Is Your Process Flow Making Too Many Twists and Turns?

How various types of pipe fittings and piping components can cause performance problems in pumps

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Does your pump "shake, rattle, and roll?" Does your pump have cavitation, vibration and/or noise problems? Does your pump require a lot of maintenance, have impeller, bearing and/or seal problems? In your pumping process, is your pump losing head, capacity and efficiency? Are you thinking about purchasing a new, bigger, better, more expensive pump to solve these problems? Will these problems go away when you install your new pump? Probably not, because in 95% of the pump problems mentioned above, it generally is not the pump causing these problems.

The real cause could lie in the pump's suction and discharge line piping and/or what type of piping components are being used. The location and type of pipe fittings and piping components in your pump's suction and discharge piping can all influence the performance of your pump. Pump manufacturers design their equipment on the assumption that a straight uniform flow of fluid enters the suction nozzle. This is the way the manufacturers design their test loops, and this is the premise on which they test and rate their pumps.

The first place to look for flow turbulence problems is in the suction line piping. Is there an elbow or tee in the line that is in close proximity to the pump's suction nozzle? For maximum performance, a uniform nonturbulent flow of fluid into the suction nozzle is required. Most pump manufacturers and piping consultants will tell you that at least 10 pipe diameters of straight pipe length are required between a pipe fitting such as an elbow or tee and the pump's suction nozzle. (Ten pipe diameters of a straight length of pipe are required after an elbow or tee, before the flow turbulence created by the elbow or tee settles down, and the flow becomes uniform again.)

ARE ELBOWS THE PROBLEM?

The piping elbow is the most common and probably the single greatest cause of flow turbulence in suction line piping. As the fluid makes the ninety-degree turn through the elbow, the geometry of the elbow causes the fluid to separate. The fluid then becomes turbulent, with a reverse flow area and a concentrated accelerated flow area at the downstream side of the elbow (Fig. 1). This flow turbulence continues downstream of the elbow and does not start to settle down and become uniform again until it travels at least ten pipe diameters away from the elbow. Consequently, when a pump (or a control valve, measurement equipment etc., for that matter) is located immediately downstream of the elbow, it will see the flow turbulence created by the elbow and will be adversely affected by it. The flow turbulence created by the elbow can cause cavitation, vibration and excessive noise when it enters the pump, all of which will negatively affect performance.

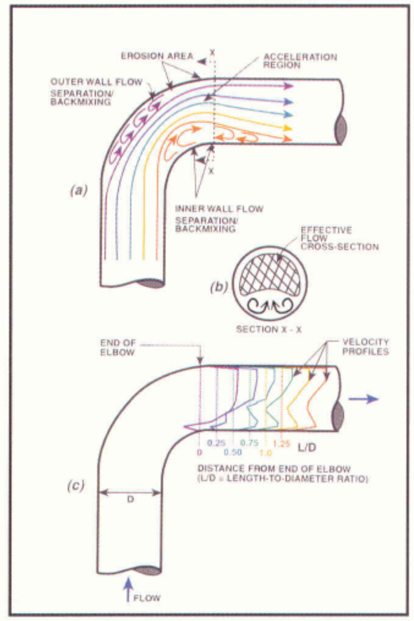

Fig. 1. Turbulent flow at the exit of an elbow

LONG VS. SHORT RADIUS

Look around your plant. How many pumps do you see that have the proper

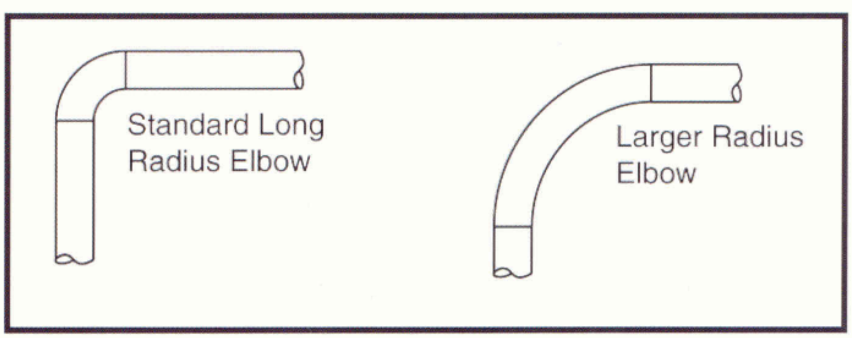

Fig. 2. A larger radius elbow will lessen the flow turbulence effects caused by the elbow.

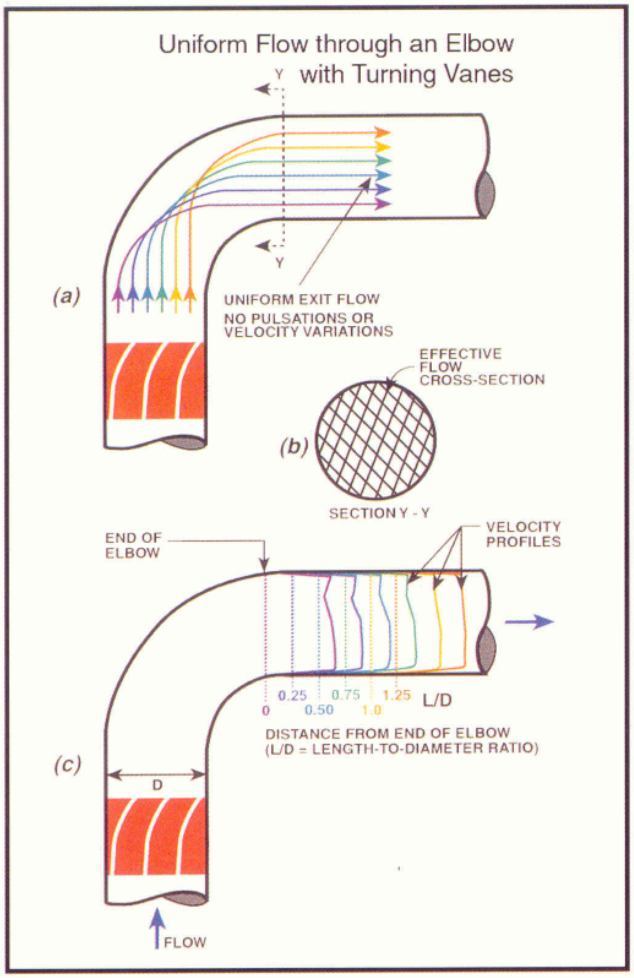

Fig. 3. Uniform flow through an elbow with turning vanes

ten diameter pipe lengths of suction piping before the pump's suction nozzle? You could probably count them on one hand, and they are all probably on non-critical pumping applications. If your pumps do not have the proper length of suction piping after the elbow (or tee), there are a few things that you can do to improve the flow to the pump. First, check to see what type of elbow is being used (long radius or short radius). In almost all cases, a long radius elbow should be used, because a long radius elbow creates less friction and causes less turbulence to the flow in the piping system. Remember that if you are using a long radius elbow close to the suction inlet of a double suction pump, the plane of the elbow should not be in the same plane as the pump shaft, but should be at a right angle to the pump shaft. Having the elbow positioned this way will create a more even flow to both sides of the double suction impeller.

Almost everyone agrees that the best way to correct a bad suction piping design is to repipe the system properly, but in most cases this is not practical and can be very expensive. One option to try, if the space is available, is to use a specially designed elbow that has a much larger radius (Fig. 2). A larger radius elbow will lessen the flow turbulence effects caused by the elbow. Again, this is not always a very practical solution and can be very expensive to implement. Another option is to put turning vanes on the inlet side of the elbow that neutralize the flow turbulence. The space needed for this option is small, the cost is not expensive when compared with the other alternatives, and it will produce a uniform flow of fluid at the exit of the elbow (Fig. 3). If you do not use any of these options, your pump can experience any one of the following problems: cavitation; vibration; noise; piping fatigue failure; reduced capacity and efficiency or frequent failure of seals, bearings, impellers, gaskets and other components. Living with these flow turbulence problems will eventually lead to increased downtime, increased maintenance costs and lost production.

CHECK THE TEE

The pipe tee is another fitting that commonly causes flow turbulence problems. When pumps are used in parallel and feed off a common header or manifold, the pipe tee will cause flow turbulence problems downstream in each branch that it is feeding. The tee will cause the same type of flow turbulence problems (separated flows with accelerated and reverse flow areas) that an elbow causes. In fact, a tee can cause more flow to go down one branch of the tee than the other branch, thus giving one section of the piping system more flow. Almost all of the pump piping manifolds in service are symmetrical, with a ninety-degree tee and equal spacing between the pumps. They look very nice to the eye but are not conducive to the best fluid flow. When you are driving down one of our interstate highways and want to exit, you are not forced to make a sudden ninety degree turn at the exit, but you are guided off of the highway with a nice gradual bend. This same principle should be used in pump manifold piping. An angular (45 degrees or less) elbow branching off of the main manifold feed line will greatly reduce the turbulence caused by a sudden turn and distribute the flow more evenly down both branches of the manifold (Fig. 4).

Suction piping guidelines for reciprocating pumps from the Hydraulic Institute Standards reads: "All bends or turns should be made with long radius elbows, 45-degree elbows, or laterals. If long-radius elbows are used, they should be installed no closer than five pipe diameters from the pump inlet…The 45-degree elbows are greatly preferred to 90-degree elbows. At no time should 90-degree short radius elbows be used." This piping practice should be applied to not just reciprocating pumps but to all pump installations.

Many times, flow turbulence problems persist even though the pump suction elbows and tees are positioned correctly and the proper ten pipe diameters of straight length pipe before the pump's suction nozzle are present. If this is the case, look to see if there are any items such as valves, strainers, measurement equipment, expansion bellows, eccentric reducers etc., in the suction line piping in the immediate vicinity of the ten pipe diameters before the suction nozzle. These common piping components could be creating a flow turbulence or amplifying an existing flow turbulence in the suction line and can play havoc with the pump's performance (Fig. 5).

MATCH THE VALVE TO THE PROCESS

Isolation valves used in the suction piping system should be of the full port design (the valve's internal bore diameter is equal to the internal diameter of the pipe) and not of the reduced port design. Again, from the Hydraulic Institute Standards: "The inlet line valve should have a flow area equal to that of the inlet line." Control valves should be located as far away from the pump's suction inlet as possible. A control valve on the discharge side of the pump should be positioned so that it prevents the surging of the fluid when the discharge is throttled. Isolation valves should be kept (and checked periodically) so that they remain in the fully open position. If the isolation valve is not in the fully open position (especially a butterfly valve), it will create a flow turbulence that will continue into the pump. Another good piping practice to remember is that the valve stems should be installed perpendicular to the pump's shaft to prevent air bubbles from forming in the valve bodies.

ARE STRAINERS NECESSARY?

In most instances, strainers are used in pump piping systems on initial startup and are taken out of service on the first shutdown. Depending on the type of strainer used, the strainer can create a severe pressure drop and flow turbulence that will only start to dissipate ten or more pipe diameters downstream of the strainer. If required, a permanent strainer should be located as far away from the suction inlet as possible. (Note: Permanent suction strainers should be sized so that they induce a minimum pressure drop at the rated flow.)

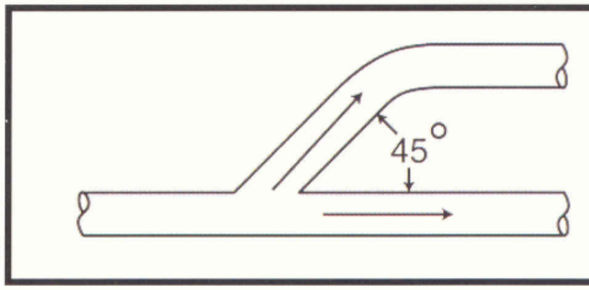

Fig. 4. The angular elbow branching off the main manifold greatly reduces the turbulence caused by a sudden turn and distributes the flow more evenly down both branches of the manifold.

MAKE SURE THE MEASUREMENT EQUIPMENT ISN'T CAUSING TROUBLE

The type of equipment used to measure the flow will determine the severity of the flow turbulence it creates. Some types of meters are worse than others when it comes to creating flow turbulence. A good rule of thumb is that no type of measurement equipment should ever be used in the final run of pipe before the pump's suction inlet.

USE THE RIGHT EXPANSION JOINTS

On hot services and in many plants, expansion joints are used in and around pumps. The most popular expansion joints are the corrugated diaphragm type. These expansion joints have ridges on their insides, which will establish a flow turbulence, especially on high flow velocities. This can be likened to a stream of water going over a bed of rocks. Corrugated expansion joints should be placed in the line as far away from the suction inlet and discharge outlet as possible. If the expansion joint is required at the suction nozzle, an anchor should always be used between the suction nozzle and the expansion joint to prevent transmitting to the pump any piping strains caused by the expansion.

USING ECCENTRIC REDUCERS CORRECTLY

If there is a uniform flow of fluid to your pump's suction nozzle, an eccentric reducer is not required, as there will not be any air pockets in the piping system. If an eccentric reducer is used next to the suction inlet, it will produce a small flow turbulence to the flowing fluid as the fluid enters the suction nozzle. Although the flow turbulence caused by the eccentric reducer is small, it may be just enough to push the pump from the acceptable to the unacceptable performance level when it comes to vibration, cavitation and/or noise.

DISCHARGE SIDE CONCERNS

Keep in mind that all of the problems mentioned above that occur on the suction side of the pump's piping system can also occur on the discharge piping side, if the same pipe fittings and components are used in close proximity to the discharge outlet. Elbows, valves, measurement equipment, expansion joints etc. will create the same flow disturbances on the discharge side of the pump. The flow turbulence that they create can restrict the flow away from the pump and can cause cavitation, vibration, noise etc. in the pump. Therefore if you have a perfect uniform flow of fluid on the suction side of your pump and your cavitation, vibration, reduced flow etc. still exists, look closely at the pump's discharge side piping and see if any of the items mentioned above could be causing the performance problems.

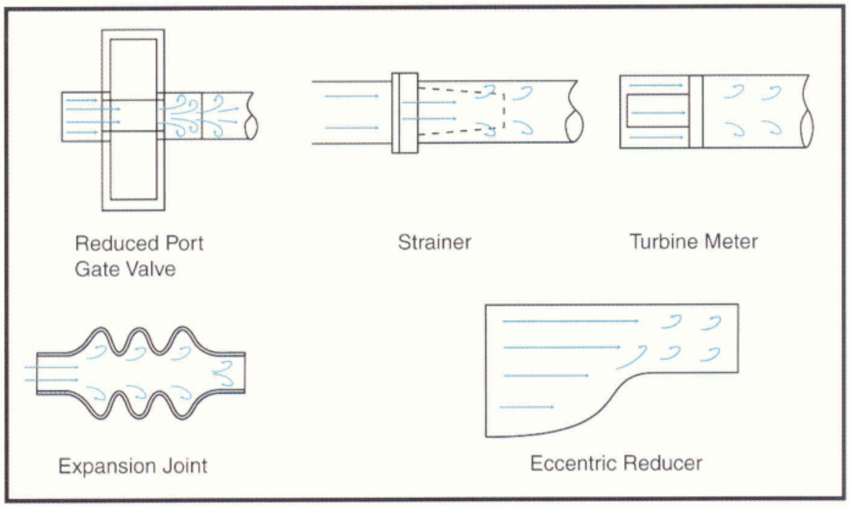

Fig. 5. Flow turbulence caused by common piping equipment and components

FINAL THOUGHTS

There are many reasons why a pump will fail and/or not perform up to the specifications for which it was designed. When these problems occur, almost everyone blames the pump, but often it is not the pump's fault at all. When problems occur like those described in the beginning of this article, look at your pump's immediate suction piping. Does the suction line piping have enough pipe length before it enters the pump's suction nozzle? If not, common pipe fittings such as elbows and tees could be causing you big flow turbulence problems. To correct this, repipe the suction piping correctly or put in flow conditioners. Even if the proper pump suction pipe lengths are present on the pump's suction side, having equipment such as valves, strainers, measurement equipment, eccentric reducers and expansion joints in close proximity to the pump's suction inlet can negate all or most of the positive uniform flow effects that you have already created. Even if the flow turbulence going into the pump was not critical enough to warrant any concern, any one of the items mentioned above could produce enough flow turbulence to make the pump's performance unacceptable. This should be remembered when trying to troubleshoot the problem.

In many existing cases where flow turbulence problems are a concern, major piping changes cannot be made. However, by possibly repositioning an expansion bellows or a valve further upstream and away from the pump's suction inlet or downstream from the pump's discharge outlet, the pump could be brought back to an acceptable level of performance. Finally, always look on your pump's discharge side piping for elbows, tees, and other piping components that could also be enhancing or creating flow turbulence problems that are negatively affecting the performance of your pump.

Richard Golomb has spent more than 30 years in the piping industry in various positions and has been with Cheng Fluid Systems for the last six years. He is a member of ASME, ISA, and is part of the review committee for the Hydraulic Institute's recent ANSI Pump Standards publication revisions. He has taught training courses all over the world and has given lectures and written many magazine articles regarding flow turbulence problems in piping systems. Golomb received a BSME from Western Michigan University and did some postgraduate work at the Illinois Institute of Technology. Send your questions and comments to rjg@chengfluid.com.