CHAPTER FIVE

PUMP INSTALLATION

AND

COMMISSIONING

Pump Installation and Commissioning

After proper specification, selection, sizing, inspection, and testing, installation is the next key factor in the reliable operation of any centrifugal pump. When properly installed, operated, and maintained, a pump can offer many years of trouble-free service.

However, when pumps are incorrectly installed, maintenance and operational problems will impede its performance.

Careful preparation and planning is needed to insure proper installation of all pumps. It is a coordinated effort between the supervising engineer, the mechanical and electrical contractors, and suppliers.

The installation process is a series of many steps.

6.1 Site Location

This is one of the pre-installation activities. Prior to the receipt of the equipment, drawings specifying layout dimensions are available and this enables one to select and mark out the site location for the equipment.

Ergonomic considerations are a prime factor in the selection of a proper site. When equipment is accessible for maintenance, technicians perform better and operators activate and control it more efficiently.

A pump or its motor that is difficult to access and maintain becomes a cause for longer downtime and lower availability.

Poor workmanship due to difficult access leads to lower reliability.

Safety is the main aspect. A difficult site has a higher probability of accidents. Thus, this is a factor that requires considerable attention and has to be done by a person with good practical experience in operation and maintenance of pumps.

6.2 Receipts and Physical Inspection

All pumps and auxiliary equipment or components should be examined upon receipt for any signs of apparent damage. If any damage is indicated, it should be notified.

In case the installation is not planned immediately, it is best to store it in a clean, dry location where it will be protected from possible damage. When storing equipment, it is best to follow the manufacturer's recommendations and protect it from environmental extremes.

It is also advised to check the equipment prior to storage to anticipate any possible problems at the time of installation. It is a good idea to check sizes, design features called for on the plans and specifications, and all interface components. With these simple early checks, installation problems can be minimized to a great extent.

Following are some good recommended practices:

- All nozzles, openings should be kept covered or plugged until the piping is attached.
- The bearing housings should be filled with oil of the recommended viscosity. If greased bearings are installed, new grease should be pumped in and old one should be displaced.
- All exposed surfaces should be coated with rust preventive. If the pump is anticipated for preservation for more than 6 months then the internals too should be coated with suitable rust preventive or an oil mist.
- Pump packings with sleeves should be removed.
- Careful handling has to be taken for pumps installed with mechanical seals.

  They should not be subjected to impact or excessive vibration.

6.3 Pre-Alignment Checks

In the event of an immediate installation after the receipt of the pump, an alignment check of the pump with its motor on the base-plate should be carried out. This is to insure that it is possible to achieve the final alignment tolerances as per the specification. This check is recommended using a reverse dial indicator method or laser alignment method.

If the specified alignment is not achieved, there is still time to rectify the faults. This saves time and money and prevents quick fixes if the problem was detected at the final stages of installation. A correct alignment is necessary for pump operation.

If correct alignment is achieved, the pump and motor can be removed from the base to ease the installation and help prevent damage to critical components.

6.4 Location of Pump Foundation

Once the site location has been fixed, the location of pump foundation is often a job of finetuning to bring it in line with the existing equipment like piping, vessels, and any other.

The factors for site location are not lost here and one has to keep in mind when choosing the exact location. It should allow room for walkways, existing piping, new piping, operator, technician accessibility, and aesthetic considerations.

The aspects that can usually be altered are the orientation of the pumps face, their closeness to walls, and the height and depth of the pump foundation.

If the pump height or location is altered, one has to insure that the operating parameters of the pump can still be met. The prime consideration is the NPSH margin or ratio. If installation standards or guidelines already exist, it is essential to obtain the concerned engineer's consent.

6.5 Design and Dimensions of Pump Foundation

The pump foundation has two specific purposes:

1. It serves as a support for the pumps to operate in a safe manner.
2. The foundation mass will damp the pump vibrations.

The pump foundation must provide enough rigidity to absorb axial, transverse, and torsion loads that the rotating pump imposes. Proper structural design of a foundation requires an evaluation of soil conditions so that both dynamic and static forces are considered.

A foundation design has to take into consideration the following aspects:

- Functional support to the pump; it should have a mass – that is, at least thrice the total weight of supporting equipment.
- The foundation rests on solid or stabilized earth that is completely independent of other foundations, pads, walls, or operating platforms.
- A minimum of 3000 psi steel reinforced concrete should be used.
- The foundation's resonant frequency cannot be excited by pump operating speed or multiples of operating speed.
- All units, including the pump, gearbox, and motor rest on a common foundation.
- The foundation is designed for uniform temperatures to minimize distortion and misalignment.
- The foundation is designed taking into account the seismic activity in the region.

Some rules of thumb are followed for general pump foundation design and dimensions (Figure 6.1).

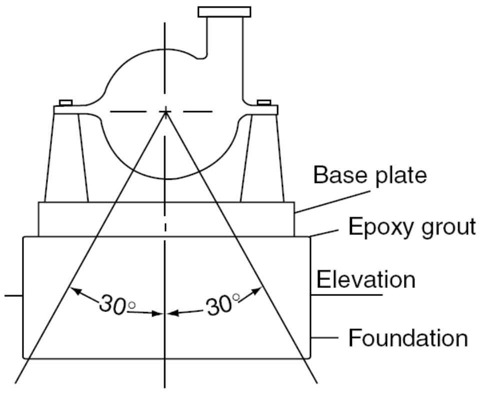

Figure 6.1 – A Pump On Its Foundation

- Drop two lines from the pump center that are 30° to the vertical. The width of the foundation should be more than its spread.
- Weight of foundation should be a minimum 3 times more than the mass of supported equipments.
- For pumps less than 500 HP, the distance between base plate edge and foundation edge, all the way around should be at least 3 in. For pumps with higher horsepower, it should be 6 in.

6.6 Excavation and Forms for Pump Foundation

Once the site location, orientation, and dimensions of the pump foundation are fixed, the data can be used to mark the location, and excavate a correctly sized cavity to the correct depth. The usual requirements are a cement saw, jackhammer, air supply, wheelbarrow, shovels, a small front-end loader, a disposal method for the excavated material, and permits for digging.

It usually takes a maximum of two days to excavate for an average-sized centrifugal pump.

Once the right size excavation has been carried out, the next step is placing the forms. These can be reusable forms or one-time use forms. It is important that the forms are true, solid, well-braced, and liquid-tight. The leak tightness is required as epoxies have a tendency to seep through small holes, a lot more readily than the cements.

Once the forms are installed, it is essential to insure that these are level, square, and securely fastened to the floor or the ground.

This is essential as the weight of the cement and epoxy would bear on the forms and could easily cause it to shift. If the form shifts during pouring, the job has to be terminated and restarted.

When epoxy pours are considered, it is essential to the insides of the forms with anti-stick materials. This helps in removal of the forms without having to destroy them.

Wax is a good anti-stick material, it coats well and the forms can be coated before they are assembled and installed.

6.7 8.7 Rebar and Anchor Bolts

The next step in the installation process is to install the rebar and pump hold-down bolts.

Depending on the dimensions of the foundation, the numbers of rebar rings and posts are installed. A foundation of 60"(L) × 60"(W) × 36"(D) would typically have three rings of rebar tied to eight posts of rebar (Figure 6.2).

Figure 6.2 – Rebar Bolts

The rebars are placed several inches from the sides, top, and bottom of the foundation. These are equally spaced from the top and bottom.

Once the rebar is installed, anchor bolts are provided. The length of the anchor bolts is typically 10 to 15 times the bolt diameter. This is required for proper stretch to develop the design holding force (Figure 6.3).

Figure 6.3 – Straight and J-Type Anchor Bolts

If epoxy grout is allowed to grip the anchor bolt, the bolt will break at the grout surface even when tightened to the design torque. This requirement is met at the foundation design stage and this recommends the use of bolt sleeves in the concrete. When sleeves are used, they should be filled with non-binding material like sand, flexible foam, or wax to prevent epoxy from bonding to the anchor bolt.

The exposed length of the anchor bolt from top of the concrete to the bottom of the base plate could also be wrapped with one layer of weather stripping and one layer of duct tape.

An acceptable hold-down or an anchor bolt for most ANSI pumps is 5/8 in. J-bolt mounted in a 1-1/2 in. pipe. The pipe is at least 6 in. long.

The J-bolt extends past the top of the pipe by a minimum of the pump base height plus1-1/2 in.

The J-bolt extends past the bottom of the pipe an inch or two before the 'J' bends.

A washer is welded to the bottom of the pipe. The J-bolt passes through it. Subsequently, the J-bolt is welded to the washer.

It is important that the bolts are true to themselves and with respect to the other bolts.

This can be achieved by having a single bracket that secures all the bolts.

The stage is now set for pouring of concrete and epoxy.

6.8 Pouring

The pouring of the concrete mix is carried out slowly while stirring the cement. A cement truck does this; however, if the site is not accessible by a truck, the cement can be pumped or loaded onto a wheelbarrow and transferred to the site.

6.8.1 Concrete Mix Pour

Curing of freshly poured concrete must occur before epoxy grout is applied. The epoxyconcrete bond is sensitive to the presence of moisture and this needs to be prevented at all times. In either instance, trowel-finish the top of the pad when the cement is ready for finishing.

It is recommended to carry out ASTM 157-80 concrete shrinkage test to determine when the shrinkage drops to the minimum. This is an indicator of the end of the chemical reaction between cement and water, which causes the concrete to cure.

In the absence of the above test the following thumb rule is adopted:

- Standard concrete (5 bags mix) – 28 days
- Quick setting concrete (6–7 bags mix) – 7 days

One method to check on moisture is to tape one square feet of plastic sheet over the concrete block and leave it overnight. If there is moisture on the underside of plastic, the concrete is still not ready for epoxy grout. This should be repeated until no moisture is seen under the plastic sheet.

Surface preparation of the new concrete begins two to three days after the pour. It maybe necessary to chip the top 1/2" to 1" from the surface of the foundation to remove the cement-rich surface called laitance. The laitance is a weak surface created when concrete is cast and would not provide for proper adhesion or support for the grout that is added under the base plate.

Usually sand blasting is the technique used to remove the laitance and expose the aggregate. The most common method is to wait for the concrete to cure and then chip the laitance with light-duty pneumatic hammers. Jackhammers and sharp pointed chisels should not be used for chipping.

All foundation edges should be chamfered at least 2 to 4 in. at 45° to remove stress concentration. All dust, dirt, chips, oil water, and any other contaminants should be removed and the foundation should be covered.

6.8.2 Epoxy Pour

Sometimes it maybe necessary or advantageous to have the entire foundation made out of epoxy.

The initial costs are higher but these foundations offer:

- Superior vibration dampening
- Better chemical resistance
- Faster curing time. Even the quick setting cement does not cure before 7 days to bear the forces needed to attach the equipment. The epoxy gets cured in 24h, and allows the equipment installation to begin almost immediately

The procedure involves mixing the epoxy parts A (resin) and B (hardener) as per the instructions. It is better to mix both the parts completely and not leave behind unmixed parts. Unmixed parts are a hazard and need special disposal. However, the mixture of the two parts is not hazardous.

The next step involves adding the mixed resin into an empty mortar mixer, and then adding the aggregate. The aggregate consists of pure silica, some with the texture of sand, and some with the texture of pea gravel mixed at a specific ratio.

The ratio is based on the ambient conditions. Pure silica is used instead of sand and pea gravel because of its superior heat-sink capabilities. This also adds to the overall strength of the pour. Once the silica aggregates are added to the mixed resin, they should be mixed until a uniform consistency is achieved. The mixing is done slowly to ensure that no air is entrained in the batch, as air is detrimental to the overall strength of the pour. A spiralblade mortar mixer is best suited for this application.

The mixed epoxy should then be poured into the hole, and the process repeated until the pour is complete.

An average-size foundation maybe poured in less than 4 h when properly administered. Any finishing touches need to be completed before the epoxy cures.

The next step involves placing the base plate and grouting it.

6.9 Base Plate and Sole Plate Preparation

It is recommended to remove all the equipment from the base plate or sole plate prior to grouting.

This helps to:

- Level the plate
- Reduce unwanted distortion.

The pump and motor/turbine/engine can be mounted after the base plate has been properly grouted.

The base plate surface to be in contact with the grout should be coated with an inorganic zinc silicate or any compatible primer. The base plate should have bare or rusted surface and should be free of blisters. The surface should also not be smooth, as this may not allow for proper bonding with the epoxy grout.

It should be checked that the base plate is provided with at least one grouting opening in each bulkhead section and/or each 12 sq. feet of base area as a minimum. Vent holes should be provided at the corners of each bulkhead compartment. These insure that no voids are created by trapped air.

The corners of all base plates should be rounded to 20 in. radius. When epoxy cures, it shrinks and rounding prevents stress corrosion in the grout. If sharp corners were left, it would eventually cause cracking of the grout.

Before placing the base plate on the prepared foundation, it should be free from oil, grease, and rust.

After the base plate is rested on the foundation it should be supported on leveling screws, rectangular leveling shims or taper wedges placed close to the foundation bolt to prevent distortion. Leveling screws should be adequately coated with grease/wax to prevent adhesion of epoxy to the screws. The base plate should then be leveled side-to-side, end-to-end, and diagonally to within 0.002 in. per foot. The machined surfaces have to be flat and parallel. The mounting surface tolerance should remain the same even after the anchor bolts have been tightened.

Once leveling has been achieved, it should be confirmed that all the wedges/shims are in contact with the base plate and foundation. The foundation bolts are then evenly tightened and the levels are rechecked.

Before the grout is poured, the elevation of the machined surfaces should be checked to insure that it would allow for a minimum of 1/8" shim thickness under the driving equipment.

Insure that eight alignment positioning screws are provided for positioning the driver.

The machined mounting surfaces should extend 0.1 in. beyond the pump and driver feet on all sides.

Two holes should be drilled and tapped on the base plate flanges on each side of the anchor-bolt holes to make provision for 1-1/2 in. jack/leveling screws.

The coupling guard bolts should be greased and inserted in the base plate. It is difficult to drill and tap holes in case they are filled up with epoxy grout.

6.10 Grouting

The term 'grout' refers to a hardenable material such as a mortar, concrete, or epoxy, which is placed under and around the base plate to assure intimate contact with thefoundation.

The main reasons for grouting are:

- To provide uniformly distributed load bearing surface
- To provide effective damping to machinery vibration
- To fill cavities and cover projections thereby eliminating unsafe conditions and improving performance.

There are basically two types of grouts in use:

1. Epoxy grout, consisting of three parts, resin, hardener, and an aggregate
2. Cement plus a natural or metallic aggregate

6.10.1 Epoxy Grout

The first step in the process to carry out an epoxy grout is to layout the forms. These forms should be of heavy-duty design as the weight of epoxy is nearly 2.5 times than that of the concrete. It is recommended to use 3/4 in. plywood with adequate bracing.

The surface of the forms that will come in contact with the epoxy needs to be wax coated to insure their easy separation after the epoxy has hardened. Usually, three coats of wax are applied with sufficient intervals between the coats to allow for penetration of wax in the wood and drying.

The forms should have 1 in., 45° chamfer in the vertical and horizontal edges so that the mating of the forms allows for minimum seepage of epoxy from the forms. If required a leak-tight joint can be formed with the use of a plastic type of sealant at all joints and at the interface with the foundation.

The base plates that have been designed as per API requirement require two-pour grouts:

- To fill the void between the concrete and the base plate flanges
- To fill the void between the base plate flange and the top of the base plate.

If the free surface of the grout at the base-plate flanges is confined the 6–7 in. higher, grout level at the top of the base plate can be filled in one pour.

The vent holes usually 1/2 in. in diameters that are drilled allow the air to escape as the grout is poured from the center of the base plate to the edges. When the grout overflows from the vent holes, duct tape is used to cover the holes and the filling operation is continued.

One-pour grout can be accomplished in 45 min and after the curing is complete in 24 h, the forms can be removed. In case the ambient temperature is above 25ºC, the pump and its driver can be installed after the forms are removed.

A two-pour job needs more time and cost.

Epoxy grouts have a narrow range for mixing and placement. This range is from 10ºC to 35 ºC for best life, flow ability, and curing. When the temperatures are lower, low-temperature accelerators can be added with the foundation and base plate kept heated. When temperatures are high, temporary shades can be placed over the base plate 24 h before the pouring and 48 h after pouring of the grout.

With a temperature-conditioned grouting, insure that all tools tackles are in place and that all items in the checklist have been ticked.

The next step is to mix the grout. This can be done in a wheelbarrow with a mortar-mixing hoe or in a motorized concrete or mortar mixer The latter maybe used in case of when the grout area is larger (10 units or more). Care should be taken to keep the blade speed limited to 15 rpm.

When hand mixing is used, two wheelbarrows are used to insure that there is a continuous supply of grout to men pouring it in the forms.

In either of the cases, mixing has to be done slowly with due care taken to prevent formation of froth or air entrapment in the pour mix. Mixing is done for 3–5 min after adding the hardener to the resin.

It is better to record the timing of mixing and pouring of the grout and insuring that it is done as per the specifications.

The pouring of the grout is done slowly using a large funnel placed about a meter above the base plate to provide the necessary force to push the grout out of the vent holes. Alternately, a positive displacement pump maybe used to perform the same function.

Random grout samples maybe taken along with the ambient temperature and location of grout for analysis and records.

When the epoxy begins to harden, it is better to form domes to insure that no water accumulates in the low areas. These can be removed after 24h. The jackscrews can be relieved after 3 days.

After full-cure, sealing material (duct tape) and the wedges or shims should be removed. Silicone caulking is used to fill the shim holes. The anchor bolts are then tightened to the recommended torque.

The grout job should be checked for voids by ringing the base plate with a hammer. A good job will sound like hitting a lead plate and the one with voids will ring like a bell.

6.10.2 Concrete grout

The procedure for the cement-based grout is quite similar to the one adopted for the epoxy grout (Figure 6.4).

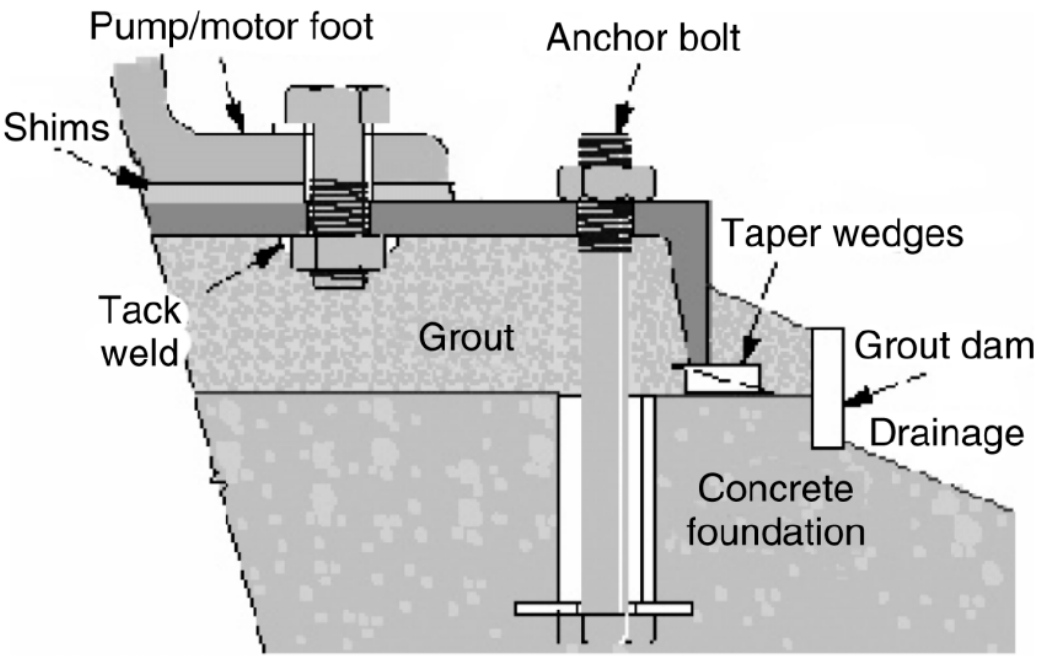

Figure 6.4 – Concrete Grout (Image Source – Berkeley Pumps – USA)

As in the epoxy grout procedure, the first step is to layout the forms and similar precautions need to be taken.

When the foundation is of concrete, the top surface should be kept saturated with water for a specified period of time as per the recommendations of the grout manufacturer. This water from the top of the foundation and boltholes should be removed just prior to placing the grout.

Precautions should be taken to insure that grout does not enter the anchor bolt sleeves and hence the sleeves are filled with non-bonding pliable material such as asphalt or silicone rubber molding compound to prevent a water pocket around the bolt.

A duct tape maybe used to wrap around the exposed threads of anchor bolts to prevent direct contact between the grout and the anchor bolts.

The temperature conditions required are again quite similar to the one stated for the epoxy grout. The temperature range has to be maintained in this case for a minimum of 24 h after pouring of the grout.

The preparation of grout has to be done as per the instructions with the right amount and quality of oil-free water.

The placement of the grout has to be done rapidly and continuously. It is recommended to start placing the grout from one end of the base plate and work toward the other end to insure that all air is positively vented and no air pockets are trapped.

Grout should be cut back to the bottom outer edge of the base plate or sole plate and tapered to the existing concrete. The top of the grout on base plates with flange-type support should be at the top of the flange. The top of the grout on base plates with solid sides and soleplates should be 1 in. above the bottom of the base plate or underside of the sole plate. The outside top edges of the grout should be chamfered at 45º.

After the initial set, it should be trimmed to the levels indicated in the drawings. After the complete curing of the grout has been achieved, it should be checked for air voids with a hammer test. Any voids detected should be pressure grouted.

The forms can be taken out after 24 h. The leveling shims and wedges may also be removed after the grout has cured. The voids from these should be filled with grout without the aggregate.

When leveling screws are used these should be removed after the grout has cured to allow the full equipment weight to be distributed evenly over the grouted area. The holes should be caulked with putty.

Subsequently, the anchor bolts should be tightened to the right torque.

The pump and its driver are then ready for installation.

6.11 Installation of Pump and Driver

Once the grout is cured and the pump base is clean, the pump and its driver can be installed. The bolts that were used to seal the needed boltholes can be removed. The pump should be in operation-ready condition when it is installed on the base.

Whether the driver is an electrical motor or a turbine, they should be placed at the locations indicated in the drawings. It is essential to confirm the distance between the shaft ends (DBSE).

The DBSE should be set with the pump and driver shafts pulled toward each other. For motor drives with sleeve bearings, the DBSE should be set with the motor shaft at its magnetic center.

In case of an electric motor, the motor should be wired correctly to insure the correct direction of rotation. This check has to be carried out before the equipment is coupled up.

Pumps, seals, or magnetic drive bearings can be ruined if operated dry or in reverse.

After the rotation check, the motor should be de-energized and breaker should be locked out.

In the subsequent step, the pump and the motor are aligned to the final tolerances using a reverse dial gage or a laser alignment tool.

This is also the stage during which a soft foot condition of the pump could manifest itself. The hold-down bolts are loosened one at a time and a dial gage is used to record the movement between the machine foot and the base plate or the sole plate. Any movement in excess of 1 mil (0.025 mm) is an indicator of soft foot and should be corrected by adding the required amount of shims under the feet.

When the pump is being aligned with a steam turbine, it is usually carried out at ambient conditions. When steam is introduced, the centerline of the turbine is raised leading to misalignment.

To account for this phenomenon, the vertical growth is computed. The easy rule to compute the growth is: The rise of equipment centerline from base is 1.2 mils for every inch of height from base to centerline for every 100ºC rise in temperature; or 1.2 mm for every meter height for every 100ºC rises in temperature.

Thus, if an impulse steam turbine has an exhaust temperature of 130 ºC with an ambient temperature of 30ºC, the rise in temperature is 100ºC. If the height from base of foot to shaft centerline is 12 in., then the rise due to thermal growth is 14.4 mils.

After the alignment is completed, the piping associated with the pump and steam turbine should be bolted.

Once this is completed, the alignment should be checked and similar readings should be obtained. If this is not the case, then the piping should be investigated and suitable corrections should be made. If this is left unattended, this can cause stress on the pump casing and nozzles.

After the alignment has been approved, the support pads for the pumps and drivers should be drilled at two locations for providing taper dowels. These dowels should be preferably located at the end, which has the thrust bearings.

6.12 Associated Piping and Fittings

The following are some of the recommended practices in regard to piping associated with the centrifugal pumps (Figure 6.5).

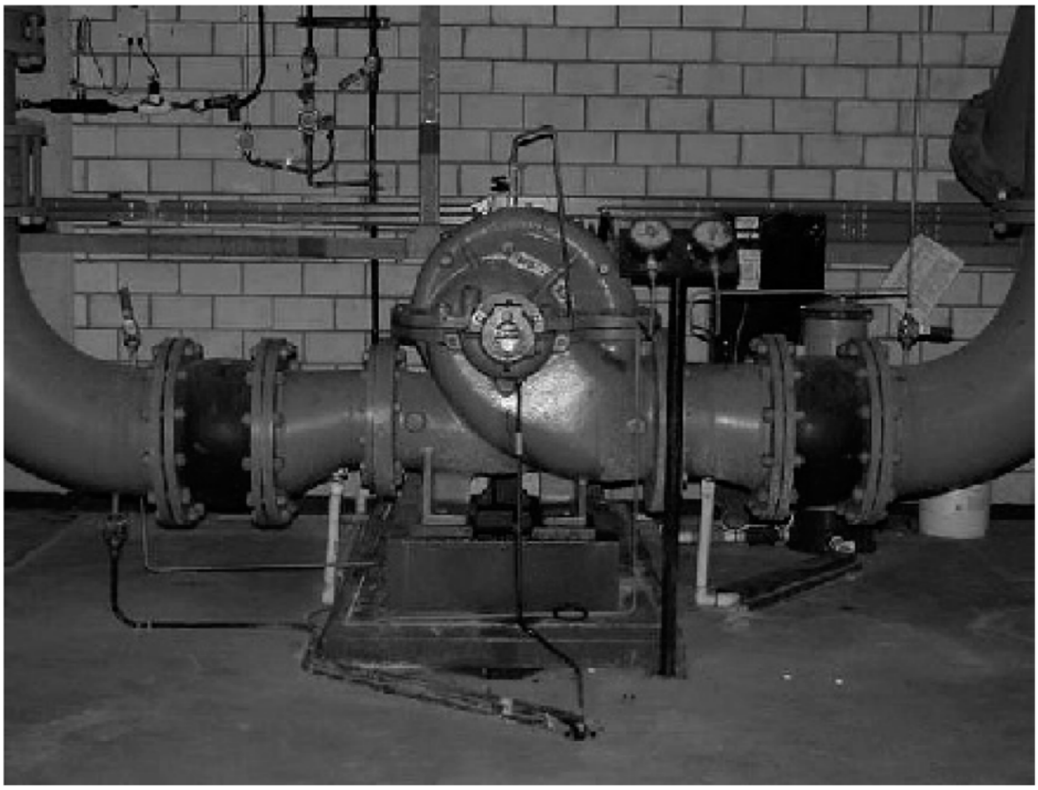

Figure 6.5 – Typical Piping Layout Associated with a Horizontal Centrifugal Pump

Piping associated with the pump must be anchored and supported independently of the pump. In absence of adequate anchorage, the expansion and contraction of line can cause the transfer of forces to the pump casing. When the pipes are not supported, their weight is borne by the pump casing and nozzles causing them to deflect and crack. The seal life of the pump also gets affected due to this strain.

It is important that the connections be carefully aligned axially, angularly, and in length. The flange boltholes too have to be in phase with the pump nozzle holes.

One good check to perform is to disconnect all the suction and discharge flanges on the pumps. If levers are required to force the pipe flange on to the pump nozzles (to facilitate bolting of the flanges), one can be certain that the pumps will sooner or later start giving bearing and other problems.

6.12.1 Inlet Piping (Figure 6.6)

- The piping run and the connection fittings should be properly aligned and supported separately to reduce strain on the pump casing.
- The straight run of the piping leading to pump suction nozzle should be at least 3 to 6 times the diameter of the pipe from the upstream elbow.
- The elbow should be of a standard type or of the long radius type.

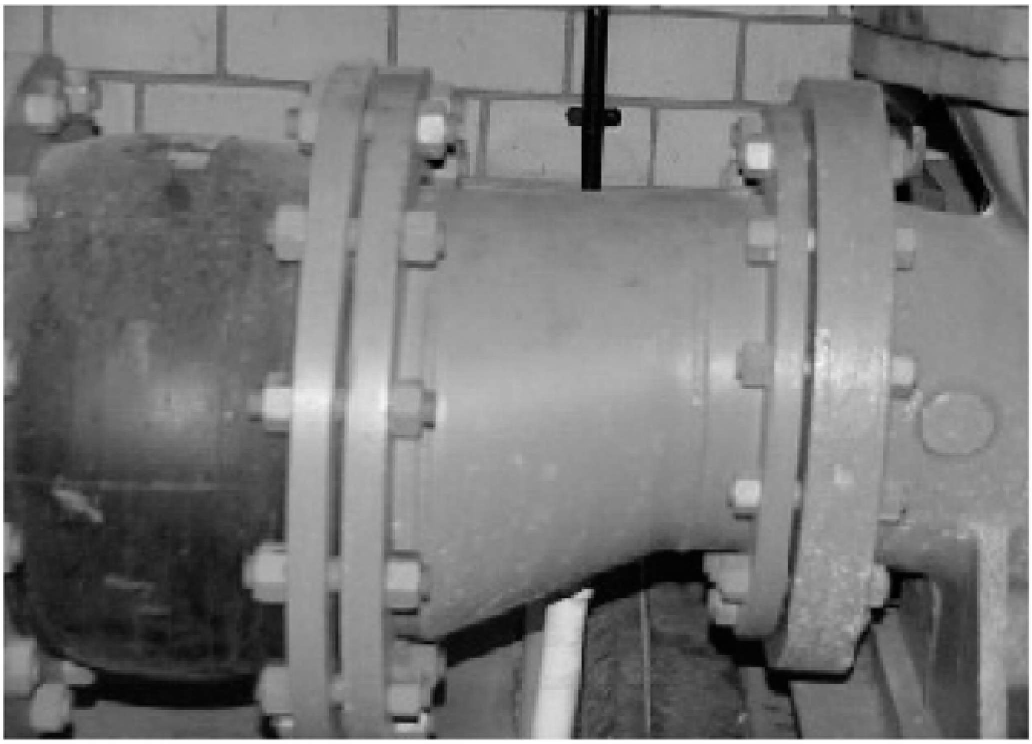

Figure 6.6 – Inlet Piping

- If the pump has a negative suction, all suction piping must be airtight.
- Suction pipe size should be at least one commercial size larger than the opening of the pump inlet.
- The reducer joining the straight length of the pipe in the pump line should be an eccentric reducer with the flat side of the reducer as the topside.
- The straight length of the pipe after the eccentric reducer should be 2 times the pipe diameter.

- The suction pipe should be sized to insure a liquid velocity of not more than 2 to 3 m/s.
- All suction pipes in negative suction should have a continuous rise to the pump suction inlet. A 6 mm per 100 mm minimum slope is recommended. This may not be required in a flooded suction.
- In a negative suction, no isolation valves are recommended but can be provided in the flooded suction. Isolation valves even in open condition contribute to pressure losses due to friction and result in lowering of the available NPSH. In pumps with higher negative suction lift, NPSH-a is on the lower side and addition of a valve does not help the cause in any way.
- In a negative suction, the minimum depth of submergence of the strainer should be at least 3 times the pipe diameter, measured from the upper row of holes of the strainer. The distance between the bottom of the strainer and the floor of the sump should be considered as 2 times the pipe diameter.
- In case of a bellmouth or funnel with D = 2d, the optimum distance between the rim of the bellmouth and the bottom of the sum should be approximated 0.5d. If this is larger it leads to the formation of eddies and vortices as shown in Figure 6.7. Swirling vortices can cause the air to be drawn in the suction pipe interfering with the pump performance.

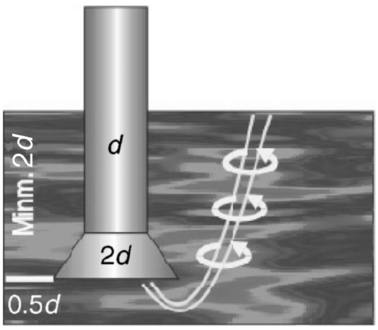

Figure 6.7 – Formation of eddies and vortices

- The minimum submergence should at least 2d.
- The suction strainer must be at least 4 times the suction pipe area and the mesh size should screen out solid particles that could clog the impeller (Figure 6.8).

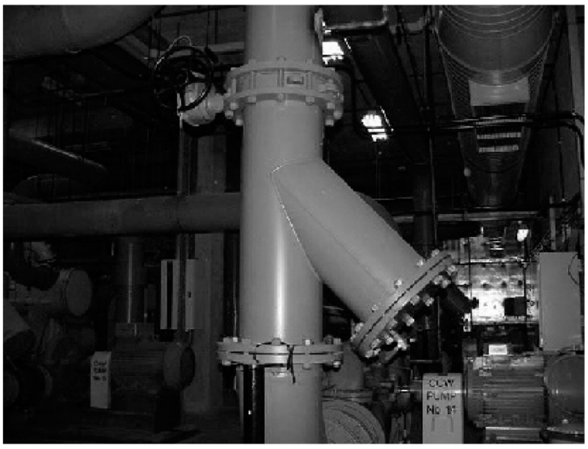

Figure 6.8 – A Y-Type Suction Strain in the Pump Suction

- There should be a provision to drain the contents between the isolation valves in the suction and pump casing.
- There should be a tapping provided for installing a pressure gage in the suction.

6.12.2 Discharge piping (Figure 6.9)

- The piping run and the connection fittings should be properly aligned and supported separately to reduce strain on the pump casing.
- Discharge pipe size should be at least one commercial size larger than the opening of the pump outlet.
- The number of fittings and size changes should be minimum to prevent fluid friction losses.

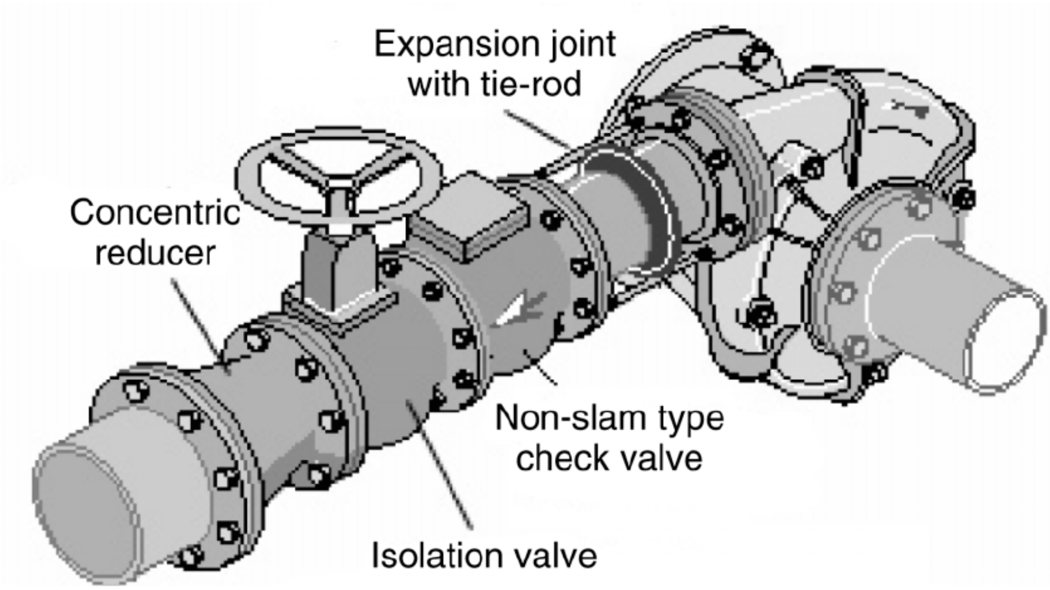

Figure 6.9 – DISCHARGE PIPING
(IMAGE SOURCE – BERKELEY PUMPS – USA)

- The check valve used in the discharge should be of the non-slam type to prevent hydraulic shocks.
- The isolation valve is provided downstream of the check valve so that these can be taken up for servicing whenever required.
- Concentric reducers are installed in the discharge pipe to minimize friction losses.

- There should be a pressure tapping as close as possible to the pump outlet and before the isolation valve to measure the pump shut-off head (Figure 6.10).

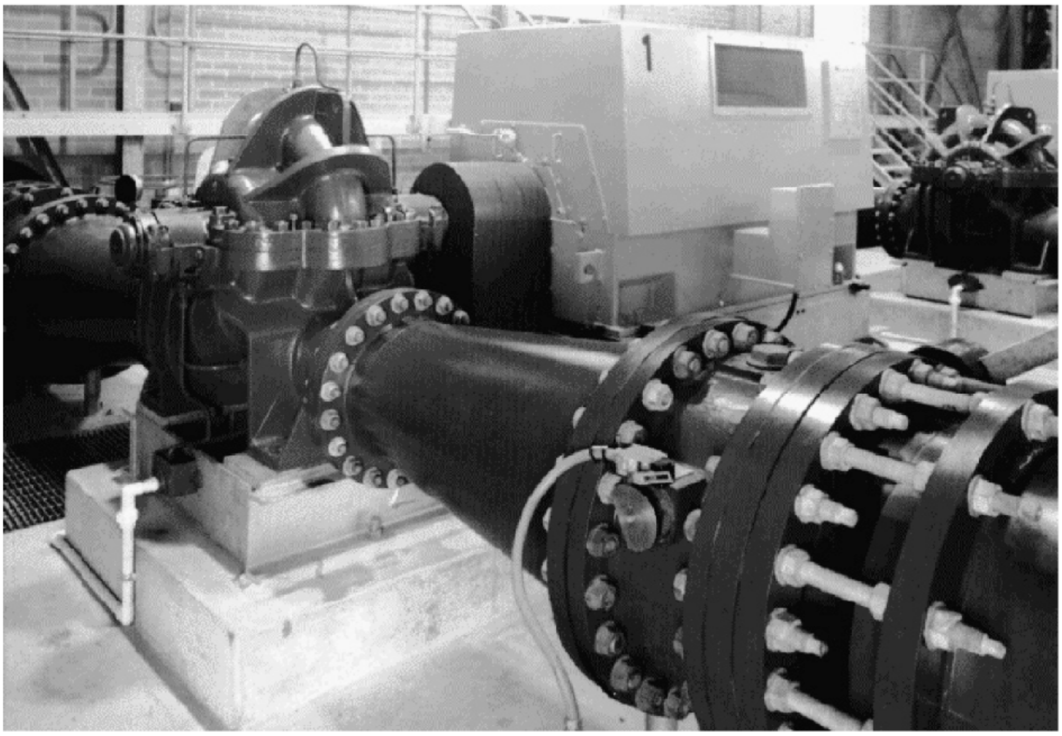

Figure 6.10 – Notice the Pressure Tapping on the Pump Discharge

- Another pressure tapping downstream of the reducer is a good indicator of the pump operating pressure.
- Expansion joints maybe used only after a careful piping analysis, especially when the discharge pressures are on the higher side.

6.13 On-Site Installation and Commissioning of the Pump Set

Once the shop tests have been witnessed and verified by the owner or the owner's appointed representative, the pump is then disconnected and transported to the site for installation and commissioning.

It is important to note that once the pump has been installed, checked, pump and system properly primed, and finally tested and set up, the pump may or may not operate at the design point (flow – Q and head – H) as calculated. There are a number of reasons why a difference in Q and H values could arise. These are:

- There could be a difference between the 'as designed' and the 'as constructed' system configurations, i.e. differences in the run of the system pipe work, the number of bends and/or quality of fittings could have altered, etc. This would impact on frictional resistance that the pump must overcome in operation, which could either increase or decrease, thus causing the operating point to differ from the design point.
- If at the design stage too much allowance is made when evaluating frictional resistance – Hf, then it is possible that the pump selected could be oversized, i.e. operate off the performance curve or too far to the right of the BEP.
  - ☐ If during commissioning of the pump the operating point is measured to be within a margin of ±2.5% of the design point, then the evaluation of the total system resistance Hts is considered to be good.
  - ☐ If the operating point is measured to be within a margin of ±5% of the design point, then the evaluation of the total system resistance Hts is considered to be satisfactory.
  - ☐ If, however, operating point is measured to be greater than 5% of the design point, then the system would need to be checked out. It is always good practice to have the pump manufacturer's representative involved at the time of installing, testing, and commissioning of the pump set(s) to insure satisfactory operation of the pumps right through their designed life cycle.
- Change in the properties of the fluid being pumped would affect the operating point.
- There could also be other anomalies that could be introduced from the time of the shop test to the time of installation and testing – such as the wrong impeller size, pump speed, or incorrect direction of rotation. All these could adversely affect the operating point.

It is worth noting though, that once the pump performance curve has been established and drawn up at the shop test, the performance curve tend to remain consistent so long as there is no mechanical damage or wear and tear to the pump. So if anomalies arise and the pump has not been dismantled or mechanically altered in any way, the reason for the discrepancy could be with the system layout or system components, which would need to be checked.

Commissioning test logs, similar to those drawn up at the pump shop tests must be filled and held on record as part of the offer and acceptance protocol. Further, based on the operating point at commissioning, the system resistance curve needs to be developed and drawn up for the pump and system. These documents are to be referred to at a later date at the time of verifying the pump and system performance.

6.14 Pre-Operational Checks

Pre-operational checks are mainly focused toward the auxiliary systems:

- For pumps fitted with double mechanical seals (back-to-back) with an external pressurized sealant supply, it is necessary to flush and clean the lines prior to their connection with the pump.
- If the pump casing has been pressurized, it is essential to check if the sealant supply pressure is 1–1.5 kg/cm2 above the pump casing pressure. Pressure lower than this can cause the inner seal to open up, which contaminates the process fluid.
- When the pumps are equipped with tandem mechanical seals, the overhead reservoir that facilitates the thermosyphon circulation for the outboard seal needs to be thoroughly cleaned by oil flush prior to its connection with the pump.
- All cooling water lines connected to the pumps and turbines need to be flushed.
- It is necessary to confirm that the supply and return cooling water lines are connected to their correct headers.
- Bearing housings should be drained of their oil and refilled with fresh oil of correct viscosity.
- If the pump lubrication is with the oil mist system, it should be up and running for almost 12 h before the start-up.
- The oil mist piping should be sloping toward the equipment without any sags or low spots.
- Verify that oil reaches all bearings.
- It is necessary to reconfirm
  - ☐ Direction of rotation of the motor
  - ☐ Over speed trip setting of a steam turbine
  - ☐ Greasing of coupling
  - ☐ Earthing of equipment.
- If the pump and turbine are provided with a separate lube oil system then all alarms and trips have to be checked and tested.
- Rotate the pump by hand and look for any rubs.
- Place the coupling guard and tighten the bolts/screws.
- Inform the electrical department to energize.

6.15 Preparation for Start-Up

After the above-mentioned checks have been completed, the stage is set for the start-up.

The sequence from now is:

- Pump suction valve is opened slowly and all the joints are checked for any leakage.
- The pump casing is opened to vent any vapor. This can be tricky in case of flashing hydrocarbons so it has to be done a numerous times.
- If the pumping temperature is high, the pump should be allowed to warm up.

- For multistage pumps with long rotors, it would be a good idea to keep rotating the rotor 180° after every 30 min.
- The sealant and cooling water lines are opened and circulation of the liquids is insured.
- The opening of the discharge valve is dependent on the type of centrifugal pump. For low specific speed pumps, it is kept closed and opened for higher specific speed pumps. This prevents overloading of the motor drive.
- Once these checks are made, it is time to confirm if the electrical supply has been energized.
- The pump is started!

6.16 Pump in Operation

- Once the pump has started, check the discharge pressure and insure it is along expected lines. If the pressure does not come up, the most probable reason is that the pump has not been primed properly. The pump should be stopped and re-primed.
- In case of a low specific speed pump, the discharge pressure falls when the discharge valve is opened.
- The flow rate should be confirmed.
- Vibration measurements of the entire train should be taken with a data collector. The overall and filtered readings should be recorded. The frequency plots be recorded and stored. These should be studied for possible defects.
- The overall vibration reading can vary with the point of operation on the pump curve. Therefore, it is recommended to record vibration reading and frequency plots at the 4 or 5 operating points that include the normal and rated points.
- The mechanical seal leakage should be confirmed. It is possible that there could be leakage in the initial stages, which may settle down after wear-in.
- The bearing temperatures of both the pump and motor/turbine should be not more than 10–20° above ambient. A temperature higher than this is an indicator of bearing in distress unless they are of the greased type. In that case, the most probable cause is over greasing. A vibration or a shock pulse analysis can confirm this fact. In such a case, it is better to wait for 24 h and allow the flow out of excess grease.
- Once steady state has been achieved, it is recommended to carry out a performance check of the pump and know its efficiency. It is recommended that this should be plotted on the pump characteristic curves.

When the trial is completed, shut the discharge valve partially and switch off the motor.

An eye should be kept on any reverse rotation of the pump. This allows a check of the non-return valve.