9	227	147	246	160	276	182	295	200	324	217						
8	221	144	236	154	262	174	277	188	303	203						
7	213	138	224	146	246	163	258	176	279	188						
6	202	131	210	137	229	152	238	163	256	173						
5	190	124	195	127	212	141	218	150	233	159						
4	177	116	181	118	195	131	199	138	213	145						
3	165	108	168	110	180	121	182	127	194	133						
2	154	100	157	102	168	113	169	119	180	124						
1	147	95	149	97	159	108	159	113	169	118						
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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HEN-WAY "OVERHAUL" Slide-Rule "overhaul" insert as:

Overhaul
HEN WAY

Length	100		200		300		400		500		600		700		800	
Max. GPM	60	53	60	53	70	66	70	66	80	79	80	79	60	59	60	59
Attack	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T
Overhaul	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T
Laterals Operating													Add a 'HEN-WAY' before proceeding			
10																
9																
8																
7																
6																
5													Overhaul		Overhaul	
4									Overhaul		Overhaul					
3					Overhaul		Overhaul						133	88	142	95
2	Overhaul		Overhaul						126	76	127	76	128	81	137	88
1					112	61	113	62	121	69	122	70	123	74	132	81
0	101	50	102	51	108	56	109	57	115	92	116	62	119	69	128	76

Overhaul
HEN WAY

Length	900		1000		1100		1200		1300		1400		1500		1600	
Max. GPM	70	66	70	66	65	72	65	72	70	79	70	79	75	85	75	85
Attack	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T	20C	1/4"T
Overhaul	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T	10/23C	1/4"T
Laterals Operating					Add a 'HEN-WAY' before proceeding								Add a 'HEN-WAY' before proceeding			
10																
9																
8									Overhaul		Overhaul		Overhaul		Overhaul	
7					Overhaul		Overhaul						212	182	221	189
6	Overhaul		Overhaul						186	150	195	157	205	172	214	179
5					169	129	178	136	181	142	190	149	197	158	206	165
4	157	114	166	121	163	121	172	128	172	129	181	136	190	149	199	156
3	153	107	162	114	156	111	165	118	167	122	176	129	182	137	191	144
2	146	98	155	105	151	103	160	110	160	111	169	118	175	127	184	134
1	143	93	152	100	145	96	154	103	155	104	164	111	167	117	176	124
0	136	85	145	92	140	90	149	97	147	96	156	103	161	110	170	117

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The Android Phone App and iOS Phone App are very similar in the same regard. Again, these significantly reduced Engine Pressure (EP) results shall **never** be utilized or exercised at any time during the risk of any extreme fire behavior in that required emergency mitigation procedures and actions may be deemed necessary accordingly.

Compare the **"ATTACK"** figures at **479 PSI**… impossible to pump… to the **"OVERHAUL"** figures **337 PSI** that appears innocent. That's a **142 PSI reduction** in Engine Pressure (EP) that is now possible to pump… but NEVER during Emergency Operations! **DO NOT TAKE THESE RESULTS FOR GRANTED EVER!**

Again, this is where it is CRITICAL that radio communication SHALL BE maintained AT ALL TIMES with every 1" X 100' lateral nozzle operator so that in the event of an EMERGENCY, in which a 'slop-over' *[ESCAPE!!!]* occurs, ALL non-affected nozzle operators can immediately SHUT-DOWN in order for ALL Engine Pressure (EP) to be made immediately available to support the nozzle(s) of the affected area to effectively address the suppression needs and fully mitigate the incident as quickly and efficiently as possible.

"ATTACK" mode

Standard

SET OPTIONS	Feet	PSI
HEAD	320	139
Length	1100	RESET
Attack	20/60C	1/2"T
Overhaul	10/23C	1/4"T
Laterals		
7		
6		
5	479	445
4	468	428
3	448	401
2	422	367
1	392	328
0	359	288

"OVERHAUL" mode

Standard

SET OPTIONS	Feet	PSI
HEAD	320	139
Length	1100	RESET
Attack	20/60C	1/2"T
Overhaul	10/23C	1/4"T
Laterals	OVERHAUL	OVERHAUL
7		
6		
5	337	300
4	330	289
3	317	271
2	303	252
1	288	233
0	275	218

Again, for the first time in Fire Service history, a tool actually dictates precisely when and where to add a booster pump to re-establish and maintain an effective fire stream to ensure firefighter safety as required upon **NFPA 1002 8.1 & 8.2.1(A), NFPA 1041 1.1 & 1.2.2, and OSHA 29 CFR 5(a)1 & 1910.156(c)1 & 2 accordingly.** **EVERY WILDLAND FIRE APPARATUS DRIVER/OPERATOR IS REQUIRED BY LAW TO UPHOLD THESE STANDARDS WITHOUT ELIMINATION OR DEVIATION UNDER ANY CIRCUMSTANCES EVER!**

<u>Chapter Five</u>: The Basics – Definition of Terms

To be briefed on the basics of wildland fire hydraulics, we must first understand the four (4) components that accurately calculate proper Engine Pressure (EP) upon the four (4) mathematical variables to ensure adequate Nozzle Pressure (NP); which is critical to create an effective Fire Stream; which in turn is critical to ensure the safety of every firefighter directly involved in the execution of any progressive wildland hoselay at literally every step of this extremely effective and regularly executed fire suppression tactical operation.

To begin, we must always first consider the minimum required <u>**Nozzle Pressure (NP)**</u> of the "Attack-Nozzle" at the end connection of the hose before working our way back to the primary pump of the fire engine. Depending on the style of nozzle used (expressed in thread size and type), the internationally recognized NFPA standard requires a minimum of 50 PSI when utilizing a straight-bore "TIP" (T) style nozzle (listed by bore inside diameter and resulting GPM) and a minimum of 100 PSI for a "Combination" (C) style nozzle that produces both variable fire streams and patterns at variable flow rates expressed in Gallons Per Minute (GPM) accordingly.

The second consideration is <u>**Friction Loss (FL)**</u>. This is the most complex variable of the calculation process that is directly affected upon the amount of water flowing (GPM) through any individual section of any given pipe (or hose) at a specific diameter at the specified Nozzle Pressure (NP) at 50 PSI for a Straight-bore 'TIP' nozzle or 100 PSI for a Combination style nozzle presented as:

- **Friction Loss (FL) = (GPM/100)^2 * Coefficient of the hose * Length of hose/100'**
    - **Coefficient of 1 ½" Hose – Multiplier is <u>24</u>**
    - **Coefficient of 1" Hose – Multiplier is <u>150</u>**

In the simplest terms, given the viscosity of water at normal atmospheric temperatures and pressure, the flow rate (GPM) has a direct impact on this pressure loss. In regards to wildland firefighting, each section of an inch and a half (1 ½") "Attack-Line" or "Trunk-Line" in a hoselay is directly affected by the resulting flow (GPM) of the attack nozzle at the prescribed minimum required pressure <u>***AND***</u> the increased flow of water (GPM) in each affected section upon <u>**ADDING**</u> the flow of water (GPM) of each successive one-inch (1") by 100' lateral that is utilized for mop-up/overhaul purposes to 'secure' and 'anchor' the fire line of any given wildland fire today. A critical factor that increases the Friction Loss (FL) component in each individual affected and therefore unique section of hose exponentially that can <u>***NEVER***</u> be disqualified nor disregarded in this internationally accepted and instructed mathematical calculation process <u>***EVER.***</u>

Then, once the Friction Loss (FL) of each individually affected section of the "Attack-Line/Trunk-Line" is accurately determined per their unique flow rates (GPM), this **subtotal** Friction Loss (FL) of all sections is then added together to the combined **subtotal** Friction Loss (FL) of each individual one-inch (1") by 100' lateral currently in operation. The sum of these two (2) figures, therefore, represents the ***GRAND TOTAL*** **Friction Loss (FL)** variable that is necessary to accurately calculate the total proper Engine Pressure (EP) for the entire progressive hoselay accordingly.

In the simplest terms, the inquiry, ***"Is not Friction Loss a direct mathematical function of Gallons Per Minute?"*** …is, therefore, a resounding and confirmed, ***"Yes!"***

The third mathematical variable is **Appliance Loss (A)**. This is based upon the number of inline one and a half-inch (1 ½") "Tees" necessary to connect and supply each one-inch (1") by 100' lateral utilized for mop-up/overhaul purposes. Again, in the same exact manner, a large boulder can slow the overall rate of water down a river or stream, each one-inch (1") water-restrictive stem/valve assembly that spans the full diameter within each of these one and a half (1 ½") "Tee" causes an Appliance Loss (A) pressure loss determined at an estimated 5 PSI each in the same manner.

The final and fourth (4^{th}) mathematical variable is the addition (+) or subtraction (-) of **HEAD pressure (H)**: This is the calculated increase of pressure [PLUS (+) upon the increase in elevation above the fire pump to the highest nozzle of the hoselay] or calculated decrease of pressure [MINUS (-) upon the decrease of elevation below the fire pump to the ***first operating nozzle of a hoselay ONLY!***] upon the weight of water at 0.434 PSI per foot ($\pm$) elevation change.

For structure firefighting purposes, this is a no brainer by comparison in that each floor above or below the ground floor of a pumper is typically 10 feet; in which this figure is subsequently rounded off to 5 PSI per floor. Upon counting from the second (2^{nd}) floor and going up from there, we add a **PLUS** (+) 5 PSI per floor. Conversely, when fighting basement fires, this amount is subtracted as a **MINUS** (-) 5 PSI per basement floor below the ground floor in which both are compensated at the pump upon the internationally accepted methodology to calculate Engine Pressure (EP) accordingly as well.

But when it comes to wildland fire fighting, this variable is not so easily calculated. The fire apparatus driver/operator must multiply **0.434 PSI/ft.** upon his/her **'*best estimation*'** of the change in elevation of the rise over the given run of several hundred feet and more that is often visually obstructed by vegetation and other land features that makes this nearly impossible to determine at (+) or (-) 25% accuracy; to then be utilized to attempt to accurately calculate proper Engine Pressure (EP).

But now, upon the REAL-TIME Geographic Positioning System (GPS) utilized worldwide, the verified location of all personnel and resources (via radio communication due to the lack of an internet connection in remote areas) can be placed on a two (2) dimensional United States Geographic Survey (USGS) map. This is an extremely effective phone app that can be downloaded to any Android or iPhone (i.e. ***Topo Maps***) that not only identifies the (±) change in elevation in either 20 ft. or 40 ft. intervals to accurately prove this last variable of the Engine Pressure (EP) calculation process, but In the same manner, a Land Surveyor measures all property lines from a known **BENCHMARK**, when standard GPS technology is utilized in conjunction with 'AVL' equipped fire apparatus, fire line safety is immensely enhanced! Personnel radio-notify their REAL-TIME situational awareness (longitude and latitude in degrees and seconds and distance and bearing) from their 'AVL' fire vehicle **(BENCHMARK)** to communicate to dispatch and adjoining crews that meet literally all safety criteria of **Section 5** of the ***"Wildfire Management Technology Advancement Act of 2018"*** as well. A first in Fire Service history!

Let's again review the internationally recognized Engine Pressure (EP) calculation formula as stated below upon the adherence to the correct methodology in that the ***GRAND TOTAL*** Friction Loss (FL) component is always based upon the water flow (GPM) in each individually affected section of hose that changes upon the placement and operational use of every successive one-inch (1") by 100' lateral utilized for mop-up/overhaul mitigation purposes accordingly.

- **Engine Pressure (EP) = Nozzle Pressure (NP) + *GRAND TOTAL* Friction Loss (FL) + Appliance Loss (A) + [(+) or (-)] HEAD (H)**

It is a fire apparatus driver/operator's duty, upon the incredible responsibility for the safety and security of his/her personnel, that he/she must do his/her absolute best to accurately calculate each individual component upon as much confirmed intelligence that can be obtained in the field before adding all four (4) variables to accurately calculate the actual Engine Pressure (EP). But especially upon the need in REAL-TIME to establish and maintain the required minimum Nozzle Pressure (NP) at every step in a wildland fire hoselay that truly meets and exceeds every directive enforced by the mandate of the ***OSHA General Duty Clause*** umbrella to maximize firefighter safety under all conditions always.

The design and purpose of the world's FIRST ever Wildland Fire Engine Pump Pressure/ Hydraulics Calculator as both a mechanical Slide-Rule and the Android and iOS format phone apps is not only to solve this extremely complex formula accurately under all conditions, but rather to calculate this incredible need with impeccable precision in mere seconds upon the implementation of just a few simple steps that establish and maintain the integrity to this portion of fire line safety that has never been experienced in Fire Service history ever before!

And now that Automatic Vehicle Location (AVL) equipment (upon redundant Cellular, VHF, and satellite GPS positioning communication methods/systems) is being installed (in over 1,200 CAL FIRE units alone) to improve the situational awareness of our fire apparatus/ resources, we can now determine by bearing and distance from these ***BENCHMARKS*** that are monitored 24/7/365, our firefighters can now be located to nearly the nearest square inch by allowing full Computer-Aided Dispatch connectivity and continuous radio communicated position updates expressed in longitude and latitude coordinates of our frontline fire response, **the *"Holy Grail of Wildland Firefighting"* has finally been fulfilled!**

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Chapter Six: The Breakdown

<u>Nozzle Pressure (NP) 'Pressure Loss':</u>

As there are many nozzle types and manufacturers worldwide, there are truly only two (2) versions that need to be considered: Straight bore "Tip" (T) and "Combination" style nozzles (C).

Straight bore "Tip" (T) nozzles are listed by thread size (i.e. 1" NPT or 1 ½" NST) and inside diameter and flow rates expressed in Gallons Per Minute (GPM) at 50 PSI in that 50 PSI must be continuously maintained at the end connection of the hose to produce the desired flow rate (GPM) to fight a fire both SAFELY and efficiently to ensure firefighter safety and therefore meet OSHA's General Duty Clause listed above. In that, an 1 ½"NST thread ½" "Tip" style nozzle will flow 53 GPM at 50 PSI nozzle pressure which has been established as the minimum size tip/flow rate established by many federal and state government agency fire departments necessary to fully engage a wildland fire advancing at a ***"moderate rate of spread."***

Wildland "Combination" (C) style nozzles, on the other hand, require 100 PSI to establish and maintain the minimum flow rate (GPM) at the end connection of the hose to fight a fire both SAFELY and efficiently as well. They are again listed by thread size and type (1" NPT or 1 ½" NST) upon their minimum GPM/maximum GPM (i.e. "20/60"; "10/40"; "10/23", etc.) and ability to not only transition from one flow rate (GPM) to the other, but also to produce a fire stream that can be both in a straight-stream fashion (similar to a straight bore "Tip") or variable 'fog' pattern from a narrow to wide-angle fire stream as well.

And in all cases, a quarter turn 'ball-valve' assembly at the hose/nozzle connection is the preferred method to initiate and adjust and then cease the rate of flow of both the straight-bore "Tip" and "Combination" style nozzles alike.

<u>Friction Loss (FL) 'Pressure Loss':</u>

To begin to fully understand how we determine this portion of the calculation process, we need to respect the internationally recognized calculation formula methodology that has been utilized for more than a century to determine the minimum parameters for all our water fire protection systems (from hydrants to sprinklers to…) to meet and exceed the minimum flow rates at the required pressure for the calculated 'fire-loading' (potential fire behavior upon anticipated fuels of 'zoned' occupancies) to prevent the 'conflagrations' experienced upon learning the hard way from the total devastation of the Great Chicago Fire and San

Francisco Earthquake of 1906 as prime examples for the need for the increased minimum fire prevention and protection system standards and requirements enforced today.

The internationally recognized and respected basic hydraulics Friction Loss (FL) formula:

- **Friction Loss = (<u>GPM</u>/100)^2 X (<u>Coefficient</u> of the Hose) X (<u>Length</u> at a specific flow rate)/100')**
  1. In that, the **<u>Coefficient</u>** for **<u>1"</u>** diameter fire hose utilizes the multiplier of **<u>150</u>**…
  2. In that, the **<u>Coefficient</u>** for **<u>1 ½"</u>** diameter fire hose utilizes the multiplier of **<u>24</u>**…

But before we begin to discuss the proper application of the formula necessary to complete this portion of the calculation process, we must first understand the physical dynamics involved to arrive at such a result.

Again, let's consider any typical river or creek coursing down-stream in that the water flow is fast and efficient at the top and in the middle of the primary flow area, yet much slower on the edges and therefore at the bottom as well. Friction loss (FL) is best understood as this component, given the measured viscosity of water under normal temperatures and atmospheric pressures, that upon the water making contact with the edges (in this case the bottom and sides) of its designated channel, 'eddies' are created as it moves downstream, in that the overall rate of flow is therefore reduced by this resulting friction.

In the exact same way, a pipe, given its cylindrical shape in that the inside diameter determines the surface area to volume ratio, again given the measured viscosity of water, turbulence or 'eddies' are created at a predictable size and rate, in that the more water is forced through a given pipe, the larger these 'eddies' become. As these 'eddies' increase in size, the overall 'usable' inside diameter of the pipe is therefore reduced. As the 'usable' diameter is exponentially reduced, its volume or capacity to flow water is then equally exponentially reduced even regardless of a manufacturer's efforts to ensure the inside surface of the hose is created as smooth as possible.

Practically speaking, ***"What does all this mean?"***

- This is why when we double (2X) the water flow (GPM) in a given pipe or hose, the Friction Loss (FL) component increases by a multiplier of two (2) squared… or four (4) times the amount.
- In that three (3) times the flow of water (GPM) in the same pipe is three (3) squared… or nine (9) times the amount of Friction Loss (FL).
- And yet, if we attempt to maintain the same flow rate (GPM) but in a pipe one-half (½) the original diameter of the first, the resulting Friction Loss (FL) component increases by a multiplier of 32 times!

In that, if we look at any internationally recognized Friction Loss (FL) table, per the supporting evidential exhibits attached, we find this consistently illustrated as true. This is why we experience such an incredible benefit upon establishing a second dual/parallel 'Supply-Line' when attempting to flow large quantities of water over great distances from a hydrant to the fire. The Friction Loss (FL) component is calculated by squaring the fraction equal to "½" the GPM in each… in that "½" the flow times (X) "½" the flow then results in "¼" the Friction Loss (FL) which then (as the coefficient of the hose always remains constant), therefore results in a 75% reduction in Friction Loss (FL) when calculating the **TOTAL** necessary water pressure and resulting flow to complete the evolution simply by adding just one (1) more parallel line.

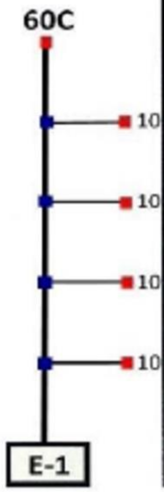
Another example, upon laying yet a third (3rd) parallel 2 ½" Attack-line, as in pressurizing a high flow (GPM) portable monitor nozzle (appliance) to establish exposure protection from a more advantageous strategic location that may be over a great distance, the Friction Loss (FL) component is reduced in that the equally divided "1/3" the flow (GPM) times (X) "1/3" the flow (GPM) results in "1/9" the Friction Loss (FL). This, therefore, results in an 89% reduction in the Friction Loss (FL) component upon calculating the **TOTAL** Engine Pressure (EP) required to establish the desired exposure protection when incidents of this magnitude require the same.

…per the internationally recognized calculation methodology above that has been respected and adhered to by all affected local, state/province, and federal entities requiring its proper application to establish adequate water fire protection worldwide for well over a century and a half.

However, this is where it gets a little dicey for the wildland fire apparatus driver/operator. He/she must calculate the rate of water (GPM) through each individually affected section of 1 ½" 'Attack-line'/'Trunk-line' that is utilized in a progressive hoselay in that the rate of flow (GPM) in each individual section is directly affected by the actual flow rate (GPM) of the attack nozzle **PLUS** the flow rate (GPM) of all successive operating individual one-inch (1") by 100' laterals at specific intervals further up the 'Attack-line'/'Trunk-line' accordingly.

In other words, in a one and half inch (1 ½”) by 1,000’ ‘Attack-Line’/‘Trunk-Line’ hoselay, with a 1 ½” 20/60 ‘Attack’ combination nozzle flowing ***60 GPM*** at **100 PSI Nozzle Pressure (NP)**, and a total of four (4) 1” by 100’ laterals every 200’, each equipped with a 10/23 GPM combination nozzle flowing ***10 GPM*** for mop-up/overhaul purposes, the following breakdown is evidenced as follows:

1. **Between 800’ and 1,000’** the 1 ½” 20/60 ‘Attack’ combination nozzle causes **60 GPM** to flow through this 200’ section at ***8.6 PSI*** Friction Loss per 100’… or ***17.2 PSI TOTAL*** Friction Loss (FL) in this specific 200’ section of 1 ½” **only**.



Standard			Length
GPM	FL	A	
60	8.6	5	1,000'
60	8.6		
70	11.8	5	800'
70	11.8		
80	15.4	5	600'
80	15.4		
90	19.4	5	400'
90	19.4		
100	24.0	0	200'
100	24.0		
Total:	158	20	0'
Laterals FL:		6	
Nozzle Pressure (NP):		100	
TOTAL (before 'HEAD'):		284	

Avail. Pressure to 400:	116
Max. HEAD in Feet:	266
Max. Length @ 29% Grd:	900

2. **Between 600’ and 800,’** the 1 ½” 20/60 ‘Attack’ combination nozzle causes **60 GPM** to flow through this 200’ section is then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 800’ in that **70 GPM** causes ***11.8 PSI*** Friction Loss per 100’… or ***23.6 PSI TOTAL*** Friction Loss (FL) in this specific section **only.**
3. **Between 400’ and 600’** the 1 ½” 20/60 ‘Attack’ combination nozzle causes **60 GPM** to flow through this 200’ section is then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 800’ and then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 600’ in that **80 GPM** causes **15.4 PSI** Friction Loss per 100’… or ***30.8 PSI TOTAL*** Friction Loss (FL) in this specific section **only.**
4. **Between 200’ and 400’** the 1 ½” 20/60 ‘Attack’ combination nozzle causes **60 GPM** to flow through this 200’ section is then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 800’ and then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 600’ and then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 400’ in that **90 GPM** causes **19.4 PSI** Friction Loss per 100’… or ***38.8 PSI TOTAL*** Friction Loss (FL) in this specific section **only.**
5. **Between the Fire Engine and 200’** the 1 ½” 20/60 ‘Attack’ combination nozzle causes **60 GPM** to flow through this 200’ section is then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 800’ and then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 600’ and then **ADDED** to the additional **10 GPM** for the 1” by 100’ lateral at 400’ and then **ADDED** to the additional **10 GPM** for the

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1" by 100' lateral at 200' in that **100 GPM** that causes **24.0 PSI** Friction Loss per 100'… or ***48.0 PSI TOTAL*** Friction Loss (FL) in this specific section **only.**

The **subtotal Friction Loss (FL)** of each of the five (5) individually calculated sections of the 1 ½" 'Attack-Line'/'Trunk-Line' is determined by **ADDING each result of each individually affected section as *17.2 PSI*** + ***23.6 PSI*** + ***30.80 PSI*** + ***38.8 PSI*** + ***48.0 PSI*** to thus equal (=) **158.0 PSI**

It is then necessary to calculate the Friction Loss (FL) component for the water pressure loss of each 1" by 100' lateral per the internationally recognized formula and methodology above in that each 100' length with a 10/23 GPM combination nozzle flowing **10 GPM** has a Friction Loss (FL) of ***1.5 PSI each***. Since we have one at 200', a second at 400', a third at 600', and finally a fourth at 800':

The **subtotal Friction Loss (FL)** for all **four (4)** 1" by 100' laterals at **1.5 PSI** each is (=) **6.0 PSI.**

The **GRAND TOTAL Friction Loss (FL)** component required to accurately calculate proper Engine Pressure (EP) is proven by **adding the subtotal Friction Loss each of the five (5) individually affected sections of the 1 ½" 'Attack-Line' at 158.0 PSI to the subtotal Friction Loss (FL) of all four (4) 1" laterals at 6.0 PSI which equals (=) 164.0 PSI.**

Appliance Loss (A) Pressure Loss:

Again, we calculate for the Appliance Loss (A) in the same manner that a large boulder restricts the flow of water in a river or creek in that any other parasitic obstruction within any plumbing and/or pipe or hose must also be considered in the same manner as well.

Given there are four (4) 1 ½" X 1" 'Tees' (each with interior 'water-restrictive' valve stem assemblies) in the 1,000' hoselay above, we shall calculate each at **5 PSI** in that **four (4)** times (X) **5 PSI** equals (=) **20 PSI**

The **TOTAL PRESSURE LOSS** is the addition of the **Nozzle Pressure (NP) [100 PSI]**, ***PLUS*** (+) the **GRAND TOTAL Friction Loss (FL)** of the 1 ½" Attack-line/Trunk-line **[158 PSI]** and the Friction Loss (FL) TOTAL of all four (4) 1" by 100' laterals **[6 PSI]** equals (=) **164 PSI** ***PLUS*** (+) **Appliance Loss (A)** at **[20 PSI]** which equals (=) **284 PSI**

This is the initial figure that the Slide-Rule and both phone apps provide **BEFORE** we add and shall always respect that this only provides a maximum of **116 PSI** remaining PSI of the 400 PSI maximum Engine Pressure (EP) that our fire apparatus can produce to SAFELY allow for the final component – **HEAD (H) pressure** – in which 116 divided by 0.434 PSI/ft equals **266 feet or a 26.6% Grade over a 1,000' run.** Any steeper than this maximum amount of vertical elevation [(+) HEAD] to also be compensated at the fire pump, the OSHA General Duty Clause 5 (a)(1) requirement to establish and maintain an effective fire stream for firefighter safety will then, therefore, be severely compromised.

Secondly, when we calculate for the maximum length at a 29% Grade, in a 1,000 run this is therefore 290'. 290' times (X) 0.434 PSI/ft equals 126 PSI. 400 PSI minus (-) 126 PSI equals 274 PSI available to pump water at all. The calculations for 60 GPM 'Attack' and all four (4) laterals operating at 10 GPM requires 276 PSI at 900'. Given it is only 2 PSI more than the maximum at 274 PSI calculated, it would likely be safe enough to pump a 900' hoselay at a 29% grade. But nothing longer nor nothing steeper is possible without violating 29 CFR 1910.156 training and performance standards upon NFPA's 1041 Instructor Qualification Standards.

It is only at this point, given the other factors that determine when TOTAL Engine Pressure (EP) reaches and shall never be allowed to exceed its maximum 400 PSI pump pressure available, a hoselay 'Attack-line'/'Trunk-line' still cannot be SAFELY extended even one (1) more 100' length to 1,100 of 1 ½" 'Attack-Line/'Trunk-Line' even with only two (2) 1" laterals operating at 283 PSI because the HEAD at this continuous rise-over-run for the next 100' distance will increase from 290' to 319 feet. When we multiply 319 times 0.434 PSI/ft equals 138 PSI in Total HEAD pressure loss. If we only have 117 PSI available before exhausting the maximum Engine Pressure (EP) at 400 PSI, we are therefore in direct violation of 29 CFR 1910.156 upon NFPA 1041 Instructor Qualification Standards as well.

The final concern, however, when establishing minimum Nozzle Pressure (NP) at the end of a 1,000' hoselay with up to four (4) laterals operating simultaneously, is when the resulting Friction Loss (FL) component is reduced as mop-up/overhaul operations are being completed and there are subsequently only three (3) 1" by 100' laterals operating yet four (4) water-restrictive "Tees" that remain in place. The end result is only **90 GPM** flows through the first 400' of 1 ½" 'Attack-Line/'Trunk-Line' between the Fire Engine to next (2^{nd}) operating lateral at 400' up the hoselay. Thus this lowers the calculated **Grand Total Friction Loss (FL)** variable a full **10 PSI** in which the Nozzle Pressure (NP), Friction Loss (FL) of both the 1 ½" and the 1" hose, and the appliance loss of four (4) "Tees" at 5 PSI each drops this subtotal to **274 PSI**.

And again, when only two (2) 1" by 100' laterals of the original four (4) total are operating, the end result is only **80 GPM** will be flowing through the first 600' of the 1 ½" 'Attack-Line/'Trunk-Line' between the Fire Engine to the next (3^{rd}) 1" by 100' lateral operating. Thus, this again lowers the overall **Grand Total Friction Loss (FL)** variable a full **28 PSI** in which the Nozzle Pressure (NP), Friction Loss (FL) of this reduced water- flow-rate within the 1 ½" and the 1" hose, and the appliance loss of four (4) "Tees" at 5 PSI each drops this subtotal to **256 PSI** accordingly.

Again when only one (1) 1” by 100’ laterals of the original four (4) total are operating, the end result is only **70 GPM** will be flowing through the first 800’ of the 1 ½” ‘Attack-Line/’Trunk-Line’ between the Fire Engine to the next (4th) 1” by 100’ lateral operating. Thus, this again lowers the overall **Grand Total Friction Loss (FL)** variable a full **51 PSI** in which the Nozzle Pressure (NP), Friction Loss (FL) of this reduced water- flow-rate within the 1 ½” and the 1” hose, and the appliance loss of four (4) “Tees” at 5 PSI each drops this subtotal down to **233 PSI** accordingly.

If no 1” by 100’ laterals of the original four (4) total are operating, the end result is only **60 GPM** will be flowing through the first 1,000’ of the 1 ½” ‘Attack-Line/’Trunk-Line’ between the Fire Engine to ‘ATTACK nozzle. Thus, this again lowers the overall **Grand Total Friction Loss (FL)** variable a full **78 PSI** in which the Nozzle Pressure (NP), Friction Loss (FL) of this reduced water- flow-rate within the 1 ½” and none within the 1” hose, plus the appliance loss of four (4) “Tees” at 5 PSI each drops this subtotal down to **206 PSI** accordingly.

When considering **OVERHAUL** operations, when the 20/60 GPM nozzle is reduced to only 20 GPM and all other nozzles remain at 10 GPM, these figures exponentially change at a similar rate as well. But again, these Engine Pressure results shall ***ONLY*** be utilized during operations when you are confident an aggressive attack is significantly reduced, realizing full well that the color-coding of each result shall remain unchanged as a ***WARNING*** that in the event of the need to escalate to ‘ATTACK’ mode, every effort shall be made to temporarily cease (shut-down) all other ‘unaffected’ overhaul lines/laterals so those isolated to the area of the emergency event will have the minimum required Engine Pressure (EP) to produce the minimum Nozzle Pressure to ensure firefighter safety per 29 CFR 1910.156 upon NFPA 1041.

(±) HEAD (H) Pressure Loss and/or Gain:

The subtotal of the Nozzle Pressure (NP), Friction Loss (FL) and Appliance (A) loss on the Slide-Rule and both phone apps, when subtracted from 400 PSI, instantly determines if the driver/operator can execute this possibility, yet always ***BEFORE*** it shall ever be attempted to maintain firefighter safety.

Any USGS Topo Map immediately provides our GPS location on a grid map that illustrates isobars that indicate either 20’ elevation gradients (at lower elevation areas) or 40’ elevation gradients (at higher elevation areas) that allow us to count the accurate positive (+) or negative (-) change in elevation between a driver/operator’s (fire apparatus) location and an established waypoint(s) to indicate accurate ***REAL-TIME*** radio-communicated situational awareness/location of all fire personnel up per their known bearing and distance from an Automatic Vehicle Location (AVL) equipped fire apparatus that serves as the **BENCHMARK** reference accordingly.

Free Download Available at: FireDepartment.net

Friction Loss Calculator - 100 Feet of 1 ½" Hose

GPM	FL	GPM	FL	GPM	FL	GPM	FL	GPM	FL	GPM	FL	GPM	FL	GPM	FL
1	0.0	51	6.2	101	24.5	151	54.7	201	97.0	251	151.2	301	217.4	351	295.7
2	0.0	52	6.5	102	25.0	152	55.4	202	97.9	252	152.4	302	218.9	352	297.4
3	0.0	53	6.7	103	25.5	153	56.2	203	98.9	253	153.6	303	220.3	353	299.1
4	0.0	54	7.0	104	26.0	154	56.9	204	99.9	254	154.8	304	221.8	354	300.8
5	0.1	55	7.3	105	26.5	155	57.7	205	100.9	255	156.1	305	223.3	355	302.5
6	0.1	56	7.5	106	27.0	156	58.4	206	101.8	256	157.3	306	224.7	356	304.2
7	0.1	57	7.8	107	27.5	157	59.2	207	102.8	257	158.5	307	226.2	357	305.9
8	0.2	58	8.1	108	28.0	158	59.9	208	103.8	258	159.8	308	227.7	358	307.6
9	0.2	59	8.4	109	28.5	159	60.7	209	104.8	259	161.0	309	229.2	359	309.3
10	0.2	60	8.6	110	29.0	160	61.4	210	105.8	260	162.2	310	230.6	360	311.0
11	0.3	61	8.9	111	29.6	161	62.2	211	106.9	261	163.5	311	232.1	361	312.8
12	0.3	62	9.2	112	30.1	162	63.0	212	107.9	262	164.7	312	233.6	362	314.5
13	0.4	63	9.5	113	30.6	163	63.8	213	108.9	263	166.0	313	235.1	363	316.2
14	0.5	64	9.8	114	31.2	164	64.6	214	109.9	264	167.3	314	236.6	364	318.0
15	0.5	65	10.1	115	31.7	165	65.3	215	110.9	265	168.5	315	238.1	365	319.7
16	0.6	66	10.5	116	32.3	166	66.1	216	112.0	266	169.8	316	239.7	366	321.5
17	0.7	67	10.8	117	32.9	167	66.9	217	113.0	267	171.1	317	241.2	367	323.3
18	0.8	68	11.1	118	33.4	168	67.7	218	114.1	268	172.4	318	242.7	368	325.0
19	0.9	69	11.4	119	34.0	169	68.5	219	115.1	269	173.7	319	244.2	369	326.8
20	1.0	70	11.8	120	34.6	170	69.4	220	116.2	270	175.0	320	245.8	370	328.6
21	1.1	71	12.1	121	35.1	171	70.2	221	117.2	271	176.3	321	247.3	371	330.3
22	1.2	72	12.4	122	35.7	172	71.0	222	118.3	272	177.6	322	248.8	372	332.1
23	1.3	73	12.8	123	36.3	173	71.8	223	119.3	273	178.9	323	250.4	373	333.9
24	1.4	74	13.1	124	36.9	174	72.7	224	120.4	274	180.2	324	251.9	374	335.7
25	1.5	75	13.5	125	37.5	175	73.5	225	121.5	275	181.5	325	253.5	375	337.5
26	1.6	76	13.9	126	38.1	176	74.3	226	122.6	276	182.8	326	255.1	376	339.3
27	1.7	77	14.2	127	38.7	177	75.2	227	123.7	277	184.1	327	256.6	377	341.1
28	1.9	78	14.6	128	39.3	178	76.0	228	124.8	278	185.5	328	258.2	378	342.9
29	2.0	79	15.0	129	39.9	179	76.9	229	125.9	279	186.8	329	259.8	379	344.7
30	2.2	80	15.4	130	40.6	180	77.8	230	127.0	280	188.2	330	261.4	380	346.6
31	2.3	81	15.7	131	41.2	181	78.6	231	128.1	281	189.5	331	262.9	381	348.4
32	2.5	82	16.1	132	41.8	182	79.5	232	129.2	282	190.9	332	264.5	382	350.2
33	2.6	83	16.5	133	42.5	183	80.4	233	130.3	283	192.2	333	266.1	383	352.1
34	2.8	84	16.9	134	43.1	184	81.3	234	131.4	284	193.6	334	267.7	384	353.9
35	2.9	85	17.3	135	43.7	185	82.1	235	132.5	285	194.9	335	269.3	385	355.7
36	3.1	86	17.8	136	44.4	186	83.0	236	133.7	286	196.3	336	271.0	386	357.6
37	3.3	87	18.2	137	45.0	187	83.9	237	134.8	287	197.7	337	272.6	387	359.4
38	3.5	88	18.6	138	45.7	188	84.8	238	135.9	288	199.1	338	274.2	388	361.3
39	3.7	89	19.0	139	46.4	189	85.7	239	137.1	289	200.5	339	275.8	389	363.2
40	3.8	90	19.4	140	47.0	190	86.6	240	138.2	290	201.8	340	277.4	390	365.0
41	4.0	91	19.9	141	47.7	191	87.6	241	139.4	291	203.2	341	279.1	391	366.9
42	4.2	92	20.3	142	48.4	192	88.5	242	140.6	292	204.6	342	280.7	392	368.8
43	4.4	93	20.8	143	49.1	193	89.4	243	141.7	293	206.0	343	282.4	393	370.7
44	4.6	94	21.2	144	49.8	194	90.3	244	142.9	294	207.4	344	284.0	394	372.6
45	4.9	95	21.7	145	50.5	195	91.3	245	144.1	295	208.9	345	285.7	395	374.5
46	5.1	96	22.1	146	51.2	196	92.2	246	145.2	296	210.3	346	287.3	396	376.4
47	5.3	97	22.6	147	51.9	197	93.1	247	146.4	297	211.7	347	289.0	397	378.3
48	5.5	98	23.0	148	52.6	198	94.1	248	147.6	298	213.1	348	290.6	398	380.2
49	5.8	99	23.5	149	53.3	199	95.0	249	148.8	299	214.6	349	292.3	399	382.1
50	6.0	100	24.0	150	54.0	200	96.0	250	150.0	300	216.0	350	294.0	400	384.0

1½!!

single hose

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Friction Loss Calculator - 100 Feet of 1" Hose

GPM	FL	GPM	FL	GPM	FL	GPM	FL	GPM	FL	GPM	FL	GPM	FL	GPM	FL
1	0.0	51	39.0	101	153.0	151	342.0	201	606.0	251	945.0	301	1359.0	351	1848.0
2	0.1	52	40.6	102	156.1	152	346.6	202	612.1	252	952.6	302	1368.1	352	1858.6
3	0.1	53	42.1	103	159.1	153	351.1	203	618.1	253	960.1	303	1377.1	353	1869.1
4	0.2	54	43.7	104	162.2	154	355.7	204	624.2	254	967.7	304	1386.2	354	1879.7
5	0.4	55	45.4	105	165.4	155	360.4	205	630.4	255	975.4	305	1395.4	355	1890.4
6	0.5	56	47.0	106	168.5	156	365.0	206	636.5	256	983.0	306	1404.5	356	1901.0
7	0.7	57	48.7	107	171.7	157	369.7	207	642.7	257	990.7	307	1413.7	357	1911.7
8	1.0	58	50.5	108	175.0	158	374.5	208	649.0	258	998.5	308	1423.0	358	1922.5
9	1.2	59	52.2	109	178.2	159	379.2	209	655.2	259	1006.2	309	1432.2	359	1933.2
10	1.5	60	54.0	110	181.5	160	384.0	210	661.5	260	1014.0	310	1441.5	360	1944.0
11	1.8	61	55.8	111	184.8	161	388.8	211	667.8	261	1021.8	311	1450.8	361	1954.8
12	2.2	62	57.7	112	188.2	162	393.7	212	674.2	262	1029.7	312	1460.2	362	1965.7
13	2.5	63	59.5	113	191.5	163	398.5	213	680.5	263	1037.5	313	1469.5	363	1976.5
14	2.9	64	61.4	114	194.9	164	403.4	214	686.9	264	1045.4	314	1478.9	364	1987.4
15	3.4	65	63.4	115	198.4	165	408.4	215	693.4	265	1053.4	315	1488.4	365	1998.4
16	3.8	66	65.3	116	201.8	166	413.3	216	699.8	266	1061.3	316	1497.8	366	2009.3
17	4.3	67	67.3	117	205.3	167	418.3	217	706.3	267	1069.3	317	1507.3	367	2020.3
18	4.9	68	69.4	118	208.9	168	423.4	218	712.9	268	1077.4	318	1516.9	368	2031.4
19	5.4	69	71.4	119	212.4	169	428.4	219	719.4	269	1085.4	319	1526.4	369	2042.4
20	6.0	70	73.5	120	216.0	170	433.5	220	726.0	270	1093.5	320	1536.0	370	2053.5
21	6.6	71	75.6	121	219.6	171	438.6	221	732.6	271	1101.6	321	1545.6	371	2064.6
22	7.3	72	77.8	122	223.3	172	443.8	222	739.3	272	1109.8	322	1555.3	372	2075.8
23	7.9	73	79.9	123	226.9	173	448.9	223	745.9	273	1117.9	323	1564.9	373	2086.9
24	8.6	74	82.1	124	230.6	174	454.1	224	752.6	274	1126.1	324	1574.6	374	2098.1
25	9.4	75	84.4	125	234.4	175	459.4	225	759.4	275	1134.4	325	1584.4	375	2109.4
26	10.1	76	86.6	126	238.1	176	464.6	226	766.1	276	1142.6	326	1594.1	376	2120.6
27	10.9	77	88.9	127	241.9	177	469.9	227	772.9	277	1150.9	327	1603.9	377	2131.9
28	11.8	78	91.3	128	245.8	178	475.3	228	779.8	278	1159.3	328	1613.8	378	2143.3
29	12.6	79	93.6	129	249.6	179	480.6	229	786.6	279	1167.6	329	1623.6	379	2154.6
30	13.5	80	96.0	130	253.5	180	486.0	230	793.5	280	1176.0	330	1633.5	380	2166.0
31	14.4	81	98.4	131	257.4	181	491.4	231	800.4	281	1184.4	331	1643.4	381	2177.4
32	15.4	82	100.9	132	261.4	182	496.9	232	807.4	282	1192.9	332	1653.4	382	2188.9
33	16.3	83	103.3	133	265.3	183	502.3	233	814.3	283	1201.3	333	1663.3	383	2200.3
34	17.3	84	105.8	134	269.3	184	507.8	234	821.3	284	1209.8	334	1673.3	384	2211.8
35	18.4	85	108.4	135	273.4	185	513.4	235	828.4	285	1218.4	335	1683.4	385	2223.4
36	19.4	86	110.9	136	277.4	186	518.9	236	835.4	286	1226.9	336	1693.4	386	2234.9
37	20.5	87	113.5	137	281.5	187	524.5	237	842.5	287	1235.5	337	1703.5	387	2246.5
38	21.7	88	116.2	138	285.7	188	530.2	238	849.7	288	1244.2	338	1713.7	388	2258.2
39	22.8	89	118.8	139	289.8	189	535.8	239	856.8	289	1252.8	339	1723.8	389	2269.8
40	24.0	90	121.5	140	294.0	190	541.5	240	864.0	290	1261.5	340	1734.0	390	2281.5
41	25.2	91	124.2	141	298.2	191	547.2	241	871.2	291	1270.2	341	1744.2	391	2293.2
42	26.5	92	127.0	142	302.5	192	553.0	242	878.5	292	1279.0	342	1754.5	392	2305.0
43	27.7	93	129.7	143	306.7	193	558.7	243	885.7	293	1287.7	343	1764.7	393	2316.7
44	29.0	94	132.5	144	311.0	194	564.5	244	893.0	294	1296.5	344	1775.0	394	2328.5
45	30.4	95	135.4	145	315.4	195	570.4	245	900.4	295	1305.4	345	1785.4	395	2340.4
46	31.7	96	138.2	146	319.7	196	576.2	246	907.7	296	1314.2	346	1795.7	396	2352.2
47	33.1	97	141.1	147	324.1	197	582.1	247	915.1	297	1323.1	347	1806.1	397	2364.1
48	34.6	98	144.1	148	328.6	198	588.1	248	922.6	298	1332.1	348	1816.6	398	2376.1
49	36.0	99	147.0	149	333.0	199	594.0	249	930.0	299	1341.0	349	1827.0	399	2388.0
50	37.5	100	150.0	150	337.5	200	600.0	250	937.5	300	1350.0	350	1837.5	400	2400.0

1"
singlehose

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3.3 Friction Loss in Fire Hose

Friction loss is the resulting resistance as water (fluid) moves along the inside wall of either a hose, pipe, or hose fittings.

Points to remember about friction loss:

1. Friction loss increases as flow (gpm) increases.
2. Total friction loss varies with length -- the greater the length, the higher the friction loss.
3. Friction losses on reeled hose average about 21 percent more than for straight hose lays.
4. Friction loss is nearly independent of pressure.
5. Friction loss varies with type, lining, weave, quality, and age of the hose.
6. Friction loss increases 4 times for each doubling of water flow. Reducing the diameter of a hose by 1/2 will increase the friction loss by a factor of 32 for the same flow.

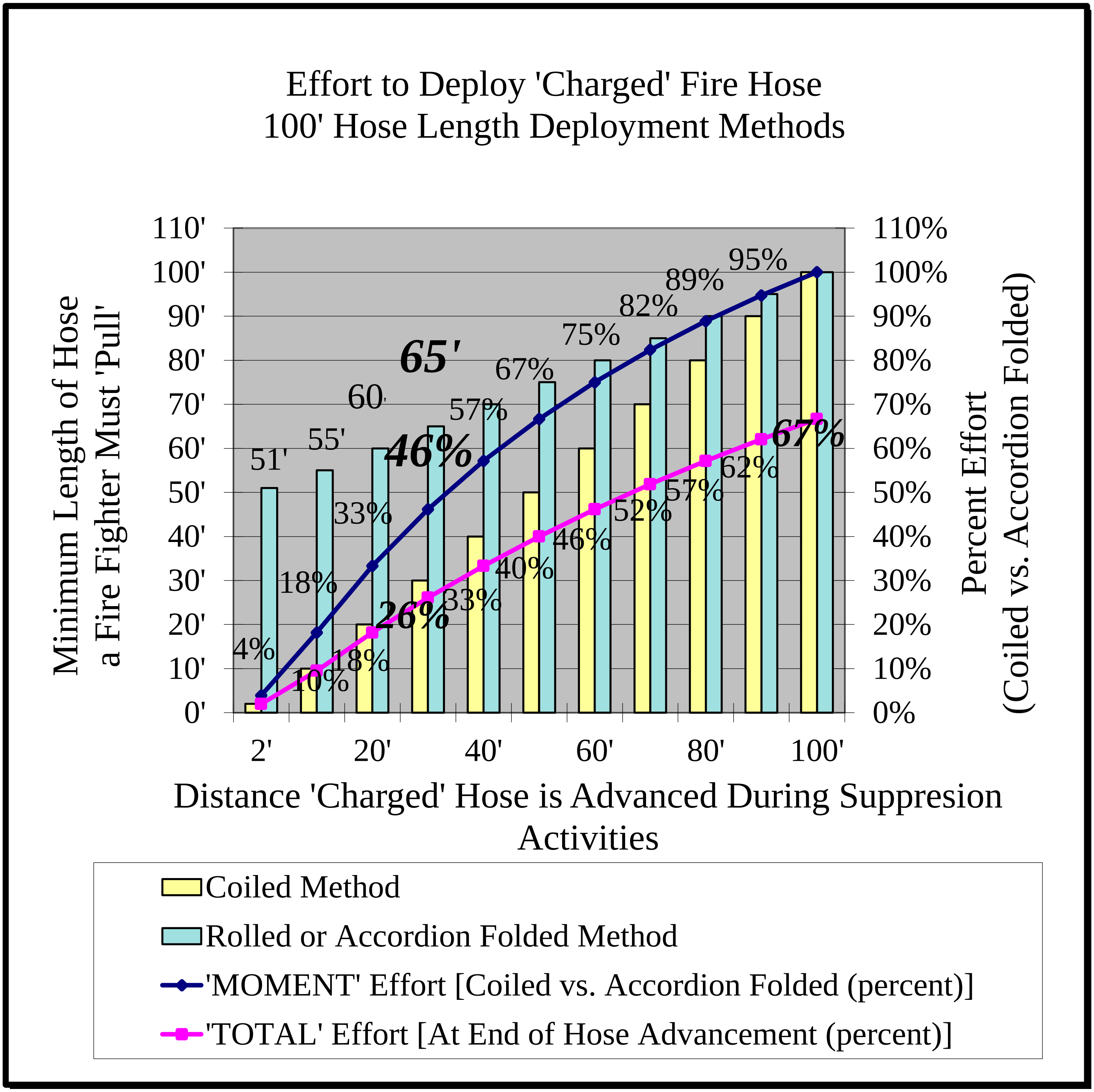
To account for friction loss, the pressure at which the pump is working must be increased. The pump pressure must also be or decreased to compensate for the head loss or gain, to produce the desired nozzle pressure.

The NWCG is the authority to all wildland fire training standards set nationwide as a template for the rest of the world to follow. Please take a moment to visit their website at https://www.nwcg.gov to obtain the information you need to push your career forward in the direction only you know that will best serve you… so you can better serve others.

BE SAFE… BE FIRELINE SAFE!

Effort to Deploy Fire Hose

'Bundle' (Coiled) vs. Folded/'Double-Donut' Rolled
'Moment' and 'Total' Energy Expended/Required



The purpose of this graph is to mathematically prove the advantages of utilizing the Laws of Physics that apply to a basic garden hose found 'coiled' at its water supply (faucet) also applies to ALL fire hose in that the 'Moment' energy and 'Total' energy to deploy two (2) basic methods are fully illustrated and compared.

The two (2) basic configurations include first, the traditional and most popular 'minuteman' or 'triple-fold' flat load or 'double-donut' roll (100') that requires literally every fold (to fit within an specific compartment or cabinet on fire apparatus is then a pre-engineered water restrictive kink) that MUST FIRST always be painstakingly unfolded before the first drop of water is adequately pressurized to produce the necessary Nozzle Pressure (NP) for firefighter SAFETY. The second (and least popular?) is the 'Coiled' method (i.e. Cleveland, Gnass, etc.) that can be fully charged literally in mere seconds… within feet of is pressurize source… and especially even in confined spaces in which ZERO manipulation of the hose is ever required to secure FULL Nozzle Pressure (NP) at literally every stage of deployment… from within feet of a fire apparatus… up to the full length of the hose. [**http://HoseRoller.net**]

Please carefully identify each component of this graph. The ***BLUE BAR*** graph illustrates the typical 50' 'tail' of hose that is dragged behind a firefighter when advancing/pulling a 150' 'pre-connect' or 'Live-Line' of folded hose or the minimum of 50' behind a 100' 'Double-Donut' roll of hose that is (stupidly) unrolled, in reverse, back down the very hill just traversed.

The ***YELLOW BAR*** illustrates the 'tail' of hose that is dragged behind a firefighter when advancing/pulling 100' of hose from a 'high-rise' or wildland ('Cleveland'/Gnass) 'Bundle' or the last 100' of hose of any (properly) prepared coil configuration pre-connect a firefighter must pull to advance from the location in which a hose bundle is simply dropped on the ground and CHARGED! …no matter where the 'Bundle' is placed during the deployment process as I demonstrate in scene #1: AFTER walking around a parked car and then walking through into one (1) bay door to exit a second/adjacent garage/bay door, thus fully wrapping the solid post between each, the hose is then FULLY charged… with NO KINKS… and then deployed to its full length in less than 40 seconds… never pulling any more charged hose than what I ever needed from the moment the hose was pressurized up to its full length. And only ONE (1) firefighter to accomplish this entire evolution but in record time!

Any other hose-load configuration (Flat-Load, Triple-Fold, modified Minute-Man) with any tail whatsoever would immediately cease all forward progression at the first right-angle turn at the first rear tire of the car. But instead, I demonstrate an EFFORTLESS deployment that simulates advancing up to the point of entry into a burning building, and near effortless advancement of fully charged line into the building, with full nozzle protection at every step of the way to a fire victim, while simultaneously creating an excellent indicator for emergency egress (follow the hose back to SAFETY) by the shortest distance out of the danger zone. In other words, a hose 'bundle' can be advanced DRY and with NO effort to a point at which water is finally necessary for the protection from and suppression of the fire. As long as the hose is coiled to its 'Minimum Critical Inside Diameter' for all kinks to be prevented, it can then be fully pressurized in mere seconds from the moment the pump panel valve is opened.

The ***BLUE LINE*** graph illustrates the amount of ***MOMENT EFFORT*** given as a percentage in effort/energy to simply advance/pull any hose at any one point in the deployment process given at a specific distance when comparing the 'Bundle' method vs. that of a folded/rolled method. The ***BOLD*** example upon advancing **30' of 'COILED' hose [*YELLOW BARs in a triangular illustration*] is *46%* of the effort to pull the same charged hose, but because it is folded or rolled to always have at least a 50' tail, it is compared to the 65' length of folded/rolled hose** [***BLUE BAR***] that is being dragged at that 30' foot distance from the point at which the hose was first charged.

The ***MAGENTA LINE*** graph illustrates, as a percentage also, the comparison of ***'TOTAL'* EFFORT OF THESE COMPARED HOSE ADVANCE** evolutions of the Coiled 'Bundle' Method vs. that of the folded/rolled method from the point of commencement. The coiled method at 2' feet is 4% of the moment effort, at 10' feet it was 18% of the moment effort, at 20' feet it was 33% of the moment effort, and at 30' feet it is 46% of the moment effort…

…but what is key is the TOTAL EFFORT from start to finish. The TOTAL EFFORT of the entire evolution, when you measure the SURFACE AREA under all* YELLOW BARS *compared the SURFACE AREA under all the corresponding BLUE BARS, it is then, therefore, evidenced the TOTAL EFFORT from zero (0') to 30' only 26%!

Hence, in the same way, that the video at **http://HoseRoller.net** [and **http://HoseCabinet.com**] demonstrates that one firefighter can do the same work as four (4)… in one quarter (¼) the time… and a quarter of the effort… and with absolutely NO water restrictive kinks EVER! The graph above is the mathematical evidence this evolution of deploying hose from a coil configuration is exactly as all claims are demonstrated as far more efficient than most are even aware, let alone could ever imagine!

The choice is yours! Fold that long flat stuff on that horse wagon… that motorize cart… that $750,000.00 PIERCE! Are you such a traditionalist that you cannot be open-minded to what technology mathematically proves!?! Truly, is there any other method that produces such an incredible calculated and documented result… EVER!?!

About the Author

Richard William Hoffmann, Sr., proud father of one of the youngest ever Special Forces Rescue Swimmers in Naval history… who is now fulfilling his life long, inspired dream as a naval aviator assigned stateside at Oak Harbor Naval Air Station… is not only the creator of the world's first-ever seven (7) variable Excel spreadsheet to complete any Engine Pressure (EP) calculation in the Standard wildland hoselay configuration but has now created both the Android and iOS phone apps and the mechanical slide-rule that can be utilized in the field in REAL-TIME… literally, in a matter of moments, able to solve this incredibly complex mathematical calculation process for the sole purpose of establishing and maintaining an effective fire stream based on predictable and irrefutable laws of physics that have not been disputed in well over the past century.

Not only has Mr. Hoffmann mastered this process in a manner that literally anyone in the field with a basic understanding of Fire Hydraulics (Fire Engine Pump Pressure Calculations) can employ this technology, but he has also invented one of the world's first-ever portable fire hose rollers (it actually fits in nearly any compartment of a standard fire apparatus) that rolls up every length of dry and flat fire hose from a 50' ft. length of ¾" "Peanut Line", graduating through the attack-lines clear up to a 100' ft. length of Agnus 5" LDH weighing upwards of 125 lbs. or more!

The hose roller allows for a dual function that rolls fire hose both in a single or double 'donut' roll AND coils dry empty fire hose to it's 'Critical Minimum Inside Diameter'. This allows any attack-line or 'pre-connect' to be instantly charged and deployed in a matter of seconds and within mere feet from the rig… to provide a level of Firefighter SAFETY like no other hose deployment method ever attempted at any other time in Fire Service history. Please do enjoy the video [http://hoseroller.net] that the Dean of Students of the Fire Science Division of Texas A & M University requested the copyright of his online video to teach literally EVERY firefighter, up through the ranks of all command staff, who walks through their doors this method since 2006.

This video has over 128,000 international hits. Mr. Hoffmann has received countless correspondence from firefighters from five continents asking, ***"How in the world did you ever figure out such a (SIMPLE-STUPID) method anyway?*** The answer…by utilizing simple laws of physics that most firefighters have taken for granted since implementing 'garden hose' technologies as a child just as I did when I was instructed to fill my doggy's water bowl at age five (5). May I, therefore, ask the simple question,

"***Would you ever fold a garden hose?"*** **If not, WHY NOT!?! …cuz it don't flow water no more!"**

A picture is worth a thousand words… what's a video demonstration worth to you!?! Especially if you KNOW it can save your life! Yes, 500 gallons on board, flowing at full pressure in a matter of seconds… within mere feet from your apparatus… three (3) pre-connects deployed simultaneously from three (3) personnel… able to fight fire at full nozzle pressure… at any distance from the engine up to the full length of deployment… up at risk or engaged in a full-force burn-over… more accurate than an air-tanker or helicopter drop… therefore able to protect our personnel… our greatest resource… at every step of a secured safe egress. **[http://BurnOver.HFTFire.com** as seen at **http://HoseRoller.net]**

In addition to being the only person to invent the first-ever functional fire hose cabinet design and deployment method. This is still waiting to be submitted to our nation's Senate and Congress to be mandated nationwide as the ONLY acceptable methodology and design… in an industry shut down since 2001… literally, three (3) and a half months before his second patent issued **[http://HoseCabinet.com]…**

Mr. Hoffmann has since been able to modify his hose roller to fully function as an Eight-to-One (8-1) mechanical advantage Rope Rescue Winch [**http://RescueWinch.com**] that is able to lower (belay) up to four (4) rescuers and their Stokes rescue baskets complete with all gear to the victims of a vehicle that has careened off a 150' foot cliff; and raise each one, with each patient securely strapped in, at an 8 to 1 advantage in that 50 pounds of effort yields 400 pounds of work accomplished. Never before has something been this innovative for fire and rescue personnel in the Fire Service ever as well!

On his time off when he is not enjoying the beach with awesome company of many friends who have supported him through one incredible trial after another, he applies his creative side by rendering spectacular photographs into even more spectacular digital paintings. In June 2011, he was one of the featured artists at the Ankeny Art Center, Ankeny, Iowa. Please enjoy his work at **http://RHPhotographics.com** and his online video playlist at **http://Paintings.RHPhotographics.com** as well.

It is truly Mr. Hoffmann's desire that any and/or all of these many inventions, of course his most recent that our Creator has blessed him the responsibility of completing to fruition, the world's first-ever Wildland Fire Hydraulics Engine Pressure Calculator: Slide-Rule and Phone Apps **[https://HydraulicsApp.com]** will serve this industry in a way to make a difference for others that the world has yet to ever experience! Mr. Hoffmann looks forward to hearing from you and would love to receive your feedback!