Watchouts to help avoid a Thermal Rise in Dead Heading Portable Pumps

In any pumping arrangement, the very real probability of deadheading a pump, intentionally or otherwise, is a very real prospect to be concerned with. Two previous cases have already taken place where such an event produced injuries. The **Crescent Fire Scald Injury** from 2017, involving two Type 3 engines parallel pumping into a line with 734 feet of elevation, and the most recent one the **Lost Horse Creek Fire** pump burn injury in 2023, where a Mark 3 pump was used to pump water up 753 feet of elevation and into an existing pump at the top of the hill while plumbed into the same line. Opposing pressures.

In both of these scenarios, the head pressure was greater than the pump discharge pressure provided resulting in a deadheading scenario.

On the next page, you will see a rough sketch of what the setup was stated to be arranged according to the report of the Crescent Fire. We are told that the length of the hose lay was between 1,000 – 1,500 feet. Since the focus of this writing is to convey how easy it is for one to be involved in a deadheading situation, we will only concern ourselves with those elements involved.

In the sketch drawn, you will see a depiction of two USFS Type 3 Engines each of which was pumping into a 1 ½” hose to a wye and then to the main trunk line.

The Head is 734 feet, and $734^{ft}$ x .434 = 318 psi in head pressure.

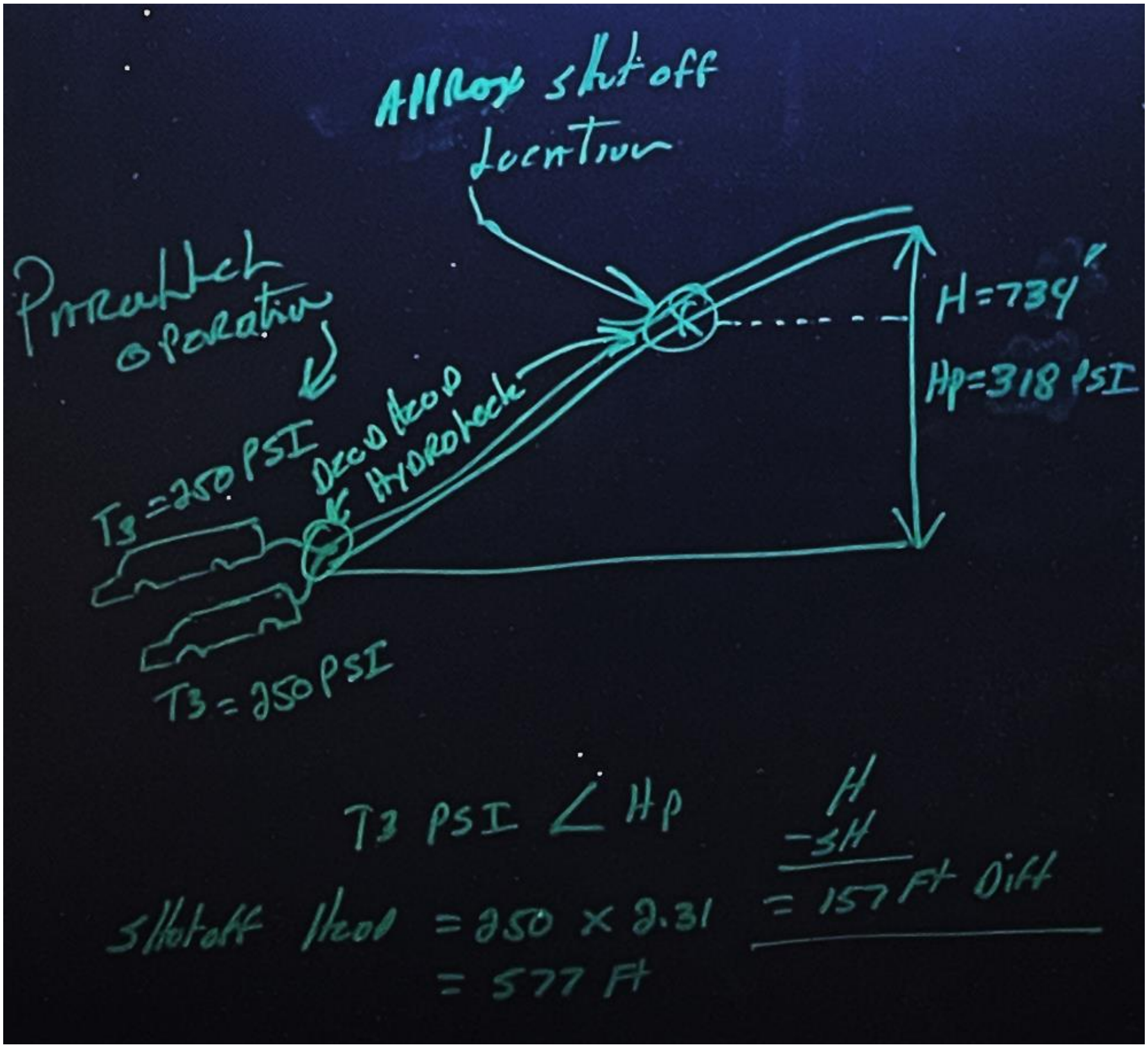
Each engine was pumping to 250 psi. In this type of arrangement, the two pressures are NOT added together.

The Engines are 68 psi below the required head pressure and even if there was only 1 engine plumbed into the trunk line there would still have been a deadheading action taking place for this very reason assuming the water demand is beyond the shutoff head point.

Thus, we have the following: $Type\ 3\ pdp\ <\ Hp\ \therefore\ Dh(dead\ head)\ is\ likely\ to\ be\ at\ 100\%$

The Shutoff Head is the elevation that water is raised to and stops at (zero flow), based upon the pressure setting to which a pump is set. Thus, it changes and is never the same. Shutoff Head in feet is expressed in the following manner as is essentially what you have already been taught in S-211 or PMS-419 except it is stated simply as head pressure. However, the term head pressure may be stated as shutoff pressure and means that once the pressure is reached the flow is essentially shutoff and will cease to rise further.

$$S_h = \frac{psi\ x\ 2.31}{specific\ gravity} = \frac{250\ x\ 2.31}{1} = 577.5, ft$$



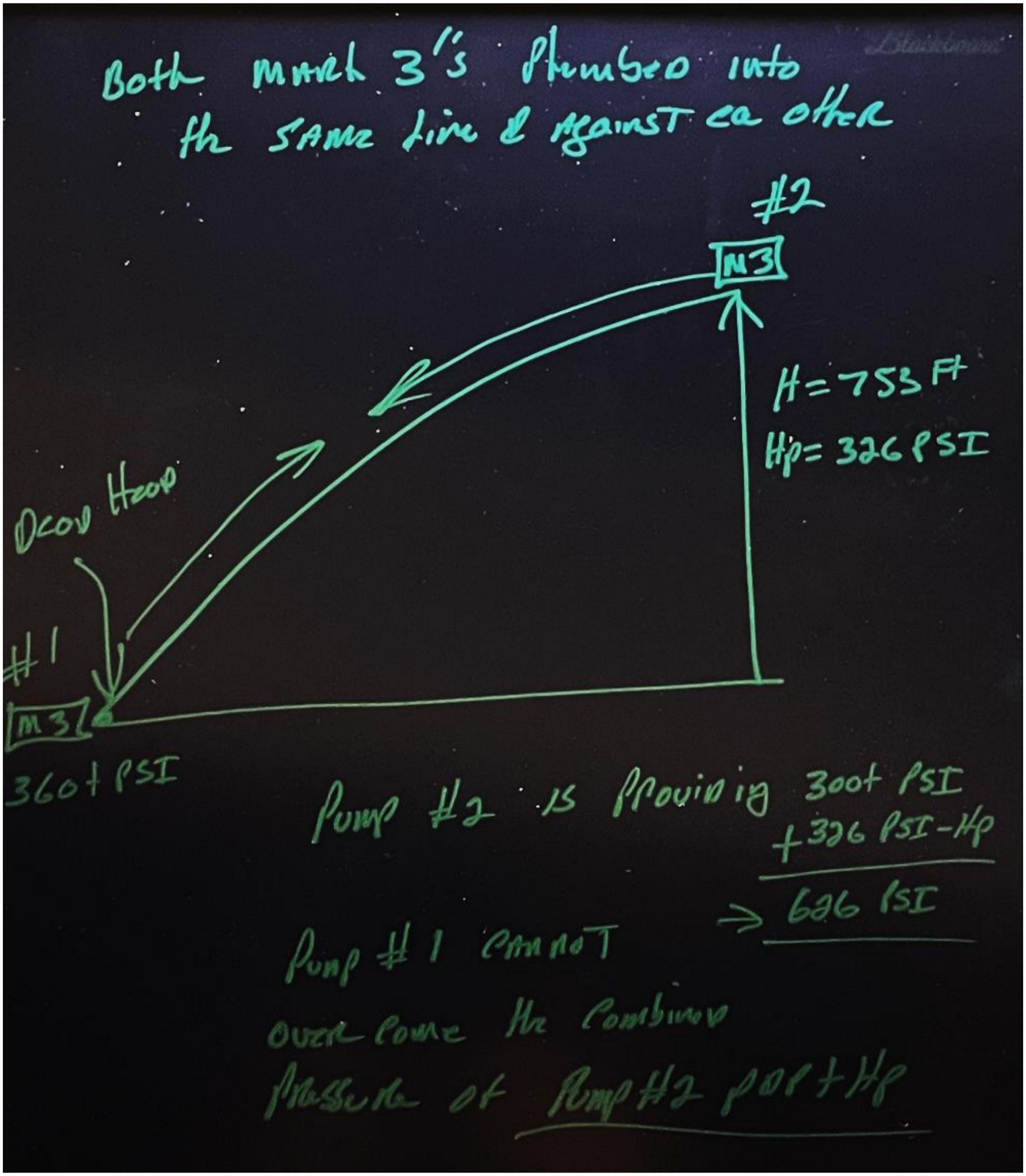

In the Crescent Fire sketch, you can locate the area where the dead head was taking place in conjunction with a potential for hydro-locking on the bottom. This exacerbates an already bad situation.

Also, one should note the difference in head. The pump is only reaching 577 feet and this is 157 feet short in elevation from its target point. Keep in mind this 157ft elevation difference translates to a horizontal difference estimated to be approximately 300 feet assuming a constant slope ratio.

Both engines on the bottom are fighting with each other while at the same time not able to reach the top of the hill.


Sat Image taken 7/2/2017, this is the day after the incident took place.

The Lost Horse Creek Fire involving two mark 3's plumbed into each other sets up the same basic situation. Some may say it is different, however, the result is still the same. Let us look below.




In this sketch, we see that the elevation of Pump#2 is at 753 feet with a head pressure of 326 psi. We now have to add the pump discharge pressure, which we can only assume what pressure this would be, and we'll simply use 300psi as a simple estimate. We can then assume with the two pressures added together that the pump on the bottom would have a net effect of over 600 psi.

Single Jacket forestry hose usually has a working pressure of 450 psi and a test pressure of 600 psi with a burst pressure of 900 psi range.

We stated this was essentially the same thing as the Crescent Fire scenario, now we'll demonstrate why it is and how.

The combined head and pump discharge pressures creating an estimated amount of 626 psi would produce an equivalent shutoff head ($S_{h}$) of:

$$S_h = \frac{psi\ x\ 2.31}{specific\ gravity} = \frac{626\ x\ 2.31}{1} = 1{,}446, ft$$

In this case, it might as well have been if a single Mark 3 pump was trying to pump water straight up a 1,500-foot mountain. We can, however, break this down a bit further.

Let us continue to assume the pump on the bottom, Pump#1, is at full pressure, 380psi. Then let us subtract that from the 626 psi to obtain 246 psi remaining. Now let us further subtract 326 psi from the actual head pressure. This places the pump at -80 psi or:

$$S_h = \frac{psi\ x\ 2.31}{specific\ gravity} = \frac{-80\ x\ 2.31}{1} = -184.8, ft$$

another 184 feet lower in hydraulic effect than it was located at. This pump did not stand a chance and is now in full deadhead mode. We now begin to show the thermal effect of deadheading assuming maximum RPM at zero flow.

The Thermal rise of water inside the pump chamber needs a few assumptions, such as the capacity of the water in weight inside of it. Estimates can be estimated from ½ gallon to 1 gallon for our purposes. The Horsepower is required and so is the Specific heat of water. Then the following formula may be used to determine how fast a mark 3 or any other pump can heat up from a baseline temperature in Deg f per minute.

$$\Delta T_r / \min = \frac{42.4\ x\ Pso}{w1\ x\ Cp} = \frac{42.4\ x\ 10}{4.17\ x\ 1} = \frac{424}{4.17} = 101.7\ degf\ \left(\frac{1}{2} gallon\right)$$

$$\Delta T_r / \min = \frac{42.4\ x\ Pso}{w1\ x\ Cp} = \frac{42.4\ x\ 10}{8.34\ x\ 1} = \frac{424}{8.34} = 50.8\ degf\ (1\ gallon)$$

*Pso is Pump horsepower at shutoff, W1 is the weight in lbs of water inside the pump chamber, and Cp is the specific heat of water, usually for this type of equation 1 is used.*

On the previous page, we can then see that if our Mark 3 pump holds 1 gallon of water within the pump head, and the initial temperature of the water is 50 degrees f, then in 3 minutes the temperature will now be at 200 degrees f.

On the other hand, if the pump head holds ½ gallon, then it will reach 200 degrees in about 1.48 minutes.

There are several major caveats to these scenarios, and how dangerous they and hydraulics are such as that with standard apparatus pumps such as Darley's, the seals are often only good to 160 degrees f and will then begin to fail. The high temperatures move down the pump shaft and heat the bearing gearbox oil and then they begin to erode.

On the hose, the nylon material usually will start to shrink inside the hose fittings at the discharge ports while the fittings are expanding due to the heat rise and coefficients of thermal expansion, and due to the pressures, it makes such easy for fittings to blow apart.

Again, pressurizing the system turns this into a pressure vessel and while the water could be well above boiling temperature it will not boil until the pressure is reduced to the atmospheric pressure equivalent for the boiling temperature altitude.

A good rule of thumb to get into is this: if the head pressure demand alone, will consume 50% of the total pump pressure capability, obtain a second pump. Obtain and learn the Mark 3 pump curve and how to work with the pressures. Learn how to calculate the number of pumps and the pump spacing. It is your life and livelihood that depends on your ability to use these pumps properly and safely.

One issue with the Lost Horse Creek fire that certainly aided in the problem was the fact there was no check and bleeder valve connected to the pump.

Understanding the Capacities of the Mark 3 & any other pump is on the wildfireengineer.com site. The purpose of this writing is to bring awareness to the possible dangers of deadheading pumps and the potential effects by stating opinions. Such does not relieve anyone of their sound judgment and decision-making.

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