Chapter 5 – Solids Thickening and Dewatering Systems

Thickening and dewatering are important components of biosolids management programs. The proper solids concentration is critical in stabilization processes from aerobic digestion to advanced alkaline stabilization. The recent advances in solids thickening and dewatering have increased performance and capture rates while often reducing chemical and polymer consumption, electrical usage, space requirements and odor potential. In addition, automation has reduced the degree of operator attention required, further reducing the cost of operation.

When evaluating thickening and dewatering equipment, it is important to "start with the end in mind". Consider downstream processes and alternatives when establishing design criteria. For example, thickening waste activated solids prior to anaerobic digestion will increase the detention time in the process. However, the volumetric loading to the digester also should be considered. Maximizing thickening efficiency may not maximize digester performance.

Consider the impact thickening or dewatering will have on the sidestreams returning to the liquid stream treatment process. Increased dewatering efficiency will reduce cake transportation cost or potentially eliminate the need for supplemental fuel in an incineration process. However, it also will create a sidestream flow returning to the liquid stream process of the wastewater treatment facility. This sidestream could impact the capacity of the facility and ultimately its performance.

Also consider the impact solids conditioning will have on biosolids quality and characteristics. The use of lime as a conditioning agent as part of recessed chamber press dewatering operation adds solids and raises the pH of the biosolids. These additional solids may impact downstream processes. The increased pH may be a benefit in meeting pathogen reduction requirements. The increased pH also will result in the release of ammonia. This release may create an odor concern for some processes.

Changing polymers or changing from another conditioning agent to a polymer may impact the characteristic of biosolids. In a number of instances, changing polymers is believed to be the cause of odors. More data is required before any definitive conclusions can be made. However, noting the odor associated with a biosolids cake or product prior to and after any change in conditioning agents is recommended. The importance of bench scale testing for performance and product characteristics cannot be overemphasized.

5.1 Solids Thickening

Solids thickening reduces the volume entering subsequent solids processing steps. Thickening technologies include gravity, centrifugal thickening, gravity belt thickeners, and rotary drum thickeners. These thickening methods differ significantly. The following sections describe the processes and present design information and operational controls.

General Controls
A number of controls should be considered in the design and operation of any solids thickening

technology. They include:

- Dry weight of solids to thicken
- Downstream solids handling processes
- Period of thickening operation
- Relationship of desired period of operation to downstream process operation
- Pre and post thickening storage requirements and capacity
- Solids conditioning requirements

Each control should be addressed in the planning or optimization of a solids thickening system.

5.1.1 Gravity Thickeners

In gravity thickening, solids are concentrated by the gravity-induced settling and compaction. Gravity thickening of solids provides a two-fold benefit: concentration and flow equalization/storage. Gravity thickeners typically are used for thickening of primary solids. They also are used to thicken combinations of primary and waste-activated solids (WAS) and, in some cases WAS only. Primary solids gravity thicken easily as they typically settle quickly and achieve a high solids concentration, 4 to 6 percent, without chemical conditioning. The presence of (WAS) complicates gravity thickening and typically results in sporadic performance. WAS settle slowly and resist compaction, resulting in reduced loading rates. WAS also have a tendency to stratify because of the flotation effect of gas produced from continuing biological activity.

Gravity thickeners typically consist of a circular tank with a side water depth of 10 to 13 feet. Gravity thickener tank diameters range significantly. Floor slopes of 2:12 to a 3:12 are typical. (WEF MOP 8, 1992)

Operational Controls

A number of items should be considered in the design and operation of a gravity thickening system. They include:

- Solids Loading Rate
- Hydraulic Overflow Rate
- Odor Potential

Solids Loading

A critical consideration for gravity thickening is the solids loading expressed as total solids per unit area per unit time. Typical solids loading rates for various types of solids are presented in Table 5.1. If site-specific solids settling or pilot scale data can be obtained, they should be used for design. Table 5.1 also provides the typical concentrations that will be achieved by gravity thickening.

Overflow Rate

Another important consideration is the overflow rate. Overflow rates between 380 and 760 gpd/sq ft are typically used for primary solids. Overflow rates in the 100 to 200 gpd/sq ft range are used for thickening secondary solids. A high overflow rate can result in excessive solids carry -- over. A low overflow rate (corresponding to high thickener detention times) can result in septic conditions causing floating solids and odors. A dilution water supply is often used to maintain minimum overflow rates and minimize septicity problems. Chlorine, potassium permanganate, or hydrogen peroxide addition to the thickener, usually through the dilution supply, can also be used to reduce odor.

Odor Potential
Gravity thickeners are often a significant odor source in a treatment facility. They are typically covered to control odors for treatment.

Table 5.1 Typical gravity thickening performance and loading rates for various types of solids

Type of Solids	Feed Solids Concentration, %	Expected Underflow Solids Concentration, %	Solids Mass Loading lb/d/sq ft
Separate Solids			
Primary	2.0-7.0	5.0-10.0	20-30
Trickling Filter	1.0-4.0	3.0-6.0	8-10
Rotating Biological Contactor (RBC)	1.0-3.5	2.0-5.0	7-10
Waste-activated Solids (WAS)			
Primary+WAS	0.5-1.5	4.0-6.0	5-14
	2.5-4.0	4.0-7.0	8-16
Primary +Trickling Filter	2.0-6.0	5.0-9.0	12-20
Primary+RBC	2.0-6.0	5.0-8.0	10-17
Tertiary Solids			
High Lime	3.0-4.5	12.0-15.0	25-60
Low Lime	3.0-4.5	10.0-12.0	10-30
Iron	0.5-1.5	3.0-4.0	2-10
Alum	0.5-1.5	2.0-4.0	2-10

Source: WEF MOP 8, 1992

5.1.2 Gravity Belt Thickeners

Gravity belt thickeners (GBT) have become a popular method of thickening WAS. They have low energy requirements, are relatively easy to operate and require limited attention following start-up. In gravity belt thickening, solids are concentrated as free water drains by gravity through a porous horizontal belt. Successful gravity belt thickening requires chemical conditioning, typically using a polymer. GBTs are particularly suitable for the thickening of WAS before further processing and for thickening digested sludges as a volume reduction measure before transport.

Equipment and operating variables that influence GBT performance for a particular solid include polymer dose, feed rate, polymer and solids mixing, belt speed, ramp use and angle, belt type, and plow configuration.

Solids capture for WAS or digested solids thickening using a GBT typically will range from 90 to 98 percent with a polymer addition of 3 to 10 lbs/dry ton. Thickened WAS

concentrations of 4 to 8 percent are readily achievable; digested biosolids can be thickened to 10 percent.
Equipment and operating variables that influence GBT performance for a particular solid include polymer dose, feed rate, polymer and solids mixing, belt speed, ramp use and angle, belt type, and plow configuration.

Operational Controls
A key operational control consideration for a GBT is the feed rate. Loading rates to gravity belts vary significantly. A loading rate at or below 150 gpm/meter of belt width should provide good performance.
Other operational control considerations for GBT installations include:

- The need for adjustable rate solids feed and polymer feed
- Pressure drop requirements for the solids/polymer mixing device
- Provision of adequate flow and pressure for the belt washwater supply
- Building ventilation and odor control

5.1.3 Dissolved Air Flotation Thickeners

Dissolved air flotation (DAF) thickening concentrates solids as a result of the attachment of microscopic air bubbles to suspended solids, reducing their specific gravity to less than that of water. The attached particles then float to the surface of the thickener tank for removal by a skimming mechanism. DAF thickening has been commonly used for WAS. It generally is not used for primary solids or attached growth solids because gravity settling for these types of solids is more economical.

The feed solids to a DAF thickener are normally mixed with a pressurized recycle flow before entering the tank. The recycle flow rate typically varies up to 100 percent of the feed rate; the recycle flow is pressurized up to 75 psig. The recycle flow is normally DAF tank effluent, although providing water from another source as a backup is recommended. The recycle flow is pumped to an air saturation tank where compressed air enters and dissolves into the recycle. As the pressurized recycle containing dissolved air is admitted back into the DAF tank, the pressure release from the recycle forms the air bubbles for flotation. A typical bubble-size distribution would contain bubble diameters ranging from 10 to 100 μm. Solids and air particles float and form a sludge blanket on the DAF tank surface while the clarified effluent flows under the tank baffle and over the effluent weir. Capture of suspended solids is typically greater than 90 percent.

Polymer is frequently used to enhance DAF performance. Polymer addition allows an increase in solids loading rates and solids capture, but less effectively increases float solids concentrations. Polymer should be introduced at the point where the recycle flow and the solids feed are mixed to get the best results. Good mixing to ensure chemical dispersion while minimizing shearing forces will provide the best solids-air bubble aggregates.

Operational Controls
The solids loading rate of a DAF thickener is generally 0.4 to 1.0 lb/hr/sqft to produce a thickened WAS of 3 to 5 percent TS. Adding polymer increases the solids loading rate to

as much as 2.0 lb/hr/sq ft without negatively impacting performance. Polymer additions of 4 to 10 lbs per dry ton are common. WAS sludge volume index (SVI) is a solids characteristic that correlates well with DAF performance. An SVI of 125 or less is required for optimum performance.

DAF thickeners are designed hydraulically to operate in the range of 0.5 to 2 gpm/sq ft, with a suggested maximum hydraulic loading of 0.8 gpm/sqft.
The quantity of air provided in DAF thickening is defined in terms of an air: solids dimensionless weight ratio. Adequate flotation is achieved in most municipal wastewater thickening applications at ratios of 0.02 to 0.06.

5.1.4 Rotary Drum Thickeners

A rotary drum or rotary screen thickener functions like a gravity belt thickener allowing free water to drain through a porous media while solids are retained on the media. Rotary drum thickeners are often used as a prethickening step with belt filter press dewatering. They are well suited for the thickening of high-fiber sludges such as those in the pulp and paper industry and also for thickening either raw or digested biosolids that contain a significant primary solids fraction. Their success with municipal WAS is variable and dependent on solids characteristics. Polymer requirements are a concern because of floc sensitivity and shear potential in the rotating drum. The thickener uses a rotating drum with wedge wires, perforations, stainless steel fabric, polyester fabric or a combination of stainless steel and polyester fabric as the porous media.

The drum either is equipped with a center shaft mounted on a steel frame or is mounted on four trunnion wheels supporting its outer perimeter. A variable speed drive unit rotates the drum at approximately 5 to 20 rpm. Conditioned solids enter the drum and filtrate drains through the screen openings. Solids are conveyed along the drum by a continuous internal screw or diverted angle flights and exits through a discharge chute. Washwater is used to flush the inside and outside of the drum cleaning the screen openings of solids.

Operational Controls

The performance of a rotary drum thickener is similar to GBTs. Rotary drum thickeners typically require less space than other thickening methods and have a relatively low capital cost. The need for polymer conditioning and necessary operator attention are O&M cost related considerations. Rotary drum thickeners offer the flexibility of varying process performance with sludge feed and polymer feed rate control and drum speed adjustment. Equipment sizes and configurations vary among manufacturers. Design considerations include control of solids and polymer feed rate, drainage, and screen washwater supply.

Solid bowl conveyor centrifuge technology has proven to be widely successful in solids thickening.

5.1.5 Centrifuge Thickeners

Centrifuge thickeners use centrifugal force to separate solids. Centrifuges are commonly used for thickening WAS and other biological solids. They also have been used to thicken stabilized biosolids to reduce transportation costs. The most common centrifuge technology is the solid bowl conveyor, which has proven to be widely successful in solids thickening. The two basic configurations of solid bowl conveyor centrifuges are countercurrent and cocurrent. The primary differences between thickening and dewatering centrifuges are the configuration of the conveyor toward the liquids discharge end of the machine and the location and configuration of the solids discharge ports.

Operational Controls

Features differ substantially among centrifuge manufacturers. Table 5.2 lists the major design and operating variables that influence the operation of a horizontal solid bowl centrifuge. In general, performance of a centrifuge, as measured by thickened solids and solids capture, can be adjusted to desired values by modifying feed flow rate, bowl and conveyor differential speed, polymer addition, and pool depth. For a particular solid, polymer addition allows increasing the hydraulic loading while maintaining solids capture and thickening solids performance. Polymer use also improves achievable solids capture efficiencies typically to over 90 percent.

Table 5.2 Factors affecting centrifugal thickening.

Basic Machine Design Parameters	**Adjustable Machine and Operational Features**	**Sludge Characteristics**
Flow Geometry	Bowl Speed	Particle and Floc Size
Countercurrent	Bowl and Conveyer	Particle Density
Co-Current	Differential Speed	Consistency
Internal Baffling	Pool Depth and Volume	Viscosity
Bowl/Conveyor Geometry	Feed Rate	Temperature
Diameter	Hydraulic Loading	SVI
Length	Solids Loading	Volatile Solids
Conical Length	Flocculent Use	Sludge Age
Pitch and Lead		Sludge Septicity
Maximum Pool Depth		Floc Deterioration
Sludge and Flocculent		
Feed Points		
Maximum Operating Speed		

WEF MOP-8, 1992

Design considerations for centrifuge thickening include:

- Provide effective wastewater degritting and screening or grinding. Where wastewater screening or grinding is inadequate, grinders should be provided on the solids feed to the centrifuge to avoid plugging problems.
- Use adjustable rate feed pumping with positive flow rate control from a feed source that is relatively uniform in consistency. A mixed storage or blend tank is recommended.
- Consider centrate-handling delivery to either primary or secondary treatment

processes, venting, and foam suppression.
- Provide water for centrifuge flushing when equipment shutdown occurs.
- Consider the need for heated water supply to periodically flush grease buildup.
- Ensure proper ventilation and consider odor control.
- Consider struvite formation potential when thickening anaerobically digested sludge.
- Provide flexibility within the polymer feed system.

5.2 Solids Dewatering

Dewatering is an important step in a number of solids and biosolids management programs. Dewatering removes a significant amount of water from the solids entering the process and greatly reduces the volume. Dewatering solids from 2 percent to 20 percent reduces the volume of the material an order of magnitude. At 2 percent, one dry ton will require 60 cubic yards of storage volume. Dewatering to 20 percent solids reduces the volume to 6 cubic yards. There are a number of dewatering technologies available. The following sections describe the processes and present design and operational information.

General Operational Controls
A number of operational controls should be considered in the design and operation of any dewatering system. They include:
- Dry weight of solids to dewater
- Type of solids being dewatered
- Downstream solids handling process
- Period of dewatering operation
- Relationship of desired period of operation to downstream process operation
- Pre- and post-dewatering requirements and capacity
- Dewatered solids transport
- Solids conditioning requirements

Each operational control should be addressed in the planning or optimization of a dewatering system.

> *Solids are dewatered using three operational stages: chemical conditioning, gravity drainage, and compaction in a pressure and shear zone.*

5.2.1 Belt Filter Press Dewatering

Belt filter presses have one or more moving belts to dewater solids using a combination of gravity drainage and compression. Solids are dewatered using three operational stages: chemical conditioning, gravity drainage, and compaction in a pressure and shear zone.

A number of variables affect the performance of the belt filter press:
- Solids characteristics
- Type of chemical conditioning

- Belt pressures developed

Press configuration, type of gravity drainage, belt speed. Although performance data indicate significant variations in the dewatering capability of different types of solids, a belt filter press is generally capable of producing a dewatered cake between 18 and 25 percent total solids. Solids capture rates ranges from 80 to 95 percent.

The operation of the belt filter press begins when the polymer-flocculated solids enters the gravity drainage zone. Filtrate from the gravity zone is collected and piped into a drain system. The thickened solids leave the gravity zone and enter the compression zone. Dewatering occurs as the solids are squeezed between two porous belts. The pressure increase begins in the "wedge" zone where the two belts are brought back together following the gravity zone. Pressures continue to increase as the solids pass through the wedge zone and enter the high -- pressure or drum pressure stage of the belt filter press. The belts travel around several drums or rollers of varying diameters to maximize shearing action. The shear forces in the high -- pressure section are great enough to release some of the bound water and possibly some intercellular water.

The major components of the belt filter press include its frame, belts, rollers and bearings, belt tracking and tension system, belt wash system, cake discharge blades, drive system, control panel, and flocculation system. Support systems for the belt filter press include polymer conditioning, feed pumps, belt washer supply, and dewatered cake conveyance. Information regarding the components and the support systems can be found in WEF Manual 8 1992. The information is summarized in this section.

Frame
The structural mainframe of the belt filter press is normally constructed of steel. All components of the belt filter press system are supported and attached to this frame. Corrosion is an important consideration because of the variety of environments and material to be handled. Coatings that provide corrosion resistance and longevity include epoxy paint systems, hot dipped galvanizing, and fiberglass encapsulation. Because polymer can attack the zinc in galvanized steel, frequent washdown of the frame is necessary.

Belts
Most belt filter presses have two sets of operating belts made of woven synthetic fibers. Seamed and seamless belts are available. Seamed belts have either stainless steel clipper-type seams or zipper seams; they tend to wear quickly at the seam. This, in turn, wears the rollers and the doctor blade. Zipper-type seams provide less discontinuity that clipper seams and have a longer life. Seamless belts are continuously woven endless belts that have a longer service life than any other type belt. Belts should be evaluated relative to the expected solids characteristics, solids capture required, and durability.

Rollers
Rollers support the belts and provide tension, shear, and compression through the pressure stages of the belt filter press. Rollers can be made of a variety of materials

including stainless steel. Corrosion and structural considerations are important. Rubber coatings are generally preferred, at least on the drive rollers. Roller deflection at the rated belt tension of at least 40 lb/in should be limited to 0.05 in. at roller midspan. Perforated stainless steel rollers are used in initial pressure stages by some manufacturers to enhance drainage.

Bearings

Bearings are an extremely important part of the belt filter press. Many manufacturers mount the bearings directly on the mainframe, making them accessible for maintenance and service on the exterior of the units. These bearings are normally of the pillow-block-type construction and should be rated for a life of 300,000 hours. Bearings should be double- or triple-sealed to reduce contamination and wear. They also should be self-aligning. Split-house type bearings are necessary when ready access is unavailable outside of the mainframe. A centralized lubrication system is recommended to enhance maintenance.

Belt Tracking

A belt-tracking system keeps the belts centered on the rollers. The belt-tracking system requires sensing arms connected to a limit switch to sense movement in belt position. A continuously adjustable roller senses a shift in belt position and automatically adjusts the belt position; this roller is connected to the response system that is pneumatic, hydraulic, or electrically operated. An automatic, continuous modulating control must be an integral part of the system.

Belt Tension

Belt tension during operation is both maintained and controlled pneumatically, hydraulically, or mechanically. Increasing belt tension increases belt-dewatering pressure. Several manufacturers offer separate control systems for both the upper and lower belts so that each can be adjusted independently. An automatic adjustment system, similar to that described for tracking, is necessary. Belt life decreases as belt tension increases.

Belt Washing

A high-pressure belt wash system cleans each belt after dewatered cake discharge. A belt wash station is normally provided for each belt. The belt wash system provides a high-pressure water spray to remove any residual solids, grease, polymer, or other material that binds the belt. Self-cleaning nozzles are suggested, however, most manufacturers provide a manual cleaning feature that includes a hand-wheel operated brush device mounted internally in the nozzle header pipe.

Drainage

Drainage must be provided to collect and transport filtrate and washdown water. Collection-housing units and drainage piping, connected to the belt filter press, should discharge to a sump or floor drain system directly below the unit. When sizing the drainage system, the filtrate plus washwater flows must be included. A 2.0 meter belt press can discharge from 175 to 200 gpm of filtrate and washwater. The sidestream flow from the dewatering system should be discharged.

Discharge Blades
The discharge or doctor blade is normally a knife-edge constructed of ultrahigh molecular weight plastic. The doctor blade, typically located at the outlet end of the high-pressure section, scrapes the solids from the belt onto a collection system. The blade's adjustment should be inspected frequently as poor blade adjustment reduces belt life. Doctor blades can be reground or sharpened by a machine shop to extend useful life. Double-edged blades should be considered to reduce frequency of replacement or resurfacing.

Operational Controls
A number of items should be considered in the design and operation of a belt filter press. Control include:

- Hydraulic and Solids Loading Rates
- Solids Conditioning
- Flocculation System
- Systems Control

Loading Rates
The capacity of a belt filter press is based on hydraulic and solids loading rates. The solids loading rate is typically the more limiting of the two. Hydraulic loading rates to a belt filter press range between 45 and 60 gallons per minute per meter of belt filter press width, (gpm/m). Solids loading rates range between 480 and 600 dry pounds per hour per meter of belt filter press width, (dlb/hr/m). Table 5.3 presents hydraulic and solids rates for belt filter presses dewatering a variety of solids. The table presents ranges of loading rates applied and the results experienced.

Solids Conditioning
Polymer conditioning systems typically include chemical metering pumps, polymer storage and mixing equipment, polymer and solids mixer, and controls. Some installations operate directly from the drums of delivered polymer, eliminating the need for mixing and conditioning tanks and feed pumps.

Flocculation System
Belt filter presses typically have a system to flocculate and agglomerate the solids after polymer addition. This system normally has a flocculating tank unit, a static mixer, or an inline Venturi-type mixer. Each unit is design to mix the solids with the conditioning chemicals. Flocculation tanks provide a longer detention time and allow slower mixing of the solids and the polymer. This often results in improved performance.

System Controls Panel
Controls panel is designed for each application to operate the belt filter presses and the auxiliary systems. Critical alarms should be annunciated and a system emergency power shutdown should be provided. The controls should be located in a dry area within sight of the belt press but away from potentially corrosive atmosphere or spray from equipment washdown.

Table 5.3 Typical Belt Filter Press Performance Data

Type of Solids	Feed Solids %	Loading per meter belt width gpm	Loading per meter belt width dlb/hr	Dry polymer lb/dry ton dry solid	Cake solids % Typical	Cake solids % Range
Raw primary (P)	3-7	30-51	800-1200	2-8	28	26-32
Waste activated solids (WAS)	1-4	10-40	100-400	6-20	15	12-20
P+WAS (50:50)	3-6	21-51	400-700	4-16	23	20-28
P+WAS (60:40)	3-6	21-51	400-700	4-20	20	18-25
P+Trickling Filter (TF)	3-6	21-51	400-700	4-16	25	23-30
Anaerobically digested:						
P	3-7	30-51	800-1200	4-10	28	24-30
WAS	3-4	10-40	100-300	8-20	15	12-20
P+WAS	3-6	21-51	400-700	6-16	22	20-25
Aerobically digested:						
P+WAS, unthickened	1-3	10-51	300-500	4-16	16	12-20
P+WAS (50:50), thickened	4-8	10-51	300-500	4-16	18	12-25
Oxygen activated WAS	1-3	10-40	200-400	8-20	18	15-23

(WEF MOP – 8, 1992)

Polymer type, injection points, aging time, and mixing energy are all variables that directly relate to cost-effective dewatering.

Metering pumps are generally the positive displacement diaphragm, rotary lobe, or progressive cavity. Variable frequency drives should provide for variable polymer feed. Polymer storage system should be sized to take advantage of bulk delivery.

The type of mixing equipment required will vary, depending on the selected polymer, viscosity, and solids characteristics. Before injection, polymers are mixed into a dilute solution between 0.25 and 0.50 percent by weight. In addition, a metered, potable water supply connected to the mix tank discharge is recommended to further dilute the polymer solution and thoroughly disperse the polymer into the solids.

Polymer system controls are extremely variable. System range from simple, mechanical systems with mixing provided by water supply pressure, to more complex systems, including microprocessor-based control of batching sequence, especially where both dry and liquid polymer systems are used.

5.2.2 Centrifuge Dewatering

Centrifuge dewatering uses centrifugal force to separate solids from liquid. Advantages of centrifuge dewatering systems include enclosed operation, which reduces odor potential, good dewatering performance, reduced operator attention and safety. Dewatered solids concentrations of 30 to 35 percent have been reported using a centrifuge. Mixtures of primary and waste activated solids routinely dewater to solids concentrations above 22 percent. Solid bowl centrifuges, which operate with a continuous feed and discharge, are used almost exclusively for solids dewatering.

Advantages of centrifuge dewatering systems include enclosed operation, which reduces odor potential, good dewatering performance, reduced operator attention and safety.

Two types of solid bowl centrifuges have proven successful -- the countercurrent flow and the co-current flow designs. Major differences in the designs relate to the location of the feed ports, the removal of centrate, and the internal flow patterns of the liquid and solid phases.

In the co-current flow configuration, the solids travel the full length of the bowl while the liquids travel in a parallel pattern with the solids phase. Conduits remove the liquid, which then flows over the discharge weirs.

In the countercurrent design, feed enters the centrifuge at the junction of the cylindrical conical sections. Solids travel to the conical end of the centrifuge while the liquid travels in the opposite direction. The liquid overflows weir plates located at the large diameter end of the centrifuge.

Polymer is generally added either into the feed compartment or through an injection port within the machine. At a number of facilities, polymer is added at points upstream from the centrifuge. Multiple polymer injection points provide flexibility in system operation.

Typical dewatering performance for a solid bowl centrifuge is presented on Table 5.4.

Table 5.4 Dewatering performance for solid bowl centrifuges

	Solid Bowl		
		Solids Capture, %	
Type of Solids	**Cake Solids, %**	**Without Polymer**	**With Polymer**
Raw			
Primary	25-35	75-90	90+
Primary and trickling filter	20-25	60-80	90+
Primary and waste activated	12-30	55-65	90+
Primary and rotating biological contactor			
Secondary Solids			
Trickling filter	10-20	60-80	90+
Waste activated	5-15	60-80	90+
Pure oxygen waste activated	10-20	60-80	90+
Anaerobically digested			
Primary	25-35	65-80	85+
Primary and trickling filter	18-25	60-75	85+
Primary and waste activated	15-20	50-65	85+
Aerobically digested			
Waste activated	8-10	60-75	90+

Metcalf and Eddy, Inc., 1991

Operational Controls
A number of items should be considered in the design and operation of centrifuge dewatering systems. They include:

- Hydraulic and Solids Loading Rates
- Polymer Addition
- Cake Discharge
- Centrate Handling
- Control Systems

Hydraulic Feed and Solids Loading Rates
The hydraulic feed rate and the solids loading rate are important control variables in the operation of a centrifuge. The hydraulic feed rate to the centrifuge impacts the solids capture rate. The solids loading rate impacts the cake solids performance. Increasing the hydraulic load will decrease the solids capture and may increase polymer consumption. When solids loading rate changes occur, a corresponding change in the differential speed is required. The best performance is achieved at minimum differential speed and at a feed rate that matches the reduced volumetric conveying capacity (USEPA, 1987). The selected hydraulic feed rate should minimize floc shear and turbulence.

Polymer Addition
As discussed, the location of the polymer injection points requires careful consideration. The design, generally, will allow polymer feed directly into the solid bowl centrifuge and upstream of the centrifuge, either before or after the feed pump. Maximum flexibility is needed to allow future modifications of the system. Design considerations also include

the space requirements of the polymer feed system and pilot testing a range of polymer concentration.

Cake Discharge
Direct gravity discharge, belt conveyors, screw conveyors, or pumps are used to convey the cake from the centrifuge. Conveyors require a great deal of cleaning and maintenance for reduced odor and consistent operation. Pump systems are a popular way of conveying the cake. They allow the maintenance of a "closed system".

Centrate Handling
The centrate generated during dewatering usually is discharge downstream from preliminary treatment. Centrate piping must be properly sized and sloped to prevent centrate backups; long radius bends are recommended. If struvite build up is a concern, the ability to add ferric chloride should be considered. Ferric chloride binds with the phosphate ion preventing struvite buildup.

Because polymers can often produce foam or froth, a froth spray is required. A sampling line from the centrate discharge line to the sample sink should be provided. This will allow a simple check of performance.

Controls
Electrical control provisions and interlocks are an important part of centrifuge dewatering system. The centrifuge drive motor should run at full speed before the feed control can function. The control circuitry shuts down the centrifuge and shuts off the feed to the centrifuge if any centrifuge malfunction occurs.

A water flush system should be interlocked with the centrifuge on-off controls. After each shutdown, the centrifuge should be water flushed. Plant water can be used for centrifuge flushing. (USEPA, Process Design Manual, 1979).

Recessed chamber presses, operated as a batch process, use a pressure differential to dewater a liquid/solids slurry.

5.2.3 Recessed Chamber Press Dewatering

Recessed chamber presses, operated as a batch process, use a pressure differential to dewater a liquid/solids slurry. The main advantage of a recessed filter press system is that it generally produces cakes drier than those produced by other dewatering alternatives. Recessed chamber presses also have adaptable operation to a wide range of solids characteristics, acceptable mechanical reliability, and high filtrate quality that lowers recycle stream treatment requirements. The main disadvantages of recessed chamber presses are substantial quantities of conditioning chemicals or precoat materials, periodic adherence of cake to the filter medium, which requires manual removal, and relatively high Operation and Maintenance costs.

Solids conditioning, generally required to produce a low-moisture cake, involves adding lime and ferric chloride, polymer, or polymer combined with either inorganic compound to the solids before it is filtered. Several installations use only polymer for conditioning.

Their experience has shown that a small decrease in performance is offset by savings of chemical costs, reduced ammonia odors, and reduced overall volume of cake produced. (WEF MOP-8)

Operational Controls
A number of items should be considered in the design and operation of recessed chamber dewatering systems. They include:

- Standby capability
- Access
- Corrosion protection
- Conditioning system
- Precoat system
- Feed system
- Washing system, and
- Cake handling

Standby Capacity
Capacity must be provided for periods when the equipment can not be operated.

Access
Adequate access must be provided to maintain the dewatering system. A minimum of 4 to 6 feet is recommended at the ends of the filter presses. A clearance of 6 to 8 feet is recommended between filter presses. Height clearance must be sufficient for removal of plates.

Corrosion Protection
Because filter presses require frequent washdown, the area around the press should be constructed of corrosion resistant materials. The floor around the equipment and the support structure are also subject to the corrosive nature of the cleaning agents. The chemical-handling facilities for bulk storage and preparation of conditioning chemicals must also be corrosion resistant.

Conditioning System
Most recessed chamber systems use lime or ferric chloride for conditioning. The lime and ferric chloride are typically added in the conditioning tank on a batch basis. Some facilities have converted to polymer for conditioning. Polymer is easier to work with and can be added “in-line” rather than on a batch basis.

Precoating
The precoat system aids cake release from the filter media and protects the media from blinding. Solids with a high biological content, that are difficult to dewater, have a tendency to stick to the filtration media. The two types of precoat systems that have been used are dry material feeding and wet material feeding. The dry material system is used for larger installations and for those that operate on a continuous basis.

Feed System
The recessed chamber press feed system must deliver the feed solids to the presses under varying flow pressure conditions. The feed system should complete the initial fill cycle by achieving an initial pressure of 10 to 20 psig within 15 minutes to minimize uneven cake formation.

Washing System
Filter media washing, either by water spray or acid wash, is an essential component of good press operation. Washing removes residual cake and grease impregnated in the filter media. It also reduces buildup behind the filter media on the filter drainage surface. Water spray wash method is a portable spray-wash unit. The acid wash method uses cleaning in place of filter media. A dilute solution of hydrochloric acid is pumped into an empty filter press in the closed position. The acid is circulated through the plate chamber and discharged.

Cake Handling
Cake handling requirements depend on the management practice. When trucks are used to transport the cake, the simplest procedure is to allow the cake to discharge directly into the truck. Recessed chamber presses can also discharge onto a conveyor system.

The cake conveying system can pose a major housekeeping problem. Each point of cake transfer onto a conveyor provides an opportunity for cake material to fall or cling in the immediate area. The return runs of a conveyor continually release cake material that was not removed at the discharge point.

The number of cake transfer points and the drop distance at any cake transfer point should be minimized. Discharge chutes of flexible material at each cake transfer point can be provided to reduce loss. Skirt boards can be installed on belt conveyors to assist in containing the cake on the conveyor. Drip troughs should be provided to collect any spillage. The troughs should be rounded and sloped to drain for washdown.

Ventilation
Ventilation of the filter press building is essential for operator comfort, odor reduction, and fume protection. Solids conditioning is the greatest source of odor. In particular, when solids are conditioned with lime or ferric chloride, significant amounts of ammonia are released as pH rises. The fumes are most noticeable when the press is opened for cake discharge.

Recessed chamber presses are either fixed volume or variable volume. Both types can be reliable when proper attention is given to the maintenance and operation. The major operational difficulty encountered in pressure filter installations is inconsistent clean separation of the cake from the filter media. This problem may indicate the need for filter media wash or increased chemical conditioner dosages.

Fixed-Volume Press
The fixed-volume press has a number of plates held rigidly in a frame to ensure

alignment. These plates are pressed together either hydraulically or electromechanically between a fixed and moving end. A filter cloth covers the drainage surface of each plate and provides a filter medium. Solids are pumped into the press and collect in the chamber until a feed pressure is reached. The feed pump is then stopped, and the individual plates are shifted, allowing the cakes to be discharged.

Variable-Volume Press
The variable-volume press incorporates a flexible membrane across the filter plate face. This compresses the filter cake within the plate chamber, increasing the dewatering rate and decreasing cycle time.

5.2.4 Vacuum Filtration

Prior to the 1970s vacuum filtration was the most common form of mechanical dewatering in the United States (USEPA/625/1-87/014 Design Manual, Dewatering Municipal Wastewater Sludges, September 1987) from the mid 1920s until the late 1950s. The drum rotary vacuum filter was the most common. The belt type filter using stainless steel coils was introduced in 1951. The belt type filter with stainless steel coils mesh or a synthetic fabric was the popular until the mid 1970's.
The operating vacuum filter has three zones:

- Pickup zone
- Drying zone
- Discharge zone

In the pick up zone, the drum is submerged to between 20 and 35 percent of its depth in the reservoir of conditioned solids. While submerged, a vacuum is applied. This vacuum causes the solids to stick to the media while the filtrate passes through.

As the drum rotates, the solids attached to the media enter the cake drying zone. The drying zone represents 40 to 60 percent of the drum circumference.

When the solids reach the discharge zone the vacuum is removed. The cake is released from the media prior to the media re-entering the pick up zone.

Typical performance data for rotary vacuum filters is presented on Table 5.4. The table provides a summary of performance for filters incorporating coil and cloth media.

The major components of the rotary vacuum filter press include its frame, coils or filter media, vacuum pump, cake discharge blades, drive system, control panel, and flocculation system. Support systems for the press include conditioning system, feed pumps, and dewatered cake conveyance. Information regarding the components and the support systems can be found in the USEPA design Manual for Dewatering Municipal Wastewater Solids.

Operational Controls
A number of items should be considered in the operation of a vacuum filter. Operational controls include:

- Solids Loading Rate
- Vacuum Level
- Drum Speed and Solids Conditioning

Loading Rates
The capacity of a rotary vacuum filter is based on hydraulic and solids loading rates. The solids loading rate is typically the more limiting of the two. Solids loading rates range between 3 to 6 dry pounds per square foot per hour for blended primary and secondary solid per hour per meter of filter press width, (dlb/hr/m). Table 5.3 presents hydraulic and solids rates for belt filter presses dewatering a variety of solids. The table presents ranges of loading rates applied and the results experienced.

Table 5.5 Typical Dewatering Performance Data for Rotary Vacuum Filters – Coil and Cloth Media

Sludge Type	Feed Solids Conc. %	Chemical Dosage[1] lb/dry ton		Loading Rate[2] dry lb/ft2/hr	Cake Solids %
		$FeCl_3$	CaO		
Raw P	4.5-9.0	40-80	160-240	4-8	27-35
WAS	2.5-4.5	120-200	240-720	1-3	13-20
P + WAS	3-7	20-80	180-240	3-4	18-25
P + TF	4-8	40-80	180-240	2-6	23-30
Anaerobically Digested					
P	4-8	60-100	200-260	4-7	25-32
P + TF	3-7	80-120	300-400	4-7	18-25
P + WAS	5-10	80-120	200-350	4-8	20-27

[1] All values shown are for pure $FeCl_3$ and CaO. Dosage must be adjusted for anything else.
[2] Solids loading rates are impacted by feed solids concentration. Increasing the solids concentrations normally gives a higher yield.
Source: USEPA Dewatering Design Manual 1987.

Vacuum Level
The vacuum level associated with filter operation ranges from 1.4 to 2.0 cubic feet per min. per square foot (cfm/ft^2) at 5 pounds per square inch (psi). If the solids loading to the filter is greater than 5 to 10 lb/ft^s/hr the vacuum air flow should be increased to between 4.0 and 6.0 cfm/ft^2.

Drum Speed and Solids Conditioning
The optimum drum speed, vacuum level and solids conditions are best determined by bench scale testing. Performance will be impacted by feed solids content. Feeds solids below three percent will be difficult to dewater. Solids capture on well operated filters range from 85 percent for course media to 98 percent for close weave media.

5.2.5 Drying Beds
Sand drying beds provide a low-tech means of solids dewatering. They are popular at wastewater treatment facilities with capacities below 5 million gallons per day (USEPA 1979). Performance is impacted by weather conditions, and is better in arid regions of the

country.

Drying beds fall into four categories:

- Conventional drying beds
- Paved drying beds
- “Wedge-wire” drying beds
- Vacuum assisted drying beds

Conventional Beds
The elements of a conventional sand drying bed include a sand and gravel layer constructed over an underdrain system. Sand drying beds also include sidewalls, partitions, distribution systems, and, in some installations, wheel runways and/or enclosures.

A gravel layer (8 to 16 inches in depth) is usually constructed over the underdrain system. Gravel size ranges from 0.1 to 1.0 inches in diameter.

The sand depth on beds range between 9 and 18 inches. A minimum depth of 12 inches is recommended to reduce the frequency of sand replacement caused by losses from cleaning operations. Good quality sand with a uniformity coefficient that is under 3.5 is recommended. Effective size of sand grains between 0.01 and 0.03 inches is also recommended.

Sand drying beds can be covered with glass or translucent fiberglass panels to enhance drying. Completely covered drying beds minimize the impact of precipitation and insulate the operation during cold periods. Covered beds usually require less area than do open beds. Open beds located in arid climates evaporate cake moisture faster than covered beds.

Operational Controls
The operation of a conventional sand drying bed is impacted by the following:

- Solids concentration of the feed
- Depth of solids applied
- Sand/underdrain system performance
- Solids conditioning digestion provided
- Pan evaporation rate
- Type of removal method used, and
- Ultimate disposal method used.

Solids Loading
Solids loading criteria for sand drying beds are 10 to 25 lb/yr/sqft for open beds and 12 to 40 lb/yr/sqft for enclosed beds (USEPA, 1979).

Chemical Conditions
In some cases, drying bed installations include chemical conditioning. Conditioning helps improve the drying capacities of the beds.

Polymer Addition
If a drying bed system includes polymer addition, a minimum of three polymer addition points are recommended for optimum effectiveness. One near the suction side of the pump, another at the pump discharge, and the third near the discharge point to each bed.

Total Drying Time
The total drying time required depends on the desired final moisture content, and also relates to the means of removal and subsequent use. Ultimate bed sizing is a function of evaporation, solids application depth, and applied solids concentration.

The time required to achieve a liftable cake depends more on the initial solids content and percentage of total water that is drained than on the initial drainage rate. This is particularly significant from a dewatering standpoint since the time required for evaporation of moisture is longer than that required for drainage. Therefore, the total time the solids must remain on the bed is controlled by the amount of water that must be removed by evaporation.

The depth of applied solids affects the drainage rate. (Quon and Johnson 1966) The recommended initial depth of solids on a drying bed ranges from 8 to 16 inches. The applied depth should result in a solids loading rate between 2 and 3 lb/sqft.

Paved Drying Beds
There are a limited number of paved drying beds. The advantages of paved drying beds include equipment access and reduced maintenance. Most beds are rectangular in shape, 20 to 50 ft wide by 70 to 150 ft long. Concrete, asphalt, or soil cement is used for drying bed liners.

Wedge-wire Drying Beds
In a wedge-wire drying bed, solids spread onto a horizontal, relatively open drainage media. The bed has a shallow, rectangular, watertight basin fitted with a false floor of wedge-wire panels with slotted openings of 0.01 inches. An outlet valve to control the rate of drainage is located below the false floor.

The procedure used for dewatering solids begins with the movement of water or plant effluent into the unit until a depth of approximately 1-inch over the wedge-wire is reached. Water reduces the uneven buildup of solids on the wedge-wire screen. The drainage water is allowed to percolate at a controlled rate, through the outlet valve in the underdrain system. After the free water has been drained, the solids further concentrate by drainage and evaporation until it is removed.

Wedge-wire beds normally can dewater between 0.5 and 1.0 lb/sqft per application. The loading rate depends on the initial solids concentration of the solids applied. Most solids can be dewatered to a solids concentration of 8 to 12 percent solids within 24 hours. Solids loading rates of 180 to 365 lb/yr/sqft are typical with product total solids ranging between 8 and 12 percent.

Vacuum-Assisted Drying Beds

Vacuum-assisted drying beds incorporate the use of a vacuum pump with a sand drying bed. Solids are applied to a depth of 12 to 30 inches. Polymer, used to enhance performance, is injected to the sludge in the inlet line. Filtrate drains through the multimedia filter into a sump. After the solids drain by gravity, a vacuum system is started. A vacuum of 10 to 25 in. Hg is created.

When the cake cracks and vacuum is lost, the vacuum is shut off and solids removed. Vacuum systems are capable of dewatering a dilute solid to 14 percent total in approximately 24 hours. Solids recovery can approach 95 percent.

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