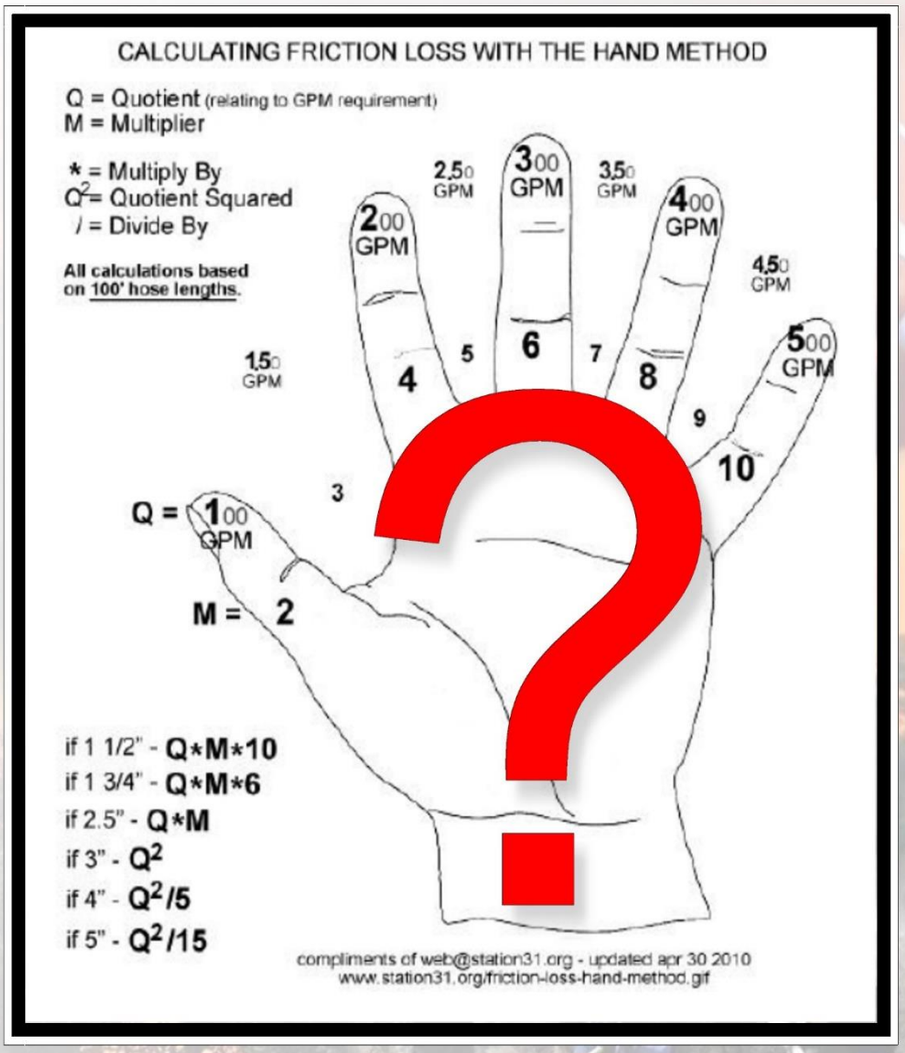
(Wildland)
Hand Hydraulics



Simplified!

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Before discussing every pump operator's primary goal, we must respect the need for every law, rule, regulation, and (SOP) directive is a direct result of the 20/20 hindsight of an incident or circumstance upon another's pain and suffering. The stop sign phenomenon! **NFPA 1002** is very unforgiving that no driver/operator (DO) shall get behind the wheel of any water-pumping fire apparatus until one can demonstrate competency to:

- ***"Produce an effective fire stream at the rated flow of the nozzle."***

But until we compensate for all inherent water flow pressure losses, the minimum Nozzle Pressure (NP) necessary to ensure nozzle fire crew SAFETY will never be possible. Total Pressure Loss is the sum of *ALL* Friction Losses (FL) plus any relevant Appliance (A) pressure loss plus Elevation (H), both up or down. We then research the hose and nozzle manufacturer specifications to determine Nozzle Pressure (NP) to then resolve desired **Engine Pressure (EP)** upon the formula:

Pump Discharge Pressure (PDP) = NP + FL + A (+/-) H

The most challenging aspect of estimating ***[Emphasis added!]*** PDP is, of course, the Friction Loss (FL) component. In that, many variables play a role outside the six (6) constants identified by the NWCG:

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.

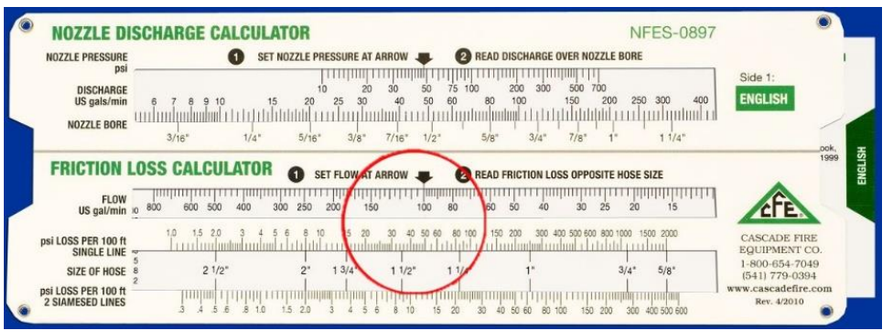
To reduce Friction Loss (FL) in the field, one must either increase the diameter of the hose, use a shorter hose length, utilize parallel (***http://HENway.org***) hose lays, or reduce the tip's size and maintain the same nozzle pressure. Only the latter two can be achieved with the slightest difficulty.

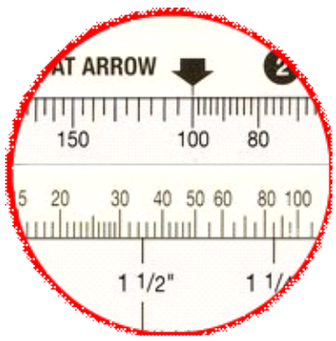
All who embark must demonstrate requisite knowledge. But given that this article addresses wildland fire ground hydraulics, we will focus our

perspective on the criteria established by the ***National Wildfire Coordinating Group*** (NWCG) in all references and applications.

Why is this so important? Real simple. Firefighter safety is only established and maintained upon one's ability to understand the theory and apply all conventional and non-conventional methods to quickly and efficiently yet accurately determine Engine Pressure (EP). And do so to prevent adversely affecting necessary water flow at the nozzle to ensure firefighter safety at all times. In the comfort of a classroom, it was one thing to ace or struggle like hell to demonstrate proficiency in a final exam in a hydraulics course years ago. Still, it is a separate matter to accomplish this requirement in REAL-TIME in the field where the law (NFPA 1002) requires it.

Not only is the feat nearly impossible at the scene of any given incident, but it is significantly more challenging when we lack the tools, technologies, and resources few possess or are even aware exist to help us on our journey. Equally, it's still another to estimate Friction Loss every 100' feet using a mechanical slide-rule updated in 2006 to compensate for an unexpected error since 1944 as:





It again is an entirely different matter to meet OSHA Section 5(a) to calculate *'TOTAL'* Engine Pressure (EP) in REAL-TIME with either an electronic or mechanical device in the field. For example, a phone app (that can never be relied upon due to imminent failure) or equally sophisticated mechanical slide-rule must always ensure firefighter nozzle-person safety. And do so quickly and efficiently the moment any fire hose advancement or configuration changes.

Then we must inquire, are we genuinely upholding NFPA 1041 and OSHA 29 CFR 1910.156 (C)(1) and (C)(2): ***"Firefighters shall be trained properly and in a manner not to endanger them."*** So where do we draw the line regarding just *'winging it'* upon any *'rule of thumb'* that may remain as established for decades?

"Upon pointing one's thumb up at arm's length, increase Engine Pressure (EP) until the nozzle firefighter's boots rise a full thumbnail off the ground!

Then and only then is the driver/operator permitted to reduce the throttle by half a turn!" *Hydraulics reduced to simplest form! …OMG!*

More of anything has not always proven to be better, but looking at the other side concerning personnel safety, what if the maximum Engine Pressure (EP) that fire pumping apparatus can generate safely is insufficient? How and when do we genuinely know if we breach these limits? And still, be compliant with the ***'Holy Grail'*** requirement of REAL-TIME location and situation status verification, and the ability to send an immediate 'SOS' distress signal, especially when standard operations cause any risk of loss of communication with our personnel (i.e., splitting the crew to babysit the grappling-hook water-restrictive-kink up to 90' feet behind the nozzle personnel during a wildland fire double donut hose deployment.)

Today's technologies have vastly improved the execution of strategically planned operations compared to the complacency of traditionalists established by the unavoidable guesswork to perpetuate the unquestioned 'norm' of long ago. For example, it was Standard procedure that budgetary needs determined the limits to purchasing handheld radios to establish essential communication during my first days in the fire service through the mid-1980s. And primarily only because the decision-makers of the time got by without them, it was the attitude *'newbies'* certainly could also.

And upon no feedback from the field to verify if adequate nozzle flow and pressure are generated correctly, primarily upon multiple lengths extended uphill, it's been commonplace to *'guestimate'* the slope with no idea how much HEAD (H) to add to the overall equation as well. Need I say more? The best we could do is hope to apply in the field what we thought we might remember in class years ago. Lastly, when do we truly have the time to invest the effort to perform math calculations when prioritizing incident mitigation, resource coordination, crew supervision, and rescue and evacuation of fire victims in the wake of any emergency or disaster?

And once we are flowing the adequate nozzle pressure for our crew's safety, can we estimate the actual delivered GPM/LPM rate of any given water tender and determine how large our portable storage capacity must be to support such operations? And especially when everything goes to hell without under-ordering, and just as importantly, over-ordering resources to place adjacent jurisdictions in a '*CODE-RED*' status with no water tenders available in case of a simultaneous incident. ***http://WaterTenderApp.com***

Yet concerning fire ground hydraulics, many apps today, like never before, help us to determine 'TOTAL' Engine Pressure when engaging in structural fighting. But what about Wildland Fire control and mitigation?

Regardless of the application, upon strict, unvarying guidelines of NFPA 1002, is it not our duty and responsibility to be fully informed of the *'WHY'* in 2006, the ***San Dimas Technology and Development Center*** in San Dimas, California, replicated the tests that determined the ***'Moody Chart's'*** results of 1944? Wouldn't it be wise to apply today's technology of a B-1 bomber and not that of a B-17 antique to verify or refute as many as 10,000 analyses completed during WWII to determine a more accurate MEAN AVERAGE of the "C" coefficient to estimate Friction Loss (FL)?

And then establish the record of the maximum flow rates in any given 100' foot length of a specific diameter hose or pipe when compared side by side to another of equal diameter. We can then finally apply *Darcy-Weisbach's* formula of 1903 (hydraulics) upon the *Hazen-Williams Equation* calculation formula in the 19th century to theorize (water) fluid velocity (GPM/LPM) and delivery rates based on specific, measurable results of each hose manufacturer.

However, when theory collides with practical results in the field, the lack of nozzle pressure is no excuse for one's inability to compensate for all pressure losses generated to ensure firefighter safety. The "C" coefficient values in every credible article, manuscript, and chart remind us that practical field testing is the only true methodology to predict and demonstrate adequate Pump Discharge Pressures (PDP). Without it, personnel safety cannot be established or maintained.

Since this article focuses primarily on wildland fire application, we will reference the USDA Forest Service-approved hydraulics slide-rule results created to measure the Friction Loss (FL) at every 100' upon the internationally accepted formula:

Friction Loss (FL) = (GPM/100)^2 * "C" * L/100'

Each result is added and totaled with all other results from each GPM affected section in any wildland fire hoselay. The 'Standard' methodology proven most efficient under most conditions today is a 1.5" single jacket hose line (that serves as attack and supply) with 1.0" laterals (every 200' ft.), Engine Pressure (EP), or PDP is the sum of all factors.

However, to be NFPA 1041 compliant (firefighters are to be trained correctly and in a manner not to endanger them), the incredible variance of the "C" coefficient demonstrated a **46% ERROR for the 1 ½" hose and a 67% ERROR for the 1" hose**. For 62 years, we had no idea the unquestioned Friction Loss (FL) results were the cause of every unanticipated reduced

nozzle pressure affected by this unknown—an unknown upon an internationally recognized calculation formula in place for 120 years.

Please note that different hose manufacturers publish their results based on rigidity and expansion under pressure [i.e., Key Hose 1.5" hose NOT designed for Wildland and multiple length extension, declares a Friction Loss (FL) "C" component at less than fourteen (14)]. Therefore, this article will remain objective only to the NWCG adjustment to the Standard as evidenced by the USDA Forest Service mechanical slide rule herein.

1.5" diameter hose (the primary trunk/attack/supply line of any wildland hose lay) is evidenced **in error as NOT the recognized multiplying factor of 24, but rather *35*. That is an incredibly significant *46% error* upon the Laws of Physics *demand CHANGE to ensure firefighter SAFETY!***

Additionally, it is further verified that the MEAN AVERAGE Coefficient for a **1.0" diameter hose** (diameter of every lateral on a wildland hose lay) was NOT the "C" multiplying factor of **150**... but instead ***250***. An incredible ***67% error to again demand necessary CHANGE to ensure firefighter SAFETY!***

Hence, 60 GPM in a 1.5" is measured today at approximately 12.5 PSI/100' (and not 8.5 PSI/100' as previously believed) and is now the recognized Standard for over sixteen (16) years. What does your SOP require?

Please respect Battalion Chief Robert Avsec's (ret.) article in *FireRescue1.com* on March 13, 2017, titled: *"How to calculate and overcome friction loss."* *There are two ways to calculate friction loss: the theoretical method or the fireground method — here's the fireground method.*

I want to take this opportunity to expand on his article to illustrate the simplicity of performing an identical process to determine wildland fire hydraulics. Even Battalion Chief Robert Avsec's HAND-HYDRAULICS article on technology invented decades ago; his multiplication factor (F) of (10) supports the new coefficient for 1.5" is now 35 and not 24 as once believed.

First, to understand the theory, many references (articles and video presentations) are published online for your convenience. To recap, we assign the number one (1) to the thumb and, in sequence, each successive number through five (5) to the remaining four (4) fingers of one's left hand; this represents "Q," which is GPM divided by 100 up to 500 GPM. In between each finger, we add 50 GPM to include estimations for 150 GPM, 250 GPM, etc.

Next, we establish the multiplier "M," starting with the number TWO (2) at the base of the thumb and number THREE (3) between the thumb and

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index finger, and so on. Finally, we progress with each multiplier (M) accordingly assigned between and upon each finger until we arrive at ten (10) on our left pinky finger.

The ratio of the volume of water to the surface area of the hose lining determines the final coefficient factor. For example, 1.5" dia. hose is SAFER to be assigned ten (10) as the multiplication factor. It may be closer to nine (9), but ten (10) is much simpler to multiply in the field. An example for 150 GPM through 200' of the hose is:

[1.5 * 3 * 10 * (200/100) = **90 PSI FL**] Conversely, the **SDTDC Standard** calculates [150 GPM/100)^2 *35 * 200'/100' = **78 PSI FL**] Again, to get us in the ballpark.

However, regarding the 1.75" hose, Battalion Chief Robert Avsec is again correct, though his multiplying factor could initially seem a bit low at six (6).

[2.0 * 4 * ***6*** * (200/100) = **96 PSI FL**] Conversely, the **SDTDC Standard** calculates [200 GPM/100)^2 ****14*** * 200'/100' = **112 PSI FL**]

As I referred to *Key Hose*, many manufacturers do all they can to deliver more water more efficiently to create hoses that flex/expand to a larger inside diameter (ID.) Many 1.75" lengths measure up to 1.88" inside diameter (i.D.). This MEAN-AVERAGE coefficient "C" has been recorded as low as 9.5 instead of 14. When doing the math, that's only ***76 PSI***! That is over **35 PSI LESS pressure loss at 30%** upon achieving only a mere 1/8" of an inch larger inside diameter.

Shifting this application back to Wildland, what if we have neither a ***https://HydraulicsApp.com*** nor a ***https://HydraulicsSlideRule.com*** to determine proper pump discharge pressure (PDP) for firefighter safety?

The typical method of deploying a wildland fire 'hose-lay' involves 100' foot 1" inch laterals at every 200' feet of 1 ½" hose; I have simplified the entire process by assigning a pre-Head (H) pump pressure to each finger. However, there are two (2) methodologies of deploying wildland fire hoses, either as a single trunk/supply/attack line or a dual/parallel trunk/supply/attack line (***http://HENway.org***). All 'Head' (H) pressure losses are then calculated upon not counting the contour lines) by hand as well.

At first, I went through the incredibly arduous process of using the same mathematical process by assigning a multiplier to the flow rate in the same way the referred article goes into the complex description to revive an outdated methodology. Then, to much surprise, only to discover that upon flowing water at either one (1) of two (2) attack nozzles rates, 60 PGM or 75

GPM, it is possible to assign each finger and palm of a hand only the maximum (pre-Head) pump pressures at every 200', 400', 600', 800', 1,000', and 1,200' distances. And always respecting the MAXIMUM pump pressure of a Type-3 or Type-6 Wildland Apparatus is governed to STOP at 400 PSI.

Regardless of the flow rate and resulting Friction Loss (FL), Head (H) pressure is determined (only when a hard copy or digital map illustrating each elevation contour line is unavailable) by:

1. Extend one hand (closed fingers and flat) to full arm's length level with the ground and point to the slope before you.
2. Rotate the wrist 90 degrees until facing the palm of a hand with the thumb side up, and pinky down.
3. Adjust up or down on the vertical axis until level with the ground.
4. The top of the hand represents approx. 12.5% slope…
5. When you place the other hand in the same configuration, yet on top of the first, it represents approx. 25% slope
6. Count the number of lengths of the hose lay extended as your "Run."
7. If you stacked two (2) hands, this would be 25%.
8. 25% of 800' is roughly 200' of elevation.
9. 200' of elevation is roughly 100 PSI to be added to the Pump Pressure written on your ring finger.
10. If flowing **60 GPM** in the ***Standard*** mode:
    a. 275 PSI Pump Pressure ***PLUS*** 100 PSI Head (H) = **375 PSI** Pump Discharge Pressure (PDP)
11. If flowing **75 GPM** in the ***http://HENway.org*** mode:
    a. 200 PSI Pump Pressure ***PLUS*** 100 PSI Head (H) = **300 PSI PDP (at 75 PSI Less EP at an incredible 56% better *'knock-down.'*)**

Again, this is quick and dirty to merely get you in the ballpark to ensure proper pump pressure to produce ***an effective fire stream at the rated flow of the nozzle*** **(NFPA 1002)** to satisfy every requirement of the ***'Holy Grail'*** in wildland fire fighting. These calculations can only be achieved upon continuous communication with your crews in the field to meet every mandate of the ***Wildland Fire Management Technology Act of 2018***: Verified location and situation status with the means to send an immediate distress signal before it's too late to dispatch resources to assist evacuation.

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CALCULATING FRICTION LOSS WITH THE HAND METHOD

Q = Quotient (relating to GPM requirement)
M = Multiplier

All calculations based on 100' hose lengths.

L=100'-200'
Q = 60 GPM
EP=125

L=300'-400'
Q=70 GPM
EP=150

L=500'-600'
Q=80 GPM
EP=200

L=700'-800'
Q=90 GPM
EP=275

L=900'-1,000'
Q=100 GPM
EP=350

M =

if 1 1/2" - Q*M*10
if 1 - Q*M*

Note: ALL EP's are pre 'HEAD' calculations

60 GPM 'Standard' Attack

compliments of web@station31.org - updated apr 30 2010
www.station31.org/friction-loss-hand-method.gif

@ 100' to 200' - ***Thumb*** - Pump 125 PSI
@ 300' to 400' - ***Index*** - Pump 150 PSI
@ 500' to 600' - ***Middle*** - Pump 200 PSI
@ 700' to 800' - ***Ring*** - Pump 275 PSI
@ 900' to 1,000' - ***Pinky*** - Pump 350 PSI
@ 1,100 to 1,200 - ***IMPOSSIBLE*** @ 425 PSI

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HFT Fire *"TOTAL"* Wildland Engine Pressure Slide-Rule



The world's first-ever to estimate accurately in mere seconds!

CALCULATING FRICTION LOSS WITH THE HAND METHOD

Q = Quotient (relating to GPM requirement)
M = Multiplier

All calculations based on 100' hose lengths.

L=100'-200'
Q = 60 GPM
EP=125
M =

L=300'-400'
Q=70 GPM
EP=150

L=500'-600'
Q=80 GPM
EP=200

L=700'-800'
Q=90 GPM
EP=175

L=900'-1,000'
Q=100 GPM
EP=225

L=1,100'-1,200'
EP=225

if 1 1/2" - Q*M* 10
if 1 - Q*M*

Note: ALL EP's are pre 'HEAD' calculations

60 GPM
'HENway'
Attack

compliments of web...station31.org - updated apr 30 2010
www.station31.org/firefloss/handmethod.gif

@ 100' to 200' - ***Thumb*** - Pump 125 PSI
@ 300' to 400' - ***Index*** - Pump 150 PSI
@ 500' to 600' - ***Middle*** - Pump 200 PSI
@ 700' to 800' - ***Ring*** - Pump 175 PSI
@ 900' to 1,000' - ***Pinky*** - Pump 225 PSI
@ 1,100 to 1,200 - ***Palm*** - Pump 225 PSI

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CALCULATING FRICTION LOSS WITH THE HAND METHOD

Q = Quotient (relating to GPM requirement)
M = Multiplier

All calculations based on 100' hose lengths.

L=500'-600'
Q=95 GPM
EP=250

L=300'-400'
Q=85 GPM
EP=200

L=700'-800'
Q=105 GPM
EP=350

L=900'-1,000'
Q=115 GPM
EP=425

L=100'-200'
Q = 75 GPM
EP=150
M =

L=1,100'-1,200'
EP=550
Q=125 GPM

if 1 1/2" - Q*M* 10
if 1 - Q*M*

Note: ALL EP's are pre 'HEAD' calculations

compliments of web@[illegible]tion31.org - updated apr 30 2010
www.station31.org/friction-loss-hand-method.gif

75 GPM 'Standard' Attack

@ 100' to 200' - ***Thumb*** - Pump 150 PSI
@ 300' to 400' - ***Index*** - Pump 200 PSI
@ 500' to 600' - ***Middle*** - Pump 250 PSI
@ 700' to 800' - ***Ring*** - Pump 350 PSI
@ 900' to 1,000' ***IMPOSSIBLE*** @ 425 PSI
@ 1,100 to 1,200 ***IMPOSSIBLE*** @ 550 PSI

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HFT Fire *"TOTAL"* Wildland Engine Pressure Slide-Rule



The world's first-ever to estimate accurately in mere seconds!

CALCULATING FRICTION LOSS WITH THE HAND METHOD

Q = Quotient (relating to GPM requirement)
M = Multiplier

All calculations based on 100' hose lengths.

L=100'-200'
Q = 75 GPM
EP=150
M =

L=300'-400'
Q=85 GPM
EP=200

L=500'-600'
Q=95 GPM
EP=250

L=700'-800'
Q=105 GPM
EP=200

L=900'-1,000'
Q=115 GPM
EP=275

L=1,100'-1,200'
Q=125 GPM
EP=250

if 1 1/2" - Q*M* 10
if 1 - Q*M*

Note: ALL EP's are pre 'HEAD' calculations

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www.station31.org

75 GPM 'HENway' Attack

@ 100' to 200' - ***Thumb*** - Pump 150 PSI
@ 300' to 400' - ***Index*** - Pump 200 PSI
@ 500' to 600' - ***Middle*** - Pump 250 PSI
@ 700' to 800' - ***Ring*** - Pump 200 PSI
@ 900' to 1,000' - ***Pinky*** - Pump 275 PSI
@ 1,100 to 1,200 - ***Palm*** - Pump 250 PSI

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