Pumps and Piping Systems in Coating Industry

Selection of materials of construction for pumps, valves, and piping for optimum satisfaction of process requirements and life expectancy provide a study in engineering economics.

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Since coating solids content and coating formulation both vary to a considerable degree, the problems involved in pumping and circulating coatings will not be the same for all systems. In the low solids range, coatings behave generally in a Newtonian manner, and the characteristics of the system are relatively easy to determine. However, as the solids content is increased, the flow behaviour changes from Newtonian to any of a number of anomalous flow patterns. These flow patterns cause considerable difficulty in determining the circulation characteristics of a system and the horsepower requirement of the pump to be used.

In addition to considerations of circulation, the physical nature of the components is of importance. Selection of materials of construction for pumps, valves, and piping for optimum satisfaction of process requirements and life expectancy provide a study in engineering economics. Coupled with this aspect are operational problems, such as power demand of pumps and system maintenance. Owing to the relatively abrasive nature of many coatings, special requirements must be met to ensure satisfactory performance and minimum maintenance.

Types of Pumps

Pumps of many different manufacturers have been employed for service with coating. Particular models described below were chosen as representative of the various types used, and no implication is intended that other pumps of the same types would not perform satisfactorily. Pumps descriptions are necessarily brief. Additional information should be obtained from the manufacturers.

Centrifugal Pumps

For low-solids coating – and in some cases for higher solids, low-viscosity coatings – a centrifugal pump may be satisfactory. One of the laminations of this type of pump is a sharply increased horsepower demand with coatings of relatively high viscosity and solids, which may be higher than that of some other types of pumps for such coatings. Determination of horsepower demand for pumps handling coatings is often quite difficult, since the head loss characteristics of the system depend on the characteristics of the particular coating being used, and vary considerably with coatings of different flow properties.

The speed of a centrifugal pump handling coatings should be chosen so as to minimize erosion in service. Lower speeds generally decrease the amount of maintenance required. However, lower speeds require a larger pump for a specified volume delivery, that is, a pumps of higher cost. Each application must be analysed to arrive at an economic and operational compromise.

Conventional ring packing is generally used with coatings, although mechanical seals are also used. With ring packing, a lantern-type liquid seal ring in the stuffing box may be used. Water is connected to the real ring and the water pressure adjusted to counterbalance the pressure from the pump. This helps to keep the coating from entering the packing and causing leakage. It is important that the water pressure should not be so high so as to cause water leakage into the coating of the pump. Because of the danger of leakage, some users prefer not to use water in the stuffing box.

A difficult problem has been to pump slurries consistently and effectively. Slurry is a watery mixture or suspension of insoluble matter and may be of different consistency from a solid-material-to-water ration of about 5 per cent to about 25 per cent. The term “slurry” is generic for different types of watery mixtures or suspensions of insoluble matter including mud, which is a mixture of earth and water, and pulp which is a mixture animal or vegetable matter and water or other liquid. The pulp may be pulp of fruit such as apples, pears, peaches or plums for example, vegetables such as carrots or peas, other food products such as sugar cane, or wood such as used in the manufacture of paper. Pulp may also be a mixture of pulverised ore or white lead and water. All of these slurries are difficult to pump with pumps of conventional type.

The self-priming centrifugal pump includes housing having an inverted frusto-conically shaped lower portion. A centrifugal impeller is suspended from the shaft of a motor mounted in the top portion of the housing. This centrifugal impeller includes a solids collector member, which is removably attached to the lower end of the impeller. A cylindrical inlet tube, integral with the frusto-conical shaped lower housing portion, extends into the interior of the centrifugal impeller, through an opening in the lower end of the solids collector member. The lower end of the inlet tube extends below the bottom of the frusto-conically shaped lower housing portion and is adapted to be immersed into the fluid to be pumped. An inverted dish shaped impeller member is located above the centrifugal impeller and directs and impels fluid pumped by the centrifugal impeller towards a plurality of efflux ports located in the pump housing. An air hole is located in the conical wall of the centrifugal impeller to allow air to escape as the pump is priming.

Moyno Pumps

This type of pump is widely used in the coating field for transfer and circulation of high solids, high viscosity coatings. It operates on a “progressing cavity” principle, employing a helical rotor and a stator with a double internal helical thread. By design this pump is basically a positive displacement unit, and the precautions noted with gear pumps should be followed in regard to circulation. However, the capacity versus head relationship is affected by the coating and the pump discharges pressure, so that the output is dependent on the nature of the system and the particular coating used. Moyno pumps are capable of developing substantially greater discharge pressure than centrifugal pumps.

Moyno pumps may be purchased with a variety of rotor and stator combinations. One such combination that is economical and has proved satisfactory with pigmented aqueous coatings is a chromium plated tool steel rotor and a Buna N rubber stator. This is termed CDQ construction when used with a cast iron pump body. All wetted parts are in contact with chromium and Buna N. Moyno pumps generally are run at substantially lower speeds than centrifugal pumps in coatings service. The life of the pump internals is affected considerably by speed of operation, and the manufacturer’s recommendations should be obtained for a specific coating and system.

While it is desirable to run any pump dry, it is desirable to run any pump dry, it is imperative not to allow the Moyno pump to operate without fluid between the rotor and rubber stator. It is obvious that sufficient friction and heat could be developed within the close pump clearances to destroy the rubber lining. Suitable measures should be taken to stop the pumps when it no longer has fluid to pump, or to ensure that there is always fluid available.

Gear Pumps

Positive displacement rotary gear pumps have been employed for transferring and circulating coating. Unlike a centrifugal pumping system, the positive displacement pumping system must be protected against shutoff downstream of the pump. To accomplish this it is sometimes desirable to provide a circulation loop with takeoffs to the operating points, with the excess coating returning to the supply. In this way the pump always has free discharge in the event of shutoff of all the operating points. A pressure control valve may be installed downstream of the use points to ensure that there is sufficient pressure for coating to flow to the operating points, and, by opening on increased pressure at shutoff of the operating points, to allow full recirculation. An alternative method is to provide recirculation from the discharge side of the pump to the suction side by means of a manual or automatic valve. Because of the close clearances employed with gear pumps, there is the possibility of erosion between the rotor and pump casing by abrasive materials. In this event, the clearance is increased and pumping characteristics change with time. Gear pumps in coating service should be run at substantially lower speeds than centrifugal pumps. It suggested that a minimum section size of 2 in. be used with coating, even if the volume requirement indicates less.

A gear pump with two meshing gears, in which the trunions of the drive gear are mounted for rotation in the housing of the gear pump, eventually in special bearings, whereas the driven gear has no trunions, but is loosely mounted in the housing and pressed by fluid pressure in such a manner against the drive gear and the housing so that the gears will mesh with each other without play on the flanks of the gear teeth.

In known gear pumps of the aforementioned kind the portion of the housing engaged by the gear teeth extends only over a short part of the circumference of the gears, at the outlet side of the pump which is covered by two side plates. The driven gear is only pressed onto the inner surface of the housing and the drive gear by the fluid pressure acting thereon. Such a pump, in which the driven gear may be mounted in such unstable manner is suitable only for very small feed pressures. Such a pump is, however, completely unsuitable for greater outputs and pressures.

Piston Pumps

Piston pumps, such as the Deming Triplex, have been used to transfer coatings. Their use at present is not widespread, and other types of pumps, which require less maintenance, are generally obtainable for less cost.

A compact lightweight water purifier has been developed for use by the hikers who must obtain their water from the land over which they travel. The purifier utilises a reverse osmosis module, which converts brackish water or sea water to potable water. Such a purifier requires a pump which should operate at relatively high pressure, typically in the range of 400 to 1000 psig, and be suitable for manual operation, and be resistant to the corrosive saline water to which it is exposed. The pump should also be of a size and configuration suitable for incorporation into and use with the portable purifier.
A pump with a rack and pinion gear drive, with the rack gear formed integrally with the piston was developed for use with the purifier, but was not satisfactory. There was excessive wear in the moving parts and substantial corrosion during use. Also, the pump was difficult and tiring to the operator.

Diaphragm Pumps

Diaphragm pumps have been considered to a minor extent. By control of the stroke in air motor operation, flow control can be obtained. This type of pump has no stuffing box.

Diaphragm pumps are widely used in industry to perform small jobs in which a regulated and controlled flow is desired. For larger jobs involving 8 or 10 inch pipes, diaphragm pumps are usually replaced by centrifugal pumps. Although diaphragm pumps have superior flow control and regulation capabilities, centrifugal pumps have been found to be more reliable in performing the larger jobs.

In the conventional fluid pump of this type, a sealing member is installed between a portion of an operation rod of the piston assembly and the inner wall of a pump housing so that the flexible diaphragm made of a resilient material, such as rubber and the like, is protected from permeation of the lubrication oil to cause hardening and breakage of the diaphragm. The sealing means of the conventional type has, however, a drawback that the sealing feature of the sealing means becomes less in a short period of time since the sealing area against the operation rod is small.

In a diaphragm pump of the type described, there are provided a pump chamber into or out of which pressure fluid is fed, on one side of a diaphragm and a pressure fluid chamber into or out of which a pressure fluid adapted to deflect the diaphragm, such as for instance oil, is fed, with the diaphragm positioned between the pump chamber and the pressure fluid chamber, while there are provided for the pump chamber two check valves adapted to open or close alternately, one of the check valves being connected to the pressure fluid reservoir containing a liquid such as paint, and the other of the check valves being connected via a discharge pipe to a spray gun. In addition, the pressure fluid chamber communicates with a cylinder, in which a plunger reciprocates. The plunger is moved back and forth by means of a cam or the like so as to raise or lower the fluid pressure in the pressure fluid chamber, thereby deflecting the aforesaid diaphragm so as to expand or contract the volume of the pump chamber alternately. At the time of expansion, the paint or the like is drawn by suction through one of the ckeck valves, and at the time of contraction, the paint is supplied via the other check valve to a spray gun or the like.

A relief valve is provided between the pressure fluid chamber or cylinder and the pressure fluid reservoir, thereby preventing an excessive pressure rise in the pressure fluid chamber. For instance, in case a nozzle of the spray gun is closed, the load acting on the pump chamber is increased, so that the diaphragm can no longer be operated or deflected, so the pressure of the fluid in the pressure fluid chamber becomes too high during a compression stroke, in which the plunger is moved towards the diaphragm. However, at this time the pressure fluid is bled via the relief valve into the pressure fluid reservoir, thus ensuring safety of the diaphragm pump. For instance, when the nozzle of a spray gun is opened, with the relief valve being set to a high pressure level, then the pump chamber starts delivering the paint under pressure, while the diaphragm is repeatedly deflected to a large extent proportional to the progress the plunger stroke through the medium of a pressure fluid, in response to the back and forth displacements of the plunger. However, it is rare that the fluid pressure in the pressure fluid chamber exceeds the adjusted pressure level for the relief valve, so that little or not fluid is bled through the relief valve.

However, if the relief valve is set to a relatively low pressure level, then the pressure of the fluid in the pressure fluid chamber necessarily exceeds the adjusted pressure level for the relief valve, in the course of the pressurising stroke of the plunger, after which the pressure fluid is continuously bled into the pressure fluid reservoir via the relief valve, until the termination of the pressurising stroke. Accordingly, in this case, during the pressure reducing stroke following the pressurising stroke or during the time from the pressure reducing stroke to the beginning phase of the subsequent pressurizing stroke, an amount of pressure fluid corresponding to the amount of pressure fluid which has been discharged from the cylinder and pressure fluid chamber during the pressurising stroke should be supplied from the pressure fluid pump to the cylinder and pressure fluid chamber.

To this end, a passage for supplying the pressure fluid is provided between the pressure fluid reservoir and the cylinder or the pressure fluid chamber, However, if the internal pressure is a vacuum, the pressure fluid flows at a high speed through the aforesaid passage, so that the pressure fluid is agitated vigorously, thereby producing heat due to internal friction. The temperature rise stemming from the heat of the pressure fluid reduces the allowable operating speed of the pump, thus leading to deterioration of the pressure fluid. Many attempts to solve this shortcoming have been proposed in different patents.

Pump Drives

Motors can be connected to pumps in a number of ways. The general types are: (1) direct connected drives, (2) belt drives and (3) variable speed drives.

Direct connected drives are commonly operated at fixed speeds of approximately 1750, 1150, 850 rpm, etc., corresponding to the common operating speeds in which motors are supplied. This type of drive is suited to constant operating conditions.

Belt drives allow greater flexibility in pump operating speeds. They may be designed for any fixed speed by proper choice of motor drive, and may be easily changed to another fixed speed if conditions so dictate. In addition, economics in motor cost may be realised by purchasing a higher speed motor and reducing the pump speed by drive ratio.

Variable speed drives can be of several types. Among those generally employed are the mechanical type (such as the PIV) and the eddy current coupling type (such as the Dynamatic). These units allow pump speeds to be varied as desired throughout the range of the drive. Cost and operating requirements dictate the specific unit to be chosen for a particular case.

Materials Of Construction

Piping: Many different materials, including carbon steel, copper, bronze, brass and stainless steel are used in piping systems for coatings and their components. Carbon steel pipe is satisfactory in most cases from a corrosion standpoint. Copper, bronze and brass are satisfactory for service with solutions and suspensions nearly neutral, but should be avoided for the higher pH ranges. Stainless steel is resistant to corrosion and, in addition, offers increased system cleanliness in comparison with carbon steel piping. Thin wall 304 stainless steel piping can generally be used for coating plant service, making the price of stainless steel more acceptable.

Generally, all these materials may have application in a coating plant. For example, it may be desirable to use carbon steel for clay slurries, brass for starch solution, and stainless steel for coating. Process requirements determine the expenditure that must be made. Cost comparisons between acceptable materials should be made on an installed basis rather than the price of the materials may differ in their installation cost.

Valves: Types of valve materials used for coating vary widely. Cast iron, copper, brass, bronze and stainless steel are among the ones generally used. Process considerations apply similarly to piping. However, valve materials do not always have to be similar to piping materials. Economics can be made by proper matching of the two- for example, cast iron valves in stainless steel lines. Again, process requirements dictate the compromise, which can be tolerated.

Among the type of valves used are gate, plug, ball and butterfly. Non-lubricated plug valves are preferred over the lubricated type, and the eccentric plug valve is well adapted to on-off operation. A three-way plug valve may sometimes be used to replace two two-way valves. In certain applications, pocketing of coating can be avoided by such use, and economics may be realised. Butterfly valves are among the most economical valves in stainless steel construction. They many be purchased with a throttling plate to make them suitable for regulating, as well as for on-off service.

Pumps: Pump materials involve the same consideration as valves; that is, they may or may not be of the same material as the piping, depending on economics and requirement of the system. Frequently, cast iron pumps may be satisfactory instead of higher priced stainless steel pumps. Trim on cast iron pumps should be stainless steel rather then bronze for the higher pH ranges. Certain types of pumps may be purchased in which the parts to be wetted are made of a more suitable material than the rest of the pump. Moyno pumps, which provide a rubber liner and a chromium-plated rotor, are an example of this type.

Piping design: Design of a piping system should include considerations of convenient operation and easy cleaning. Valving should be arranged for easy identification and convenient access, and should be located to enable compete cleanout of the system. If possible, drain connection should be provided on both sides of equipment such as pumps, so that water can be flushed through the system and drained to the sewer. Horizontal runs of piping should generally be sloped so that they will drain and not crate pockets.

In sizing of the piping, flow velocities should be determined so as to provide an optimum cost relationship between pipe size and horsepower. Proper sizing may be difficult since head loss in high-solids systems varies considerably with coating compositions, solids and viscosity. The flow type of the coating, the amount of thixotropy, and the method of viscosity determination should be considered when determining the viscosity change through the system due to shear. As with most anomalous flow measurements, calculation of a realistic head loss becomes quite complex, and experience becomes the best criterion. Desirable velocities will very for different types of coatings and different systems, but may fall within about 2-6 fps.

Design of gravity lines is especially critical. The optimum angle for proper flow during operation must be determined for each coating to ensure that flow of high viscosity coatings will take place with suitable velocity. For high-solids coatings it appears desirable to have a minimum slope of one foot in 10 ft. of run.

Control Methods In Piping Systems

Systems for transferring and circulating coatings may be generally divided into two types: direct supply, and supply from a circulation loop. Methods used for control will depend upon which of these types is used and upon which of these types is used and upon the type of pump in the system.

Direct Supply

For direct supply systems using a centrifugal pump with relatively low-solids, low-viscosity coating, several means may be employed for control. In transferring coating from a large tank to a smaller tank (such as to recirculation tank from a storage tank), there are two alternatives: the coating may be continuously regulated proportionally to the level in the smaller tank or it may be regulated intermittently. In proportional regulation, a level controller supplies a signal to a throttling valve allowing coating to flow into the tank approximately at the rate at which it is withdrawn. In intermittent regulation, the level controller in the tank provides a high and low-level signal to an on-off valve, allowing the valve to open at low level and closing it at high level. A circulation loop should be provided from the pump discharge to a point below the coating level in the supply tank, so that when the valve is closed on high level the pump does not operate against shutoff head. A partially closed hand valve in the recirculation lines is generally suitable to control pressures, so as to allow coating to flow to the point of use when the automatic valve is open and top provide a relief when it is closed.

Various types of level control elements have been operated with some degree of success, including float valves, bubble pipes, and diaphragm transmitters. Differential pressure-type diaphragm level transmitters mounted as nearly flush as possible to tank-wall appear to be satisfactory with both high and low-solids coatings. It is desirable to install the transmitter so that it remains submerged in the coating and will not be subjected to alternate wetting and drying, which leads to coating buildup on the diaphragm.

For direct supply systems using a positive displacement pump, the discharge of the pump must be throttled. Two general methods of level control that are employed with these pumps to transfer from a large tank to a smaller one are: (1) varying pump speed, and (2) starting and stopping the pump. Regulation of pump speed may be used for proportional control of level in the small tank. Starting and stopping the pump is used for intermittent control of the level. Control signals may be obtained in either case from a level controller in the small tank. The signal could go to a variable speed for proportional control, or to the pump motor starter through pressure switches in the case of intermittent control.

Circulation Loops

Circulation loops may be employed with both positive displacement pumps and centrifugal pumps. Coating is generally supplied to points of use by means of level control operating a valve in a takeoff line from the circulation header. Control may be proportional or intermittent. The amount of coating required be supplied to the use point, and the remainder is recirculated. The pump may run continuously. To ensure adequate pressure at the takeoffs for proper flow to use points, a pressure regulating valve is sometimes installed downstream of all the use points. The pressure is set so that the valve closes sufficiently to allow proper flow to the use points when the takeoff valves are open. When the takeoff valves are closed, the valve opens to allow full recircualtion.

Conclusion

To properly design a piping system for a coating operation, it is imperative that the requirements of the system be known. The degree of flexibility required, the average operating conditions, and the extreme operating conditions should all be defined. Properties of the coatings should be determined on a realistic basis.

The degree of automatic control desired and required should be outlined. Provision for future expansion, if desired, should be considered when sizing equipment and piping.

When all these fundamental factors have been resolved, the selection and sizing of system components may be done on a proper basis. Many types of pumps, pipes, valves and controls are available. The key to successful application is realistic analysis of the nature of the coatings to be handled and the requirements of the system.

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Reference Book:

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