Hydraulic design considerations for pump suction piping.

by W.C. Krutzsch

The subject of piping design has been treated extensively by technical societies, trade associations, architectural and engineering firms, piping manufacturers, and others. If one wishes to learn some of the essentials of this technology, it is not difficult to find them in intensive, short courses offered by continuing education organizations, or by the extension course divisions of some universities.

Should you pursue such a course, you would probably find yourself learning how to design piping arrangements which are safe, economical, and functionally suitable to contain and convey a fluid under specified conditions of temperature and pressure. To serve that purpose, most systems will contain one or more pumps, with which we shall be concerned here, or compressors or blowers.

In some pumping systems the pump is located at the source of the liquid, and the entire piping system is on the discharge side of the pump, in which case such a piping design is undoubtedly adequate. In most cases, however, some portion of the piping system is on the suction side of the pump, and additional concerns, some of which are discussed in this article, must be addressed.

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It is generally accepted among pump engineers that of all the hydraulic problems likely to be encountered with centrifugal pumps, the vast majority will be associated with the inlet side. For the most part, these problems will arise either from faulty design or manufacture, or from pump misapplication. But even if the design and manufacture are precisely correct and the pump is perfectly matched to the operating conditions, the pump can only perform properly if it is supplied with a steady flow of liquid arriving at the pump suction flange under sufficient absolute pressure to equal or exceed the npsh required by the pump, and with uniform velocity with no rotational component.

The failure of the suction piping to deliver the liquid to the pump in this condition can lead to noisy operation, random axial oscillations of the rotor, premature bearing failure, and cavitation damage to the impeller and inlet portions of the casing. The chances of any or all of these events occurring increase with pump size and suction specific speed, or, in other words, with decreasing values of npshr. These problems are also functions of the liquid handled, with troubles less likely to occur with hydrocarbon liquids than with cold water.

When troubles do arise, remedial action can be costly, if not impossible, because the only "fix" in most cases is a major revision of the piping arrangement. Therefore, it is important to avoid the problem in the first place.

Adequate priming or venting is required.

One important consideration in suction piping design is adequate priming or venting. Some literature is available on this particular subject. For example, the

Hydraulic Institute Standards, 13th edition, 1975, include illustrations of typical-configurations for suction piping where the source of the liquid is below the pump, like those shown in Figure 1.

As indicated at the left in this illustration, the line should preferably slope constantly upward toward the pump. Horizontal lines can also be tolerated, but if very long, they may be susceptible to installation inaccuracies or settling effects. In this case, high points may exist where air can be trapped, conceivably reducing the effective cross section of the pipe, increasing the liquid velocity, and thereby the friction loss in the suction line.

Even more likely, however, is the possibility that for pumps operated intermittently, where the suction line is kept full by a foot valve at its intake, a large slug of air may be swept into the pump during a restart, causing a partial or complete loss of pump prime. Any high point in a suction lift line, such as a clearance space in the body of a valve installed with its operating shaft vertically upwards, may also cause such priming interruptions. As a consequence, it is normally recommended that gate valves be installed with their shafts horizontal rather than vertical. This is not necessarily true with butterfly valves, however, which do not present clearance space problems, but which do have a nonretractable member positioned at all times in the fluid stream.

In modern piping systems, even where pumps operate against a static lift, foot valves are only infrequently used, and each pump must therefore be primed before start-up. In such cases, the point of connection between the priming device and the pump should be at the highest point on the casing, which will be above the pump suction flange. The preceding discussion about avoiding other high points in the suction line remains applicable. Information about various forms of priming devices and further details on their associated piping systems may be found in the *Pump Handbook* (McGraw-Hill, 1976).

Reducers for lower velocities.

Figure 2, which has also been adapted from the Hydraulic Institute Standards, illustrates a special case of a piping installation properly designed to avoid creation of an air pocket in the suction line. Reducers are frequently installed just ahead of the pump suction in order to permit lower suction pipe velocities and, therefore, lower friction losses than would otherwise occur. When the liquid source is below the pump, the reducer should be eccentric and should be installed with the flat side up.

As shown in Figure 3, if the source of the liquid is above the pump, a preferred arrangement would be the use of an eccentric reducer with the flat side down. In this case, however, the orientation is not critical, nor is the choice between eccentric or concentric reducer, except in the case of end-suction pumps, as will be discussed shortly. Under any circumstances, however, reducers used at the pump suction should be of the conical type (constant convergence angle) rather than the contour type frequently found in wrought fittings. The latter produce more abrupt changes in velocity which are undesirable immediately ahead of the pump.

For end-suction pumps, additional cautions about the application of reducers must be observed because of the close proximity of the impeller inlet to the suction flange. The following precautionary guidelines should be considered:

- Limit reducers at the pump suction to a change in diameter of one pipe size, such as 12′ x 10′, or 24′ x 20′.
- Where suction lines larger than one size over the suction flange must be used, two or more standard reducers may be installed in series, or a specially fabricated reducer with low convergence could be used (10 degrees maximum total included angle).

  Alternatively, more abrupt reducers may be kept remote from the suction flange with a constant diameter straight pipe between the reducer and the pump flange. For suction flange velocities less than 10 feet per second, this piping section should be at least 3 diameters long, and otherwise at least 5 diameters long.
- When the source of the liquid is above the pump, concentric reducers are preferred for end-suction pumps.

Piping velocities.

The discussion of reducers leads naturally into the subject of piping velocities. These velocities should generally not exceed the value which exists at the pump suction flange. In the simplest of systems, where the inlet pipe is a straight line between the liquid source and the pump suction, the velocity in the pipe itself can be the same as at the pump suction, provided the line losses do not preclude the availability of adequate npsh at the pump suction. Examples include a bottom suction pump straddling a tunnel, or an end-suction pump taking suction through a pipe penetrating a side wall of a wet well. The entrance diameter in these cases is a function of

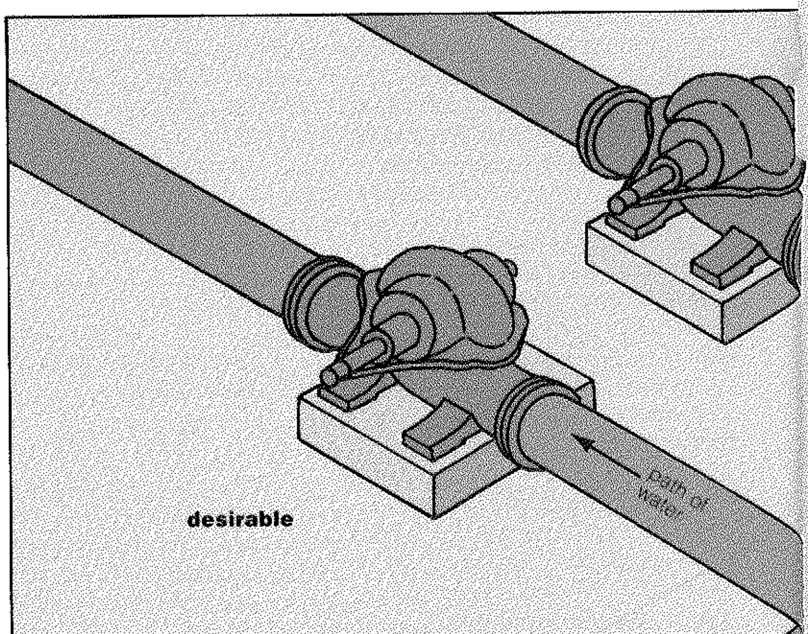


Figure 1—Acceptable and unacceptable suction line designs showing an air pocket at high point.

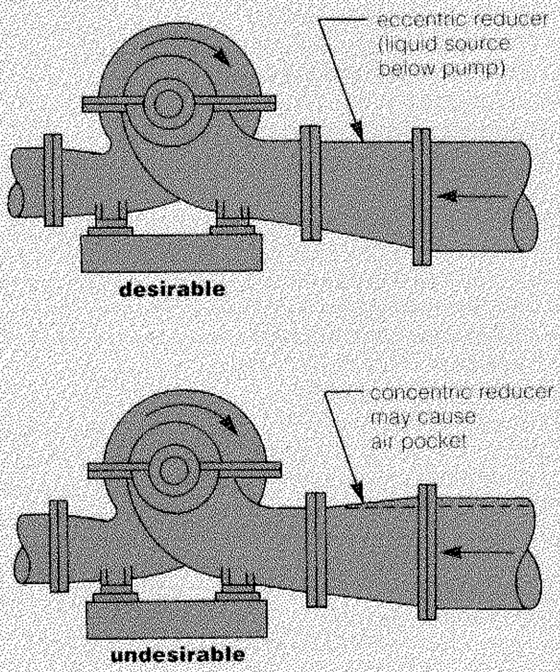
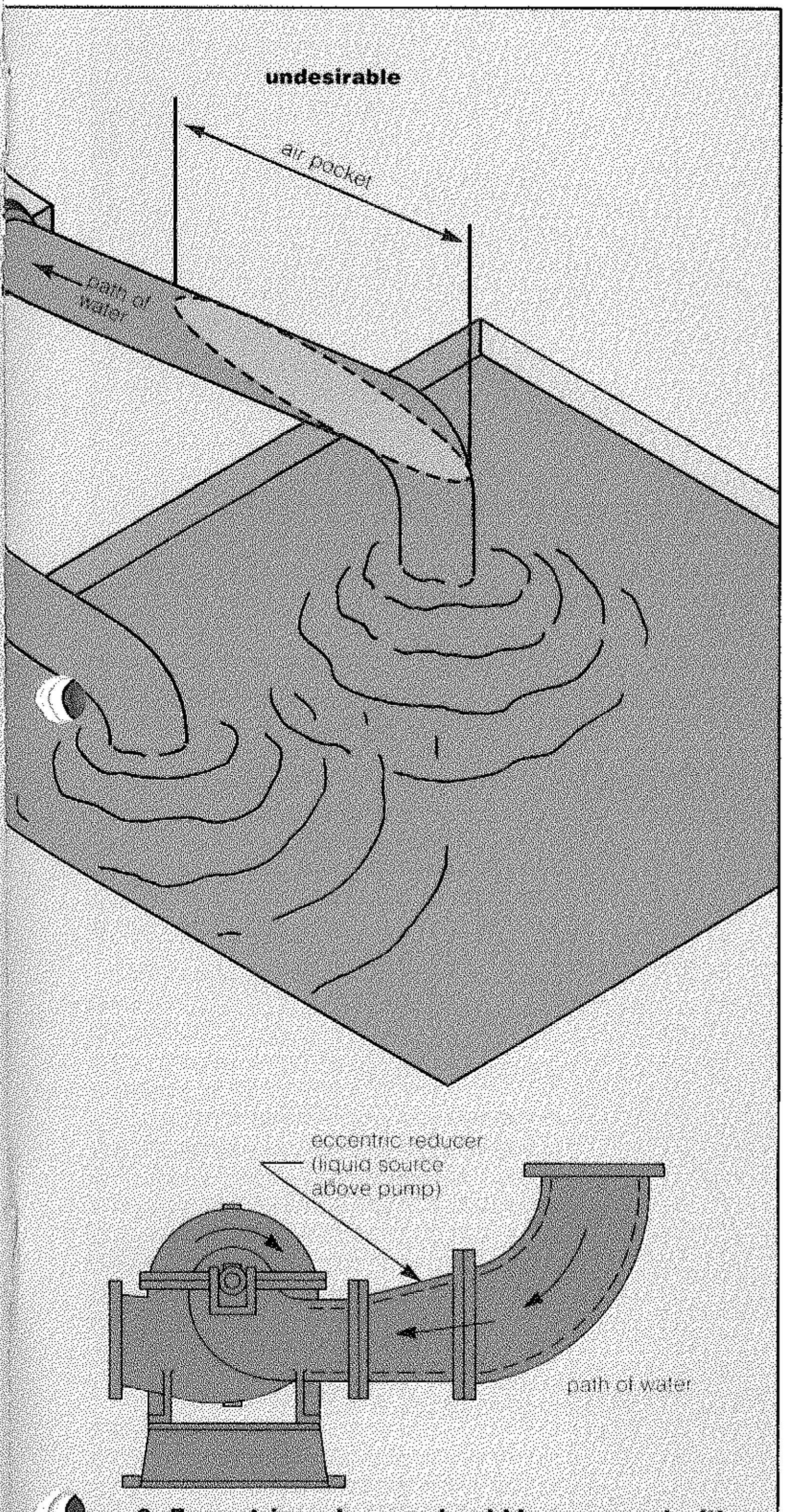


Figure 2—Eccentric reducer at pump suctions avoids creation of air pocket in the suction line.



ure 3–Eccentric reducers should be arranged with the bottoms flat when supply source is above the pump.

submergence, to be discussed in a subsequent article.

As the configuration of the suction pipe close to the pump becomes more complex, the velocities must decrease. The effect of fittings on line loss is still significant, but even more important is its influence on velocity profile and swirl. Therefore, it is not a purpose of this article to provide limiting values of velocity, which can vary widely depending on npsh, type of service, size of pump, and nature of the liquid, but rather to indicate reasonable velocity ranges.

For most industrial centrifugal pump designs, suction flange velocities will vary between approximately 8 feet per second and 15 feet per second. The standard reducer between any two consecutive standard pipe sizes (between 10 inches and 30 inches) will reduce these values to ranges of approximately 4.5 to 5.5 feet per second and 8.4 to 10.4 feet per second. Below 10 inches, a one size reduction in diameter may affect a greater reduction of velocity; above 30 inches the effect will be less.

At a suction line velocity of 5 feet per second, a straight run of pipe equal to five pipe diameters should be adequate to rectify irregularities in the velocity profile which result from a 90-degree change in flow direction through an elbow or tee. But this may still be inadequate to stop a swirl generated by two or more such fittings in planes at right angles to each other. Under these circumstances, it may still be necessary to install straightening vanes at least two pipe diameters in length within the straight approach section.

At suction line velocities of 10 feet per second, the straight section will probably have to be at least 10 diameters in length, but

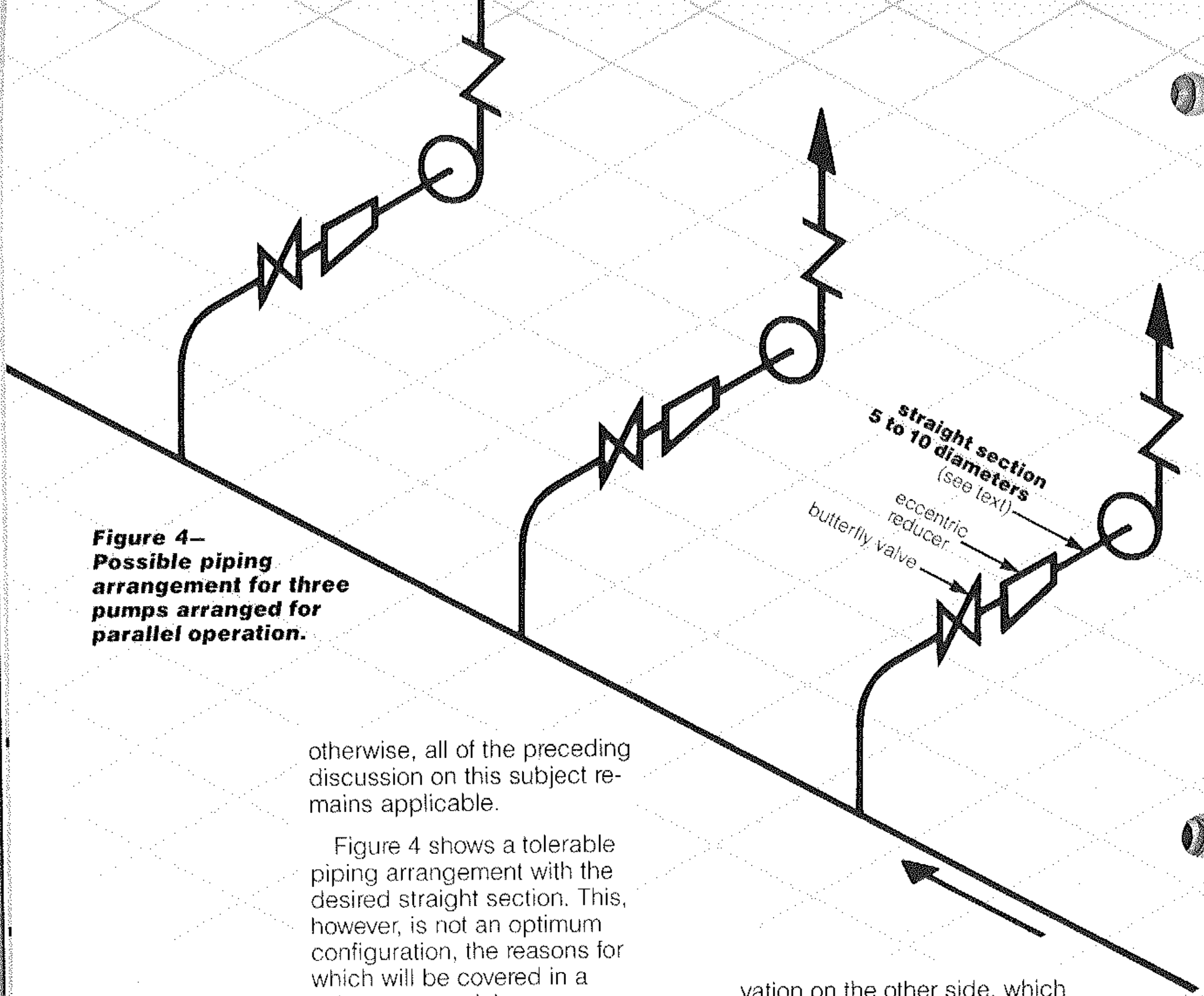


***Figure 4—
Possible piping arrangement for three pumps arranged for parallel operation.***

otherwise, all of the preceding discussion on this subject remains applicable.

Figure 4 shows a tolerable piping arrangement with the desired straight section. This, however, is not an optimum configuration, the reasons for which will be covered in a subsequent article.

Limit the use of elbows.

The installation of an elbow at the suction flange of a double-suction pump, where the plane of the elbow is parallel to the pump shaft, is unacceptable. This arrangement is illustrated on the right of Figure 5, which has been adapted from the Hydraulic Institute Standards.

When liquid flows through an elbow, or from the run into the branch of a tee, both higher pressures and higher velocities are developed on the outside of the turn. This is not a contradiction of Bernoulli's Law, which applies to individual streamlines, because this phenomenon arises from a convergence of streamlines as a result of inertia. This results in fluctuating higher pressure and capacity on one side of the impeller at its inlet, and virtual starvation on the other side, which upsets the axial balance of the rotor and may cause cavitation on the low-pressure side. The result is axial oscillation of the rotor, overloading of the thrust bearing, noisy operation, and possible cavitation damage.

Installation of an elbow at the suction of a double-suction pump should be limited to arrangements in which the plane of the elbow is at right angles to the pump shaft, as shown on the left in Figure 5. This applies whether the source of the liquid is above or below the pump and for bottom-suction as well as side-suction pumps.

In the case of single-suction pumps, whether side, top, or end suction, the orientation of an elbow at the pump suction is normally not critical, but may become so if the pump suction specific speed is over 10,000 in

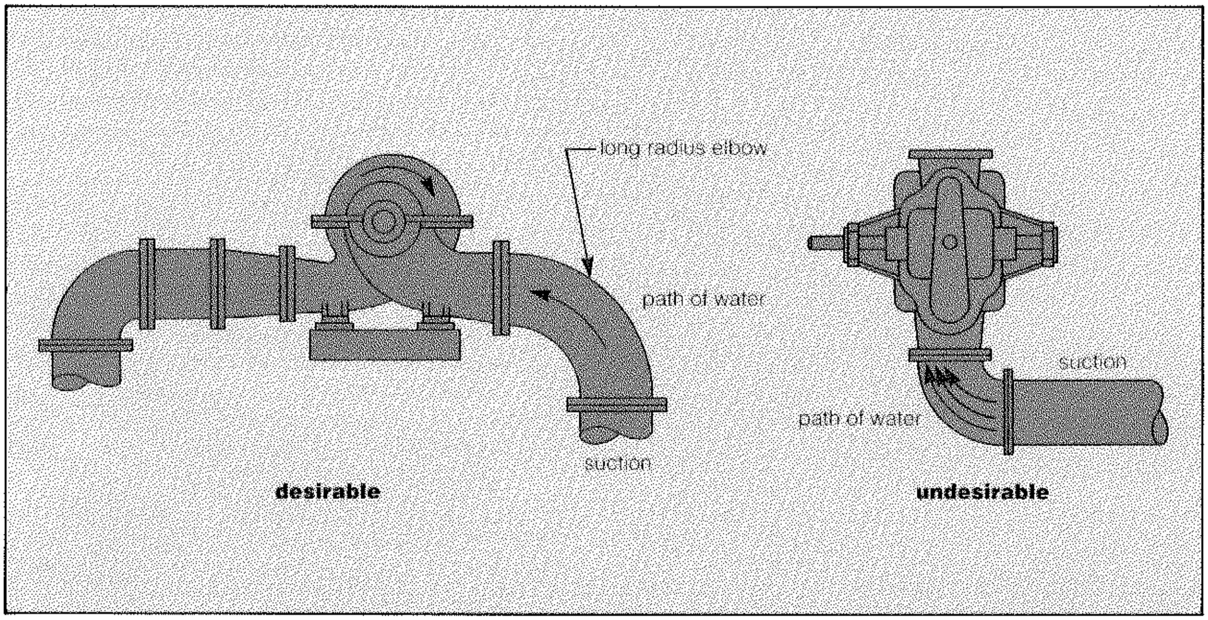


Figure 5—Elbow at the inlet of a double-suction pump must be installed in plane at right angles to the pump shaft, as shown at left. Orientation at right may cause serious problems.

U.S. units. Above this value a straight approach should be provided as already discussed. Below this value, if an elbow must be used, it should be of the long-radius, constant-diameter type. Reduction from suction line size, if necessary, should be accomplished with a reducer downstream of the elbow (Figure 6).

In this article we have considered the importance of avoiding air pockets in pump suction lines, proper selection and installation of reducers, and the orientation of elbows upstream of double-suction pumps. In addition, it has been suggested that some combinations of multiple fittings just ahead of a pump could cause serious flow disturbances at its inlet unless compensating modifications are made to the piping.

In a subsequent article we will explore the last point in greater detail, discuss other typical arrangements for both process and water pumps, and cover some of the special considerations involved in suction piping designs for liquids which are close to boiling.

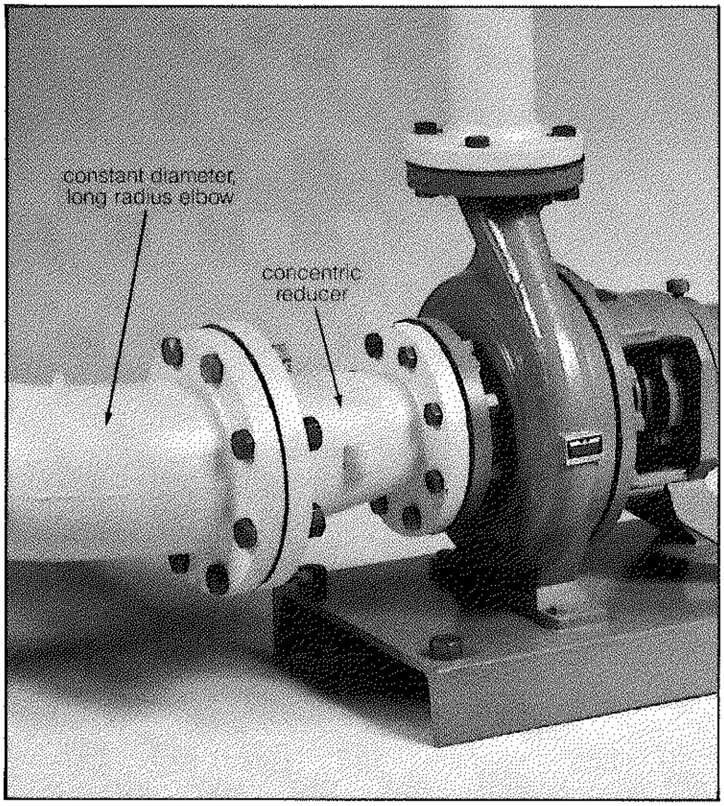


Figure 6—Preferred arrangement of reducer and long radius elbow on a single-suction pump when straight pipe approach cannot be provided.