U.S. Department of Energy
CHP Technical Assistance Partnerships
NORTHWEST

A Guide to Pumping Manure Slurries in Centralized Biogas Digester Systems

March 2007 (Revised October 2013)
WSUEEP07-001 Rev. 02 2013

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Acknowledgements

This study was funded by the Northwest CHP Application Center with support funding from the U.S. Department of Energy's Distributed Energy Program and from the State of Washington.

Thanks to the following people who provided review and comments:

Ryan Bartelheimer, Snohomish Conservation District
Charles Bird, BSI Environmental
Tom Huffman, Hydro Engineering, Inc.
Bob Jansen, Agricultural Market Manager, Cornell Pumps
Richard Mattocks, Environomics LLC
Josh Niels, Vaughan Company, Inc.
Karl Wight, Daritech, Inc.

This Acknowledgement does not imply that the reviewers endorse everything presented in this guide

Disclaimer

While the information included in this guide may be used to begin a preliminary analysis, a professional engineer and other professionals with experience in pumping manure slurries should be consulted for the design of a particular project.

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Introduction

Manure slurries are often pumped as part of the ordinary operation of dairies for irrigation of fields and transfer of manure to storage tanks. These applications are typically over relatively short distances of 1,000 feet or less. Slurries may also be pumped longer distances, for example, to deliver manure to a central biogas digester.

In a centralized biogas digester system, substrates – such as manure and food waste – are delivered to a central digester plant from several sources. These substrates may be either trucked by tanker truck or pumped through a piping system to the digester. At the digester, "biogas," composed largely of methane, is produced and then combusted to generate electricity, to supply heat for processes or buildings, or for use as a transportation fuel.

This guide provides general information in sizing and selecting piping, pumps and other components for the transfer of dairy waste in pipelines over relatively long distances (greater than approximately 1,000 feet) for applications such as centralized biogas digester systems. Topics included are:

- Typical characteristics of dairy waste and manure slurries
- Information on piping, pumps and components appropriate for this application
- How to calculate system head losses for slurries
- Suggestions for minimizing pathogen transmission between dairies

While the information included in this guide may be used to begin a preliminary analysis, a professional engineer and other professionals with experience in pumping manure slurries should be consulted for the design of a particular project. Refer to the "Resources" section at the end of this guide for contact information for several engineering consultants, equipment suppliers and manufacturers with experience in this type of project.

Characteristics of Dairy Waste

Manure slurry consists essentially of solids suspended in water. Manure slurry typically contains bedding materials (such as straw and sand) and water used in flushing and washing. It may contain rainwater from uncovered concrete slabs if roofs are not guttered. Manure slurry is typically gritty, with grit coming from concrete slabs, feed, and bedding materials. The slurry may contain large solids such as rocks, concrete chunks, identification tags, and hoof blocks.[1] Stringy masses of straw and other large solids can cause plugging of pumps and prevent proper seating of valves. Grit and sand increase abrasion of the surfaces of piping, pumps, valves and other components.

The total solids content of the slurry strongly affects friction loss in piping. Solids content of manure slurry typically ranges from approximately 2% to 10%. Table 1 gives total solids of dairy waste typical for herds with moderate to high milk production (USDA 1999). Solids content may be adjusted to a certain extent by, for example, dilution with wash water, or diversion of rain water from the manure storage tank. Note in centralized digester systems, there may be a trade-off between diluting the slurry so it is pumpable, while still maintaining a solids content that is optimum for the digester.

Manure slurry tends to be acidic, which may affect pump seals and other components. Be sure to discuss this issue with manufacturers to ensure that pump and valve materials are appropriate for your application.

Improving the Pumpability of Manure Slurries

It is possible to pump manure slurries with solids contents as high as 10% or so. A solids content above about 8% results in very high friction losses when pumped. Regardless, avoidance of settling and plugging (see guidelines below) must be prioritized over minimizing friction losses.

Note that it is not just the solids content that affects pumpability, but also the particular mix and size of materials contained in the slurry. A solids content of 8% on one day may be more difficult to pump than a 10% slurry on another day at the same farm, or more difficult to pump than another 8% slurry at a farm down the road.

Guidelines for improving pumpability and avoiding settling and plugging are:

1. While some dilution will be required for the slurry to flow well, avoid *excessive* dilution of the slurry. Large solids stay entrained better in slurries that are thicker, but at the expense of higher friction losses.

2. Maintain sufficient fluid velocity to keep solids entrained. The optimum velocity will vary depending on characteristics of the manure. Considering that manure slurries typically contain large solids that are prone to settling, a design velocity of 5 or 6 feet

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[1] A “hoof block” is a wood block that is glued to a cow’s hoof to help a damaged hoof heal.

per second (fps) is often recommended. A slurry with a more uniform consistency may require velocities of only 3 to 5 fps.

3. Arrange PVC pipe so the bell end is directed toward the supply pump. This way the slurry does not strike the butt end of the inner pipe directly, essentially making a smoother transition over the joint.

4. After transfer of manure slurry, flush the pipeline with clean water or digested effluent.

5. Use variable speed diesel pumps or variable speed drives with electric pumps to give the flexibility to operate the pump at the best speed given the characteristics of the slurry (refer to "Pumps" section below).

6. Consider using chopper pumps and/or grinders to improve the consistency of the slurry and reduce the size of large solids (refer to "Pumps" section).

Table 1. Typical Total Solids of Dairy Waste

Waste Source	Total Solids (% by weight)
Lactating Cow, as excreted	12.50
Milk House	0.28
Milk House & Milk Parlor	0.60
Milk House, Milk Parlor & Holding Area (holding area scraped or flushed)	1.50
Lagoon, Anaerobic Supernatent*	0.25
Lagoon, Anaerobic Sludge*	10.0
Lagoon, Aerobic Supernatent*	0.05

Source: USDA (1999), Tables 4-3 to 4-7.

* "Supernatent" is taken from the upper layer of a storage lagoon or tank, while "sludge" is taken from the bottom.

System and Pump Curves

System curves and pump curves – which show the relationship between flow rate and total head – are used in sizing piping, selecting pumps and analyzing energy use. In system curves, the total head represents the sum of the static lift (i.e. the vertical distance the fluid must be lifted) plus the operating pressure plus friction losses or pressure drops due to the fluid moving through the pipe, valves, and fittings. The intersection of the pump and system curves indicates the total head that the pump must be capable of providing at the specified flow given the characteristics of the system.

Pump curves are available from pump manufacturers (refer to "Resources" section below). System curves must be calculated for the piping system and are based on pipe length and diameter, number and types of valves and fittings, pipe material, differences in elevation, and fluid characteristics, as discussed below. In the design process, system curves are often plotted for several pipe diameters. Then, one diameter is selected so the fluid velocity falls within a recommended range and friction losses are reasonable. What is considered "reasonable" may be a compromise considering factors such as initial cost, energy use, and pump performance.

In Figure 1 illustrates example pump and system curves of a hypothetical case. The point of operation of the pump is found by the intersection of the pump's curve with a system curve, which should occur at a high pump efficiency. The intersection of the system curve with the vertical axis equals the sum of the static head and operating head. The yellow shaded area in this example indicates flow rates that result in a fluid velocity of between approximately 4 and 6 feet per second (fps), which brackets velocities often recommended to keep solids entrained.

For a pump serving more than one farm, as in Figure 2, each farm will have its own system curve. If all points of operation – the intersection of the system curve and pump curve -- do not have sufficient velocity or a good pump efficiency, some aspect of the system should be changed, such as changing the pipe diameter, selecting a different pump, using more than one pump, using a variable speed diesel powered pump, or using a variable speed drive for an electric pump.

Figure 1. Example system and pump curves

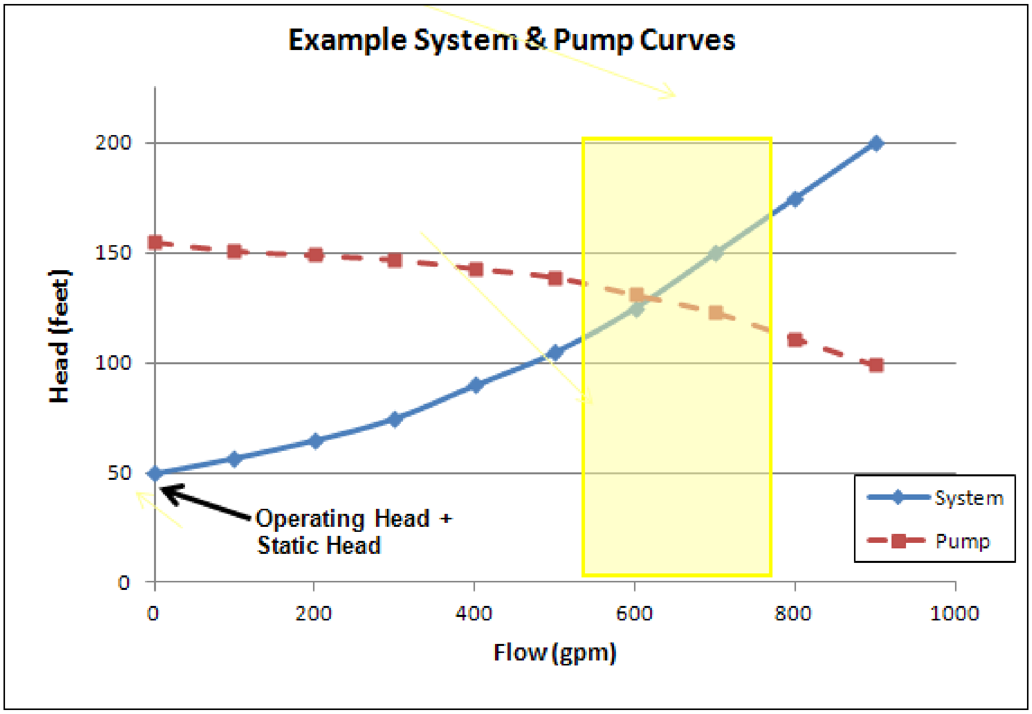
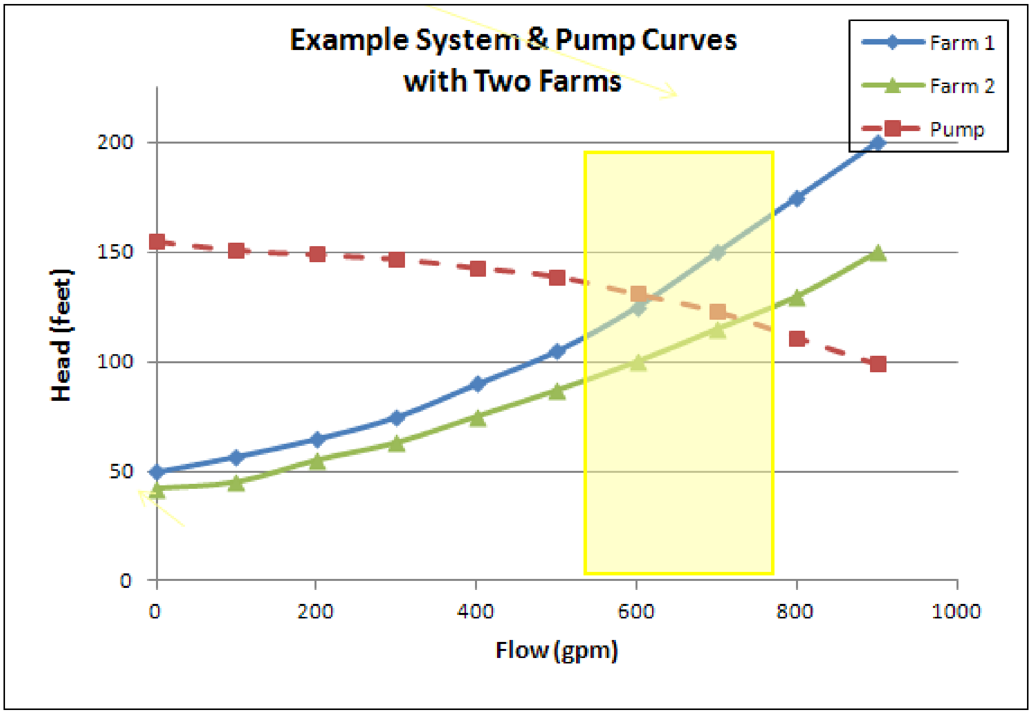


Figure 2. Example system and pump curves with one pump serving either Farm 1 or Farm 2



Calculating System Curves

Total Dynamic Head

The total dynamic head that a pump must develop to move a fluid through a piping system at a particular flow rate is the sum of the following components:

- Operating pressure
- Static discharge head (equal to the elevation of the surface of the liquid in the discharge tank, or the discharge outlet if open to the air, minus the elevation of the pump datum)
- Static suction head (equal to the elevation of the pump datum minus the elevation of the surface of water in the suction bay, i.e. the dairy's storage tank)
- Velocity head h_v at the discharge nozzle of the pump where

$$h_v = \frac{V^2}{2g} = 0.0155V^2 \text{ for } V \text{ in [fps] and } h_v \text{ in [feet]}$$

- Friction head loss h_f

These components are all fairly straightforward except for the friction loss, which requires a slightly more detailed calculation.

Operating Pressure

Nozzles, fixtures or sprinkler heads at the discharge require pressure to operate properly, referred to as the operating pressure. The range of the operating pressure varies depending on the type of nozzle or head. High pressure systems, such as traveling guns and high pressure center pivots or sprinkler systems, may require operating pressures up to 100 psi. Low pressure spray systems may require 15 to 50 psi. For most irrigation systems, the operating pressure is constant.

Calculating Friction Head Loss

To calculate friction losses, we first calculate the friction head loss for clean water, using standard engineering methods outlined in texts such as Crowe, et al. (2005). The result for clean water is then multiplied by the friction loss ratio, which accounts for both the greater viscosity of slurries compared to water and the slurry's "non-Newtonian" behavior.[2]

Friction loss ratios have been determined experimentally for many types of slurries and are cataloged in references such as Colt Industries' *Hydraulic Handbook* (1973). For pumping manure slurries, friction loss ratios for digested sludge are commonly used. Figure 3 shows the friction loss ratio as a function of velocity for digested sludge with solids contents ranging from 4% to 10% and for pipe diameters from 6" to 10".

[2] In essence, the viscosity of Non-Newtonian fluids varies as fluid velocity changes, in contrast to Newtonian fluids, such as clean water, which have constant viscosity.

Friction Loss Calculation Summary:

1. *Calculate the friction loss for clean water by standard engineering methods.*
   The friction head loss for clean water $h_{f,w}$, is first calculated using the Darcy-Weisbach equation

   $$h_{f,w} = f \frac{L}{D} \frac{V^2}{2g}$$

   where L is the effective length of pipe (including both suction and discharge lines and the effective length of valves and fittings), V is the velocity, D is the inner diameter of the pipe and f is the friction factor. The friction factor f is found using either an empirical correlation[3] or the "Moody diagram."[4] To use either, you will need to know the roughness of the pipe used in the system. The absolute roughness[5] of PVC pipe – which is typically used in manure piping – may be estimated as ranging from about 6×10^{-5} inches to 2×10^{-4} inches, or as given in manufacturer's data. Typical roughness of other materials is given in references such as Crowe, et al. (2005).

2. *Adjust the friction loss for clean water using the friction loss ratio.*
   The friction head loss for the slurry h_f is calculated by

   $$h_f = R_f h_{f,w}$$

   where the friction loss ratio R_f is found from Figure 3.

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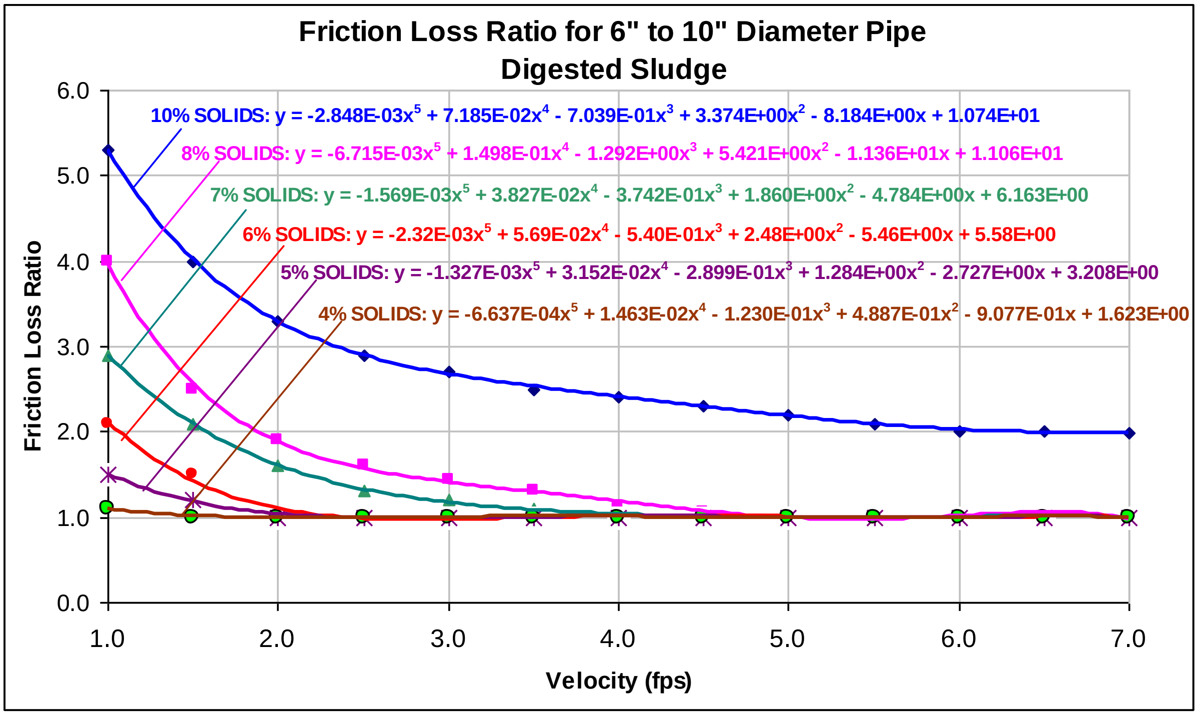
[3] An empirical relationship, such as the Swamee-Jain correlation (Crowe et al, Eq. 10.26) is useful if a spreadsheet or math software is used to automate calculations.

[4] The Moody diagram is shown in Figure 10-8 of Crowe et al (2005).

[5] Absolute roughness is based upon the average height, spacing, and form of the roughness projections on the inside surface of the pipe. Note that roughness increases with age, which in turn increases pumping requirements.

Figure 3. Friction Loss Ratios for Digested Sludge Slurries with 4% to 10% Solids*



* The friction loss ratio is the ratio of the slurry friction loss to that for clean water.
Sources: Adapted from Figure 44 of *Hydraulic Handbook* by Colt Industries and Table 11-1 of *Agricultural Waste Management Field Handbook*, U.S. Department of Agriculture, Soil Conservation Service, June 1999, www.wcc.nrcs.usda.gov/awm/awmfh.html.

Piping

In the type of system considered here, manure slurry is pumped through a pipeline from each dairy to the central digester facility and digested effluent is returned from the digester back to the dairies. Supply of raw manure may be accomplished by stationary pumps located at each dairy or by a mobile trailer pump that is shared between the dairies. Digested effluent is returned to dairies by a central pump located at the digester facility.

A single, shared pipeline may be used for both the supply of raw manure and the return of digested effluent. Alternatively, separate pipelines may be used for supply and return. Selection valves are located at all tees or wyes off the main pipeline to farms. These are arranged and operated so that raw manure slurry is allowed to run only from dairy to digester directly, with piping to other dairies shut off.

Pipe Size

To avoid settling of solids, which could result in plugging, the pipe diameter should be sized to maintain a minimum velocity of approximately 5 fps. In addition, the pipe diameter should remain constant, so the slurry does not experience abrupt changes in velocity. It is very important that all passages through the piping system, including the pump and valves, are large enough to easily pass masses such as clumps of straw. Pipe diameters less than 6" are not recommended.

Pipe Material

Typically PVC pressure pipe rated for 200 pounds per square inch (psi) is used for this type of application, except high density polyethylene (HDPE) is recommended under road, railroad and stream crossings. Any metal components should be coated with asphalt, plastic or epoxy to retard corrosion. All joints must be sealed so the pipe is water tight. For PVC pipe diameters of about 8 inches or greater, gasketed joints are recommended due to the difficulty of making solvent welded (i.e., primed and glued) joints on large pipe. Both gasketed and solvent-welded joints are designed to be leak-free over a lifespan of a hundred years or more, if properly assembled.

PVC pipe should be arranged so the bell end is directed toward the supply pump, so pipe joints are less likely to cause settling of solids.

Grade

As much as possible, the pipeline should be run so it is level or has a continuous grade (up or down). In particular, crests where the pipe comes up to a high point and then back down should be avoided because air tends to get trapped at these high spots and increases the head loss and, if the manure is pumped fast enough, some of the air can move through the pipeline, causing pressure surges. Tri-action valves (see "Other System Components" section below), located at all high points, minimizes this condition. Low points also should be avoided, as much as possible, due to increased settling of solids. Clean-outs should be provided at low points in the pipeline, where feasible, to minimize the downtime in the event that the pipeline plugs up.

Flushing

After transfer of manure slurry, the piping should be flushed with clean water or digested effluent to avoid problems with plugging. If a single pipeline is used for both supply of manure to the digester and return of effluent back to the dairies, piping will be flushed with effluent as a regular part of the operation. If separate return and supply piping are used, however, the need for back-flushing with clean water must be considered.

Fittings

Fittings such as tees and wyes create dead ends where debris can accumulate. To minimize accumulation, use true wyes instead of tees. Pipe diameter should ideally remain constant throughout the system, but this is especially true at tees or wyes. Choppers or grinders (see "Pumps" section below) may be used to reduce debris size and hence accumulation at fittings. If practical, consider eliminating tees and wyes by running separate pipelines to each dairy.

Pumps

For supplying manure slurry to a central digester and returning digested effluent back from the digester to the dairies, both return and supply pumps may be required. Pump(s) may be either diesel-powered or electrically driven. Electrically driven pumps are more efficient and less expensive to operate. With diesel pumps and variable speed drives on electric pumps, pressure in the pipeline can be increased slowly to minimize pressure surges in the system.

Return pumps at the digester will handle effluent, which will have a lower solids content than manure slurry.[6] This difference should be taken into account when sizing return pumps versus supply pumps. In addition, head loss may vary dramatically in piping to the farms, depending on their relative distances to the digester. Diesel-powered pumps or electric pumps with variable speed drives give the flexibility to operate the pump at the best speed for each site. More than one pump may also be used – for example, both a high-head and low-head pump – to accommodate the variation in head.

For supply from the dairies, stationary pumps may be located at each farm. Alternatively, a mobile pump on a trailer may be shared between dairies. If a mobile pump is used, variation in head should be considered, as for the return pump.

Pump Selection

Be sure to consult with pump manufacturers and manufacturer's product information to ensure that:

- Pump materials and construction are appropriate for the possibly abrasive and acidic nature of the manure slurry to be pumped.

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[6] The solids content of digested effluent may be estimated from data in Table 1 for aerobic and anaerobic supernatants.

- The largest expected solid or mass can pass through the impeller and volute.
- For good pump performance, the operating point of the pump given the system in which it will be used is such that (1) its head is not much lower than the head at peak efficiency and (2) its capacity is not much higher than the capacity at peak efficiency.

Refer to the “Resources” below for contact information of pump manufacturers and dairy equipment suppliers.

Pump Type

Two general types of pumps are used for transferring manure: centrifugal and displacement. Centrifugal pumps are preferable for longer distances because starting torque requirement is lower and they are less susceptible to plugging. Centrifugal pumps are available for pumping manure slurries having maximum total solids up to 10 to 12%. Displacement pumps (helical screw, piston, air pressure transfer, and diaphragm) have maximum flow rates that are much lower (less than about 300 gpm for helical screw and diaphragm pumps and less than about 150 gpm for piston and pneumatic pumps). Helical screw pumps have lower maximum solids capability (4-6%) and cannot handle hard or abrasive solids.

Vertical- or inclined-shaft centrifugal pumps have a relatively wide clearance, which helps to avoid plugging. A closed impeller is efficient with liquid waste, but plugging with tough, stringy solids and chunks can be troublesome. A semi-open or open impeller is less efficient, but is also less prone to plugging and is able to handle semi-solids. Although generally inefficient, a sloped and curved semi-open impeller design minimizes flow cavitation and solids plugging. In selecting return versus supply pumps, keep in mind that the solids content of digested effluent will be much lower and so plugging will be much less of a concern for return pumps.

Feed Pumps

Centrifugal pumps require either a flooded suction (i.e. pump located below the storage tank) or a feed pump. Since manure will typically be pumped from buried storage tanks or lagoons, a feed pump is usually required.

Choppers and Grinders

Chopping or grinding can be used to condition the slurry by breaking up tough materials, improving the pumpability of the slurry. As an added benefit, the reduction of particle size improves anaerobic digestion. Standard non-clog pumps may be used to feed in-line grinders to accomplish this, or chopper pumps alone can accomplish this. Chopper pumps use sharp hardened impellers to pump and chop at the same time.

Choppers and grinders can be problematic and so are not universally recommended. Sizing piping to maintain high velocities and following other guidelines summarized in the section titled “Improving the Pumpability of Manure Slurries,” will reduce the need for choppers and grinders.

Pump Motors and Starting Torque

The high friction factor at start-up shown in Figure 2 does not necessarily result in high starting loads on the motor. Friction losses, proportional to the square of velocity, are very low since the fluid velocity is also low at start up. In addition, centrifugal pumps by nature generally have low starting torque requirements. Even if the outlet is blocked completely, they start and accelerate to speed and pressure with ease. The only circumstance in which they might need extra starting torque would be if the pump body itself had some obstructions jamming the impeller at the time it was started. Using an open impeller design reduces this chance.

If a positive displacement pump is used, a higher starting torque may be required because the fluid must begin to move when the shaft begins to turn. In this case, a NEMA Design C motor may be required (rather than the more common NEMA Design A or B motors), but at the expense of lower efficiency.

Pump Start Up

If the pipeline is empty when starting the pump, it may be necessary to restrict the flow initially by gradually opening a valve at the pump. Alternatively, pressure can be slowly increased by using a variable speed drive with an electric pump or a diesel pump. If flow is not restricted, a centrifugal pump will start at a flow rate that is too high, often resulting in cavitation and loss of pump prime, and possibly resulting in water hammer.

Valves

Selection Valves

If multiple dairies are connected to a digester, selection valves are required at all tees or wyes such that a pathway from one dairy directly to the digester can be isolated without inadvertently sending raw manure to other dairies. Valves should be arranged to minimize "dead ends" that may compromise flushing of the line and so increase the risk of pathogen transmission.

It is important to consult the manufacturer to ensure that valve type, materials and construction are appropriate for the application. That said, knife-gate valves and straightway diaphragm valves are generally well-suited for transferring abrasive slurries. Both of these valve types have an unobstructed flow path when open. Knife-gate valves are particularly suited for use with slurries that may contain solid masses. However, if pathogen transmission is a concern, straightway diaphragm valves are preferred because they have no cavities that can harbor contamination and have bubble-tight shut-off. Ball valves, globe valves and butterfly valves generally should not be used in slurry piping.

If separate return and supply piping is installed, check valves (i.e., one-way valves) can be used instead of manually-operated selection valves in supply piping. Return piping would still require manually opening and closing valves. Check valves should be suitable for use in sewer, slurry and sludge applications. Note that pathogen transmission is already minimized by using separate return and supply piping and so the presence of cavities within the valve is not as much of a concern as with manually operated valves with shared piping. (Refer to the section "Minimization of Pathogen Transmission" below.)

Keep in mind that closed valves will prevent isolated sections of piping from naturally draining. This will impact freeze protection requirements if these sections include above-ground portions.

Water hammer[7] due to abruptly closing selection valves is not a concern, since valves are only operated when the pump is not running.

Throttling Valves

Throttling valves may be used to reduce excessive flow rates from dairies and to improve the point of operation of the pump, for example, to avoid cavitation. Such throttling should be avoided, however, because it reduces the flow path and may result in plugging. If throttling valves are used, straightway diaphragm valves are preferred because of their streamlined flow path and good control characteristics. These should be easily accessible for clean out. For

[7] Water hammer can occur when a valve is turned off abruptly, sending a pressure wave down the pipeline that can damage the piping system.

example, a throttling valve might be installed at the very end of the pipeline where a mobile pump is connected with a flexible hose connection.

Other System Components

Air Venting, Pressure Relief and Vacuum Protection

Tri-action or combination valves serve three functions: air venting, pressure relief and vacuum protection. Combination valves should be provided at all high points in the piping where feasible and where environmentally sound.[8]

For safety reasons, bleed-off valves must be provided at all access and clean-out ports to ensure pressure is relieved before a cap is removed. In addition, pressure relief should be installed in any section of piping that can be isolated by valves.

Clean-Outs

Clean-out ports are not universally recommended because they introduce edges that can cause settling of large solids. Sizing piping to maintain high velocities and following other guidelines summarized in the section titled "Improving the Pumpability of Manure Slurries," will reduce the need for clean-outs. If a plug occurs and clean-outs are not installed, however, the repair will involve digging up a portion of the pipeline.

If clean-outs are used, they should be installed at regular intervals, especially at all low points where feasible. To determine the spacing of clean-outs, contact a local company that performs high-pressure water jetting of storm, sewer and/or septic drainfield piping. In particular, find out the maximum length of their jet hose and get their spacing recommendations.

Freeze Protection

The requirement for freeze protection can be reduced or eliminated if above ground piping is designed to drain completely when not in use. During freezing weather, manure may freeze at the dairies, so pumping in freezing weather would be unlikely to occur. Even if the pipeline is operated in freezing weather, pumping at the velocities required to prevent settling protects against freezing. Therefore, the primary freezing risk is due to slurry standing in piping that is not drained. Note that the ability of piping to drain will be impacted by closed selection valves.

[8] Automatic pressure relief may release untreated manure slurry from the supply line to the environment. Relief valves must be located to minimize negative consequences if this occurs.

Minimization of Pathogen Transmission

The risk of pathogen transmission is an important consideration when several dairies are connected to a central digester by a shared pipeline. As a first line of defense, ensure that all participating dairies implement good manure management practices, so pathogen movement and multiplication on each farm is minimized. For more information on best management practices, refer to the New York State Soil & Water Conservation's worksheet "Water-Borne Pathogens" available at: www.agmkt.state.ny.us/SoilWater/AEM/forms/Water-BornePathogens6-05.pdf.

Pathogen transmission via the pipeline can be minimized by the following design and operation strategies:

1. *Back flushing with effluent*
   A single pipeline may be used to both supply manure slurry to the central digester and return effluent back to the dairies. In this case, the risk of pathogen transmission can be minimized by flushing the pipe by immediately returning digested effluent back to the same dairy after delivery of raw manure from that dairy. Flushing is also recommended to avoid problems with plugging.

2. *Separate return and supply pipe*
   Alternatively, separate return and supply piping may be used, with the disadvantage of a greater cost of installation. Pathogen transmission in this case is less likely than with shared supply and return piping, since the return piping is never contaminated with raw manure slurry.

3. *Valve selection*
   Diaphragm valves have no cavities and minimal contact surfaces that can harbor pathogens. In contrast, knife-gate valves – which are also suitable for slurry service – contain cavities that may promote contamination. Note this issue is of concern primarily if a single pipeline is used for both return and supply.

4. *Location of Relief Valves*
   Automatic pressure relief valves should be located to minimize negative consequences in the event that they release untreated manure slurry from the supply line to the environment.

Resources

Dairy Equipment Suppliers and Consultants

Daritech, Inc.
8540 Benson Rd.
Lynden, WA 98264
Phone: (360) 354-6900, (800) 701-3632
Website: www.daritech.com

Farmers Equipment Company
17893 State Route 20
Burlington, WA 98233
Phone: (360) 757-6081
Website: www.farmersequip.com

Hydro Engineering, Inc.
115 East Main Street
Norwood Young America, MN 55397
Phone: (800) 833-5812
Website: www.hydro-eng.com

Pump Manufacturers and Suppliers – Agricultural Waste

Daritech, Inc.
8540 Benson Rd.
Lynden, WA
Phone: (360) 354-6900, (800) 701-3632
Website: www.daritech.com

Hydro Engineering, Inc.
115 East Main Street
Norwood Young America, MN 55397
Phone: (800) 833-5812
Website: www.hydro-eng.com

Vaughan Chopper Pumps
364 Monte-Elma Road
Montesano, WA 98563
Phone: (888) 249-CHOP (2467), (360) 249-4042
Website: www.chopperpumps.com

Volgesang USA (manufacturer of grinders and lobe pumps)
Phone: (800) 984-9400
Website: http://vogelsangusa.com

Engineering Assistance

BSI Environmental
12312 SE River Road
Milwaukie, OR 97222
Phone: (503) 513-5457
Mobile: (503) 318-5065
Fax: (503) 513-5466
Website: www.bsienvironmental.com

Hydro Engineering, Inc.
115 East Main Street
Norwood Young America, MN 55397
Phone: (800) 833-5812
Website: www.hydro-eng.com

Daritech, Inc.
8540 Benson Rd.
Lynden, WA
Phone: (360) 354-6900, (800) 701-3632
Website: www.daritech.com

Anaerobic Digester Equipment, Consulting and Engineering Assistance

Andgar Corporation
6920 Salashan Pkwy, A-102
Ferndale, WA 98248
Phone: (360) 366-9900
Website: www.andgardigester.com

RCM Digesters
PO Box 4716
Berkeley, CA 94704
Phone: (510) 834.4568
Fax: (510) 834.4529
Website: www.rcmdigesters.com

Biothane Digesters
2500 Broadway/Dwr. #5
Camden, NJ 08104
Phone: (856) 541-3500
Fax: (856) 541-3366
Website: www.biothane.com

Valve Manufacturers and Suppliers

There are many valve manufacturers and suppliers that will be able to advise you on valve selection for this application. For a listing, try using ThomasNet.com

References

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