GRUNDFOS

WHITE PAPER

PIPING CONNECTION CONSIDERATIONS

by Greg Towsley

Although the fabrication and installation of the piping system may appear trivial, it is important that some basic piping considerations be observed. By following these concepts, the life of the pumping equipment and its accessories will be extended.

If good piping practices on the suction and discharge sides of the pump are not followed, it can be expected that the following problems may be experienced:

- Noisy pump and driver during operation
- Axial load fluctuations
- Excessive equipment vibration
- Premature bearing failure of the pump and driver
- Premature wear and failure of other pump parts, such as the mechanical seal and wear rings
- Cavitation damage to the impeller and inlet of the casing, and possibly the discharge
- Leakage at the flanges
- Cracking or breakage of the flanges or casing

While this article provides an overview of considerations of the piping system, it is by no means a complete reference on the subject.

Besides Grundfos' installation and operation instructions, other references should be reviewed. As they relate to pumps, the Hydraulic Institute (HI)[1] provides general piping guidelines in their Standards.

In addition to those references shown at the end of this article, other reference that can provide additional recommendations include:

- Anvil International Inc. (2001). *Pipe Fitters Handbook*. http://www.anvilintl.com/
- Heald, C.C. *Cameron Hydraulic Data*, 18th Edition. Ingersoll-Rand Company, 1995.
- Nayyar, Mohinder L. *Piping Handbook*, 6th Edition. McGraw-Hill, Inc., 1992.

Although it is not Grundfos' responsibility to design the piping system or suction intake, a review of the system by Grundfos can provide the designer comments on how the equipment will be affected by the design.

PIPING SYSTEM COMPONENTS

Before considering the overall system, an understanding of the components of the piping system and their effect on the system should be reviewed.

CONNECTIONS

Pumps can be connected to their piping systems through various means. The most basic connection is a threaded connection, typically to National Pipe Thread (NPT) standards.

Threaded connections are commonly used on smaller pumps in water applications. Other connections used in various industries include grooved or Victaulic, clamp, or Tri-clamp.

Probably the most common pump connection is a flange. Flanges are typically cast or formed integrally with the volute. As with pipe flanges, cast iron pump flanges are rated as 125# or 250# with flat faces.

Steel flanges are typically rated for 150# or 300# with 1/16-inch raised faces. These adhere to ASME/ANSI flange and fitting specifications B16.1[3] and B16.5[4], respectively.

If the system has no pressure or other limitations, cast iron flanges can be connected to steel flanges.

For most pump systems, it is preferred to utilize flat face (F.F.) flanges on both the pump and the piping connection. This flat mating flange will help insure that an acceptable gasket surface is available to obtain a good seal, and prevent breaking when the bolts are tightened.

Occasionally, a system will require increase pressure containment capabilities at connections. The use of raised face (R.F.) flanges allows more pressure to be concentrated on a smaller gasket area. However, care must be taken when tightening bolts on R.F. flanges.

If not properly tightened and torqued to the manufacturer's recommendations, the flanges can pivot along the edge of the raised face. This can cause distortion in the pump volute, as well as possibly cracking or breaking a flange.

EXPANSION JOINTS

Expansion joints can be used when the piping system can expect axial movement due to thermal expansion of the liquid. The expansion joints will assist in preventing the pump from being shifted out of alignment.

Typically, they are installed in low-pressure systems. Important to the reliability of the pump and piping system is the need for proper selection and installation.

An expansion joint can be installed on the suction and discharge side of a pump. The location should be on the opposite side of the piping support, or anchor, away from the pump.

If the expansion joint is placed between the anchor and the pump, a force could be caused that would be more than the pump or the system could handle. The force would be equal to the area of the maximum expansion joint inside diameter multiplied by the pressure in the pipe. In addition, according to HI[1], if the joint is not properly aligned with the pipe, the shear force and torsion may be transmitted to the equipment.

To insure that the expansion joints are effective in the piping system, they must be sized properly and the material of construction must correspond with the application.

Although these joints provide relief of axial pipe movement, they are not as flexible as many perceive. The pump and system can also be subjected to excessive forces due to poor expansion joint sizing.

ISOLATION VALVE

An isolation valve, or shutoff valve, should be installed in the discharge pipe. It assists in the priming of the pump, starting the pump, and for isolation, as may be required for pump maintenance. Except for axial and mixed flow pumps, the isolation valve should be closed before stopping pump, especially if no check valve is installed.

An isolation valve should not be used for the throttling of the pump. Throttling of the discharge isolation valve contributes to a substantial waste of energy in the pump. Should an existing discharge valve be found to be throttling the pump excessively, a correctly sized pump should be installed, or some other variable speed drive should be considered.

CHECK VALVE

A check valve is utilized in a pump system to prevent back flow of the liquid when the pump is stopped. This reverse flow could cause damage to the pump, from the impeller becoming loose for example, or cause difficulty in re-priming the pump.

The check valve is located in the discharge line, between the pump and isolation, or shutoff, valve, and on the far side of the expansion joint, away from the pump. It should never be installed in the suction line. A check valve is a flow restrictor in the piping, and will cause a pressure drop.

REDUCER

A pipe reducer is a fitting that allows a change in the diameter of the pipe in the system. The information in this section is also applicable to a pipe increaser. It is important to properly size and install a reducer to insure that smooth flow through the system is not disturbed, causing damage to the equipment or the system.

Damaging turbulence and noise can occur if proper sizing and installation is not followed according to the manufacturer's recommendations.

The size of the reducer should not provide more than one reduction in size. Turbulence and excessive noise may occur if a reduction of greater than one pipe diameter is installed. The reducer should be a conical type, in lieu of the contoured design, to assist in preventing air pockets.

According to the Hydraulic Institute[1], the reducer used with an end suction pump should be placed 5 to 10 pipe diameters from the pump inlet. In addition, air pockets can be created due to installation errors.

If possible, the reducer should be installed with a slope up towards the pump to prevent air pockets. If the reducer is of the eccentric design, the sloping side should be on the lower side of the pipe, as shown in *Figures 1* and *2*. *Figure 3* provides a view of a concentric reducer installed on the suction end of an end suction pump.

ELBOW

Elbows may be required near the pump to redirect flow from the piping system into the pump. The direction the elbow is installed is critical to the nature of the flow characteristics and the overall life of the pump.

For the installation of an elbow on the suction side of a double suction pump, the direction that the elbow faces is very important. Should one be required, a long radius elbow should be used with its plane in a position at a right angle, up or down, to the pump shaft.

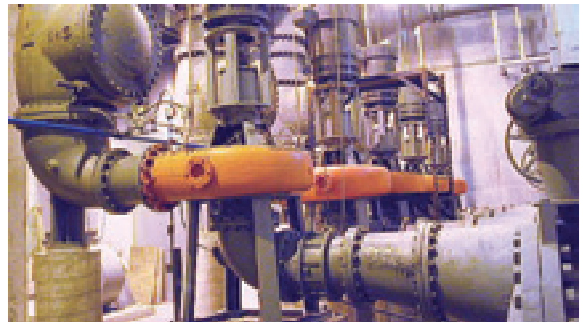


Figure 1. *Eccentric Reducers on Suction Piping*

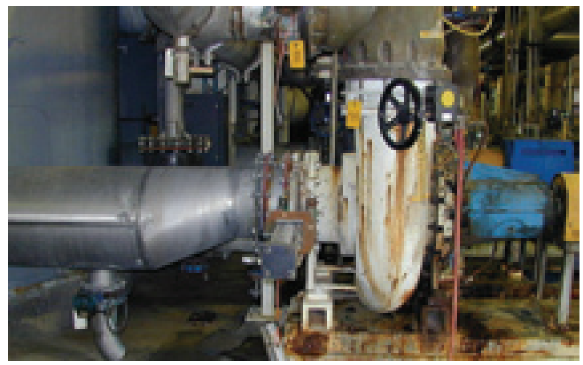


Figure 2. *Eccentric Reducer on Suction Piping*

Figure 3. *Concentric Reducer on Suction Piping*

The system should not be designed to allow an elbow to be installed with its plane in parallel to the pump shaft. The elbow in this configuration will cause uneven flow into the double suction pump.

The capacity or velocity of the liquid will be higher on one side of the impeller's inlet, causing the opposite side to be starved of flow. This causes high axial loads and an upset in the pumps axial balance, excessive noise during operation, and possible cavitation damage.

For an end suction pump, the use of no elbow is recommended on the suction side of the pump. Should one be required, it should be of the long radius design and have a straight length of unobstructed pipe between the pump inlet and the elbow of 5 to 10 pipe diameters. *Figure 4* illustrates the incorrect installation of an elbow.

STRAINER

The function of a strainer in a pump's suction piping is to keep solids out of the pump and the pumping system. A strainer can be used in most all pumps, except in large units. For the larger pumps, a temporary strainer can be installed for the start up of a new installation. This temporary strainer can be left in place until the system is clean and construction debris is removed.

Strainers will cause a moderate pressure drop in the system, until it begins to clog and accumulate solid materials. At this point, the pressure drop across the strainer will increase, and may cause the pump to starve.

Ideally, the pipe on the up stream and down stream side of the strainer should be tapped and used to monitor the pressure drop. After some experience, a set point can be determined when the strainer requires cleaning.

The cleaning of the strainer can then be added to a routine maintenance schedule.

The size of the strainer should be chosen so that the open or "free" area of the strainer is three (3) times the suction pipe area.

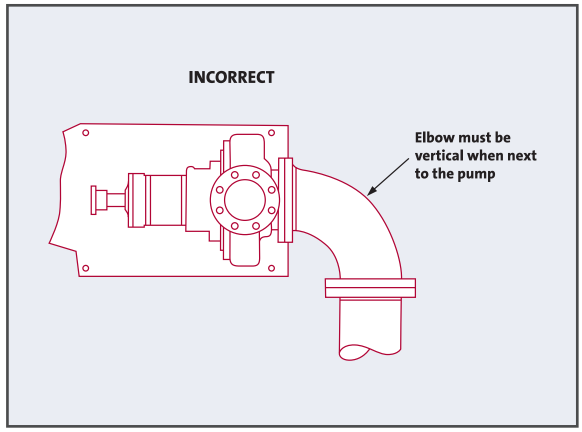


Figure 4. *Incorrect Installation of Elbow*

FOOT VALVES

Foot valves are used on the suction side of a pump to provide suction lift for pumps that are not self-priming. They act as a check valve, maintaining liquid in a pump's suction line.

A foot valve can fail the pumping system when it loses its sealing capabilities and begins to leak. In addition, it may fail the system if solids or some other type of foreign matter prevents it from closing properly.

If a pump is utilizing a foot valve for priming from a suction lift, the failure of the foot valve will cause the pump to run dry because of the lack of liquid in the pump and suction line. Operating with no liquid in the pump may possibly cause catastrophic damage to the unit.

PIPING DESIGN CONSIDERATIONS

In addition to the considerations that must be made with the various system components, the design and fabrication of the suction and discharge piping must followed according to best practices of the industry.

As with any project, it is important that the piping design and fabrication is done right the first time. If it is not done following recommended practices, it will be difficult and expensive to correct in the future. *Figure 5* shows incorrect and correct piping configurations. These should be referenced for various discussions in this article.

DESIGN

The first consideration in the design of a piping system is the sizing of the pipe. The capacity must be established not only for the entire process or system, but for the individual branches as well. The design flow should not be oversized by a large margin to prevent throttling of valves and wasting energy.

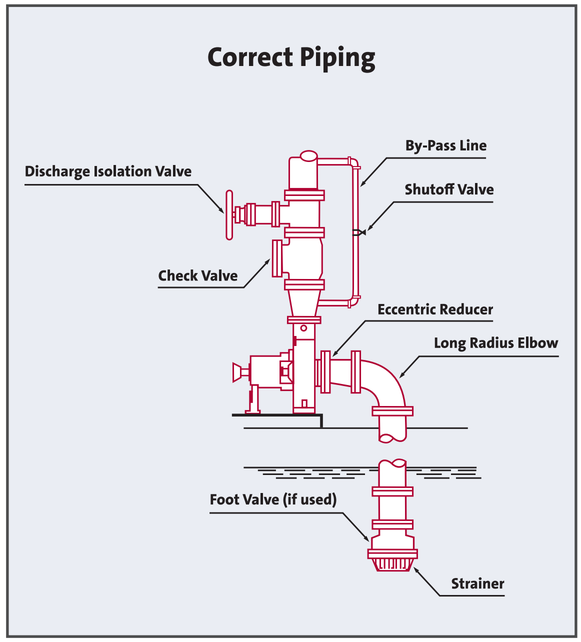
The goal of selecting the pipe size of the system is maximize the pipe sizes used, while minimizing the costs of the pipe. As pipe sizes are increased, the system head loss, due to friction, is decreased.

Additional consideration must be made for pumping viscous materials. Viscous materials have a greater friction loss than water in the same size pipe. Many of the references in this article have friction charts that assist in pipe size selection for various flow rates.

The size of the suction and discharge piping should be at least the size of the pump connections. Suction pipe should be one (1) to two (2) sizes larger than the pump connection, never smaller. A reducer can be used to in the suction line to allow for the suction pipe that is oversized.

The overall design of the piping system should be as straight and as short as possible, with a minimal about of bends or turns in the system. Sudden changes in pipe diameter will cause turbulence and head loss in a system, and, therefore, should be avoided.

A final design consideration for the piping system is for the ease of pump removal for repair. As a pump will eventually require removal and maintenance, the piping system should be designed to allow technicians to work on the pump at the site, as well as remove it safely. Liberal spacing should be maintained around the equipment.



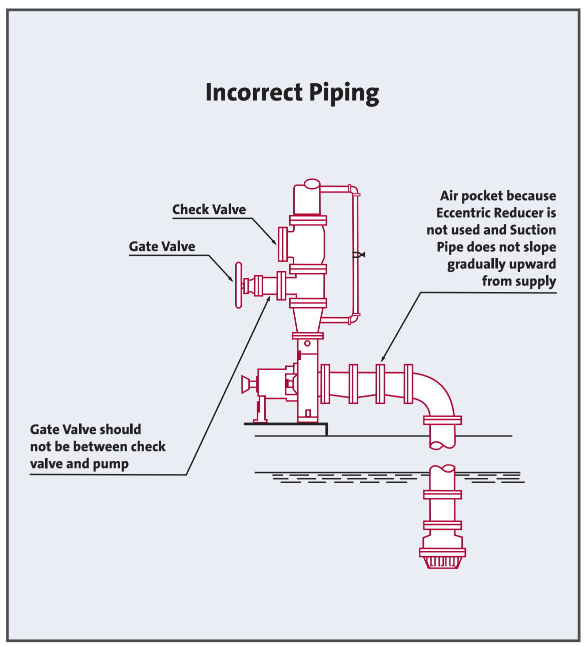


Figure 5. *Correct and Incorrect Piping Configurations*

Suction Side

The piping on the suction side of the pump is the most critical to the reliability of the pump and the system. The suction piping must have a number of design considerations that will provide:

- Steady flow of liquid
- Fully-developed flow profile (avoid disturbances in close proximity to the suction)
- Adequate Net Positive Suction Head (NPSH) available

The velocity of the liquid in the suction pipe must not exceed that of the velocity in the suction inlet of the pump. If the suction pipe is larger than the suction connection, a higher velocity in the pipe will not occur. Larger pipe will reduce the pipe velocity for a given flow rate. High temperature services may also require large pipe sizes to reduce friction and improve the NPSH available.

A velocity of 3 to 10 feet per second (2.1 to 6.8 meters per second) is recommended, with a preference of the flow to below 7 feet per second (4.8 meters per second). Velocities of more than 15 feet per second (10.2 meters per second) should be avoided. If the liquid being pumped is near its boiling point, the velocity should not exceed 3 feet per second (2.1 meters per second).

The larger pipe will also assist with the increase of the NPSH available and reduce pressure losses due to friction. In some cases, such as when handling slurries or in vertical pump columns, the velocity needs to be maintained higher than 3 feet per second (2.1 meters per second) to avoid settling (in the case of the slurries) or to ensure that suspended solids are carried up the column (in the case of the vertical pump).

The specific minimum slurry velocity depends on the slurry nature; 5 feet per second (3.4 meters per second(is a commonly applied minimum. Grundfos should be consulted in the case of the minimum recommended column velocity.

The piping configuration and fittings on the suction must be closely considered to minimize friction losses. Any unnecessary fittings, valves or accessory items should not be designed or installed in the pump suction piping. A straight length of 4 to 10 pipe diameters should be designed into the suction piping prior to the pump suction connection. If this length is not possible, the use of straightening vanes or diffusers can be installed to ensure uniform flow.

No more than one 90° perpendicular turn should occur in close proximity to the pump suction connection to prevent a swirl in the liquid. The non-uniformity of the swirl will cause excessive noise and cavitation damage to the pump. If multiple turns are required, the turns should occur in the same plane to assist in “straightening” the flow into the pump suction.

Isolation valves installed in the pump suction piping to permit pump isolation for maintenance should be installed two pipe diameters or more upstream of the suction. These isolation valves should be of a design that creates minimal frictional loss in the suction (such as gate valves).

For multiple pumps in a common system, each pump should have separate suction lines from same source or piping header. More than one pump suction on a branch may cause one unit to “starve.”

Systems with a suction head or flooded suction are the most common. For these systems, the greatest pump problems come from suction piping and layout. The suction line from the source should be fabricated free of air pockets. The inlet piping should be level or slope downward from the source of supply.

No piping should be below the pump suction flange. At the suction source, the suction pipe must be adequately submerged below the liquid surface to prevent vortices and air entrainment that may reach the pump.

In applications where a suction lift is involved, similar piping considerations must be followed. The suction line should be free of air pockets. Air pockets of any type may cause a loss of prime or delay the pumping when the pump is started. The piping should slope constantly upwards from the source to the pump. All joints must be tight to prevent the liquid from leaking out and air from entering during operation. If the pump is not of the self-priming design, the suction line must be fabricated with a means of priming the pump.

Although they are not common with a suction lift application, valves should be installed with their stems in the horizontal position to prevent the collection of air, gas or vapor at a high point. If no foot valve is used, the pump should be self-priming or it must be primed before each start. The priming point should be located at a high point of the pump casing.

For an intake structure, such as a cooling tower basin or wet pit, design recommendations of the Hydraulic Institute[2] in their standard for pump intake design should be followed. Recent research by the pump industry has allowed HI to prepare detailed recommendations for both suction pipes and wet pits.

The standards provide information about how to minimize or eliminate vortices and variations of velocity at impeller eye, entrained air or gas bubbles. The design considerations allow for optimum hydraulic performance while maximizing the reliability of the equipment.

Improper design and construction of pump intakes will disturb the inflow, causing deterioration of the pump performance and shorten pump life due to vibration and cavitation. Ideally, a model test of the intake for large or custom pumps will assist in proper design, however the expense will be high.

Discharge Side

Discharge piping in a pump system has virtually no effect on pump performance other than the head loss that it creates. Optimal discharge piping design will assist in minimizing installation and operating costs. Too small of pipe sizes, fittings and accessories will cause high velocities, increased pressures and wasted energy.

Sizing the system piping too large will increase the initial capital cost of the pipe, fittings and accessories. The discharge pipe, valves and fittings should be at least the same diameter as the pump discharge connection (normally larger), or sized with good industry piping practices.

As described previously, a check valve can be installed between the pump discharge connection and the isolation valve. If a piping increaser is utilized, it should be located between the check valve and the pump. The optimal design of the discharge line should be at an angle, such as a "Y" connection, to minimize turbulence and head loss that occurs with a right angle into a manifold.

FABRICATION

As with the design, the fabrication of the piping system must follow standard industry practices. Some industries, such as the power[5], building services[6], and chemical and petroleum[7], have standards that should be followed for reliable and safe systems. Basic practices start by recommending that the pipe, valves, and fittings be cleaned before assembly.

In addition to the pressure of the system, the pump will add additional pressure. The piping system should have a pressure rating that is equal to or greater than the maximum system pressure. Local codes are regulations should be followed. A pressure test on the system will provide a check of the integrity of the piping installation.

Pipe strain is the main element during fabrication that should be avoided to increase equipment life and reliability. As mentioned in Dufour and Nelson[8], the "piping system should be fabricated by starting at the pump flanges and then working toward the pipe rack."

Care during fabrication and alignment of the piping and fittings will help avoid problems that may require recutting, fitting, rewelding, and retesting of the pipe system. The most common cause of pipe strain is misaligned pipe flanges.

Care in alignment of the piping components help to prevent future problems. The pump flanges should line up naturally, without any additional aid. During fabrication, a simple method to determine if pipe flange faces are parallel is to see if you can visibly see a difference in the flange face planes. If the gap between the faces is visible and is not even, then it will cause pipe strain.

Other causes of pipe strain, that may impose a force and torque on the pump, include thermal growth, an inadequate piping design and support system, pressure surges, and water hammer. The effects of pipe strain include:

- Coupling misalignment
- Cracking of the piping nozzles or pump casing
- Distortion of pump casing and bearing housing
- Excessive vibration
- False appearance of soft foot conditions during alignment
- Inconsistent alignment data
- Leakage at the pump flanges
- Shortened mechanical seal and bearing life
- Wear ring contact

API-610[9] states that "acceptable piping configurations should not cause excessive misalignment between the pump and the driver." These specifications have a table that provides information on acceptable component nozzle loads that limit casing distortion and ensure minimal shaft distortion.

Standard industry practices recommend that the pipe be run from the pump to a point several feet away, where the final pipe connection can be made. During the fabrication, temporary braces and supports should be used to maintain the piping and fittings in place while the system is being completed.

During fabrication of the pipe, the piping should never be drawn into place by force, as with ratchet pullers or chain hoists. This may cause strain, breakage, distortion, or misalignment, and may affect the operation or damage the equipment.

The pipe should not be connected to the pump until grout has cured and pump/driver/base bolts have been tightened. After the fabrication of the piping system is completed, the pump installation is complete, and the connections are made to the pump, the shaft should be rotated to insure there is no binding. The alignment should be checked to determine the absence of pipe strain. The piping should be corrected if pipe strain is present and causing misalignment.

SUPPORT

Besides proper fabrication of a piping system, it is important to properly support the pipe as well. If no pipe support exists, the pipe strain will induce stress into the equipment and support system.

In determining the proper support of the piping system, the forces and moments of the piping system must be calculated. The calculations must include the weights of the pipe, the liquid in the pipe, and the pipe insulation. Thermal expansion and contraction must also be taken into account.

The suction and discharge piping must be anchored, supported, and restrained near the pump to avoid the forces and movements of the system being applied to the pump.

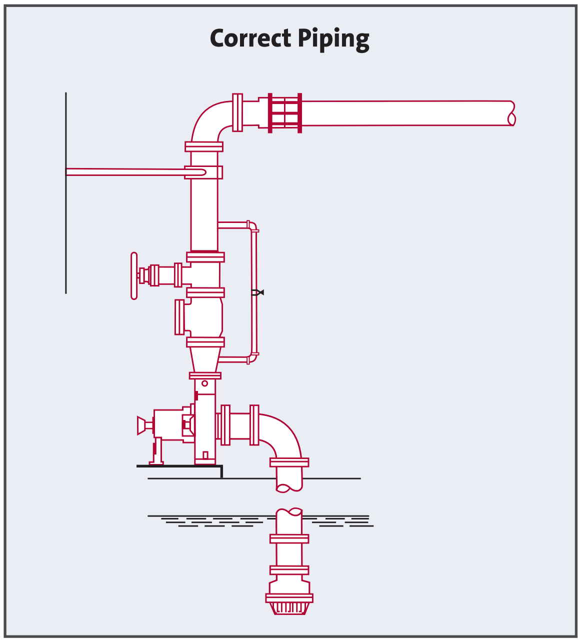
The pipe should be anchored close to the pump flanges on suction and discharge to prevent vibration and putting strain on the piping. *Figure 6* illustrates correct and incorrect piping support.

A system of hangers and braces should be used to support the piping system. The hangers and braces should be installed in a manner such that they do not have to be removed during normal maintenance on the equipment.

Long pipe runs should be supported at unequal distances to prevent resonant vibrations from occurring in the system. After the piping has be installed and supported, the alignment should be rechecked. The piping should then be adjusted if there is any significant change to the equipment's last alignment readings.

OTHER PIPING CONSIDERATIONS

Pressure gauges should be mounted on the suction and discharge of the pump. The gauges not only provide a means of monitoring the equipment, but also can be used in troubleshooting



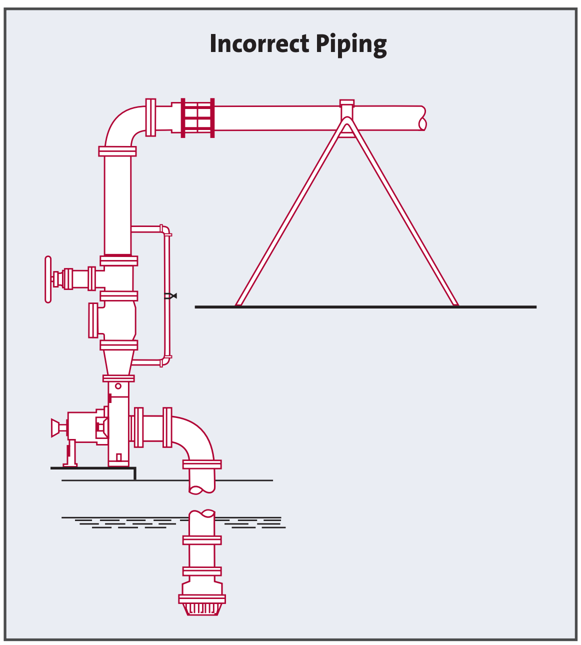


Figure 6. *Correct and Incorrect Piping Support*

problems. The gauges **MUST** be mounted before any valves or fittings. If placed after valves or fittings, false pressure readings of the pump output will be observed and will not provide accurate information. *Figure 7* provides a view of a double suction pump in a water distribution system booster station with suction and discharge flange pressure gauge connections.

Simple vents and drains should be used with pumping systems, unless handling a corrosive or toxic product. Vents should be installed on the pump casing as well as system piping high points to allow the pump and system to be completely filled. A drain will remove product out of the pump and away from the site when repairing the equipment.

When positive displacement pumps are used in a system, a means of pressure relief must be installed in the system. Without some type of pressure relief, the system pressure will continue to build when the pump is operating against a closed discharge. The weakest point in the system will eventually fail, causing damage or injury.

The rules for design of piping systems for pumping slurries may not necessarily apply as for water-like liquid. Light slurries do act similar to water. However, heavy slurries don't act like water. Heavy

Figure 7. *Double Suction Pump with Suction and Discharge Flange Pressure Measurement Connections*

slurries are considered as liquids with greater than 20% solids by volume. Typically, additional power and higher velocities are required to move heavy slurries. These systems also see greater wear to the pipe, fittings and equipment. The proper design of piping systems handling heavy slurries is very detailed and is more than can be covered in this article.

SUMMARY

Proper sizing of the piping system will result in the lowest overall pumping system life cycle cost. This requires finding the optimum balance between pipe purchase and installation costs and energy costs associated with the pipe frictional losses.

It should further be noted that the frictional losses created by piping systems can require larger pumps, motors, and power supplies to overcome the losses than if larger pipe were used.

Pump discharge pressure will also be greater when frictional losses are excessive. Proper design and fabrication will ensure that the equipment will be reliable and will not fail due to the effects of the piping system.

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ACKNOWLEDGEMENTS

Figures 1, 2, 3, and 7:
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BE > THINK > INNOVATE >

Being responsible is our foundation
Thinking ahead makes it possible
Innovation is the essence

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