In an article which appeared in a previous issue of Power & Fluids (Volume 8/No. 4, Hydraulic design considerations for pump suction piping), a number of important considerations in the design of suction piping for centrifugal pumps were discussed. Among other points, the article introduced the subject of proper orientation of elbows upstream of both double-suction and end-suction pumps.

Obviously, everything that could be said on the subject of pump suction piping design could not be covered in one short article. In this concluding segment, our discussion of pump suction piping continues with a look at problems which can be caused at the pump inlet by use of multiple fittings just ahead of a pump, unless they are properly arranged. The article also looks at other typical configurations for both process and water pumps, and covers some of the special considerations involved in suction piping designs for liquids which are close to boiling.

Hydraulic design considerations for pump suction piping: Part II

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In the article, "Hydraulic design considerations for pump suction piping," we discussed the use of elbows ahead of pumps and some of the problems they can create. Figure 4 of that article showed what was called a "tolerable" arrangement, made so only by the use of 5 to 10 diameters of straight pipe between the reducer and the pump suction flange. While tolerable, this was still considered a less than optimum configuration.

For the reader's convenience, that illustration has been reproduced here as Figure 1, alongside Figure 1a, which is basically the same illustration, the only difference being the elimination of the straight pipe. Figure 1a has been labeled undesirable. Why? How much difference does the straight pipe make?

In both cases, getting the liquid into the pump involves two right-angle changes in direction, in orthogonal planes. Such an arrangement is an invitation to serious problems.

Gross swirl.

Because high velocity and high pressure tend to develop on the outside of each turn, and because successive turns are made in planes at right angles to each other, the high-velocity streamlines migrate circumferentially around the inside of the pipe, producing a gross swirl. When the pump suction is close to the second turn, as in Figure 1a, the swirling fluid is swept directly into the pump. A pump is not designed to anticipate this, and the result may be separation at the leading edges of the impeller vanes, leading to noisy operation and cavitation damage.

Gross swirling may also result in a distorted velocity profile, in which a ring of higher velocities may develop near the pipe wall with lower velocities in the core of the flow. The acceptable deviations from absolute uniformity of flow are difficult to

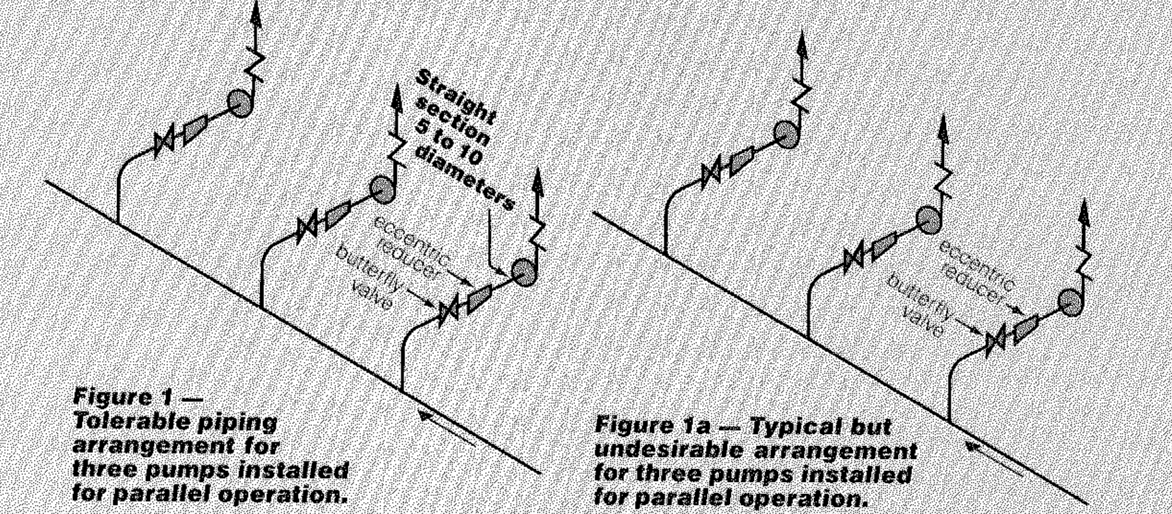

Figure 1 — Tolerable piping arrangement for three pumps installed for parallel operation.

Figure 1a — Typical but undesirable arrangement for three pumps installed for parallel operation.

predict, but a helix angle of up to 5 degrees in swirl, or a variation in the axial components of velocity of not more than plus or minus 5 percent from the mean, will rarely produce a problem in pumps with suction specific speeds below 8,500. Even these limits may be too generous, however, in pumps with suction specific speeds above 8,500.

Minimizing the effects of swirl.

The use of 5 to 10 diameters of straight pipe in Figure 1 allows the viscous shear forces in the liquid to slow down the swirl before it reaches the pump, minimizing the effects of the swirl on the performance of the pump. But as previously indicated, it is possible to design an even better configuration, as illustrated in Figure 2.

In the arrangement shown in Figure 2, there are still two right-angle turns ahead of each pump. By placing them in the same plane, however, the second turn tends to rectify the stratification caused by the first, and the fluid arrives at the pump's suction with a velocity profile almost as good as if there had been no change in direction at all.

And if the two 90-degree turns are replaced with 45-degree turns, so much the better.

Although Figure 2 shows all of the pumps located on one side of the header, they could be alternated on opposite sides to save space — without affecting the desirability of this suction piping arrangement. Also, the header, shown in Figure 2 in the same plane as the pump suction flanges, could be located at a lower elevation, as it is in Figure 1, or overhead. This can be done without compromising the validity of this recommendation, so long as both turns are kept in the same plane, which need not necessarily be horizontal or vertical.

The reducers shown in the header between pumps are purely a suggestion for a means of keeping costs down without sacrificing performance, based on the maximum capacities which must be handled in various portions of the header.

Another arrangement worthy of mention which is commonly employed in large water systems, usually with side-suction, double-suction pumps, is one similar to

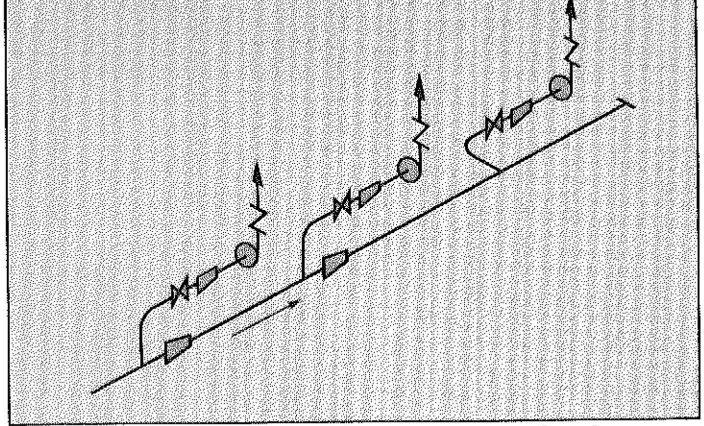

Figure 2 — Preferred piping arrangement for three pumps installed for parallel operation.

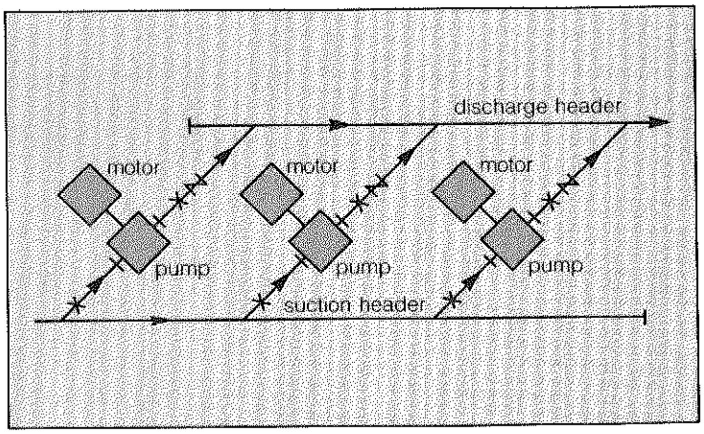

Figure 3 — Acceptable station piping arrangement for large water pump installations.

Figure 2, but where the branch line off the header is at 45 degrees rather that 90 degrees. Since the piping arrangement at the pump is usually of an in-line nature, this also allows the use of a 45-degree connection at a discharge header which is then parallel to the suction header, as shown in Figure 3.

This discussion has been deliberately limited to suction piping arrangements for dry-pit pumps because this is an area which has been generally neglected in the past. There are reasonable amounts of reference materials readily available for wet-pit pumps, as in the Hydraulic Institute Standards, the *Pump Handbook* (McGraw-Hill, 1976), and numerous technical papers which have been prepared on generic laboratory investigations and tests of scale models and prototypes of actual intake structures.

Some of the information contained in these references can and should be incorporated into suction piping designs because similar considerations may exist in closed systems, even though a free surface of the source liquid may not be visible.

Submergence levels.

In many process piping applications, a suction line may be taken off the side or bottom of a process or storage vessel. When this is done, it is necessary to insure that the submergence level over the inlet to the suction pipe is adequate to prevent vortexing, just as it would be necessary in the case of an open sump. If the submergence level is not adequate, the same hazard of vortex development will exist as in the case of an open sump.

Figure 4 indicates reasonable minimum values of submergence over the inlet as a function of liquid velocity at that point. If operating levels of liquid in the vessel cannot provide the required submergence at planned line velocities, the size of the inlet must be increased as necessary to reduce the velocity to the point where the submergence is adequate. Anti-swirl baffling at the inlet will also help control gross rotation, but it is not effective against vapor entrainment.

When the source of liquid is contained in an enclosed process vessel, the liquid may boil at its interface with the vapor in the tank, just as it would in a steam surface condenser hotwell.

Under either of these conditions, the npsh required by the pump may in some cases be quite low (under 10 feet). Maximum suction pipe velocities should be kept in the vicinity of 3 feet per second, which is substantially less than the values suggested for general service in Power & Fluids, Volume 8/No. 4. Ultimately, of course, suction pipe velocities are subject to the follow-

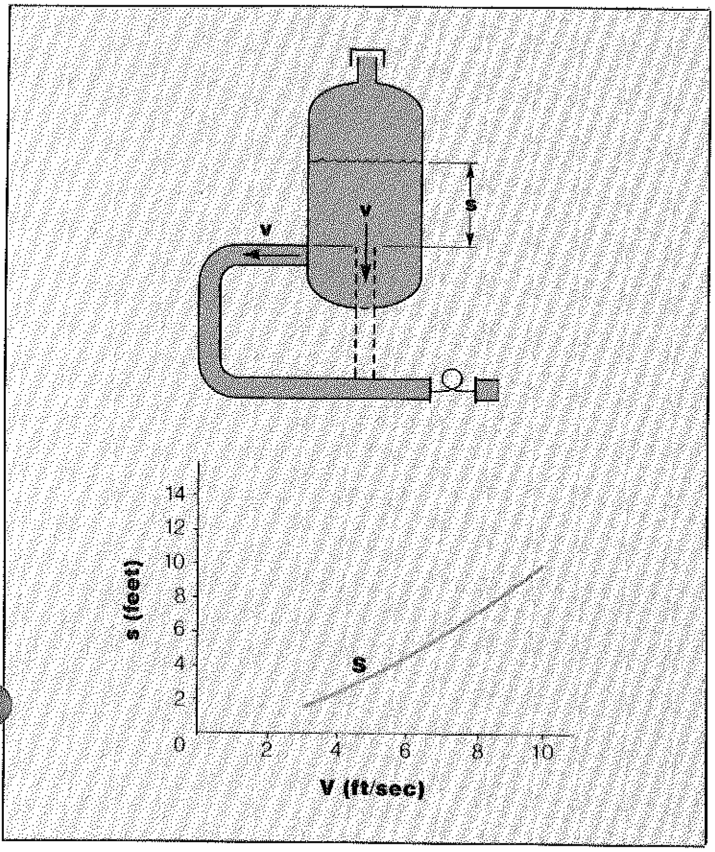

Figure 4 — Recommended minimum submergence above outlet level in tank.

ing constraints: at no point in the suction piping system can the submergence level minus friction be allowed to drop below the velocity head, nor can this be less than the npsh required by the pump at its inlet.

Pipe velocities and boiler feed pumps.

A major exception to the use of very low suction pipe velocities with liquids near boiling is a boiler feed pump taking suction from a deaerating heater. In this kind of installation, transient conditions occurring after a sudden drop in generator output can result in reduced pressure in the suction line. As a result, the large volume of water contained in an oversized suction line will prolong the duration and violence of the flashing which may occur, to the detriment of both the heater and the pump. A further discussion of this subject can be found in Igor Karassik's "Steam Power Plant Clinic #59."

When dealing with boiling liquids, it is advisable to provide suction piping which slopes continuously downwards to the pump inlet, allowing for the venting back upstream to the source of any vapor bubbles which may form in spite of the low-liquid velocities in the pipe.

Suction manifolds may also be a source of problems when handling boiling liquids with low levels of npsh and should generally be avoided. Part of the potential problem lies in the fact that the headers are usually installed horizontally, which in itself is undesirable. Another part of the problem is the differing values of friction loss which will occur between the source and the individual pumps. This may result in premature cavitation in one or more of the units.

Review piping arrangements early.

Undoubtedly, many readers will be able to point to installations identical or similar to types we've recommended against, and which have worked satisfactorily for extended periods. Even so, they should remember that the likelihood of problems will increase with pump size, higher suction specific speed and line velocities, and certain properties of the liquid handled.

Other readers, no doubt, will be able to recall problems caused by suction piping arrangements not even mentioned in these discussions. Since possible design arrangements are infinite, there is obviously no way all of them could be considered. Therefore, in the interest of avoiding serious problems, at least in the case of medium to large pumps where the suspicion of potential problems exists, or where very costly installations are involved, the proposed piping arrangements should be reviewed with the pump manufacturer early enough in the planning stage to allow for necessary changes.