Cavitation: Warning Signs and Reasons Why it Occurs

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One of the most common errors on the fireground is the tendency of pump operators to try and pump more water to hose lines than the pump is receiving. This procedure is often referred to as ' running away from the water supply' or cavitation.

Most fire department pump operators have a general idea of what cavitation is and some of the ways to go about reducing or avoiding it, but when probing beyond these very general concepts, knowledge seems to be somewhat limited in most cases.

It is a known fact that cavitation does serious damage to fire pumps. This is especially true if the pump is subjected to cavitation over a long time. Since the effects are cumulative, the damage that occurs each time the pump cavitates is added to the damage previously caused by cavitation. If prolonged or repeated cavitation is allowed to occur, pretty soon the pump will no longer function properly and it will have to be overhauled.

Understanding cavitation

Engineers or pump operators are usually trained with this in mind, but it might prove beneficial to take the training a step further and examine some of the causes and effects of cavitation in more detail. A better understanding of what is taking place inside the pump will enable pump operators to foresee and avoid unnecessary and costly damage to equipment.

First of all, to gain a better insight into what takes place inside the pump, we need to take into consideration a few of the unique characteristics of water.

We know that at sea level water will boil if its temperature is raised to approximately 212°F. This assumes a normal atmospheric pressure of 14.7 psi. If we place the water in a closed container and add pressure the boiling point rises. This is why we use pressure caps on auto radiators and pressure cookers to prepare food. It stands to reason that food will cook faster when boiled at 250 degrees than it will at 212 degrees. This elevated boiling point is obtained by adding 15-psi pressure. An auto will also stand a much less chance of running hot and boiling out its coolant if the boiling point of the coolant is raised several degrees.

So far, the best way found to achieve an elevated boiling point is with the addition of pressure. Without it, water will reach 212° and continue boiling until it has completely vaporized. The temperature of the water will not rise above 212°. Additional heat only speeds the evaporation or boiling rate. Boiling is nothing more than rapid vaporization of water. It occurs whenever the vapor pressure within the liquid becomes equal to atmospheric pressure.

We most often associate this equalization of pressures with the addition of heat, but the same results can be obtained by reducing atmospheric pressure. At higher elevations, water boils at a temperature less than 212° due to lower atmospheric pressure. Of course, lower atmospheric pressure is normal at higher elevations, but we can create the same effect at any elevation by placing water under a vacuum.

Boiling Point of Water

At sea level, 14.7 psia,

Positive Pressure		Vacuum	
PSIG	Degrees F	In. Hg	Degrees F
5	227.96	5	203.08
10	240.07	10	192.37
15	250.33	15	179.14
20	259.28	20	161.49
25	267.25	25	133.76
30	274.44	27	101.96
35	281.01	29	79.03
		29.5	58.80
		29.8	34.57

The boiling point of water is raised according to the amount of pressure applied and it is lowered according to the amount of vacuum to which it is subjected. In other words, if water in a closed container is subjected to positive pressure, the boiling point will go up. How far up it will go is determined by the amount of pressure applied. But if this same container is subjected to a vacuum, the boiling point will be lowered from the normal 212°. The greater the vacuum, the lower the boiling point will be.

Pressure and vacuum effects

The effects of pressure and vacuum on the boiling point of water are shown in the accompanying table. The boiling point of water is 212°F at sea level, where the atmospheric pressure is 14.7 pounds per square inch absolute (psia). Pressure gages at sea level show a reading of 0 pounds per square inch gage (psig). Thus, positive pressures in the table are psig, which means they are in addition to the normal sea level atmospheric pressure of 14.7 psia. Negative pressure in the table, stated in inches of mercury, are less than 14.7 psia, the normal sea level atmospheric pressure.

As you can see from the table, at 29.8 inches of mercury, the boiling point of water is 34.57°F. This is close to the normal freezing point of water, but the freezing point also is lowered when water is subjected to a vacuum. This particular characteristic of water is not important to the phenomenon of cavitation, however, and will not be pursued further.

When a centrifugal pump is attempting to discharge more water than it is receiving, a vacuum is created near the eye of the impeller. This may happen while pumping from draft or a hydrant. The real problem in either case is running away from the supply and causing a vacuum to occur.

Water flashes into vapor

As the vacuum increases, the boiling point of the water is lowered until it reaches a point near the impeller eye where it flashes into vapor and enters the impeller.

Once the vapor pockets, or bubbles, enter the impeller, the process begins to reverse itself. As the vapor reaches the discharge side of the pump, it is subjected to a high positive pressure which condenses the vapor back to a liquid. The sudden change from vapor pockets to a liquid generates a shock effect that damages the impeller and pump housing. Usually there are thousands of tiny vapor pockets rather than a few large ones. The collapse of these vapor pockets is referred to as implosions. To implode means to burst inwardly.

The damage done during any one period of cavitation is not great, but if cavitation is repeated over a long period, the effects can disable an otherwise perfectly good pump. Implosions occurring during cavitation tend to break away or erode tiny pieces of metal from moving parts and from the pump casing. When enough metal has been chipped away, the impeller becomes unbalanced thereby causing an undue strain and vibration on bearings, bushings and shafts.

The sound created by a pump while cavitating has been described as similar to that of a handful of pebbles circulating throughout the pump. This sound is not made by the numerous vapor pockets passing through the pump, as is often assumed, but it is the sound resulting from the implosion of these vapor pockets as they become subjected to positive pressure and condense.

Once cavitation begins, the pump is working at its maximum output unless the water supply can be increased. Speeding up the pump in the vain hope of increasing pressure and flow will only cause cavitation to become much worse increase the chances of pump damage and may cause an even worse occurrence, interruption of fire fighting streams already in use.

The fact that subjecting water to a vacuum has the result of lowering the boiling point, can also have a real bearing on the pump's ability to draft warm or hot water. One reason is because water that is already hot requires only a small amount of vacuum to make it give off excessive vapors. This may cause the pump to lose its prime much the same way it would if an air leak occurred from the outside.

Remember that the warmer water becomes the faster it gives off vapors until the boiling point is reached. At the boiling point, the vapor pressure of water is equal to atmospheric pressure and water reaches its maximum vaporization rate.

When taking suction from a hydrant, the temperature does not have a significant effect until the pump begins to exceed the capacity of the hydrant. Once this happens and a vacuum is created, it has the same effect of increasing vaporization because the water is nearing its boiling or equalization point just the same.

Cavitation while drafting

As stated earlier, cavitation occurs any time the pump tries to deliver more water than it is received thereby creating a vacuum on the suction side of the pump. When the pump is operating at draft, it has a vacuum on the suction side. However, when it tries to pump more than it is drafting, the pressure on the discharge side is reduced and the amount of vacuum on the suction side is increased until cavitation or loss of prime occurs.

This situation can be brought about by pumping at high altitudes, which has the same effect as low atmospheric pressure, a partially blocked suction strainer, a suction hose too long or too small, a lift that is too high, a drafting source that is too warm, or a combination of these conditions.

Don't depend on gages

It is poor practice to depend entirely on vacuum gage to indicate that a pump is nearing cavitation. This is because gage are usually tapped into the intake chamber several inches away from the leading edge of the impeller eye where the greatest amount of vacuum occurs. Some of the most experienced pump operators may he able to judge by the gage, but it is a poor indication at the best.

Indication of cavitation

Whether taking water from a hydrant or drafting, the most reliable indication that a pump is approaching cavitation is when an increase in engine rpm does not cause an increase in pump discharge pressure Small capacity pumpers usually are not overly concerned with cavitation while pumping from a hydrant, but with modern 1250, 1500 and 2000 gpm pumpers, the problem is becoming more prevalent.

If the pump is approaching cavitation and more pressure is needed but no more water is available, discharge gates may have to be choked down. This will allow pressure to increase but will result in a reduction of flow to hose lines At no time should a pump be operated under cavitation-producing conditions for long periods. There is nothing to gain by such practices but an unnecessary repair bill.

Pump operators who are knowledgeable about the causes and effects of cavitation can better operate to avoid it, thereby saving substantial amounts of money and preventing unnecessary shop time for equipment that is needed on the fireground.

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