We have had issues with four drain pumps recently and we have learned a lot by investigating each of these issues. The information below is provided so that everyone can gain a clear understanding of how these pumps work and what may be going on during operation in the field.

Some background information on our drain pumps. We have two different capacities of pumps that we call medium and high pressure. Medium pressure pumps are our older variety and they are generally used on simple cold water downhill drains (pressurized supply from the client's system). The high pressure pumps are used for hot water recycled drains and any significant uphill or curved runs. Here's the pump list:

Pump #	Type	Manufacturer	Yr Purch	Based In	Power
101	High	Flowserve (IR)		Lex	460-60
104	High	Cornell		Mex	460-60
105	High	Flowserve (IR)		Lex	460-60
106	High	Flowserve (IR)	2001	Syd	380-50
107	High	Flowserve (IR)	2001	Syd	380-50
108	High	Cornell	2008	Lex	460-60
110	High	Cornell		CA	460-60
111	High	Cornell		Lex	460-60
112	High	Cornell		Mex	460-60
114	High	Cornell	2010	Lex	460-60
115	High	Flowserve (Durco)	2011	Lex	460-60
116	High	Cornell	2011	Lex	460-60
117	High	Flowserve (Durco)	2012	Lex	460-60
100	Medium	Cornell		CA	460-60
102	Medium	Flowserve (IR)		Lex	460-60
103	Medium	Cornell		Lex	460-60
109	High	Grundfos		Retired	

These pumps are centrifugal pumps and they rely on the properties of liquids in order to operate. Liquids are not compressible. When they are placed under pressure, the volume does not change. Gas is different in this regard. When you place a gas under pressure, it compresses (reduces in size). Therefore gas in a pump causes performance issues.

There are two main gas related issues for pump performance:

1.) Cavitation
   a. This is caused when the pressure change across the pump becomes so great that the liquid being pumped converts to a gas (vapor) inside the pump. In effect the pump is pumping the fluid faster than it can be replaced and it creates a vacuum that causes the fluid to boil.

b. Cavitation is solved when the pressure differential is reduced. This can be accomplished by increasing the pressure at the pump suction side or restricting the flow on the pump discharge side.
c. In our system, with the receiver nozzle restricting discharge and the supply conditions under control, cavitation rarely occurs. Conditions that can make it occur in our system are restrictions on the supply (clogged screens, low pit level, kinked supply hose, etc) or the absence of restrictions on the discharge (using as a transfer pump with an open hose on the discharge, etc).

2.) Partial Loss of Pump Prime
   a. The pump design requires the whole pump housing to be filled with liquid. It uses the incompressible property of liquid to draw new liquid into the pump to replace the liquid that was discharged from the pump.
   b. If air gets into the pump housing, part of the suction that is created by throwing liquid out of the pump is used up by the air expanding inside the housing and this prevents a complete resupply of liquid.
   c. If air is allowed to accumulate in the pump housing, the pump starts to perform the same way as when it is cavitating – amps go down, flow goes down, the pump vibrates.
   d. Improving the pressure differential is unlikely to solve a partial prime problem. The gas is already in the pump housing – it isn't being created inside the pump as in cavitation.
   e. To restore the pump prime, the air has to be cleared out of the pump.
   f. To prevent it from reoccurring, the condition that allowed the air to get into the system has to be solved.

Summary – Cavitation caused by too much pressure differential, solved by fixing pressure situation. Partial prime caused by air in pump housing, solved by getting it out. Cause of air ingress needs to be eliminated to prevent reoccurrence.

There have been reports of reduced performance on the high pressure pumps on ground drains versus container drains. Ground drains require the pump suction to lift the water from below the pump elevation (negative suction head). Container drains have water pressure pushing the water supply into the pump from the height of water above the pump elevation (positive suction head). These pump supply conditions do affect the pump output and also contribute to the possibility of either of two pump performance conditions – cavitation or partial loss of prime.

On a ground drain, the weight of the column of water in the hose from the pit is pulled backwards by gravity out of the pump. This creates negative pump inlet pressure. The farther that the pump has to lift the water, the more negative the inlet pressure. In addition, any restrictions on the inlet also contribute to the amount of negative pressure that the pump sees. Clogged footvalve screens restrict the inlet of water and make the pump suction more negative. Long pump inlet hoses have more friction with the water than short hoses and contribute to greater negative conditions. A hose kink is another source of restriction.

So the ground drain setup creates pump supply side suction conditions that could contribute to cavitation or to partial loss of prime. How do you know which condition is occurring?

1.) With cavitation, pump performance will immediately improve if the pressure differential is improved. Clean the screens, unkink the hose, raise the fluid level in the pit and/or throttle the discharge valve. If the pump performance immediately improves you are no longer creating gas in the pump as a result of the "vacuum".
2.) With partial prime conditions, changing the pressure differential doesn't eliminate the air already inside the pump housing. The performance will continue to suffer. If you can safely open the petcock on the discharge side of the pump housing, both air and hot water will be released from the pump and the performance should immediately improve. Then the cause of the air ingress has to be solved to prevent a reoccurrence. All of those factors creating negative pressure at the pump inlet can also be factors contributing to air ingress (along with leaking hoses & couplings, vortexing due to low pit levels, lifting the footvalve to clean screens, etc.).

So here's what we learned about each of these four pumps that were reported to have a problem:

1.) Pump #117
    a. The report from the field was that during the drain the flow at the receiver seemed to be diminishing. Over time, the amps on the motor started to drop off. As the amps got lower, the pump started to vibrate like it was cavitating. The decision was made to switch it out before a safety event occurred.
    b. Upon return to the shop, inspection and test run found no performance problems. An unrelated issue with the motor starter was identified but this did not affect pump output. The motor bearings were found to be a little dry and were greased (wouldn't make low amps or affect performance).
    c. It appears that this pump experienced a partial loss of prime that caused the performance issues.
    d. Conclusion*:*
        i. There was nothing wrong with the pump that caused the loss of flow and amps.
        ii. We suspect that there was a partial loss of prime (air sucked in)
        iii. The shop will start to test for leaks in suction hoses and couplings
        iv. Long pump suction hoses will be eliminated
        v. If amps drop off and vibration occurs, field troubleshooting should determine whether the cause is a.) cavitation or b.) partial loss of prime
        vi. The shop will look at the arrangement of the bleed valve (petcock also used for initial priming) to insure safety when trying to remove air bubbles from the pump housing during operation.

vii. If there is a systematic ingress of air, the source has to be corrected.

2.) Pump #115

a. This pump was damaged last year at Wichita Falls when trash went thru it from the frit pit wood bottom. It took some time to get the pump back, assess the damage, order replacement parts, rebuild the pump, shop test it and put it back into rotation for use. About $5000 was spent completely rebuilding it with new pump shaft, impeller, seals etc. It was out of service for months.

b. Nine months after the failure, on its first time out after rebuild, it was sent to the field where it was reportedly bump tested for rotation, conducted a water test for some time, was stopped and physically moved, and then failed when restarted.

c. Upon return to the shop, this is what was found.

This photo is of the pump shaft and impeller after it was removed. The shaft is threaded on the inside and the impeller shaft is threaded on the outside. These two parts just screw together and in normal rotation, the force on the impeller from the fluid is causing the connection to be continuously tightened.

Here's a closer view of the threads on the impeller. The threads had been completely stripped for most of the shaft length.

d. In the first moments of operation after a complete rebuild, this pump was destroyed and it needed to be completely rebuilt once again.

e. It turns out that this design of shaft/impeller assembly is very sensitive to reverse rotation. When the pump starts to turn backwards and then the power is stopped, the weight of the impeller wants to keep rotating and the shaft starts to slow down due to less inertia and friction in the bearings etc. This makes the impeller want to unscrew from the shaft.

f. So it appears that this impeller was loosened from its shaft and eventually the threads stripped – either during the reverse operation or when rotated forward on the restart (after loosening).

g. Upon investigation, the operating manual for this pump says that, when installed, the pump should be uncoupled, the motor direction checked, once confirmed to be going forward, then the coupling should be reattached. It is my understanding that for a short time in the past, Hotwork actually followed this practice and shipped drain pumps to the field with the rubber coupling boot removed. I personally find this to be an unreasonable approach for our operation (ok for permanently installed pumps). So we began to investigate pump shaft designs.

h. It turns out that all of the Flowserve pumps owned by Hotwork (Ingersoll Rand and Durco varieties) have exactly the same type of shaft/impeller connection. The Cornell's have a different connection with a keyed shaft and a lock bolt thru the impeller.

i. So we have had seven pumps in operation for years that are susceptible to failure if operated for any time in reverse. We have "bump tested" direction on installation for all of these pumps on every drain project for years and years. We have one failure with the impeller "spun off" – what was different that one time? Nobody knows for sure but these are the possibilities:
   i. The newly installed parts were manufactured poorly and didn't "fit up" well (unlikely)
   ii. The shop assembly of the new parts somehow contributed – for example low assembly torque or thread lubricant (possible but nothing obvious reported)
   iii. The "bump test" was worse on this occasion for some reason – for example run longer (went faster) in reverse or tried to stop the shaft when coasting to stop (possible but Technicians report nothing unusual)
   iv. Maybe the highest risk time is just the first time. When in operation for some period maybe the threads corrode or gall. It is always harder to break an old nut loose than a new one. Once it has been operated for some time, maybe it can withstand the bump test better.

j. Conclusions:
   i. This shaft design is susceptible to failure in the way the we operate (bump test)
   ii. We will not buy anymore pumps of this shaft design
   iii. If we have another failure, we will replace the pump rather than rebuild it
   iv. When this style pump has been rebuilt, the shop will test direction uncoupled for the first operation to insure that the first time it runs it is going forward
   v. We will work with the shop to experiment with the amount of torque as a way to reduce the risk of reverse rotation failure (or Loctite or a weld bead).

3.) Pump #116
   a. This pump was reported to have leaking seals in the field.
   b. Upon return to the shop, damage was also discovered on the impeller. Currently awaiting replacement parts.
   c. Root cause still under investigation.

4.) Pump #105
   a. Returned from the field with no performance comments.
   b. In shop testing, vibration was noticed.

c. Root cause is due to alignment/balance issues with worn old style rubber gear coupling. Coupling replaced with boot style and alignment/balance re-established.
d. Seal was also replaced with cartridge type.