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Practical Tips for Reducing Pump Noise

While there are numerous reasons why a pump may be generating an abnormal degree of noise, the greatest number of questions and concerns are usually about pumps involved in cooling tower applications or problems resulting from poor suction piping design. In either instance, the following is typically experienced:

The noise is very similar, if not identical, to classical cavitation (growling or pumping gravel).

The phenomenon can occur with either a forced draft or induced draft-cooling tower.

The resulting noise tends to be more prevalent on negative suction pressure systems but will occur on positive suction pressure as well.

Unlike classic cavitation, throttling the pump discharge to a lower capacity typically has little impact on the overall noise level.

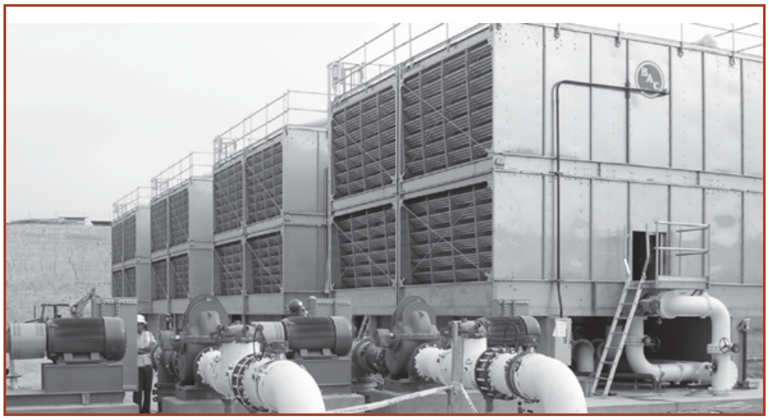

Fig. 1 Cooling tower pumps

Be it a tower application or a questionable suction piping design, the actions that follow are almost always the same: drawings are reviewed, measurements taken and the pump is double-checked to be sure it has sufficient Net Positive Suction Head (NPSH). The result - everything checks out, but the pump is still noisy. What's going on here?

Well, in addition to being very irritating, noisy pumps often mean there is diminished overall performance that can severely reduce the life cycle of the critical bearing and seal components in the pump.

There are really only two primary sources of pump noise: liquid and mechanical. Both sources produce acoustic pressure fluctuations that can be transmitted as audible noise.

For centrifugal pumps, mechanical noise is generally the result of component imbalance (impeller and/or coupler), coupler misalignment, rubbing components or improper installation of the base plate and/or motor. These mechanical mechanisms generate distinct frequencies equal to rotational speed and/or multiples (1,2,3) of rotational speed. If a noise spectra analysis is completed and it does not reveal distinct frequencies, then the noise is not being mechanically generated.

The second mechanism for generating noise is liquid sources. Liquid noise is directly produced by water movement and is fluid dynamic in character. Turbulence, flow separation (vortex), cavitation, water hammer, flashing and impeller interactions with the volute cut water are all examples of fluid dynamic noise sources.

Pulsation Sources

According to the Pump Handbook, 2nd Edition authored by Igor J. Karassik, there are generally four types of pulsation sources in pumps that are the result of liquid noise:

Discrete frequency components generated by the pump impeller involving impeller vane passing

Broad-band turbulent energy resulting from high flow velocities

Impact noise consisting of intermittent bursts of broad-band noise caused by cavitation and water hammer

Flow-induced pulsations caused by periodic vortex formation when flow is past obstructions and side branches in the piping system.

The first example - impeller vane passing - is extremely rare and can very often be ruled out. This is a pump design issue and today's sophisticated hydraulic design software allows the designer to avoid these distinct frequencies and the accompanying vane passage frequency and/or its multiples. This would only be the case if an interaction occurred between the impeller and volute cut water.

The other three examples are generally identified as broad-band noise and would occur in the 300 Hz and above frequency range as identified on a noise spectra analysis.

As mentioned previously, pump noise is similar to that of classic cavitation. Pump cavitation results from the formation of vapor bubbles when the available Net Positive Suction Head (NPSH) is lower than the required NPSH necessary for the pump. To evaluate the pump for cavitation over air entrainment, reduce the pump flow by closing the discharge valve and push the pump back on its curve toward shut-off. The noise should diminish significantly if it originated from cavitation, as lower pump flows require reduced NPSHR. If the pump noise continues after closing the discharge valve and pushing the pump back on its curve, entrained air is very likely one of the culprits. Why?

Highly aerated cooling tower water can contain as much as 4-6% dissolved air. This excess air exacerbates the potential for a noisy pumping installation. The excess air absorbed in the cooling tower comes out of solution as it flows through the piping and becomes entrained air. This air then collects in an area of the suction piping, creating an obstruction. As the liquid passes through this reduced area, its velocity is increased, creating an area of reduced pressure. At this point of reduced pressure water vaporization

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occurs with the resulting bubbles passing into the pump impeller where they collapse, producing the sound of "cavitation."

Controlling Noise

Several successful control techniques have been employed in the past to mitigate excessive noise. They include:

Increase or decrease the pump speed to avoid system resonances of the mechanical or liquid systems.

Increase liquid pressures (NPSHA, etc.) to avoid cavitation or flashing; decrease suction lift. This could include raising the tower, lowering the pump or straightening the suction piping (see below) to reduce friction losses.

Modify the pump so that the clearance between the impeller diameter and casing cut water (tongue) or diffuser vanes is increased.

Inject a small quantity of air into the suction of a centrifugal pump to reduce cavitation noises by providing a shock-absorbing cushion to minimize the impact of recondensation of water vapor within the pump impeller.

For an existing facility, the first three techniques may not be practical, as they would be extremely difficult, expensive and time consuming to accomplish. However, injecting air into the suction end has proven itself to be a very viable and cost-effective solution in many instances to cushion and minimize the impact of the collapse of the vapor bubbles. The injection of small amounts of air can usually be accomplished quickly and easily in the field with minimal expense. If the pump is pulling a vacuum, the addition of a small vacuum breaker on the suction flange works perfectly.

Alternatively, for positive pressure situations, the connection of a compressed air line to the pump suction flange, and adjusted to allow a small quantity of air into the pump, is equally acceptable. How much is enough? Use your ears! Attach the compressed air line to the pump with the air valve closed. Crack open the valve allowing a small amount of air to enter the pump. Continue to slowly open the valve until you hear the crackling cavitation noise subside or stop. Very small additions of entrained air introduced at the pump will not cause any problem to the pump or to the cooling tower/condenser circuit. This method is very desirable and has been proven on numerous occasions to be a viable solution to eliminating excessive noise. At a minimum, this approach is also an excellent analytical tool that can be utilized to better ascertain the severity of the overall noise problem.

Additional Contributing Factors

In addition to the techniques outlined previously to reduce or eliminate noise, attention must also be given to two other factors that can exacerbate the situation: vortexing of the liquid in the tower pan - which is the most common source of air within a pump - and the suction piping arrangement.

Excessive Vortexing - The amount of air entrainment contained in the pump fluid as a result of the vortexing is heavily dependent on several variables: the vortex size and the submergence level of the pump suction pipe below the water level of the pan. The most common method of eliminating vortexing in the tower pan is by the inclusion of baffle assemblies to abolish the formation of vortexes. Raising the fluid level in the pan to a sufficient depth can sometimes resolve this problem.

Suction Piping - Improper pump suction piping is one of the most significant contributors to noise, as well as to diminished overall performance of a pump. Unwittingly, many centrifugal pump troubles are the result of poor suction conditions. Coupled with the vortexing phenomenon described above, the improper layout of the pump suction piping can be a significant contributor to the generation of pump noise. In this example (fig. 2) a "Y" strainer connected to a customized "S" adapter going into a short radius elbow on the suction side of the pump resulted in very uneven and noisy flow into the pump.

Avoiding Problems

There are several field-proven best practices that should be followed to avoid these types of problems from developing. They include:

1. Suction pipe velocities should never exceed the 5 to 8 feet per second range. Otherwise, higher velocities will result in an increase in friction loss and can result in air or vapor separation.

2. Suction headers should be sized for 5 ft/sec of total system demand.

3. All suction piping pressure drops must be equal for pumps operating in parallel.

4. The suction pipe should never be smaller than the suction connection of the pump, and in almost all cases it should be at least one size larger.

5. The suction lines should be as straight as possible and no less than 5 pipe diameters in length going into the pump.

6. The addition of short radius elbows and/or tees next to the pump suction nozzle will result in an uneven flow pattern to the impeller resulting in a hydraulically unbalanced distribution of water into the dual impeller eyes. The resulting hydraulic imbalance leads to possible cavitation, vibration, and excessive shaft deflection - all of which can severely reduce the overall life cycle of the critical bearing and seal components in the pump.

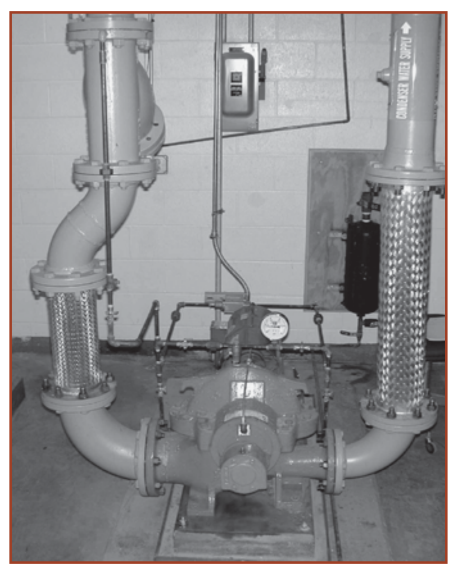

Fig. 2 Incorrect suction piping

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7. Use tapering Y-branches for multiple pumps off a header, versus straight branch headers.

8. The suction piping should be arranged with as few twists and turns as possible. When bends become necessary, a long radius elbow must be utilized.

Friction losses caused by undersized suction piping will result in an increase in the fluid velocities into the pump. As stated by the Hydraulic Institute, Pump Intake Design Standard, ANSI/HI 9.8-1998, higher suction pipe velocities increase head loss and decrease NPSH available leading to potential pump problems. While figure 3 represents an extreme situation, it underscores what happens all too frequently in some problem applications. Undersized suction piping provided as part of a "Value Engineered" approach to a project can have severe consequences to the performance and overall life of the entire system.

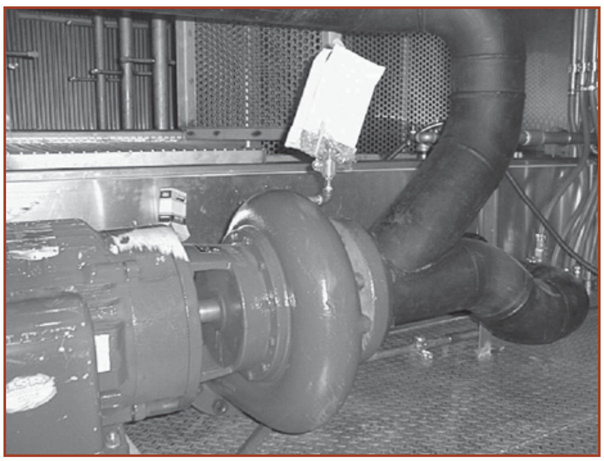

Fig. 3

Undersized and incorrectly piped suction line

In some situations pipe velocity may need to be further reduced to satisfy pump NPSH requirements and to control suction line losses. The pipe friction can be reduced by utilizing pipe sizes that are preferably one - but no more than two - sizes larger than the pump suction nozzle in order to supply pipe velocities in the 5 to 8 ft/sec range.

Eccentric reducers utilized to step down to the pump flange from the larger suction piping can also be a culprit if improperly utilized. At one recent facility visit, the reducer was installed upside down with the flat side on the bottom. If the pump liquid contains air (or vapor), as it did in this case, the air can become trapped in the sloped area of the reducer, now located on "top," and if transported into the impeller, it can create a noise similar to cavitation.

Elbows, and other flow disturbing fittings (see ANSI/HI 9.8.4.3), utilized on the pump suction flange, while convenient, can cause an uneven flow of liquid (fig. 4) into the impeller when the elbow bend is along the axis of the pump shaft. If the elbow is a short radius design you may create turbulence adequate enough to produce entrainment, which will exacerbate the problem we are attempting to eliminate. The addition of a second elbow only increases the problem, especially if it has been added in positions at right angles to each other. Numerous technical publications, as well as the Hydraulic Institute itself, state that a minimum of five pipe diameters of straight run of pipe before the pump suction flange should be provided to allow for a smooth unimpeded flow to the impeller.

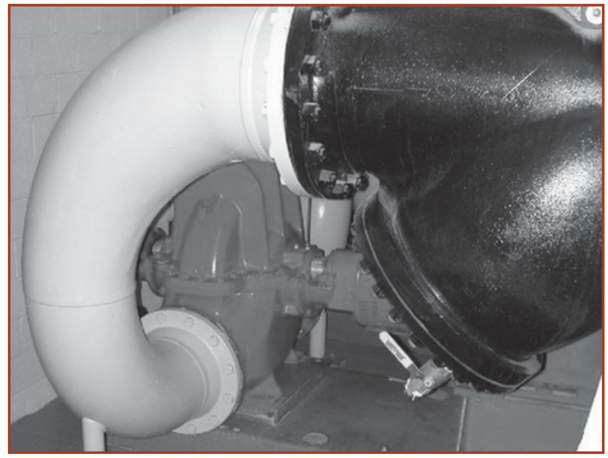

Fig. 4 Elbow on pump suction piped parallel to pump shaft

System strainers need to be located on the discharge side of the tower pumps and not on the suction side as seen here (fig. 5) and in the previous photo. On this particular project the location of basket strainers directly in front of the suction flange on a large split-case pump resulted in an unexpectantly high pressure drop that was one of the contributing factors to poor pump performance as well as higher noise levels from the pump. The pan in the cooling tower already has a strainer, so why add additional pressure loss and waste energy by adding another strainer in front of the pump?

Ratcheting Down the Noise

In conclusion, it must be understood that each job site has its own particular set of operational requirements and, therefore, there is sometimes no single solution to a noisy pump problem. Typically, there are several smaller issues present that are contributing to the overall noise problem. Review and evaluate the various pieces of the system individually as discussed above. Carefully following time-proven and field-verified practices will allow you to ratchet down the noise and reduce your operating costs.

This article was written by Bell & Gossett engineers, and was originally published in the September 2004 issue of *World Pumps* magazine. Reprinted with permission.

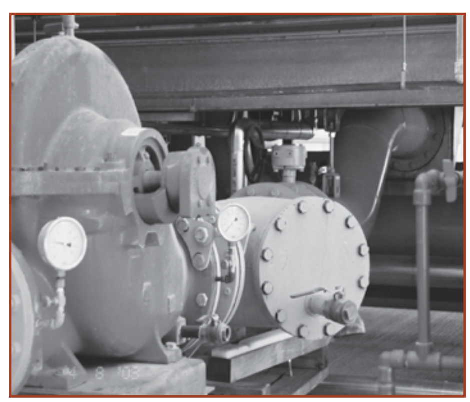

Fig. 5 Incorrectly installed strainer on suction of pump