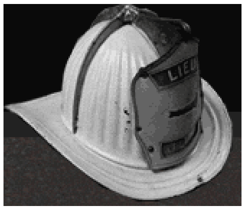

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Drafting Pit Upgrade Assessment

Tinhelmet was passed this assessment via secure channels. It is not important who did the work. I thought the nature of the work and its implications for our operations would be of interest. Enjoy as always.

BACKGROUND

Mr. X of Saudi Aramco contacted Mr___ of [...] to discuss some concerns over the design of drafting pits used for annual service testing of fire department pumpers. The following information is provided courtesy of [...] to Saudi Aramco – while it does not represent the absolute – it does represent a scientific approach to drafting pit design issues for hot weather climates.

DRAFTING THEORY

The basic premise behind drafting with a centrifugal fire pump is that we somehow lower the pressure inside the pump casing so that atmospheric pressure can push the water up the suction hose into the pump. A number of variables affect a centrifugal fire pump's ability to draft. One of the greatest impacts on drafting ability is the presence of air in the system. Since a centrifugal pump cannot pump air, the introduction of air into the pumping system proves detrimental to effective drafting. Common air leak problems include drain or bleeder valves being left in the open position, faulty intake or discharge valves that allow air to pass by when closed, or suction hose connections that do not have an air tight fit. In addition, a pump packing that is in poor condition may also allow air to be introduced into the pump casing causing an air leak problem and poor pump performance.

Next to air, elevation – or lift – is probably the most troublesome factor affecting drafting. Lift is the distance measured from the center of pump intake (eye of the impeller) to the surface of the water. As lift increases, pump capacity decreases. Of course this is directly related to the available atmospheric pressure; at sea level the maximum theoretical lift is just over 33 feet. As elevation increases, atmospheric pressure decreases, thus less pressure exists to push water up into a suction hose. In general, for every 1000 feet of elevation gain, pump lift ability is reduced by about 5 feet.

Other factors that commonly affect a centrifugal pump's drafting ability are the diameter of the suction hose and the type of strainer that is used on the end of the hose. For example, a 750 gpm pump requires a suction hose with at least a 4-1/2-inch inside diameter. On most all centrifugal pumps, by increasing the size of the suction hose diameter we will see a resultant increase in the pump capacity. There is a limit however to this concept and that is based upon the size of the pump casing and impeller as well as the available power from the motor driving the pump. Although, it is not uncommon to realize a gain of a couple hundred gpm's when suction hose size is increased during drafting operations – it is not standard practice to change suction hose size.

The size and type of strainer used for drafting operations also affects a centrifugal pump's ability to draft. There are many different types of strainers available on the market and they include the barrel strainer, low-level strainer, basket strainer, and floating strainer. Each type of strainer has its own area of specified use in which it works best. When selecting a strainer, it is important to test the strainer to ensure that it is capable of meeting the pump's rated capacity demand.

There are a few other, less common factors that affect drafting – the type of water, the temperature of the water, and aeration of the water. Because salt water is slightly denser than fresh water, it has a lower, maximum theoretical lift. However, the difference is rather insignificant when operating at sea level – which is where most all salt water is found.

Water temperature affects drafting by allowing pump cavitation to occur sooner. As the temperature of the water increases it becomes more difficult to achieve rated pump capacity due to the relationship of the boiling point, vapor pressure, and cavitation. The boiling point of water is 212 ^{0}F at 1 atmosphere or 14.7 psia (sea level). Basically, up until water reaches 212 ^{0}F and 1 atmosphere, the weight of the air molecules keeps the water molecules bunched together in the liquid state. Should we reduce the weight of the air pushing down (reduce the air pressure) then the boiling point of water also gets reduced. Therefore, the relationship that results is – the lower the pressure inside the pump – the lower the temperature at which the water molecules will move to the gaseous state.

Traditionally, pump cavitation has been described as the pump "running away from the water", or "trying to pump more water out than you have coming in." What really happens during cavitation is that the water molecules coming into the pump intake as a liquid flash to vapor upon entry into the volute (or discharge side). Basically this happens because the pressure was lowered inside the pump on the discharge side and the water was then at its new boiling point – remember, lower pressure equals lower boiling point.

So how does this relate to the temperature of the water when drafting? Obviously, if the water coming into the pump is already heated, then the molecules are more prone to flashing to the vapor state when they reach the discharge side of the pump because they may already be at the boiling point for that lower pressure. When this happens, then cavitation occurs and pump capacity is reduced. In most cases, we only experience problems with drafting heated water when we draft in climates with consistently high ambient temperatures (over 90 0F) and when conducting annual service tests on pumps where the test pit water gets heated by the mechanical heat energy of the fire pump.

The remaining factor to affect drafting is water aeration. Water aeration is normally the result of some kind of turbulence that causes air molecules to become entrained in the water. This is often caused by a water stream being directed back into the water supply source near the suction connection used for drafting.

THE SAUDI ARAMCO DRAFTING PIT SITUATION

The drafting pit situation presented by Mr. X presents several areas of challenge – most of which are inter-related and require a redesign and upgrade to the current drafting pit. As the staff at [...] understands it, the primary goal of the drafting pit upgrade or replacement project is to be able to conduct annual service tests (NFPA 1911, ed.2002 compliant) on Saudi Aramco's 2500 gpm and 5500 gpm foam pumpers. A secondary goal of the project is to provide a drafting pit that can be used for driver/operator training.

According to the data provided, the existing drafting pit measures approximately 13-feet deep, by 13-feet wide, by 23-feet long for a total volume of approximately 3887 cubic feet. Given that one cubic feet of water contains approximately 7.5 gallons of the water, then the total volume of the existing drafting pit is approximately 29,153-gallons when full. In addition, the information provided by Mr. X also indicates that no internal baffling (or separation) exists in the pit to reduce turbulence.

It appears that the most critical element of the current drafting pit situation is related to the mechanical heat energy applied to the water during a pump test and the resulting premature pump cavitation.

According to NFPA 1911 *Standard for Service Tests of Pumps on Fire Department Apparatus*, 2002 edition, pump service tests shall be performed under the following environmental conditions:

Air Temperature	0 ^{0}F to 100 ^{0}F (-18 ^{0}C to 38 0C)
Water Temperature	35 ^{0}F to 90 ^{0}F (2 ^{0}C to 32 0C)
Barometric Pressure	29 in Hg (98.2 kPa) minimum
	Converted to sea level

If we were conducting the pump test in a location where ambient air temperature was 70 ^{0}F and the water temperature was 60 0F, then the mechanical heat energy transferred to the water during the pump test might not be that significant. However, given the hot climate of Saudi Arabia, water temperature management becomes critical. Compounding this problem is the size of pumps being tested compared to the volume of the test pit.

RECOMMENDATIONS

The following recommendations are provided by [...] in no priority order and only represent ideas on how test operations could be improved:

1. Schedule annual service tests during the early morning hours (immediately post-dawn). This time period should represent the coolest part of a normal day. Avoid conducting tests mid-day or evening when water temperature in the pit would be at its highest.

2. Schedule annual service tests during the time of the year when the average ambient air temperature is lowest.

3. Using the existing drafting pit, install an insulating cover over the pit that both reflects the sun's radiant heat and provides thermal insulation. This might help reduce the radiant heating of the pit water.

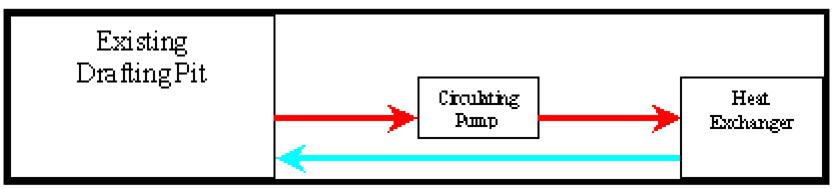
4. Using the existing drafting pit, construct a cover structure over the pit to provide relief from the sun's radiant heat. The cover could be a simple, pavilion-style roof structure that provides shade for the pit, shade for the vehicle being tested, and shade for the test crew. A wall on the southern exposure side

may also be needed to assist in shading the pit.

5. Using the existing drafting pit, install baffles to restrict the turbulence caused by the return of water into the pit – this will also reduce aeration of the water. The depth of the existing pit appears to be okay as long as it remains full and a minimum of 2-feet of water is present over top of the suction hose strainer.

6. Using the existing drafting pit, ensure that the suction port is located as far away as possible from the return port so to minimize turbulence and aeration.

7. Using the existing drafting pit, install some type of heat exchanger system that cools the water during the annual service test process. (A longer time period may be needed if the pit will be used for extended drafting operations such as driver/operator training.) The key to this installation is that it needs to be able to cool the water at a rate sufficient enough to offset the quantity of mechanical heat energy that is added by the pump being tested. A mechanical engineer should be able to design a simple heat exchanger system that's takes water from the test pit – cools it – and returns the water to the pit.



**An important note here is that the cost and design of a cooling system might exceed the cost of a new pit. Therefore, careful consideration must be given to cost estimation.*

8. Design a new drafting pit that will accommodate the testing of the 5500 gpm pump. Given the nature of the climate in Saudi Arabia an underground storage tank might possibly work best – it would minimize any evaporation problem and if buried with a couple of feet of soil over top of it, the tank would be better insulated from ambient air temperature than the existing drafting pit. One important component of a new tank design would be that it most likely require multiple, large tanks to be buried and interconnected in order to obtain the large capacity needed to absorb the mechanical heat energy generated by the 5500 gpm pump. One source contacted by [...], recommended possibly tripling the 10 gallon to 1 gpm ratio described in the Hale article referenced by Mr. X

SUMMARY

The drafting pit upgrade project identified by Mr. X is an important one that will affect the testing of the department's pumpers. The challenge is how to construct a test pit in a climate such as Saudi Arabia – perhaps the recommendations provided will provide the assistance needed to get started.

Below are photographs of a sheltered drafting pit used for annual pump service tests. The facility is located in Maryland and has 35,000 gallons of water contained in an underground storage tank.

Photo 1: This metal clad structure provides protection from the elements during periods of inclement weather. Although it is not air conditioned – it could be retrofitted if needed.

Photo 2: This lid is one of two suction ports where suction hose is dropped into the tank for drafting. The concrete floor is designed to hold the weight of the pumper.

Photo 3: The test re-entry port is designed to direct the water to the far end of the baffled, underground tank.

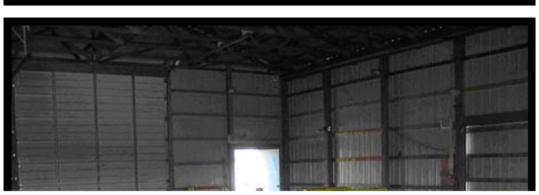


Photo 4: Looking from the other end of the

building, an additional suction port can be seen. This port is used when testing 2000 gpm pumpers.