United States Environmental Protection Agency | Water Engineering Research Laboratory Cincinnati OH 45268 | Office of Municipal Pollution Control Washington DC 20460
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EPA

# Design Information Report

## Belt Filter Presses

***The U.S. Environmental Protection Agency has undertaken a program to help municipalities and engineers avoid problems in wastewater treatment facility design and operation. A series of Design Information Reports is being produced that identifies frequently occurring process design and operational problems and describes remedial measures and design approaches which may be used to solve these problems. The intent is not to establish new design practices, but to concisely document improved design and operational procedures that have been developed from field experiences.***

***With an increased emphasis being placed on the problems of disposal of sludges from wastewater treatment facilities, there has been a growing awareness of the need for improved efficiency and reliability in the performance of in-plant sludge treatment processes. The dewatering of sludges is an important step in the total sludge processing train, and can have a serious impact on the effectiveness and cost of subsequent sludge treatment and disposal processes. The use of belt press filtration for sludge dewatering has increased in recent years, and belt presses are a frequently considered alternative when upgrading an existing facility or planning a new facility.***

### Introduction

This report discusses current problems associated with selection, design, and operation of belt filter press dewatering systems at municipal wastewater treatment facilities. The report discusses application of the press itself, as well as selection and application of auxiliary equipment associated with the belt filter press. Critical to the success of a belt filter press dewatering system is (1) an examination of equipment selection, control, and arrangement from an operational viewpoint; (2) consideration of safety, convenience of control, and accessibility; and (3) assurance of equipment durability.

Belt filter presses have been in use in the United States for approximately 15 years. The devices were developed from technology associated with the manufacture of paper, and have had a number of problems in being transferred to municipal sludge applications. Early belt press models demonstrated poor performance and durability when compared to vacuum filters and centrifuges, often requiring large dosages of conditioning chemicals and producing a poorly dewatered sludge cake. Most of these early problems have been eliminated. Although durability and lack of integrated controls can still be a problem, this is becoming less frequent as engineers specify higher quality equipment.

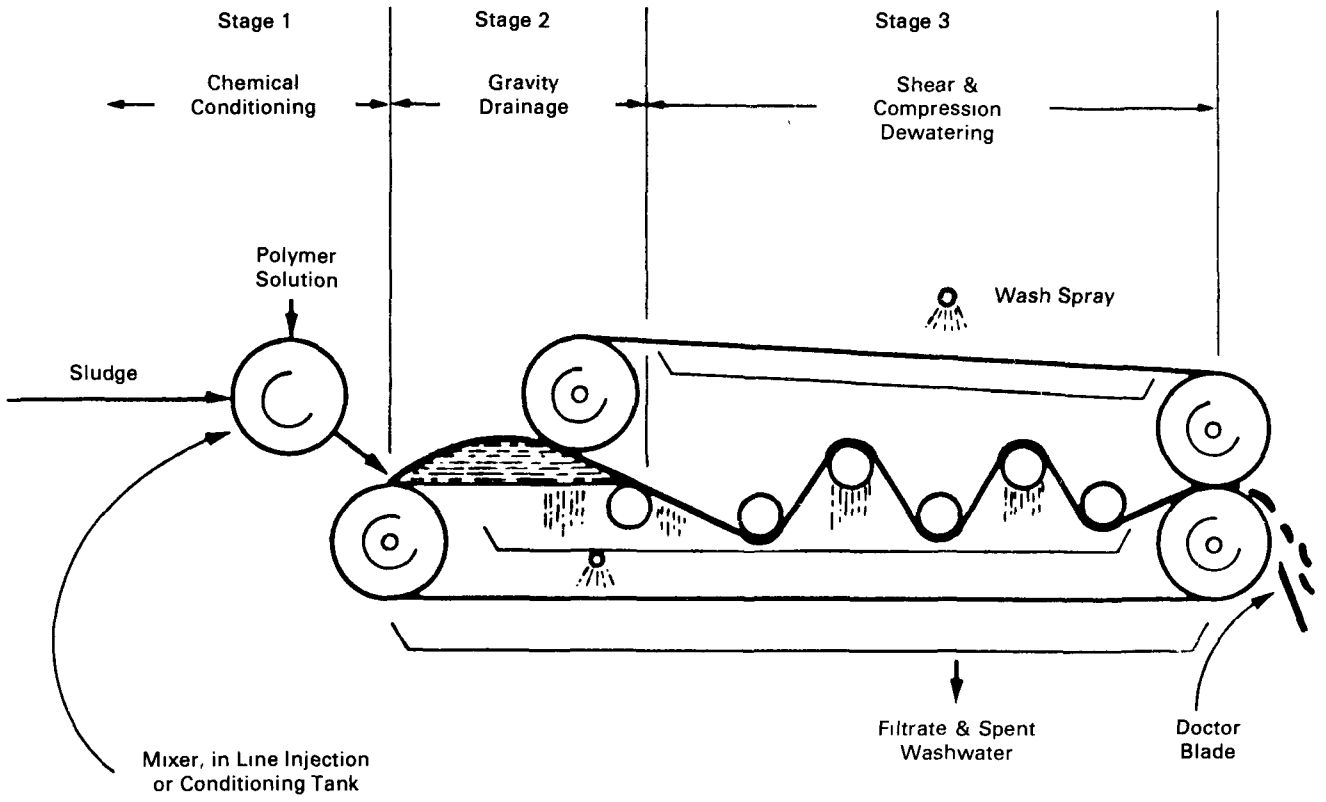
### Equipment Description

Belt filter presses are continuous sludge dewatering devices which use chemical conditioning, gravity drainage and mechanically-applied pressure to dewater sludge. A simplified schematic of this device is presented in Figure 1.

In most belt presses, conditioned sludge is first introduced to the gravity drainage section where thickening takes place through the drainage of free water. Suspended solids concentration of the sludge normally increases by a factor of three in this section. On some devices this section is provided with a vacuum assist which enhances drainage, and may help to reduce odors. Following gravity drainage, the sludge is subjected to gradually increasing pressure by squeezing between opposing cloth belts. The belts are held in place by a series of rollers that subject the sludge to shearing forces as the belts pass through a series of off-set rollers with reducing diameters that define a serpentine path. The squeezing and shearing forces thus introduced release additional quantities of water from the sludge.

Belt filter presses may be utilized to dewater nearly all types of sludges generated at municipal wastewater treatment plants. The major exceptions are sludges that are primarily chemical in nature, and biological

**Figure 1. The Three Basic Stages of a Belt Filter Press**




sludges that have been conditioned or stabilized with lime. Typical performance data for belt filter presses on various types of sludge are shown in Table I. The data are generally representative of the performance of available equipment, although loading rates and cake solids contents in the upper end of the ranges shown are not normally achieved.

In most cases, the sludge cake produced on belt presses has sufficiently high solids content to allow all types of disposal methods, including direct incineration. Because it is polymer conditioned, belt press cake has a higher volatile solids proportion than other sludge cakes, making it more amenable to incineration or composting than a sludge cake of the same solids concentration conditioned with lime and ferric chloride .

An interrelated system of auxiliary components supports the operation of the belt filter press. This auxiliary equipment includes:

1. Sludge Feed Pumps: These are continuously-operating, adjustable flow rate pumps, usually of progressive cavity design used to feed sludge to the belt press.
2. Polymer Mixing and Feeding System: Because polymer is required for sludge conditioning (see Table 1), a bulk polymer processing system is normally required to prepare and meter polymer to the feed sludge.
3. Washwater System: High pressure (410 kPa [60 psi] and greater) washwater is required to clean the dewatering belts after cake discharge.
4. Tension/Tracking Motive System: Either a pneumatic (compressed-air) or hydraulic power source is used to provide tension to the dewatering rollers and to reposition the rollers in order to keep the dewatering belts on track. Electrically-operated systems have also been used, but to a much lesser extent.
5. Sludge Cake Conveying: Belt conveyors are the most common method used for lateral conveyance of sludge, either to a truck (through a receiving and storage hopper), or other receptor.

## Design Considerations

There are approximately 20 manufacturers of belt filter presses. Each manufacturer produces a press having slightly different quality, mechanical features, and operating characteristics. The presses are available in widths from approximately 0.5 meters to 3.5

**Table 1. Typical Dewatering Performance of Belt Filter Presses***

| Type of Sludge | Feed Solids Concentration (%) | Dry Solids Loading Rate kg/hr/Meter Belt Width (lb/hr/Meter Belt Width) | | Dry Polymer Utilization mg/kg (lb/ton) | | Cake Solids (%) |
|---|---|---|---|---|---|---|
| Raw Primary (P) | 3-10 | 360-680 | (800-1500) | 1,000-5,000 | (2-9) | 28-44 |
| Waste Activated (WAS) | 0.5-4 | 40-230 | (100-500) | 1,000-10,000 | (2-20) | 20-35 |
| P + WAS | 3-6 | 180-590 | (400-1300) | 1,000-10,000 | (2-20) | 20-35 |
| P + Trickling Filter (TF) | 3-6 | 180-590 | (400-1300) | 2,000-8,000 | (3-15) | 20-40 |
| Anaerobically Digested | | | | | | |
| P | 3-10 | 360-590 | (800-1300) | 1,000-5,000 | (2-10) | 25-36 |
| WAS | 3-4 | 40-136 | (100-300) | 2,000-10,000 | (4-20) | 12-22 |
| P + WAS | 3-9 | 180-680 | (400-1500) | 2,000-8,000 | (3-15) | 18-44 |
| Aerobically Digested | | | | | | |
| P + WAS | 1-3 | 90-230 | (200-500) | 2,000-8,000 | (4-15) | 12-20 |
| P + WAS (thickened) | 4-8 | 40-230 | (300-500) | 2,000-8,000 | (4-15) | 12-30 |
| Oxygen Activated WAS | 1-3 | 90-180 | (200-400) | 4,000-10,000 | (8-20) | 15-23 |
| Thermally Conditioned | | | | | | |
| P + WAS | 4-8 | 290-910 | (600-2000) | -0- | (-0-) | 25-50 |

*Summary of data provided in references 2, 7, and 8

meters, with over 80 percent of municipal presses having either one or two meter belt widths.

The major components of the belt filter press are its frame, belts, rollers and bearings, belt tracking and tensioning systems, and its controls and drives. Other components include a flocculation system, cake discharge blades, and cake monitoring devices.

Various types and shapes of materials can be used in frame construction. Generally, welded or bolted structural steel that has been coated to resist corrosion is utilized. Bolted frames must be securely fastened with locking-type hardware to assure durability.

Belts are made of woven synthetic fibers, generally monofilament polyester such as rayon. Nylon belts are available, but are normally used for specific applications such as high pH sludges or abrasive slurries. Various material and weave combinations are available from belt suppliers. Either seamed or seamless belts are available. Seamed belts include stainless steel clipper-type seams, or zipper-types. Seamed belts tend to wear quickly at the seam due to a high degree of discontinuity at that point, and resultant wear at rollers and the doctor blade. Zipper-type seams provide less discontinuity than clipper seams and have a longer life. Seamless belts are continuously woven endless belts that have a longer service life than any other belt-type. However, seamless belts are more costly than other belt types, and only one manufacturer markets a belt press that lends itself to the use of a seamless belt.

Rollers and bearings are the mechanical heart of the belt filter press. Rollers provide the pressure and shear in the compression zone of the press, and assure proper belt support and tension. They are available in a variety of materials, including stainless steel and rubber coated steel. Perforated rollers (normally stainless steel) are used in initial pressure stages by some manufacturers to enhance drainage. The rollers are supported on and guided through bearings, normally the pillow-block type. Because they are used in a strenuous environment, highly durable, well sealed bearings are required.

Belt tracking and tensioning systems utilize electro-mechanical sensors to determine the position and force applied to the press belts. They act through the press instrumentation system to hydraulically, pneumatically or electronically realign and adjust belt position and tension. Continuously acting, rather than on-off devices, provide the least stress on the belt and machinery.

Belt press controls include the instrumentation necessary to maintain press operation. They are provided in accordance with the needs of each facility and at a minimum contain starting and stopping devices for the press and its auxiliaries, the instrumentation for the belt tensioning and tracking system, and any required safety interlocks. The main belt drive is an electric motor, as are the drives for auxiliaries such as the flocculation system and the belt washing system. Integrated, centralized controls for the dewatering system are recommended.

Most belt presses come equipped with an integral sludge flocculation system. However, this system can be varied by the user, and separate flocculation devices can be specified. The devices are normally a flocculation tank mixing drum, or in-line chemical mixers such as static-tubes.

Cake discharge is accomplished over a discharge roller and assisted by a discharge, or doctor, blade.

The position and pressure of the doctor blade against the belt press discharge roller is adjustable. The cake discharge can be monitored for weight and thickness using a number of electro-mechanical devices, none of which have been shown to be of great value.

Most manufacturers will provide estimated performance data and sizing criteria for belt presses if given the specifics of the sludge to be dewatered. Performance claims should be carefully reviewed and, where possible, confirmed through pilot testing. Specifications should contain requirements for performance bonds.

In terms of integration within the overall treatment process, belt filter press performance varies directly with the feed sludge solids concentrations (see Table 1). The performance of belt presses decreases when they are used to dewater digested sludges, particularly those associated with aerobic digestion of waste activated sludge. As with other dewatering operations, it has been found that the overall performance of the belt press can be improved if fluctuations in conditioning, percent solids, type of sludge, and sludge constituents are minimized.

## Problem Areas and Potential Solutions

The major problems encountered with use of belt filter presses can be categorized as follows:

- Problems associated with equipment quality.
- Problems related to operating practices.
- Problems related to process integration.
- Problems related to integration of auxiliary systems.

### *Equipment Quality Problems*

The problems associated with equipment quality primarily involve belt quality, type and reliability of belt tensioning and tracking systems, and roller and bearing quality. It must be noted that many of these problems are associated with the initial installations of belt presses and that the better equipment manufacturers have eliminated many of these problems. Other equipment problems include frame and instrument corrosion, inadequate safety arrangements, and poor noise control.

**Belt Tear**—Torn belts are one of the major problems associated with the use of belt presses. The causes for belt tearing range from inferior quality belt material to misalignment of the equipment to improper operation and maintenance. The major causes for belt tear and associated remedial measures are shown in Table 2. Many of these problem areas have been reduced or eliminated by general improvements in belt press design, particularly belt tensioning and tracking systems, and improved materials for the belts themselves.

**Table 2. Causes and Remedial Measures for Belt Tear**

| Causes | Remedial Measures |
|---|---|
| 1. Use of inferior quality belt material | 1. **Use high quality belts**<br>a. Replace existing belts<br>b. Specify high quality; require a 4000 hr. minimum warranty. |
| 2. Wear at seam on stainless steel clipper belts | 2. Use zipper seamed or unseamed belts<br>a Replace existing belts<br>b. Specify zipper seamed or unseamed belts. |
| 3. Failure of belt in high pressure zone due to tensioning and tracking problem (formation of creases in belt are evidence of problem) | 3. Use improved tensioning and tracking systems.<br>a. Replace tension/ tracking systems in existing presses<br>b. Specify high quality tensioning/tracking systems for new presses (separately discussed in this Section) |
| 4. Misalignment of rollers | 4. Check and adjust roller alignment and tensioning/ tracking system as necessary. |
| 5. Belt shifting and/or creasing due to:<br>a. Uneven feed distribution<br>b. Insufficient washdown | 5. Check sludge distribution and review washdown procedures, then:<br>a. Improve sludge distribution to gravity drainage zone of press if possible.<br>b Require improved washdown and press maintenance. |
| 6. High wear due to use of hard plastic doctor blade | 6. Replace blade with a more resilient ultra-high molecular weight blade. |

**Belt Tensioning/Tracking**—Low quality belt tensioning/ tracking systems are generally associated with poorer quality belt filter presses. Systems that utilize exposed gearing present a safety hazard; those which are not continuously acting will impose a jarring action on belts. Retrofit of continuous tensioning/ tracking systems on existing equipment should be considered, but this is generally difficult and costly. On new facilities, specifications should require continuously acting systems that are readily accessible for easy maintenance with properly covered gearing to minimize potential safety hazard.

**Roller Failure**—Roller failure can be caused by inferior equipment, or by passage of large material such as heavy rags on to the press. High quality, corrosion resistant rollers constructed of epoxy coated steel, rubber coated steel or stainless steel should be utilized. If problems with foreign objects are experienced, the sludge should be ground or screened prior to dewatering.

**Bearing Failures**—The causes and remedial measures for a high frequency of bearing failures are presented in Table 3. In general, durable bearings with an L-10 life (less than a 10 percent failure rate) of 100,000 hours or more should be specified.

**Press Drainage**—Poor drainage of belt presses presents housekeeping and safety problems. Improved press drainage pan designs and increased attention to design of press support wells are solutions.

**Gravity Sludge Drainage**—When insufficient gravity drainage is achieved, overall dewatering performance is diminished. Poor drainage can be a result of an insufficient gravity drainage section, or of poor spreading of sludge on the gravity drainage section. Sludge spreading is improved by provision of furrow devices that distribute sludge across the belt at the head end of gravity drainage sections. Drainage can be improved operationally by reducing press speed. However, this practice will reduce press capacity. Persistent gravity drainage problems may require the evaluation of polymer selection, sludge conditioning, belt material and weave suitability, and belt wash operation.

**Belt Cleaning**—Belt cleaning problems are related to improperly sized washwater systems and/or to clogging of spray nozzles. Washwater pumps must have sufficient pressure and flow to meet manufacturers' requirements. Washwater needs should be verified during design and certified by equipment suppliers during the shop drawing review stage, before equipment is approved for installation. Washwater pumps should be furnished by the same supplier as the belt press. Adequate access should be provided to spray nozzles and the washwater piping system so that they can be cleaned easily. Stainless steel cleaning brushes within spray header systems facilitate cleaning and should be specified. Where plant effluent is used for washwater, strainers should be installed in the system and provision for final washdown and flushing with potable water should be considered.

**Personnel Safety**—Personnel safety needs must be fully considered. Adequate safety stops and trip wires around the belt filter press and conveyors, convenient and safe equipment access, non-slip walkways and floors, and sufficient lighting must be provided and properly maintained. Sound-deadening material should be used in the walls and ceilings of dewatering rooms to reduce noise levels.

**Controls**—Insufficient equipment control is a result of an incomplete understanding of the equipment and process. Major manufacturers of belt presses have improved their controls by providing such features as continuous acting belt tensioning/tracking systems and by monitoring and alarming critical functions such as belt misalignment, belt tension and low washwater pressure. These functions can be interconnected with the press system controls such that when activated they shut down the press and auxiliary equipment. Other system controls for auxiliary equipment and chemical feed systems are the responsibility of design engineers. These controls should be located near the belt press, allowing operators to control the dewatering system while observing the equipment.

**Table 3. Causes and Remedial Measures for Frequent Bearing Failure**

| Causes | Remedial Measures |
|---|---|
| 1. Improper Alignment of rollers due to:<br>a Poor alignment during assembly or maintenance<br>b. Structural failure of frames. | 1 Properly align rollers by.<br>a Proper installation and maintenance<br>b Use of durable frames<br>c. Stiffening of frame and realignment of rollers. |
| 2. Poor bearing protection and/or improper seals | 2. Utilize double or triple sealed bearings. |
| 3. Poor bearing lubrication due to:<br>a. Poor maintenance practices<br>b. Poor bearing location and/or poor location of grease fittings | 3. Improve lubrication practices by.<br>a. Requiring ease of lubrication on new equipment<br>b Requiring proper maintenance procedures<br>c. Relocating grease fittings and/or extending them for ease of maintenance on existing equipment. |

### *Operational Concerns*

Few of the difficulties related to belt filter press dewatering are associated with operation of the units. The problems that have been encountered are outlined on Table 4. As seen in the table, operating problems can generally be corrected by providing improved hands-on training on sludge conditioning practices and equipment operation either initially or as follow up during the first few years of plant operation.

### *Process Application*

The sludge handling system in which the belt filter press is employed can have a significant impact on its performance. In some cases, belt filter press performance has been substantially affected by the processes and operations preceding it; in others, belt presses were misapplied. The difficulties associated

**Table 4. Causes and Remedial Measures for Belt Press Operational Problems**

| Causes | Remedial Measures |
|---|---|
| 1 Improperly conditioned sludge due to:<br>a. Varying characteristics of raw sludge feed.<br>b. Improper polymer selection or dosage rate.<br>c Improper point of application of polymer that results in inadequate mixing time. | 1. Improve conditioning practices by:<br>a. Assuring continuity of sludge through blending of sludge prior to dewatering. Blending facilities should be considered where not provided.<br>b. Polymers should be carefully selected and tested. Selection and dosage rate should be checked frequently, particularly when changes in sludge characteristics are expected.<br>c. The point at which polymer is applied should be reviewed and revised as necessary to assure adequate mixing. |
| 2. Insufficient gravity drainage of sludge | 2. Evaluate:<br>a. press speed/drainage time<br>b. polymer selection and sludge conditioning system<br>c. *belt weave and/or material selection*<br>d. proper operation of belt wash system |
| 3. Loss of sludge from between belts | 3. Reduce belt tension. |
| 4 Poor housekeeping | 4. Train operators to properly maintain the press area. Provide steam cleaning equipment to assist cleanup. |
| 5 Poor safety practices, including:<br>a. Removal of spray and other equipment guards to facilitate observation<br>b. Inactivation of trip-wires to facilitate access to equipment. | 5. Provide safety training and stringently enforce rules to keep safety equipment in place.<br>a. Design guards for ease of removal and replacement. (One manufacturer uses light weight panels that fasten with magnets.)<br>b. Design safety equipment to minimize interference with operation. |

with poor process integration and improper application include:

1. High pressure/tension presses are more complex and require more maintenance than lower pressure machines. When the high solids cake produced on these devices is not needed, the added maintenance and additional costs are not worthwhile.
2. Increased maintenance, reduced bearing life and increased corrosion and cloth blinding can occur in belt presses when used to dewater sludge conditioned with lime. Where lime addition to the sludge is required, the lime is most appropriately applied in mixers following belt press dewatering.
3. Because different sludges have different conditioning and press operational requirements, wide variations in sludge characteristics can result in poor conditioning and in reduced dewatering efficiency. Sludge blending facilities are needed where sludge characteristics are likely to vary widely.

### *Auxiliary Systems*

A number of problems associated with belt filter press dewatering are a result of poor selection, location, or design of the auxiliary equipment associated with the operation. Major problems with this ancillary equipment include: poor selection and location of controls, polymer system problems, poor equipment access, inconsistent sludge feed and lack of odor control methods.

**Controls**—Problems related to selection and location of controls include poor positioning of controls, a lack of centralized controls, and inadequate control interlocks.

Controls and/or monitoring equipment are often not provided for key process parameters such as washwater, sludge feed, and polymer feed rates. In addition, sampling points are not provided for analysis of feed sludge and filtrate. Such monitoring and sampling equipment should be provided to allow computation and tracking of solids capture efficiency.

The controls for the belt press and its auxiliary equipment should be centralized. At a minimum, this should include controls for the press, polymer feed system, sludge feed system and sludge cake conveyance system. Ideally the controls should be located in a separate room or enclosed behind a vision panel to protect them from moisture. If the controls cannot be isolated, the control panels should have a NEMA type 4 rating to assure instruments will be protected against the moist, corrosive atmosphere found in dewatering rooms. In addition, to help avoid corrosion problems, dried air should be used in pneumatic controls.

When controls are located in a control room, the room should have a separate air handling system and be located for ease of equipment observation. Wherever

possible, controls should be located to allow ease of observation of the belt press gravity drainage section.

The controls for each part of the sludge dewatering system should be interconnected to assure coordinated system operation. Sludge feed, polymer feed, belt press and sludge conveyor startup and shut down should be properly sequenced for either automatic or manual operation. Polymer feed should be paced on sludge feed rate through the dewatering control system. Automatic shutdown of dewatering equipment should occur for any of the following fault conditions:

1. Belt drive failure
2. Sludge conditioning tank failure
3. Belt misalignment
4. Insufficient belt tension
5. Loss of pneumatic or hydraulic system pressure
6. Low belt washwater pressure
7. Emergency stop (trip wire)
8. High sludge level on gravity drainage section

**Polymer Feed System**—Difficulties encountered with polymer feed systems include polymer processing unit malfunctions (i.e., pump and valve failures), improperly sized feed equipment, inadequate mixing of polymer and sludge, and an inability to pace polymer feed rate with sludge flow. Contract specifications should require proof of performance for polymer processing units. Polymer feed equipment should be sized to handle the broadest possible range of both liquid and dry polymer dosage rates.

**Equipment Access**--Access to the belt press and its auxiliaries is occasionally inadequate. This is often the case where equipment is retrofitted. Adequate platforms and/or walkways should be provided around presses and free space should be allowed on one side of each press for roller removal. Facilities for lifting or hoisting heavy equipment should also be provided. Monorail hoists or lifting hooks should be considered. Portable A-frames are convenient for roller removal.

**Sludge Feed**—Uneven sludge feed is associated with the use of reciprocating pumps and high maintenance is associated with the use of progressive cavity pumps. The use of reciprocating pumps is generally not recommended by belt press manufacturers and should be avoided. Progressive cavity pump problems can be reduced by removal of grit and removal or grinding of rags prior to pumping. Removal or grinding of rags is also recommended to reduce the potential for roller problems. Where service conditions permit, rotary lobe pumps can provide adequate continuous sludge feed.

**Odor Production and Control**—Where septic sludge, or sludge containing highly odorous material is dewatered, odor release within dewatering rooms can pose a significant problem. Dewatering rooms should be adequately ventilated with at least six air changes per hour. Overhead exhaust systems are helpful in eliminating odorous gases. Where odorous sludge is anticipated, odor control systems such as a carbon adsorber or a wet scrubber should be investigated to determine which system is more cost-effective for the types of odors expected. Septic sludge should be dewatered as soon as possible, and can be "freshened" using potassium permanganate and caustic soda.

## Summary

Design of belt filter press dewatering systems requires the coordination of several important considerations. The performance of a belt filter press is dependent upon various auxiliary systems that provide proper sludge conditioning and continuity of sludge feed. Monitoring and control systems are necessary to identify and respond to equipment malfunctions and changing sludge characteristics.

The following considerations and recommendations should be included in the design and operation of belt filter press installations:

A. Equipment
- Utilize durable materials for equipment construction.
- Provide sturdily constructed, properly coated frames.
- Utilize long life bearings (L-10 life of at least 100,000 hrs.).
- Utilize high strength rollers.
- Provide continuously acting tension/tracking systems.
- Utilize zipper-type seamed belts or use seamless belts.
- Utilize durable, properly woven materials for belts.

B. Performance
- Consult manufacturers for design and performance data early in design.
- Confirm performance data with other operating installations or through pilot testing during design.
- Specify high quality equipment and require a performance bond.
- Assure system integration by specifying that the dewatering system be the responsibility of a single supplier.

C. Auxiliary Systems
- Provide sludge blending prior to dewatering to enhance continuity of feed sludge.

- Either remove rags, or grind them prior to dewatering to minimize roller problems.
- Provide flexibility in points of polymer application and type of polymer to be used.
- Utilize continuously acting high pressure sludge pumps such as progressive cavity or rotary lobe pumps.
- Provide positive ventilation for odor control in dewatering rooms. Where sludges with a high odor potential are to be handled provide carbon or chemical odor control systems.

D. Controls
- Provide instrumentation to monitor such operating parameters as sludge, filtrate, and washwater flow (with provisions for sampling).
- Integrate ancillary system controls with those for the dewatering equipment and interconnect key control functions.
- Protect controls from the moist, corrosive operating environment.
- Locate controls within sight of belt presses, preferably where gravity drainage sections can be observed.

E. Safety
- Provide non-skid walkways and floors.
- Provide adequate access to equipment.
- Assure installation and maintenance of trip wires, drive guards and other protective equipment.
- Educate operators as to correct safety precautions and assure adherence to rules.

F. Operations
- Monitor system performance to assure optimum operation.
- Assure that sludge is properly conditioned, and that variations in feed sludge quality and characteristics are minimized.
- Assure proper gravity drainage of sludge.

G. Operator Training
- Provide operation and maintenance training upon completion of belt press installation.
- Provide on-going training to maintain skills; video tapes are available for this purpose.

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