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ARMY PLATE AND FRAME FILTER PRESS

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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Change No.	**Date**	**Location**

This UFC supersedes Technical Letter No. 1110-3-457, dated 30 June 1994.

FOREWORD

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CHAPTER 1

INTRODUCTION

1-1 **PURPOSE AND SCOPE.** This UFC was written to provide procedures for engineering and design, and to provide a format for documenting the engineering and design, of plate and frame filter press systems.

1-2 **APPLICABILITY**. This UFC is applicable to all DOD design, construction and operations elements, laboratories, and field operating activities having military or civil works responsibilities. The engineering and design procedures are applicable to all DOD projects. Documentation is specifically applicable to the hazardous, toxic, and radioactive waste (HTRW) programs and may be adapted to the requirements of other programs.

1-3 **REFERENCES**. This UFC should be used in conjunction with design guidance listed in this paragraph as well as those listed in Appendix A.

1-3.1 ER 1110-345-700 Design Analyses.

1-3.2 ER 1110-345-720 Construction Specifications.

1-3.3 EM 1110-1-4008 Liquid Process Piping

1-4 **DISCUSSION**.

1-4.1 **Chapter 2—Design Considerations**. This chapter provides a comprehensive overview of design and engineering considerations for plate and frame filter press systems, including:

1-4.1.1 Background information, theory, and definitions.

1-4.1.2 Principles of operation for both fixed-volume and variable-volume filter press systems.

1-4.1.3 A summary of filter press applicability, a comparison with other dewatering options, and typical operating performance.

1-4.1.4 An overview of what the designer must consider, from sludge storage through disposal, and specifically for the components of the filter press equipment and associated accessories and auxiliary systems.

1-4.1.5 A summary of legal requirements and permits.

1-4.1.6 Treatability testing requirements and procedures.

1-4.1.7 Equipment sizing criteria.

1-4.1.8 Construction materials and installation.

1-4.1.9 Operation and maintenance.

1-4.1.10 Design and construction package requirements.

1-4.2 **Chapter 3—Design Calculations**. This chapter presents the types, calculations, and documentation required in the design of a filter press.

1-4.3 **Chapter 4—Checklist for Design Documents**. This chapter presents a checklist of design documents for filter press systems, including the design analysis, plans, guide specifications, and operation and maintenance manuals.

1-4.4 **Chapter 5—Design Examples**. This chapter presents a summary of the design approach for plate and frame filter presses and three illustrative design examples.

1-4.5 **Appendix A—Bibliography**. This appendix provides additional references and sources of information.

1-5 **ACTION**. Each DOD design element will be responsible for incorporating this UFC guidance into HTRW or military construction designs for plate and frame filter press installations.

1-6 **IMPLEMENTATION**. This information will be used by personnel responsible for the design and review of projects utilizing the plate and frame filter press technology. This information will be incorporated into projects that have not passed the 90% stage of design.

CHAPTER 2

DESIGN CONSIDERATIONS

2-1 **INTRODUCTION**. Filter presses have been used successfully to dewater and reduce the volume of sludge for domestic wastewater treatment facilities since the mid-1800s. However, it was not until around 1970 that they received widespread acceptance as a practical sludge-dewatering alternative. In addition to traditional wastewater applications, filter presses are currently being used to reduce and minimize the volume of sludge being generated from water and wastewater and other treatment operations at hazardous, toxic, and radioactive waste sites, including types of remediation projects being performed for the Corps of Engineers, and may be the most appropriate dewatering option.

2-1.1 **Purpose**. This chapter provides design considerations for engineering and design of plate and frame filter presses. These engineering and design procedures will be applicable to all DOD projects. However, this documentation is specifically applicable to the hazardous, toxic, and radioactive waste (HTRW) programs and should be adapted to the requirements of other programs.

2-1.2 **Scope**. This document covers the applicability and use of plate and frame filter press technology, equipment, and ancillary technologies and equipment. Two primary systems are described: fixed-volume and variable-volume (diaphragm) recessed plate and frame filter presses.

2-1.3 **References**. A list of references, other supporting documentation, and literature used in the development of this chapter is presented in Appendix A.

2-1.4 **Background**. Pressure filtration for dewatering sludge evolved from a similar technology used to manufacture sugar by forcing juices through cloth (EPA 1979). The technology was first used successfully during the mid-1800s in England for dewatering sludge without chemical precipitation (WPCF 1983). The technology was first used in the United States from 1898 to 1917 in Worcester, Massachusetts. Until the 1970s, filter presses were not widely considered because of the large amount of manual labor required. However, with mechanization and automation of internal systems, such as plate-shifting, cake discharge, and filter cloth washing, from a batch to an automated system, the overall labor requirement decreased dramatically. In addition, the capacity of these units increased substantially, decreasing the number of presses required and, thus, reducing overall operations and labor requirements. Currently, recessed fixed- and variable-volume filter presses are used in both municipalities and industry.

2-1.5 **Theory**. Pressure filtration separates suspended solids from a liquid slurry using a positive pressure differential as the driving force. In general terms, filter pressure dewatering may be described as a combination of constant flow rate and constant pressure processes. In the beginning of the filter cycle, a constant flow rate is used to build a maximum pumping head. When the maximum pumping head is achieved, the system switches to a constant pressure until the flow rate diminishes to a predefined low level.

The plate and frame filter press process typically operates in a batch filtration cycle that involves the following steps: initial fill, increasing cake formation, approaching constant pressure filtration, and cycle termination. Figure 2-1 is a schematic of the filtration cycle, showing pressures, flow rates, and cycle times. During the initial fill period, sludge is fed into the press at a relatively high and constant rate and at a relatively low pressure. As the press fills and solids accumulate on the filter media, cake formation increases, flow rate decreases, and pressure increases. As the filter cake continues to form, filtration flow is severely restricted by a change in the porosity of the cake, and the pressure increases to a near constant rate. At a set pressure point, the constant pressure will be maintained while the solids continue to accumulate. As this step continues, the flow rate decreases and the filter cycle is terminated.

2-1.6 **Definitions**. The following provides definitions for terms used throughout this chapter:

Blinding: Adverse particle accumulation or clogging of filter cloth or media.

Cake solids: The amount of solids in the sludge cake after it has been dewatered. The term is typically expressed in percent solids, where 1% is approximately 10,000 mg/L solids.

Cloth dog: A protrusion from the rim of a non-gasketed plate over which grommets of the filter media are hooked.

Coagulation: Floc formation as the result of adding coagulating chemicals. Coagulants destabilize (reduce repulsive forces) suspended particles, allowing them to agglomerate.

Conditioning: The act of pretreating sludge (before dewatering) to enhance water removal or solids capacity by the addition of inorganic and organic chemicals, solids washing (elutriation), or thermal treatment.

Core blowing: The act of removing liquid sludge from the sludge feed port with compressed air before sludge cake discharge.

Cycle time: The time, typically defined in minutes or hours, that is required to filter one batch of material. This time includes the filtration period, core and air blowdown period, and sludge cake discharge time.

Dewatering: Reduction of moisture content in sludge, which usually results in solids concentrations of 12 to over 50%.

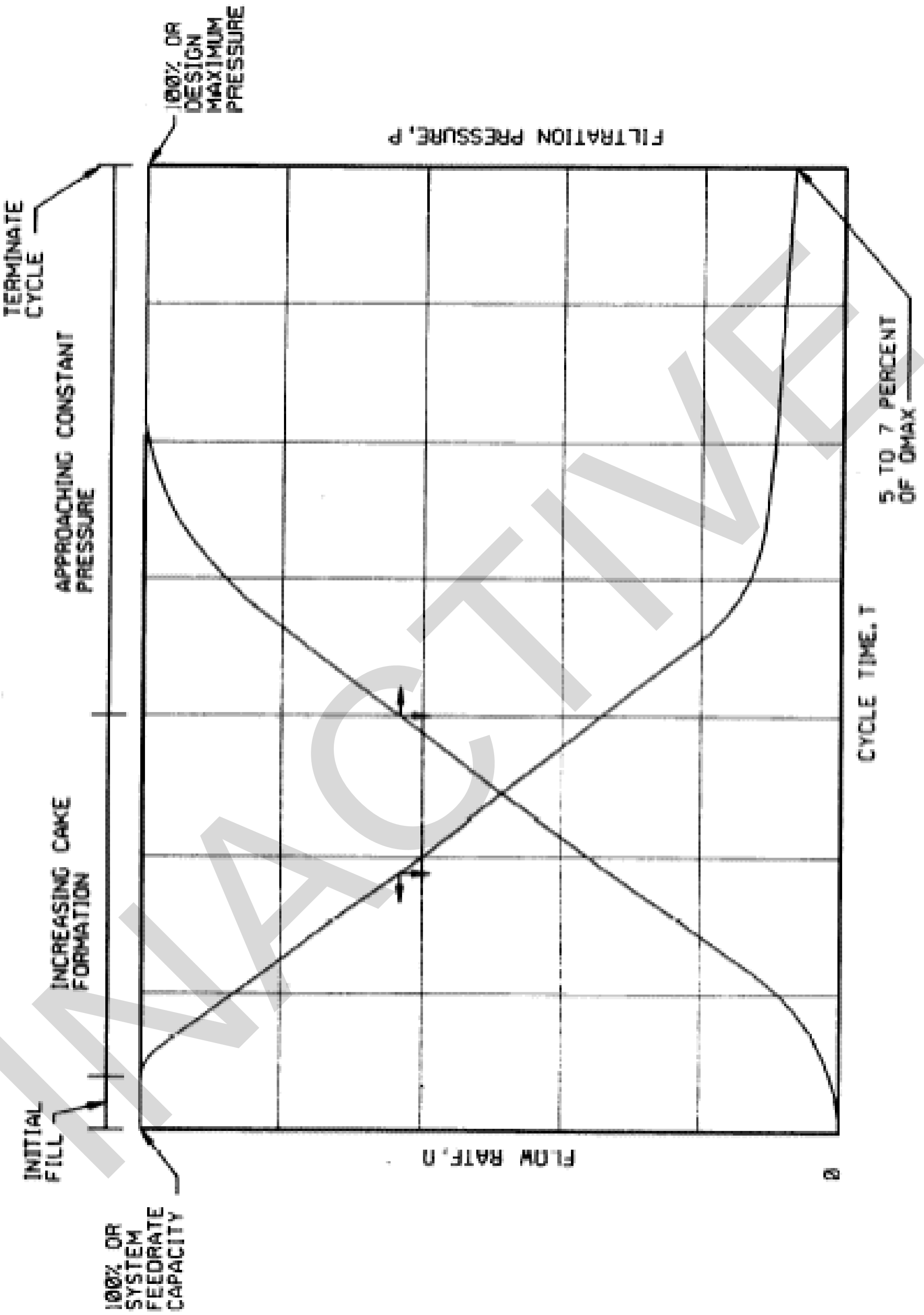

Figure 2-1. Filter press cycle relationships (WPCF 1983).

Diaphragm: An elastomeric or polypropylene membrane attached to the surface of the filter plate of a variable-volume filter press that is used to provide the "squeezing" force during the "filtration" cycle by application of pressurized water or air.

Feed solids: The total amount of solids in the sludge feed. This term is usually expressed as a percent weight of the dry solids feeding the press.

Filter cake: The volume of solids plus water that is retained within the filter press.

Filtrate: The liquid removed from the sludge during the dewatering process.

Filtration area: The total surface area through which the sludge is filtered. This area is typically a major factor that governs the rate at which the filter press will handle the sludge feed slurry.

Filtration volume: The volume of sludge feed slurry that can be passed through the filter press before it is necessary to remove the sludge cake.

Filtration: The act of separating solid particles from a liquid by passing it through a porous medium.

Filtration rate: The average rate that a particular sludge slurry will pass through a press, usually expressed in terms of liters per hour per square meter of filter area ($L/m^2 \bullet h$) (gallons per hour per square foot of filter area [gph/ft^2]).

Flocculation: Agglomeration of colloidal particles to form a loose cluster of particles that will settle at a faster rate.

Fixed-volume press: A plate and frame press that produces a sludge cake in chambers formed by fixed-area filter plates.

Precoat: A material used to coat the filter media in the filter press before sludge feeding begins. The primary function of this material is to ease sludge cake removal and prevent the media from blinding, thus reducing the filtration rate of the sludge.

Recessed plate: The recessed cavity of a filter plate that forms half of the chamber where the sludge cake develops in a plate and frame filter press.

Sludge: Solid and semisolid materials removed from the liquid wastewater stream by a wastewater treatment process.

Stabilization: A sludge pretreatment process used to make treated sludge less odorous and putrescible and to reduce the pathogenic organism content before final disposal. Stabilization results in a reduction of gelatinous organic materials that tend to retard or slow filtration of sludge.

Stay bosses: Raised surfaces on the interior main surface of the plate used to minimize plate deflection under operating conditions. When the filter is closed, the faces of bosses of adjacent plates contact one another, in effect forming solid columns from one end of the filter to the other.

Thickening: A sludge pretreatment process used to increase the solid content or decrease the moisture content in sludge prior to the primary dewatering process. The solids concentration of the resultant sludge is typically 3 to 12%.

Thixotropic: A characteristic of certain materials, often associated with sludge, that refers to a time-dependent change of decreasing viscosity and the resultant fluid-type characteristic that occurs because of applied agitation or shearing force, followed by a gradual recovery or "setting up" when an agitation or shearing force is stopped. An example of this characteristic is an ice cream milkshake, which "sets up" in its container and will only flow out when the container is rapped or jarred several times. Other examples include drilling muds, mayonnaise, and paints.

Variable-volume press: A plate and frame press that forms a sludge cake in chambers, formed by filter plates equipped with membranes or diaphragms that are expanded with water or air pressure to provide the primary "squeezing" force at the end of the filtration cycle process.

2-1.7 **Objectives**. The overall objective of this chapter is to provide engineering and design details for the plate and frame filter press technology, equipment, and ancillary technologies and equipment. This chapter also includes a discussion of the differences between the two plate and frame filter press systems (i.e., recessed fixed-volume and variable-volume [diaphragm] recessed plate and frame filter presses).
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2-2 **PRINCIPLES OF OPERATION**. The recessed plate and frame press consists of a series of plates, supported in a frame, that contain adjacent (facing) recessed sections that form a volume into which liquid sludge can be transferred for dewatering. The plates that form the recessed chambers are lined with filter media to retain sludge solids while permitting passage of the filtrate. The plates are also designed to facilitate filtrate drainage while holding the filter media in place.

During the filtration cycle, sludge is pumped under varying pressures and flow rates into the volume formed between the plates. As the filtration process continues, the filtrate passes through the solid cake and filter media. This process continues until a terminal pressure or minimum flow rate is achieved.

The two types of plate and frame filter presses typically used in dewatering sludge are fixed-volume and variable-volume presses. The fixed-volume system is the more commonly used press. However, the variable-volume press, otherwise called the diaphragm or membrane press, has become more popular in recent years. Following is a brief overview of both presses.

2-2.1 **Fixed-Volume Press**. The fixed-volume press consists of a number of plates held rigidly in a frame to ensure alignment. The plates are typically pressed together hydraulically or electromechanically between fixed and moving ends of the press. The sludge is typically fed through a large, centralized port in each plate, as shown in Figure 2-2, although some presses are corner fed. Entrained water is then forced out through filter media covering each plate to drainage ports located at the edges of the recessed area of each plate. As the filter cycle begins, conditioned sludge is fed into the filter press while the closing device holds the plates firmly together. The pressure in the inlet sludge feed pump typically ranges from 690 to 1550 kPa (100 to 225 psi). As this portion of the filtration cycle continues, the solids accumulate on the filter media in the plate cavity, and filtrate is forced through the plate drainage channels. This portion of the filtration cycle continues until a maximum pressure is obtained. This maximum design pressure is then maintained for a period during which more filtrate is removed and the desired cake solids content is achieved. The filtration cycle is typically ended when a practical low feed rate is achieved (typically 5 to 7% of the initial or maximum flow rate). The sludge feed pumping is stopped, and the individual plates are separated, allowing the sludge cake to be discharged.

2-2.2 **Variable-Volume Press**. The variable-volume press operates similarly in principle to the fixed-volume press. However, the variable-volume press incorporates a flexible membrane across the face of the recess plate. Figure 2-3 shows a schematic of a variable-volume filter press and filter cycle. The initial step of the filter cycle is similar to the fixed-volume press, but the pressure of the sludge feed is typically lower and ranges from 860 to 900 kPa (125 to 130 psi) (EPA 1982a). The filter cake starts to form when feed pumping is begun. The initial fill time is generally defined as the point when an instantaneous feed rate, filtrate rate, or cycle time (typically 10 to 20 minutes) is achieved. After the press is filled, the sludge feed pump is turned off, and the filter cake starts to form. The membrane is pressurized with compressed air or water to between 1520 to 1920 kPa (220 to 285 psi), thereby compressing the cake. Typically, 15 to 30 minutes of constant pressure is required to dewater the sludge cake to the desired solids content. When the compression cycle is completed, the air or water is released from behind the diaphragm, the plates are separated, and the cake is removed. This compression or squeezing step decreases the overall cycle time required to produce the sludge cake. In addition, the resultant cake is typically drier than those generated by a fixed-volume press. However, the variable-volume press typically generates less volume per cycle, the cakes are much thinner, and the press is typically more automated. Therefore, it is more expensive than the fixed-volume press (e.g., as much as two to three times the initial cost based on the same sludge cake volume generated).

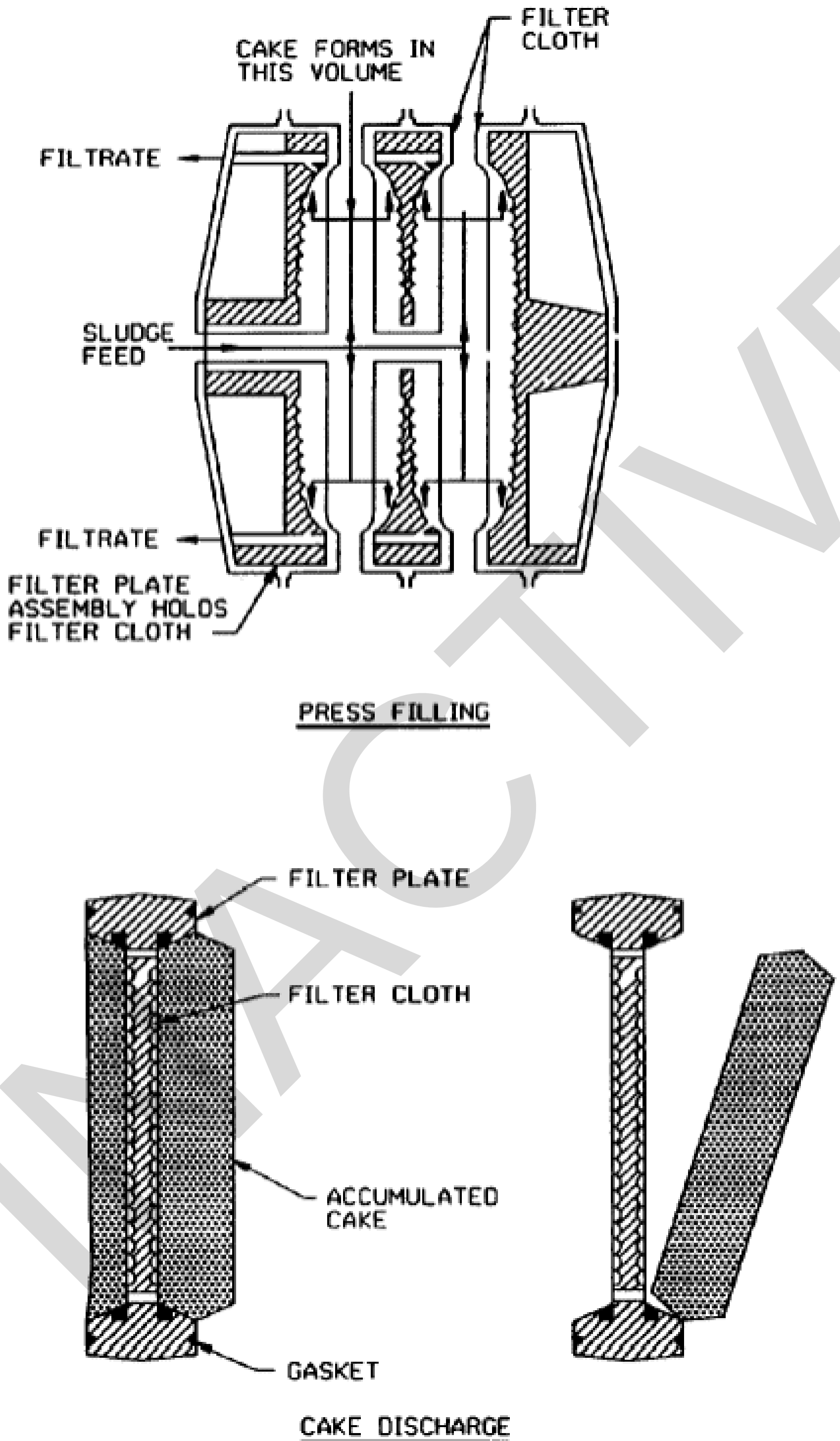


Figure 2-2. Fixed-volume recessed filling and cake discharge plate filter press (EPA 1987).

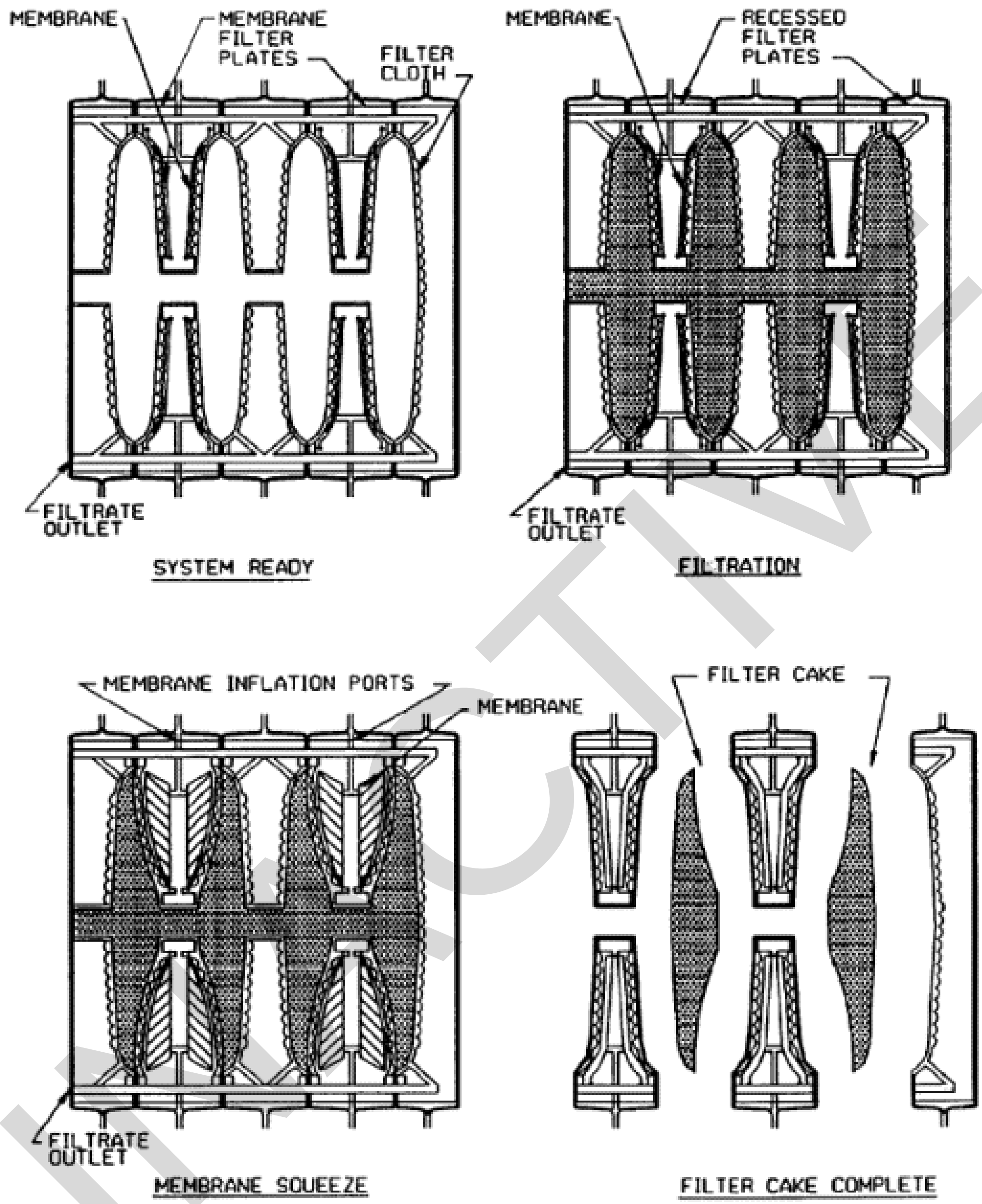


Figure 2-3. Variable volume recessed plate filter press filling and cake discharge (EPA 1987).

2-2.3 **Common Principles of Operation**. For either type of press, the filtration cycle is complete when minimum filtrate flow is achieved or the cycle time is completed, or both. Before the plates are separated to remove the sludge cake, the sludge pump is stopped, and core blowing may be done. Core and air blowing are commonly used and recommended options that may be required for filter press systems, except those with smaller presses, those with limited operation, or those for non-HTRW sites. Core and air blowing, applying compressed air to remove liquid sludge from the feed and filtrate ports, keeps unprocessed or wet sludge from running over the plates when they are separated and blinding filter media. A manual or automatic mechanical plate shifting device then controls the cake removal by separating the plates one at a time. For the fixed-volume press, the sludge cake is removed primarily by gravity onto sludge handling facilities located below the press. Sludge cake removal from the variable-volume press may be enhanced by a mechanical system that shifts the filter cloth around the bottom of each plate and then back into place when the plate is separated. After the press is opened, the cake is typically dropped from the chambers through cake breakers to break the rigid cake into a more easily handled form. After the cake is removed, filter media may be periodically washed to remove residual particles bound to them by the high pressures incurred during the filter cycle. If lime is used to condition the sludge before it is fed into the filter press, acid washing may also be periodically necessary to remove lime scale.

2-2.4 **Overview of Filter Press Dewater System**. The major components of the recessed filter plate are the frame, plates, filter cloth, plate closing mechanism, and plate shifting mechanism. These components are discussed in detail in Paragraph 2-4.7. In addition to the primary components listed above for the recessed plate and frame system, the following processes and associated accessories and auxiliary equipment are used to support its operation: liquid sludge transfer, chemical conditioning, filter precoating, filter media washing, and sludge cake and filtrate management. Descriptions and design considerations for these auxiliary components are presented in Paragraph 2-4.

2-3 **FILTER PRESS APPLICABILITY**. This paragraph presents a concise overview of sludge characteristics and dewatering system options, a comparison of filter press applications versus other dewatering processes, and typical filter press performance data.

2-3.1 **Sludge Characteristics and Dewatering Systems Options**. Sludge properties to be considered when selecting a sludge processing system include the origin and type of sludge, the quantity of sludge generated, moisture content, percent solids, and chemical composition and biological properties of the sludge, including biodegradability, specific gravity, rheological properties, dewatering properties, and suitability for use or disposal without further processing.

2-3.1.1 Sludge production primarily depends on the point at which it is generated and the mechanism and treatment process used. Typical sludges generated from water treatment processes can be categorized as primary sludge, biological sludge, and chemical sludge. Following is a summary of the generation, composition, and characteristic of each of these types of sludge.

2-3.1.1.1 **Primary Sludge**. Primary sludge is typically generated by solids separation or sedimentation and gravity settling to remove settleable solids. This sludge consists primarily of organic solids, grit, and inorganic fines. This sludge is typically pumped to downstream processing facilities for thickening, conditioning, and dewatering prior to disposal.

2-3.1.1.2 **Biological Sludge**. Biological sludge, a term typically associated with municipal-type sludge but which also applies to industrial and HTRW sludge, is generated by biological treatment processes, such as activated sludge, and fixed film bioreactors. This sludge consists primarily of conversion products from organics in the primary effluent and suspended particles that escaped the initial treatment. This type of sludge is generally more difficult to thicken and dewater than primary and chemical sludge.

2-3.1.1.3 **Chemical Sludge**. Chemical sludge is generated when chemicals, such as aluminum or iron salts, lime, or polymers, are added to precipitate suspended solids. The iron and aluminum salts, lime, and polymers are primarily used to cause the suspended solids to flocculate and coagulate. Parameters that affect the characteristics of chemical sludge include: the wastewater composition (chemistry), pH, mixing, and reaction time. Chemical sludge may also consist of suspended solids, in addition to potentially toxic material loadings and industry-specific components (i.e., heavy metals from metal processing industries).

2-3.1.2 In addition to these three primary sludge sources, mixed sludge can also exist. Mixed sludge may consist of a combination of primary, biological sludge, and chemical sludge and will have properties that are proportional to the respective composition of each original type of sludge.

2-3.1.3 Selection of the appropriate sludge dewatering process depends on several factors, including ultimate disposal or use, potential side streams, and local, state, and Federal laws. Several analyses can also be used to determine the optimum sludge dewatering process, including an initial screening of dewatering processes, an initial cost evaluation, laboratory (bench-scale) testing, field (pilot-scale) testing, and a final evaluation based on detailed design parameters. Additional criteria to consider include integration with proposed or existing wastewater treatment equipment and technologies, operation and maintenance costs, reliability of the dewatering device, existing site and environmental constraints, and compatibility with the ultimate disposal method. A general block diagram showing typical solids handling treatment and disposal methods is shown in Figure 2-4.

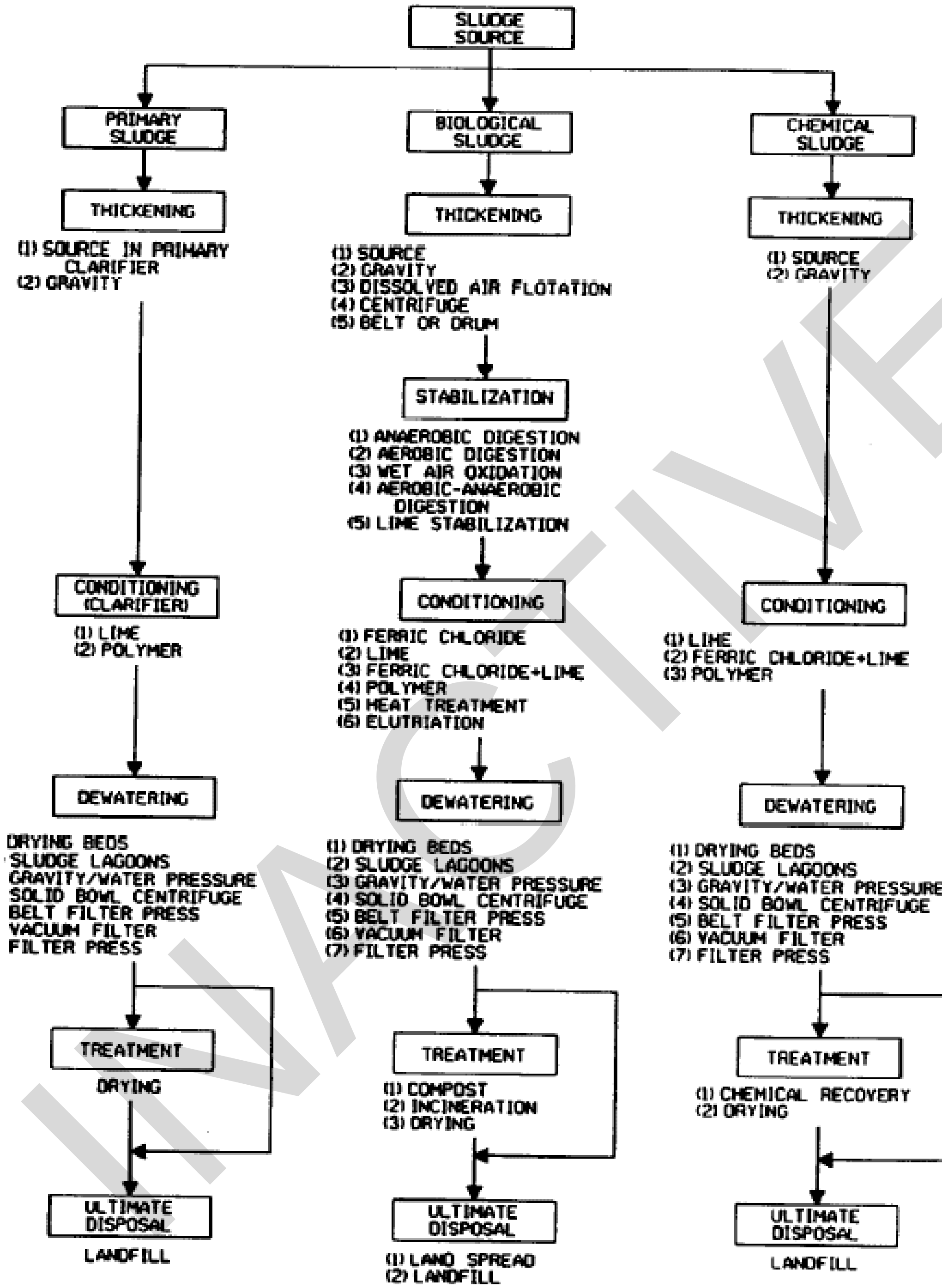


Figure 2-4. Overall schematic of sludge treatment and disposal options (EPA 1987).

2-3.2 **Comparison with other Dewatering Processes**. Table 2-1compares mechanical dewatering devices used for various sludge applications. Mechanical dewatering devices include the centrifuge, vacuum filter, belt, and pressure filter (i.e., fixed-volume and variable-volume press) presses. The following trends were noted from this information:

- The solid bowl centrifuge and vacuum filter presses generate similar results.
- The belt filter press results are better than those for centrifuge and vacuum filter presses, but are not as good as the plate filter press results.
- The fixed-volume plate filter presses will produce 6 to 10% drier cake than the continuously fed systems (i.e., centrifuges, vacuum, and belt presses).
- The variable-volume filter press can increase cake solids by an additional 3 to 5% over the fixed-volume filter press.

Table 2-1. Comparison of mechanical sludge dewatering processes for various sludge applications.

Type of Sludge	Percent Total Dewatered Cake Solids				
	Solid Bowl Centrifuge	Vacuum Filter	Belt Press	Fixed–Volume Filter Press	Variable–Volume Filter Press
Metal Finishing Waste	15–25	15–25	NR	40–55	NR
Municipal:Primary (P)	29–35	25–32	32–38	40–46	44–50
Municipal:Raw Waste Activated Sludge (WAS)	14–20	12–18	13–19	27–33	30–36
Municipal:Digested P	27–32	22–29	29–33	40–46	43–50
Municipal:Digested P&WAS	20–24	16–21	16–21	33–39	36–42
Municipal:Digested WAS	12–16	9–14	11–16	25–32	30–35
Municipal:Thermally Conditioned P and WAS	29–35	30–36	30–36	46–51	49–54
Municipal:Raw Trickling Filter (TF)	14–20	13–18	13–20	26–32	29–33
Municipal:Digested TF	16–20	13–19	14–20	NR	NR
Municipal:Raw P and TF	21–26	18–23	21–26	31–36	34–40
Municipal:Digested P and TF	20–25	17–23	20–25	29–34	33–38
Municipal:Water Alum Treatment	12–15	15–20	NR	40–50	NR
Petroleum Industry	10–15	15–20	15–20	35–50	NR
Pulp and Paper Industry	25–35	20–30	NR	35–40	NR

NR – Not Reported
P – Primary Sludge
WAS – Waste Activated Sludge
TF – Trickling Filter Sludge

Source: EPA (1982b and 1987), Eckenfelder (1981).

Overall, these results demonstrate that higher cake solids may be obtained by use of the plate and frame filter presses.

Filtration using the plate and frame filter press is generally desirable for sludge with poor dewatering characteristics or for sludge that requires a solids content more than 30%, such as sludge that is disposed of by incineration. In general, if sludge characteristics, such as concentration, are expected to change over a normal operating period, or if minimal conditioning is required, the variable-volume press may be selected over the fixed-volume press.

The paragraphs that follow compare general advantages and disadvantages of the plate and frame filter press with other dewatering processes (Table 2-2). The advantages and disadvantages of the variable-volume recessed filter press versus the fixed-volume recessed filter press are also presented (Table 2-3).

Table 2-2. Advantages and disadvantages of filter press systems compared with other dewatering processes.

Advantages	Disadvantages
High solids content cake. Can dewater hard-to-dewater sludges. Very high solids capture. Only mechanical device capable of producing a cake dry enough to meet landfill requirements in some locations.	Large quantities of inorganic conditioning chemicals are commonly used. Very high chemical conditioning dosages or thermal conditioning may be required for hard-to-dewater sludges. High capital cost, especially for variable-volume filter presses. Labor cost may be high if sludge is poorly conditioned and if press is not automatic. Replacement of the media is both expensive and time consuming. Noise levels caused by feed pumps can be very high. Requires grinder or prescreening equipment on the feed. Acid washing requirements to remove calcified deposits caused by lime conditioning may be frequent and time consuming. Batch discharge after each cycle requires detailed consideration of ways of receiving and storing cake, or of converting it to a continuous stream for delivery to an ultimate disposal method.
Source: EPA (1987)	

Table 2-3. Advantages and disadvantages of fixed-volume versus variable-volume filter presses.

Type of Dewatering Process/Device	Advantages	Disadvantages
Fixed-Volume Press	Higher volumetric capacity requires fewer dewatering cycles per day. Less complex instrumentation. Fewer moving parts. Longer plate life. Lower maintenance.	Dewaters only well conditioned sludges. More chemicals required for conditioning. Longer cycle time/per unit volume of sludge.
Variable-Volume Press	Dewaters marginally conditioned sludges. Shorter cycle time. Fewer chemicals required for conditioning. Lower operation and maintenance for sludge feed pumps. Precoating system is not required.	Limited volumetric capacity, requires more cycles per day. Mechanically complex. Complex instrumentation. Labor intensive filter cloth replacement. Higher maintenance.
Source: EPA (1982a, 1986)		

2-3.2.1 **Advantages**. As shown in Table 2-2, plate and frame filter presses have several advantages compared with other sludge dewatering systems. A high cake solids content (typically 30 to 50%) can be achieved, which is 6 to 10% higher than that achieved with other dewatering systems. A very high solids capture (98%) can be obtained. High filtrate quality can be achieved, which lowers recycle stream treatment requirements. This system can dewater hard-to-dewater sludge and sludge of varying characteristics and is mechanically reliable. In addition, this type of system may be the only one capable of dewatering sludge dry enough to meet landfill requirements in some areas.

As shown in Table 2-3, the variable-volume press system has several advantages over the fixed-volume press system. First, the variable-volume system produces a dryer cake (typically 3 to 5%) of more uniform moisture content. Second, the variable-volume press has a shorter cycle time and, thus, a higher production throughput. This shorter cycle time is a result of the more effective and uniform pressure placed on the sludge during the dewatering process. Other advantages of the variable-volume filter press include: lower operating and maintenance requirements for sludge feed pumps because the sludge can be pumped into the system at a much lower pressure; the ability to dewater marginally conditioned sludge and sludge with variable or changing characteristics to a high solids content; the use of polymers for conditioning versus lime or other inorganic chemicals that may increase the sludge volume and disposal costs; and precoats typically used to aid in the removal of sludge cake from the press are not required. A more detailed description of the applicability and use of conditioning chemicals and precoats is presented in Subparagraphs 2-4.4.5 and 2-4.6.2, respectively.

2-3.2.2 **Disadvantages**. As shown in Table 2-2, plate and frame filter presses have the following disadvantages compared with other sludge dewatering systems. The initial cost for filter presses is high, and operation and maintenance costs are high if the sludge is poorly conditioned and the filter press is not automatic. Filter cloth (water and acid) washing is labor intensive, and replacement costs are high. Larger quantities of conditioning chemicals are required and additional chemicals (precoat) may also be required to release the cake from the filter. Batch discharge versus continuous discharge after dewatering cycles may require additional facilities to receive and store the sludge cake pending further disposal. In addition, the sludge feed may require grinding and prescreening equipment, and the noise level would be very high because of the feed pumps.

The disadvantages of the fixed-volume filter press versus the variable-volume press are presented in Table 2-3. The primary disadvantage of the variable-volume press system is that the initial cost of equipment can be as much as two to three times that of the fixed-volume system. Another disadvantage is that, although the cycle time of the variable-volume press system is lower than that of the fixed-volume system, the volume of sludge generated per cycle of a similarly sized variable-volume press is generally less than the capacity of fixed-volume presses. The variable-volume press is also more mechanically complex, with complex instrumentation, and thus, higher overall maintenance.

2-3.3 **Filter Press Performance Data**. Filter press performance is typically measured as a function of the following parameters: solids content in the feed, required chemical dosages for conditioning, cake solids content, total cycle time, solids capture, solids yield, and filtrate volume (EPA 1982a). Although measured separately, these parameters are interrelated. For example, as the solids in the feed increase, the conditioning chemical dosages, total cycle time, and filter yield usually change. Another example of this interrelationship is that when the conditioning chemical dosage is increased, the solids content, solids capture, and yield all increase, while the cycle time usually decreases. However, if the sludge is over-conditioned, the sludge cake volume may increase, thus, increasing disposal costs.

2-3.3.1 **Factors Affecting Performance**. Several factors can affect filter press performance. They can typically be divided into two general categories: process factors and equipment factors. Process factors are primarily related to the characteristics of the sludge. Equipment factors can further affect the sludge filtration performance.

2-3.3.1.1 **Process Factors**. The process factors consist primarily of sludge characteristics, including particle sizes, specific gravity, sludge conditioning, and sludge storage.

a. Although no specific data are available on the particle size distribution for different sludge dewatering applications, the general effects of particle sizes on filtration are best illustrated by the following examples (WPCF 1983). First, if particles are of equal size, the resultant cake will be loosely packed and relatively unstable, especially if the filtration cycle incurred large pressure drops. Second, if the particles are relatively flat, the resultant cake may generate a relatively impervious envelope characterized by a high moisture content or fluid-like center. Ideally, a wide variety of particle sizes is desirable to keep an open matrix of particles that allows free drainage of entrained water. This effect is common for biological sludges, because their gelatinous nature allows small void spaces to be filled. Most sludge requires the use of conditioning chemicals or filter aids (i.e., fly ash) to generate the desired particle range or to provide additional structural integrity to allow for open drainage and water release. Subparagraph 2-4.4.5 provides a detailed discussion of chemical conditioning and filter aids. In addition to the use of filter aids, mixing of chemical sludge, such as alum or metal hydroxide sludge, with biological sludge may add structural integrity and aid in the dewatering of the biological sludge.

b. The specific gravity of particles can also affect the cake formation and filtration pressures. If the sludge contains a wide range of specific gravities, particles can settle in the lower chambers of the press and cause poor cake formation and unbalanced pressure in the cake. This effect keeps the larger particles from settling out. This effect is less noticeable for sludge feeds containing finely sized particles.

c. To make filtration more effective, sludge can be conditioned in several ways. Using more than one conditioning chemical, regulating the mixing energy, allowing the sludge to age, and using heat can all be combined. The treatability tests described in Paragraph 2-6 can help determine the effectiveness of sludge conditioning. Additional details on sludge conditioning effects are presented in Paragraph 2-4.4.

d. Sludge storage may also have an effect on filtration performance. Storage time can either be the period in which the sludge is stored before conditioning, or the period after initial mixing with the conditioning chemicals before filtration. Generally, prolonged storage is detrimental to filterability in either case. Additional details on sludge storage are presented in Paragraph 2-4.2.

2-3.3.1.2 **Equipment/Auxiliary System Factors**. Equipment and auxiliary system factors that typically affect sludge dewatering performance include pressure, number of plates, feed method, and mixing systems.

a. Pressure in a filter press is the overall driving force of the filtration process. Filter presses are typically designed for operating pressures of 690 to 1550 kPa (100 psi or 225 psi). In general, the higher pressure will yield higher percentages of sludge cake solids, slightly greater cake densities, and slightly shorter cycle times. High pressures are generally necessary for biological sludge. However, higher pressures do not provide increased benefits for very dense material (i.e., dense minerals, carbon, dirt, sand) or if final moisture content is not an issue (e.g., polishing applications). Typical pressure requirements for both fixed-volume and variable-volume filter press sludge dewatering applications are presented in Subparagraph 2-3.3.2, and Tables 2-4 and 2-5, respectively. Although many types of sludge can be successfully treated at either of these terminal pressures, using the higher pressure for some sludges (e.g., metal hydroxide sludge) can increase cake resistance and decrease porosity because of compression, resulting in decreased filtration flow rates. To avoid this problem, evaluate how well the lower pressure worked for dewatering a similar sludge. In addition to evaluating operating pressures, selecting proper filter media and sludge conditioning can alleviate pressure effects.

b. The number of plates in the press can also affect the overall efficiency of the filtration process and sludge cake moisture content. The effect of increasing the number of plates that is most often observed is poor distribution of sludge throughout the filter chamber. This happens especially in larger filter presses (>630 mm, 24 inches) that are fed at one end because the chambers nearest the feed entry point begin filling with sludge and filtering, while the chambers at the center or end of the press have not yet started to fill. As a result, unequal pressures develop in the press, resulting in cakes with various solids yield and moisture contents. In addition, equipment can be damaged (plates can warp and eventually break). This effect may be alleviated by using a lower pressure filling cycle or filling the press from both ends. In general, when 80 or more plates are used, feeding from both ends of the press should be considered.

c. The sludge feed method and sludge transport method are critically important to filter performance. After conditioning, it is important not to allow the floc that has formed to deteriorate. Therefore, a positive displacement pump that minimizes floc shearing, such as a plunger, piston, or progressive capacity pump, should be used to transfer conditioned sludge into the press. Centrifugal-type pumps should not be used to feed the press because the high shear force of the impeller can cause floc shearing and deterioration or can destabilize it. Additional details on sludge transport and feed pumps are presented in Paragraph 2-4.3.

d. The type and amount of mixing in the auxiliary systems that add chemicals for conditioning are important performance factors. During conditioning, the type and amount of mixing should be sufficient to ensure that the feed properly flocculates and to prevent particles from segregating because of varying size and density. High mixing or long agitation periods may increase the potential of floc shearing and further reduce the overall sludge filterability. Additional chemical conditioning considerations are presented in Subparagraph 2-4.4.5.

2-3.3.2 **Typical Performance Data**. Typical performance data for various types of sludge (including municipal wastewater, industrial waste, and various other sludges) from both fixed-volume and variable-volume presses are presented in Tables 2-4 and 2-

5, respectively. These data were complied based on actual performance data obtained from filter press manufacturers, such as those listed in Appendix A.

2-3.3.3 **Case Studies**. Following is a summary of referenced case studies from the literature. Although the studies are primarily based on the results of dewatering municipal wastewater sludge using filter presses, the information applies to HTRW sites utilizing biological treatment processes.

- EPA (1979, pages 9-59 through 9-61): Provides the performance results of a fixed-volume press application for wastewater.
- EPA (1987, pages 114 through 117): Provides a summary of performance results and operating and maintenance problems from a survey of 50 filter press wastewater applications.
- WPCF (1983, pages 87 through 92): Provides the results of several wastewater applications for both fixed-volume (low [590 kPa (100 psi)] and high [1550 kPa (225 psi)] pressure) and variable-volume filter press installations.
- WEF (1992, pages 1218 through 1222): Provides two case studies and performance results for pressure filter presses at five wastewater installations.

Table 2-4 Typical sludge dewatering performance data fixed-volume filter press.

Application[1]	Feed Solids (%)	Chemical Addition-Percent of Dry Solids[2]	Cycle Time (Minutes)[3]	Pressure (kPa)[4]	Cake Solids (%)
Aluminum Hydroxide	1 to 10	None or Polymer	120–240	690 or 1550	25 to 35
Barium Titanium Dioxide	40 to 50	None	60–90	690 or 1550	60 to 80
Brewery Grain Mash	2 to 10	Polymer or Lime-15	120–210	690 or 1550	25 to 40
Calcium or Tri-Calcium Phosphate	4 to 10	None or Lime-25	90–150	690 or 1550	30 to 60
Cement Slurry	60 to 70	None	20–60	690	80 to 90
Ceramic Clay Slurry	20 to 30	None	60–120	1550	60 to 80
Ceramic Wash Down Sludge	2 to 6	None or Polymer	90–240	1550	30 to 45
Chicken Processing Waste	2 to 8	$FeCl_3$-6 & Lime-18	90–150	1550	30 to 40
Chrome Hydroxide	2 to 6	None or Polymer	150–240	690 or 1550	25 to 35
Coal Pile Runoff	4 to 8	Lime-10	90–120	690	30 to 40
Coal Slurry	25 to 40	None	45–90	690	60 to 80
Cooling Tower Blowdown	4 to 8	Lime-10	90–120	690	30 to 40
Copper Hydroxide	1 to 6	None or Polymer	120–240	690 or 1550	25 to 40
Creosote Waste	2 to 8	Lime-30	120–180	1550	30 to 40
Domestic Septic Sludge	1 to 10	$FeCl_3$-5 & Lime-15 or Lime-15	60–210	1550	30 to 50
Fine Ash	6 to 10	None	60–120	690 or 1550	40 to 60
Flue Gas Desulfurization Oxidized Sludge	15 to 30	None	30–90	690 or 1550	40 to 60

Application[1]	Feed Solids (%)	Chemical Addition-Percent of Dry Solids[2]	Cycle Time (Minutes)[3]	Pressure (kPa)[4]	Cake Solids (%)
Fly Ash	15 to 30	None	30–90	690 or 1550	45 to 70
Foundry Sludge	5 to 15	None	60–120	690 or 1550	35 to 50
Granite Fines Sludge	20 to 40	None	20–60	690	60 to 80
Hazardous Soil/ Groundwater Sludge	10 to 20	None or Polymer or Lime-10	45–90	690 or 1550	35 to 60
Heavy Metal Fines	10 to 20	None	45–90	690 or 1550	50 to 70
Industrial Biological Sludge	2 to 6	$FeCl_3$-10 & Lime-30	120–240	1550	25 to 40
Iron Hydroxide	2 to 10	None or Polymer or Lime-10	90–150	690 or 1550	30 to 45
Iron Oxide	15 to 30	None	30–60	690	60 to 85
Landfill Leachate	1 to 3	Polymer or Lime-15	120–240	690 or 1550	25 to 40
Latex Waste	2 to 6	None or Polymer	120–180	1550	30 to 40
Laundry Waste	2 to 6	Lime-25	60–120	690 or 1550	30 to 45
Metal Hydroxides (electroplating, galvanizing, anodizing, etching, cleaning, etc.)	2 to 6	None or Polymer or Lime-15	120–240	690 or 1550	30 to 50
Municipal Primary Sludge	5 to 10	$FeCl_3$-4 & Lime-12	60–120	1550	30 to 50
Municipal Primary & Waste Activated Sludge	3 to 6	$FeCl_3$-5 & Lime-15	90–180	1550	25 to 45
Municipal Waste Activated Sludge	1 to 3	$FeCl_3$-10 & Lime-30	120–240	1550	25 to 40
Municipal Water Alum Treated Sludge	1 to 6	Lime-15 or Polymer	90–210	1550	25 to 40

Application[1]	Feed Solids (%)	Chemical Addition- Percent of Dry Solids[2]	Cycle Time (Minutes)[3]	Pressure (kPa)[4]	Cake Solids (%)
Municipal Water $FeCl_3$ Treated Sludge	2 to 8	Polymer	90–180	1550	30 to 40
Oily Industrial Wastes	4 to 15	Polymer or $FeCl_3$-5 & Lime-15	60–120	1550	35 to 60
Oily Waste Refinery Sludge	4 to 8	$FeCl_3$-10 & Lime-30 or Lime-30	120–180	1550	30 to 50
Pharmaceutical Biological Sludge	1 to 4	$FeCl_3$-10 & Lime-30	150–240	1550	25 to 35
Surface Water (Low Turbidity)	2 to 3	Polymer or Lime-25	150–180	690 or 1550	30 to 35
Surface Water (High Turbidity)	4 to 8	Polymer or Lime-15	90–120	690 or 1550	35 to 50
Surface Water (Lime Softened)	6 to 10	None	45–120	690	40 to 55
Steel Scale	15 to 25	Lime-5	45–90	690 or 1550	50 to 70
Textile Waste	2 to 8	$FeCl_3$-10 & Lime-30	150–240	1550	25 to 35
Water Based Ink Sludge	1 to 10	$FeCl_3$-5 & Lime-15	120–210	1550	25 to 55
Water Based Paint Sludge	4 to 10	$FeCl_3$-4 & Lime-12	120–180	1550	35 to 60
Wet Scrubber	5 to 15	None	45–90	690 or 1550	45 to 60
Yttrium Earth	40 to 60	None	10–20	690	85 to 95
Zinc Phosphate	1 to 10	None or Lime-15	60–180	690 or 1550	25 to 45
Zinc Sterate	5 to 10	None	20–60	690	30 to 40

[1] Application data complied from manufacturers referenced in Appendix A.
[2] Polymer dosages are not listed because several types may be commercially available and applicable for the sludge application listed.
[3] Cycle time includes mechanical turnaround (i.e., plate shifting, etc.).
[4] Pressure conversations: 690 kPa is equivalent to 100 psi, and 1550 kPa is equivalent to 225 psi.

Table 2-5. Typical sludge dewatering performance variable-volume filter press.

Application[1]	Feed Solids (%)	Chemical Addition-Percent of Dry Solids[2]	Cycle Time (Minutes)[3]	Feed/ Squeeze Pressure (kPa)[4]	Cake Solids (%)
Brewery Grain Mash	2 to 10	Polymer or Lime-15	90–180	690/1550	35 to 50
Calcium or Tri-Calcium Phosphate	4 to 10	None or Lime-25	90–150	690/1550	30 to 60
Chicken Processing Waste	2 to 8	$FeCl_3$-6 & Lime-18	90–150	690/1550	35 to 50
Creosote Waste	2 to 8	Lime-30	90–150	690/1550	40 to 60
Flue Gas Desulfurization Oxidized Sludge	15 to 30	None	45–90	690/1550	50 to 75
Fly Ash	15 to 30	None	30–60	690/1550	55 to 75
Industrial Biological Sludge	2 to 6	$FeCl_3$-10 & Lime-30	90–180	690/1550	30 to 50
Municipal Primary Sludge	5 to 10	$FeCl_3$-4 & Lime-12	60–120	690/1550	40 to 60
Municipal Primary & Waste Activated Sludge	3 to 6	$FeCl_3$-5 & Lime-15	90–180	690/1550	35 to 50
Municipal Waste Activated Sludge	1 to 3	$FeCl_3$-10 & Lime-30	90–180	690/1550	35 to 45
Municipal Water Alum Treated Sludge	1 to 6	Lime-15 or Polymer	90–150	690/1550	35 to 45
Municipal Water $FeCl_3$ Treated Sludge	2 to 8	Lime-15 or Polymer	60–120	690/1550	40 to 55
Oily Industrial Wastes	4 to 15	Polymer or $FeCl_3$-5 & Lime-15	60–120	690/1550	40 to 70
Oily Waste Refinery Sludge	4 to 8	$FeCl_3$-10 & Lime-30 or Lime-30	90–150	690/1550	40 to 60

Application[1]	Feed Solids (%)	Chemical Addition-Percent of Dry Solids[2]	Cycle Time (Minutes)[3]	Feed/ Squeeze Pressure (kPa)[4]	Cake Solids (%)
Pharmaceutical Biological Sludge	1 to 4	$FeCl_3$-10 & Lime-30	120–210	690/1550	30 to 40
Textile Waste	2 to 8	$FeCl_3$-10 & Lime-30	120–210	690/1550	30 to 40
Titanium Dioxide Process Sludge	4 to 10	None	90–150	690/1550	35 to 50
Water Based Ink Sludge	1 to 10	$FeCl_3$-5 & Lime-15	90–150	690/1550	40 to 60
Water Based Paint Sludge	4 to 10	$FeCl_3$-4 & Lime-12	90–150	690/1550	45 to 70
Wet Scrubber	5 to 15	None	45–90	690/1550	50 to 80

[1] Application data complied from manufacturers referenced in Appendix A.
[2] Polymer dosages are not listed because several types may be commercially available and applicable for the sludge application listed.
[3] Cycle time includes mechanical turnaround (i.e., plate shifting, etc.).
[4] Pressure conversations: 690 kPa is equivalent to 100 psi, and 1550 kPa is equivalent to 225 psi.

2-4. **DESIGN CONSIDERATIONS**. The design and operation of the recessed plate and frame filter press require that several key factors be considered to achieve the desired solids content. Recommendations for the equipment, operations, and auxiliary systems are discussed in detail in the paragraphs that follow.

2-4.1 **General**. Several process variables affect the efficiency of both fixed-volume and variable-volume recessed plate and frame filter press systems. In addition to the press itself, auxiliary systems may also affect the filter press performance. Specific design operating conditions for each application are based on the dewatering conditions required, such as maximum operating or terminal pressures, and associated dewatering equipment selected. A schematic of a comprehensive filter press system and its associated support systems is shown in Figure 2-5. Discussions of the applicability and use of these systems are presented in the paragraphs that follow. A general guide of typical design conditions for filter press applications is also presented in Table 2-6.

2-4.2 **Sludge Storage**. Sludge storage, as defined in this paragraph, is storage prior to dewatering. Sludge storage is an integral part of the solids treatment and dewatering process that can provide the following benefits:

- Equalizes sludge flow to downstream dewatering devices.
- Provides a more uniform feed rate and uniform sludge characteristics, which enhance pretreatment processes such as thickening and conditioning.

- Allows sludge to accumulate during both scheduled and unscheduled outages of dewatering equipment.

Depending on the type of sludge generated and subsequent treatment required, it may be stored in process tanks, sludge treatment process systems, or in separately designed tanks. Sludge may be stored in tanks from 24 hours up to several days to provide a more stable and uniform feed for downstream conditioning and dewatering processes. However, the storage time should be minimized, especially if the sludge is mixed to maintain a sludge with homogenous characteristics. Following conditioning, prolonged storage may result in an increase in the breakdown and solubilization of solid particles, thus decreasing the overall filter performance. Storage tanks for biological sludge are often provided with top-entry or submersible mechanical mixers to prevent septicity and resultant odor. Odor generated during sludge storage is typically controlled with chemicals such as chlorine, hydrogen peroxide, or iron salts. Additional detailed information on sludge storage, mixing, and odor control is presented in EPA (1979), EPA (1987), WPCF (1983), and WEF (1992).

2-4.3 **Sludge Transport**. Sludge is moved via sludge pumps before conditioning into sludge feed systems. The major design consideration for the sludge feed system is that it be capable of handling varying flows, such as 2 to 125 L/s (30 to 2,000 gpm) of a viscous to abrasive slurry at pressures ranging from 170 to 1550 kPa (25 to 225 psi). In addition to varying flows and pressures, time-dependent effects, such as thixotropic effects, can also affect sludge feed systems and pumping. Detailed information on sludge pumping and conditions that may affect sludge transport systems is presented in Eckenfelder (1981), EPA (1979), and WEF (1992).

2-4.3.1 **Sludge Feed Systems**. The sludge feed system delivers conditioned sludge to the filter press under varying flow and pressure conditions. The sludge feed system should be capable of delivering sludge under the following conditions during the filtration cycle:

- During the initial filter press fill period, the feed system should deliver the sludge at a high flow rate under low pressure.
- After the initial fill period, the feed system should continue to deliver sludge at a constant high rate, while adjusting to increases in pressure caused by solids buildup and cake formation, until the terminal pressure is obtained.
- Once the terminal pressure is obtained, the feed system should be capable of maintaining this constant pressure while allowing the sludge flow rate to decrease.
- At the end of the filter cycle, the sludge flow rate from the feed system is dropped to a minimum.

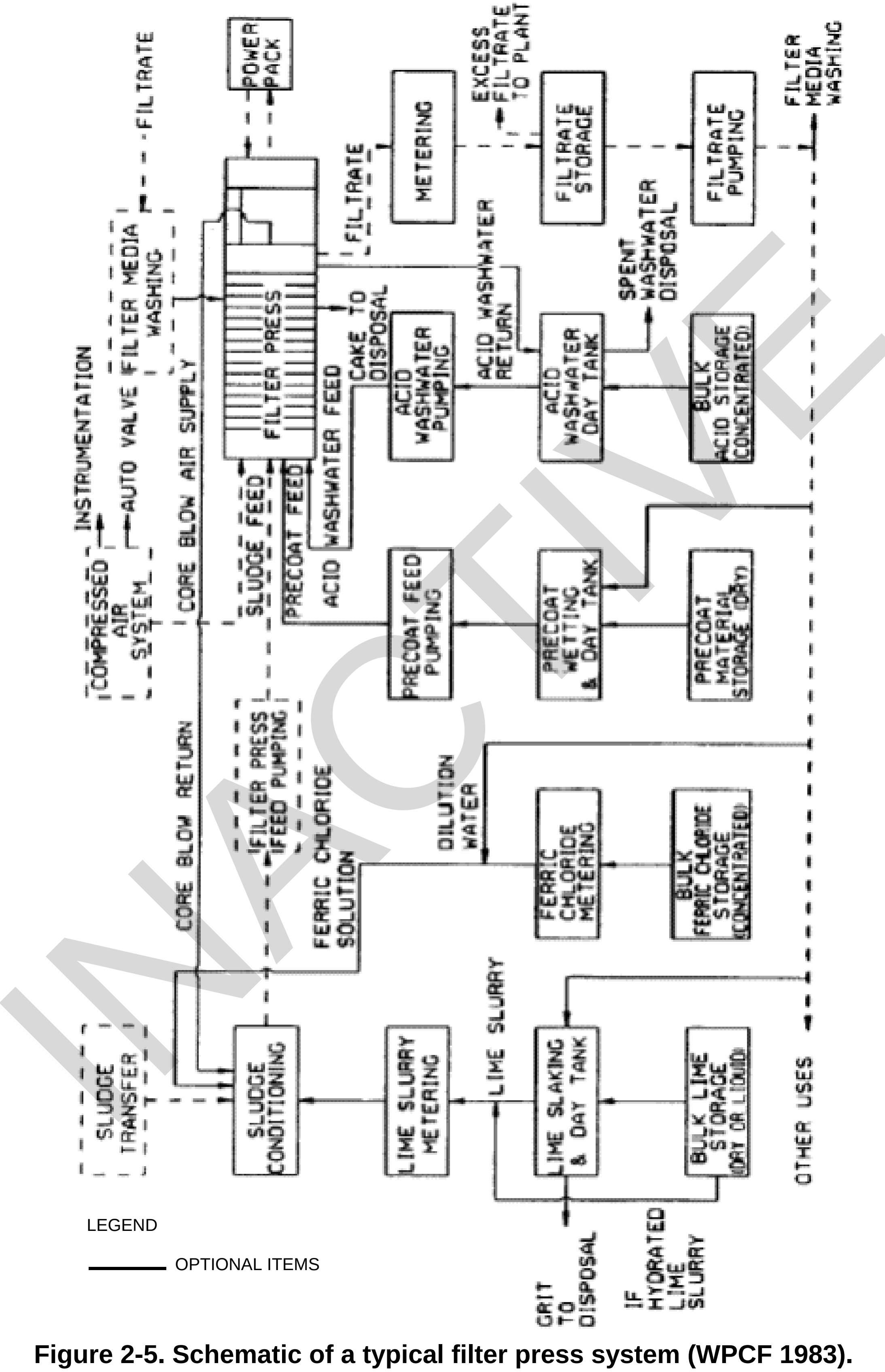


Figure 2-5. Schematic of a typical filter press system (WPCF 1983).

Table 2-6. Overview of typical design conditions for filter press applications.

Parameter[1,2]	Applicability	Typical Design Conditions[2]
Sludge Type/ Characteristics (Paragraph 3.1)	Specific to source of generation.	
Sludge Storage (Paragraph 4.2)	As required.	4 days' minimum, typical.
Sludge Transport (Paragraph 4.3)		
Feed Pump Type:	See Table 2-7 for general selection guide.	Application specific.
Feed Pump Pressure:	Application specific to sludge and types of press used.	See Tables 2-4 and 2-5 for typical pressure applications.
-Low-Pressure Unit (690 kPa terminal)	Fixed-volume press only.	350–860 kPa
-High-Pressure Unit (1550 kPa terminal)	Fixed-volume press only.	1040–1730 kPa
-Fast Press Filling (Up to 690 kPa)	Variable-volume press only.	350–860 kPa
-Membrane Water Inflation (Up to 1550 kPa)	Variable-volume press only, using water as membrane inflation media.	550–1730 kPa
Feed pressure stepping intervals:	Either type of press.	
- Low-Pressure Unit		180 kPa
- High-Pressure Unit		350–520 kPa
Sludge Pretreatment (Paragraph 2-4.4)	See Tables 2-4 and 2-5 for typical conditioning requirements for both types of presses for various sludge applications.	Specific requirements based on treatability studies (Paragraph 2-6).
Major Filter Press Components (Paragraph 2-4.5)		
Essential Components:	Required for either type of press.	

Parameter[1,2]	Applicability	Typical Design Conditions[2]
-Structural Frame (Subparagraph 2-4.5.1)	Both side bar and overhead frame types available. Overhead frame typically used for plate sizes greater than 1200 mm (48 inch) or for higher pressure applications (i.e., 1550 kPa [225 psi]).	
-Filter Press Plates (Subparagraphs 2-4.5.2 and 2-8.1.2 and Table 2-8)		Size dependent on volume of sludge cake generated per cycle.
-Filter Media (Subparagraphs 2-4.5.3 and 2-8.1.3)		
-Closing Mechanism (Subparagraph 2-4.5.4)		
-Plate Shifter (Subparagraph 2-4.5.5)		
<u>Optional Features:</u> (Subparagraph 2-4.5.6)	Can be used for either type of press if desired.	
-Safety Guards (Subparagraph 2-4.5.6.1)		
-Light Curtains (Subparagraph 2-4.5.6.2)		
-Drip Trays and Bombay Doors (Subparagraph 2-4.5.6.3)		
-Cake Breakers (Subparagraph 2-4.5.6.4)		
Filter Press Accessories and Auxiliary Systems (Paragraph 2-4.6)		
-Chemical Feed (Subparagraph 2-4.6.1)	As required for chemical conditioning, precoat, and filter media acid wash systems.	Application specific.
-Precoat (Subparagraph 2-4.6.2)	As required to reduce excessive filter washing requirements for sticky sludge applications.	Typically sized to 1.5 times the press capacity, with an application rate of 0.4 kg/m^2 over a 3-5 minute period at 0.2 to 0.3 L/m^2s.
-Filter Media Water Wash (Subparagraph 2-4.6.3.1)	Required for all applications. Both manual and automatic systems available.	10.3 MPa wash pressure typical.

Parameter[1,2]	**Applicability**	**Typical Design Conditions**[2]
-Filter Media Acid Wash (Subparagraph 2-4.6.3.2)	Used as required to reduce lime scaling on filter media for lime conditioning applications.	Typically sized to are 1.5 times the capacity of the press.
-Compressed Air (Subparagraph 2-4.6.4)		
Instrument Air	Used as required for pneumatic control.	Typically requires 690 kPa pressure.
Air Blow/Core Blow	Used as desired to reduce excessive filter media washing and provide drier sludge cake.	
Membrane Air Inflation	Typically used with variable-volume presses for no more than 150 psi pressure applications.	690-1380 kPa.
Filter Press Control Systems (Paragraph 2-10)	Applicable type (i.e., manual, semiautomatic, and automatic systems) based on the degree of desired automation. Typically degree of automation dependent on size of unit and use of accessories and auxiliary systems.	Application specific.
Sludge Cake Handling and Storage (Paragraph 2-4.10)	Typically involves only direct discharge into storage container.	4 days' minimum storage required if no other dewatering facilities exist.
Sludge Cake Transport (Paragraph 2-4.11)	Typically involves use of either conveyor, auger, or sludge cake pumping system when further sludge treatment is required.	Application specific.
Sludge Cake Disposal (Paragraph 2-4.12)	Several ultimate disposal methods are available and are dependent on the specific sludge generated.	Application specific.

1 More details are provided on design considerations and specific applications in the paragraphs referenced.

2 Conversion Factors: 1 kPa = 0.15 psi
$1\ kg/m^2 = 0.2\ lb/ft^2$
$1\ L/m^2s = 1.45\ gpm/ft^2$

2-4.3.1.1 The feed system should be designed to achieve the initial fill cycle at initial pressure (typically 70 to 140 kPa [10 to 20 psig]) within the first 5 to 15 minutes to ensure even sludge cake formation. Any imbalance in the sludge feed rate or cake formation can result in a nonuniform cake of high resistance, cloth binding, or initial poor filtration quality, and longer cycle times (EPA 1979). After this initial fill period and as the cake begins to form and resistance increases, the feed system should be capable of providing a constant flow with increasing pressures. When the maximum design pressure for the filter press is reached, the feed system must be capable of reducing the flow rate, while maintaining the constant press design pressure.

2-4.3.1.2 Two types of systems are typically used for feeding sludge to the filter press. The first system uses a single pump or several pumps in combination with variable speed drives to achieve the required changes in both flow and pressure. The second system uses the combination of a pump and pressure tank.

2-4.3.1.3 The first pumping system, often called stepping, uses one variable-speed pump or several pumps. These pumps are typically equipped with automatic controls that are used to vary their speed to achieve desired flow rates until the maximum pressure is reached, and then to reduce the flow while maintaining the constant maximum pressure. A two-pump or multiple pump system is used when the initial pressure requirements are too high or the available flow rate turndown is too limited to be achieved by the initial pump. The second pump or multiple pumps are used in conjunction with the initial pump to achieve the higher flow rates and will operate until the flow rate drops within the range of the initial pump. For an example of the use of a step-pumping system, assume that a filter press system's terminal pressure is 1550 kPa (100 psig), a maximum requirement of 2.5 L/s (40 gpm), and an filtration operating time of approximately 90 minutes. Applying a stepping pump system to this example may consist of the following sequence:

Period	**Pressure**	**Fill Rate**
Initial Fill (15 min)	170 kPa (25 psi)	2.5 L/s (40 gpm)
Filtration (30 min)	345 kPa (50 psi)	2.5 L/s (40 gpm)
Filtration (30 min)	520 kPa (75 psi)	2.5 L/s (40 gpm)
Terminate Filtration (15 min)	690 kPa (100 psi)	2.5 L/s (40 gpm) to terminal flow (5 to 7% of initial flow).

The pump and pressure tank system uses one pump and a pressure tank. The pressure tank is initially filled with sludge and pressurized with air. The filter press fill cycle is then started by allowing the sludge in the pressurized tank to be discharged into the filter press at a high rate. As the level of sludge in the pressure tank starts to decrease, the sludge feed pump is engaged to maintain a constant pressure in the tank. The pressure in the tank is also controlled by the addition or release of air. At the end of the filter cycle, the pressure tank is closed to stop the sludge feed pumping. The pump and pressure tank method does offer the advantage of a more rapid and positive fill; however, it is typically not used because it requires more equipment room and is less flexible than the integral or multiple pumping system.

2-4.3.2 **Pump Characteristics**. Sludge feed pumps should be positive displacement pumps capable of delivering sludge to the filter press over a wide range of pressures and flows. As the filter cycle begins, the pumps must deliver a maximum flow at a very low back-pressure. As the filtration cycle continues, the back-pressure increases because the solids accumulate, and the flow rate drops to a very low rate at the maximum pressure. The pumping system should be equipped with flow control devices that automatically adjust (lower) the flow rate with increasing pressure. Although several types of pumps can be used for sludge feed systems, the most commonly used are progressive cavity, piston, or piston-membrane pumps. Following is a brief discussion of each of these types of pumps and their application.

2-4.3.2.1 The progressive cavity pumps are variable-speed drive pumps that operate based on the geometrical fit between the rotating element of the pump (rotor) and stationary element (stator). The pumping action is achieved by the rotor turning eccentrically within the stator, which causes fluid to enter cavities formed between the rotor and stator at the pump inlet and to progress within that cavity to the pump outlet. These pumps are often constructed with multiple stages to achieve the high discharge pressure required for the filter press operation. These multistage pumps typically have increased pressures and decreased flow rates with additional stages, with a maximum pump speed of 200 to 250 rpm to minimize wear on the pump rotor and stator.

2-4.3.2.2 Piston pumps are generally driven by a hydraulic power pack with a compensator that varies the pump discharge while maintaining the required filter press pressure. These types of pumps typically have infinite turndown capability from maximum to zero discharge. Because the piston and cylinder are in direct contact with the sludge, these pumps should be equipped with wear-resistant pistons and ceramic-lined cylinders. Other design considerations include the proper sizing of surge arrestor vessels on the suction and discharge sides of the pump. Problems from incorrect sizing include pulsating discharge and excessive wear on the suction and discharge ball check valves. Piston pumps are normally available for pressures up to 1720 kPa (250 psig) and flow capacities ranging from 1 to 30 L/s (15 to 450 gpm).

2-4.3.2.3 Piston-membrane pumps are similar to piston pumps, except that the moving parts of the pump (i.e., piston and cylinder) have no direct contact. These moving parts are separated by a flexible membrane. This type of pump operates primarily by regulating the amount of hydraulic fluid displaced against the membrane. Piston-membrane pumps are typically available for terminal pressures of 690 and 1550 kPa (100 and 225 psig) and for flows ranging from 0.3 to 30 L/s (5 to 500 gpm).

2-4.3.2.4 Air operated diaphragm pumps can also be used for pumping sludge. Typically, the use of these pumps has been somewhat restricted because they were limited to a 1:1 ratio of air pressure to discharge of slurry pressure and most plant air systems are limited to about 690 kPa (100 psig). However, designs with 2:1 ratios (i.e., delivering slurry at 1380 kPa [200 psig] with 690 kPa [100 psig] motive air) have been recently developed that allow broader use of this type of pump.

2-4.3.2.5 Centrifugal pumps have been used with only limited success for filter press sludge pumping. Although these types of pumps have suitable flow and discharge pressure characteristics required for initially filling the filter press, the shearing force of the impeller destroys floc generated from sludge conditioning, thus reversing favorable dewatering effects. Therefore, centrifugal pumps are usually not recommended for filter press systems.

2-4.3.2.6 Following are several parameters that should be considered when selecting the appropriate pump:

- Filling time and capabilities (i.e., pressure 690 to 1550 kPa [100 to 225 psi]).
- Sludge characteristics (i.e., solids content, pH, particle size, abrasiveness, temperature, and chemical content).
- Suction conditions.
- Size of press.
- Available power source.

2-4.3.2.7 A general guide for pump applications is presented in Table 2-7. Additional information and descriptions of sludge pumping equipment are provided in the document *Design of Municipal Wastewater Treatment Plants* (WEF 1992) and are also available from equipment manufacturers such as those listed in Appendix A.

Table 2-7. General application guide for the selection of sludge pumps.

	Sludge Characteristics							
	Non-aggressive Non-abrasive		Chemically Aggressive		Abrasive		Biological	
	Pressure Required (kPa)[1]							
Type of Pump	690	1550	690	1550	690	1550	690	1550
Progressive Cavity[8]	X	X		X[2]		X		X
Piston		X[3]				X[3]		
Piston Membrane		X		X[4]		X[4]		
Air Operated Diaphragm	X	X[5]	X[6]	X[2,5]		X[5]	X	X[5]
Centrifugal[7]	X		X[4]		X[4]			

Source: Complied from filter press manufacturers listed in Appendix A.
Notes: The pumps indicated with an "X" are typically recommended for the application listed.
[1]Pressure conversions: 690 kPa=100 psi, 1550 kPa=225 psi.
[2]Stainless steel lining recommended.
[3]Typically recommended up to 6 L/s (100 gpm).
[4]Rubber lining recommended.
[5]2:1 pressure ratio required.
[6]Plastic lining recommended.
[7]Recommended for only fast fill applications.
[8]Abrasive slurries—consult with pump manufacturer; slow operating speeds are recommended when used in this type of application.

2-4.3.3 **Press Prefilling**. Before the sludge is pumped into the filter press, the press should be filled with effluent water to remove any trapped air. This step eliminates the potential for non-uniform cake distribution caused by partial filling of the press with sludge during a filtration cycle.

2-4.3.4 **Other Sludge Transfer Processes**. Other sludge transfer processes include those following the filtration cycle, such as air blowdown or core blowing, which blow compressed air through the filter press systems to remove liquid sludge.

2-4.3.4.1 **Air Blowdown**. Air blowdown is a recommended, but optional, feature that can be used prior to cake discharge to aid in the release of the sludge cake, improve its dryness, and drain the remaining liquid from filtrate ports. The air blowdown system consists of piping and valves that connect the filtrate ports with a common discharge pipe to form a manifold, through which compressed air is blown after the filtration cycle and cake discharge to remove any residual liquid in the cake or filtrate ports. The liquid removed during this process is typically returned to the sludge storage or conditioning tank. Criteria to be considered for air blowdown are air flow rate, pressure, and duration. Typical air usage requirements are based on the filter area of 0.02 to 0.07 $L/s \cdot m^2$ (0.2 to 0.8 $scfm/ft^2$) at an operating pressure of 280 kPa (40 psi) for a duration of 1 to 3 minutes.

2-4.3.4.2 **Core Blowing**. Core blowing is another recommended, but optional, feature. Liquid sludge remaining in the sludge feed ports is removed by compressed air before the press is opened at the end of the filter cycle. Although the amount of remaining liquid sludge is typically small and has little effect on the moisture content of the sludge cake, it has a tendency to run down the face of the filter media, blinding localized areas, and subsequently forming a non-uniform cake. Core blowing reduces the potential for non-uniform cake formation and minimizes the frequency of filter media washing.

Criteria to be considered for core blowing include the pressure of air required and duration, typically operating pressures ranging from 550 to 690 kPa (80 to 100 psi) for a duration of 1 to 3 minutes. Although core blowing is a recommended option that provides a desirable effect, the cost of equipment, piping, and building space should be considered before a designer selects this feature, especially for smaller systems or one not treating HTRW.

2-4.4 **Pretreatment Requirements**. Sludge pretreatment typically includes sludge degritting and grinding, and sludge conditioning. Grit is typically removed and ground at the headworks of the treatment facility to reduce wear and maintenance on downstream processes. Sludge is conditioned before dewatering to enhance water removal and to improve solids capture by chemical or physical treatment of the sludge. The most commonly used conditioning methods use chemical or thermal treatment. Chemical conditioning uses inorganic chemicals (i.e., ferric chloride and lime) or organic polyelectrolyte (polymers), or both. Thermal conditioning enhances the dewatering characteristics of the sludge by applying both heat and pressure. Although the thermal methods and other methods involving sludge thickening and stabilization can be used, chemical conditioning is used most often. Following is a brief summary of degritting and grinding, sludge thickening, and sludge stabilization, and a detailed discussion of chemical sludge conditioning.

2-4.4.1 **Degritting and Grinding**. Degritting and grinding of sludge are pretreatment methods, typically applicable to municipal wastewater, that remove materials such as trash ahead of the sludge dewater system and associated ancillary equipment to reduce wear and prevent clogging of hydraulic equipment (i.e., piping and pumps). These pretreatment methods may have only limited use at HTRW sites. Additional information on specific requirements for degritting and grinding equipment is presented in the following publications *Sludge Dewatering* (WPCF 1983) and *Design of Municipal Wastewater Treatment Plants* (WEF 1992).

2-4.4.2 **Sludge Thickening**. Although not typically required for filter presses, sludge thickening processes are often used to concentrate combined or separate sludge streams. The primary goal of thickening is to reduce the volumetric loading to, and increase the efficiency of, subsequent sludge processes. For primary and chemical sludge applications, the sludge is usually thickened at the source, such as within a clarifier or by gravity thickening. Biological sludge may be thickened by the use of gravity, dissolved air flotation (DAF), centrifuge, gravity belt, or rotary drum.

Typically, sludge thickening is not required for filter presses because filter press dewatering devices can handle sludge streams with low solids content (i.e., 2% solids). However, if thickening is required, the following references provide detailed descriptions of design considerations and guidelines: EPA (1982a), EPA (1987), WEF (1992), WPCF (1983), and GLUMRB (1990).

2-4.4.3 **Sludge Stabilization**. Sludge stabilization is primarily used to make biological sludge less odorous and putrescible and to reduce the pathogenic organism content prior to final disposal. Stabilization treatment processes include anaerobic digestion, aerobic digestion, wet air oxidation, and lime stabilization. If sludge stabilization is required, the following references provide detailed descriptions of design considerations and guidelines: EPA (1982a), EPA (1987), WEF (1992), WPCF (1983), and GLUMRB (1990).

2-4.4.4 **Thermal Conditioning**. Thermal conditioning can be used to enhance the dewatering characteristics of the sludge by applying heat or pressure, or both, in a confined vessel. This process results in the coagulation of the sludge by breaking down its gel-like structure and allowing the bound water to separate from the solid particles. Thermal conditioning is primarily suitable for biological sludge that cannot be stabilized biologically because of toxic materials.

The typical thermal conditioning process is a continuous flow that heats the sludge to 180 to 210 degrees C (350 to 400 degrees F) in a reactor under pressures of 1720 to 2760 kPa (250 to 400 psig) for 15 to 40 minutes (EPA 1987). Typically the heat treatment (HT) process and the low-pressure oxidation (LPO) process are used. In the LPO process air is added, while no air is added in the HT process. Further details of these processes are provided in EPA (1979, 1982a, 1987), WEF (1992), and WPCF (1983).

Because of the costs associated with the thermal conditioning, it is typically not advantageous to use it where other methods, such as chemical conditioning, are applicable.

2-4.4.5 **Chemical Conditioning**. Chemical conditioning is the most commonly used pretreatment method for filter presses. Factors that can affect chemical conditioning are the characteristics of the sludge, sludge handling and processing conditions, and sludge coagulation and flocculation. Because sludge can consist of various types of primary, secondary, and chemical solids of various inorganic and organic content, sludge characteristics significantly affect the sludge conditioning. The characteristics that most commonly affect conditioning and dewatering are sludge particle size and distribution, particle surface charge and degree of hydration, particle interaction, solids concentration, ratio of types of sludge (i.e., primary to secondary sludge), biopolymer production, and alkalinity (EPA 1987, WEF 1992).

a. A primary objective of conditioning is to increase the particle size by combining the smaller particles into larger, more easily handled particles. Because sludge particles are negatively charged and typically repel rather than attract one another, conditioning is required to neutralize the repulsive effects so the particles can collide and increase in size.

b. Sludge handling and processing conditions also affect sludge conditioning. For example, aged or unstabilized biological sludge that has been stored for a long period, which could be as little as a few days, causing it to turn anaerobic, requires more conditioning chemicals for dewatering than does fresh sludge. Long raw sludge storage or long transport periods can also increase the demand for chemicals and the degree of hydration and fines content of any sludge stream. Hydroxide sludges may be stored for weeks without inhibiting their dewaterability, provided the sludge feed is mixed prior to dewatering, which provides a consistent sludge feed. In addition to storage time, any preconditioning, such as the addition of chemicals for precipitation before the conditioning chemicals are used, must also be considered. The sequence in which the conditioning chemicals are added to the sludge must be considered. For example, when using a two-chemical conditioning system, such as ferric chloride and lime or two polymers, it is better to add the conditioning chemical with the anionic charge before the chemical with the cationic charge. If using both cationic and non-ionic polymer, the cationic charged polymer should be added before the non-ionic polymer. Although the types of polymers and how to apply them are specified, the minimum lag time between the two types should be several minutes to ensure adequate reaction. However, the lag time should not exceed an hour or longer, because it can decrease the dewatering performance.

c. Sludge coagulation and flocculation are the fundamental objectives of conditioning. This two-step process consists of coagulation, where the sludge particles are destabilized by decreasing the magnitude of the repulsive interactions between particles, followed by flocculation, in which colloidal and finely divided suspended particles are agglomerated by gentle mixing (EPA 1987). Following are design considerations and guidelines that can be used to optimize coagulation and flocculation conditions (WEF 1992):

- Provide variable-speed mixers in the conditioning tank or in-line mixing to minimize floc shearing of conditioned sludge.
- Use diluted chemical solution to improve mixing with the sludge.
- Provide individual conditioning for each type of sludge to maintain constant chemical feed rate and concentration.
- Locate the point of chemical conditioning as close to each dewatering unit as possible to avoid the deterioration of floc.
- Make sludge as homogeneous as possible to minimize the need for individual adjustment of polymer for multiple thickening or dewatering units.

d. Sludge conditioning for plate and frame filter presses generally requires the system to add lime and ferric chloride, lime only, or polymer, or ash or other granular material to the sludge, before filtering, to produce a low-moisture sludge cake. Lime and ferric chloride have been the conventional chemicals used for conditioning, especially for fixed-volume press systems. However, polymers have become more frequently used for the variable-volume press systems because of the decrease in sludge volume generated, reduced chemical costs, and reduced ammonia odors. Typically, biological-type sludge (i.e., municipal sludge) is chemically conditioned using ferric chloride and lime or lime alone, whereas chemical-type sludge (i.e., metal hydroxides) is chemically conditioned with either lime or polymers. The advantages of using polymers over inorganic conditioning chemicals include (EPA 1987):

- Polymers produce little additional sludge volume that would need to be disposed of. Inorganic chemicals may increase the sludge volume by 15 to 30%.
- If the dewatered sludge is going to be incinerated, polymers do not lower the fuel value.
- Polymers are easier and safer to handle than inorganic chemicals.
- Polymers result in easier operation and maintenance than inorganic chemicals that require frequent cleaning of equipment (e.g., acid baths).

e. Therefore, because reducing and minimizing volume is the primary goal of processing and disposal of sludge, as well as providing low disposal costs, polymers should be used if technically and economically feasible, especially for HTRW applications.

f. Specific sludge applications and typical types and dosages of conditioning chemicals used for both fixed-volume and variable-volume filter presses are summarized in Tables 2-4 and 2-5, respectively. Unless treatability studies have been performed and specific polymer dosages have been obtained, the preliminary design may be best developed on the basis of the use of anticipated design dosages of conditioning chemicals, such as ferric chloride or lime listed in these tables.

2-4.4.5.1 **Lime and Ferric Chloride Conditioning**. Inorganic conditioning usually uses chemicals, such as lime and ferric chloride, although other metal salts, such as ferrous sulfide, ferrous chloride, and aluminum sulfate, have been used. Ferric chloride is added before lime is added because it hydrolyzes in water and forms positively charged iron complexes that neutralize negatively charged sludge solids and allows them to aggregate. Ferric chloride also reacts with the bicarbonate alkalinity in the sludge to form hydroxides that act as flocculants. This reduction in alkalinity also lowers the pH. The lime is then added to raise the sludge pH so that the hydroxides form more efficiently from the ferric chloride reaction. Lime also reacts with bicarbonate to form calcium carbonate, which provides the sludge with additional structural integrity and porosity needed to increase the rate of water removal during the pressure filtration. The optimum dosages of both ferric chloride and lime for conditioning depend on the type of sludge and associated characteristics. Applicability and typical dosages for these chemicals for various sludge applications are presented in Tables 2-4 and 2-5.

a. The lime and ferric chloride conditioning system typically consists of sludge transfer pumps, a lime slurry preparation and feed system, a ferric chloride solution preparation and feed system, a conditioning tank equipped with a mixer, and a press feed pump system. It is usually desirable to use a sludge storage tank prior to the conditioning system to provide an inventory of the amount and type of sludge to be conditioned. This storage tank should be equipped with a mixer so that the sludge will have uniform concentration characteristics, allowing proper dosages and conditioning chemicals to be used to. A schematic of a typical lime and ferric chloride system is shown in Figure 2-6. A more detailed description of lime slurry and ferric chloride preparation and feed systems is presented in Subparagraph 2-4.6.1.

b. Ferric chloride should be added to the conditioning tanks a minimum of 10 seconds before the lime slurry is added to assist floc formation. To provide additional reaction time with the sludge, the ferric chloride solution can also be injected directly into the sludge transfer pipeline. Injection methods include direct injection without mixing, mixing at the point of entry, or injection with air. If direct injection is used, a 10 to 20-second retention period is required before lime is added to the conditioning tank. If the mechanical mixing method at the point of entry is used, an additional tank and mixing equipment are required.

c. The conditioning tank should be equipped with a mixer (typically vertical gate or turbine mixers) to ensure that the sludge and conditioning chemical are thoroughly mixed and to develop the floc. To provide adequate time for mixing and floc formation, the minimum retention time in the conditioning tank should be 5 to 10 minutes (WPCF 1983). A long retention time, 20 to 30 minutes, may be used to ensure complete mixing with the lime to minimize potential lime scale buildup in piping and filter media. However, if the retention time is longer than that required to form a good sludge floc, the floc can deteriorate and break down. The retention time may be affected by the changing sludge feed rates required throughout the filter cycle and by the use of multiple presses, if required.

d. The sludge conditioning system must be designed to meet the feed requirements of the filter press. Two methods can be used to achieve this goal. The first uses sludge transfer pumps designed to maintain a nearly constant level of sludge in the conditioning tank, while meeting the requirements of the conditioned sludge feed system to the filter press. To ensure proper chemical conditioning dosages, the lime slurry and ferric chloride feed systems are also equipped with variable-speed pumps that are controlled to match the proportional sludge flow rate into the conditioning tank. This system offers the advantages of maintaining a nearly constant retention time, but requires pumps with wider ranges of capabilities and variable-speed drives, and requires complex controls.

e. The second method uses sludge transfer and conditioning feed pumps. This system typically requires the use of intermittent but constant sludge transfer to the conditioning tank, with constant and manually adjustable control of chemical conditioning feed systems. Because this process involves intermittent sludge transfer, it also involves varying the level in the conditioning tank. Because the level in the retention tank varies, an increase in the capacity of the conditioning tank is typically required; however, less complex controls are required. This system may be more useful for smaller filter presses or those requiring less automatic or complex control.

f. In addition to the sludge transfer pumps, the volume of the conditioning tank, chemical conditioning systems, and associated feed pumps must be sized to meet the sludge feed requirements to the press. To meet changing requirements of unconditioned sludge, the chemical conditioning systems must also be flexible enough to accommodate a range of chemical dosages.

2-4.4.5.2 **Polymer Conditioning**. Organic chemicals used for sludge conditioning are primarily synthetic organic polymers. Although these polymers were originally used primarily for wastewater and easily dewatered sludge, they are now being used as a conditioning aid or as the primary conditioning chemical for all types of sludge. Polymers in solution typically have chemical reactions that are similar to those of inorganic chemicals, such as neutralizing surface changes and bridging of particles.

a. Polymers consist of three different charge types (anionic, cationic, and nonionic) and are commercially available in several forms including dry, liquid, emulsion, gel, and Mannich polymers. The most commonly used polymers for filter press applications are dry and liquid-type. The other types (i.e., emulsion, gel, and Mannich) are not as commonly used, but may be appropriate for some applications. Additional details for these types of polymer are presented in the publication *Design of Municipal Wastewater Treatment Plants-Manual of Practice No. 8* (WEF 1992).

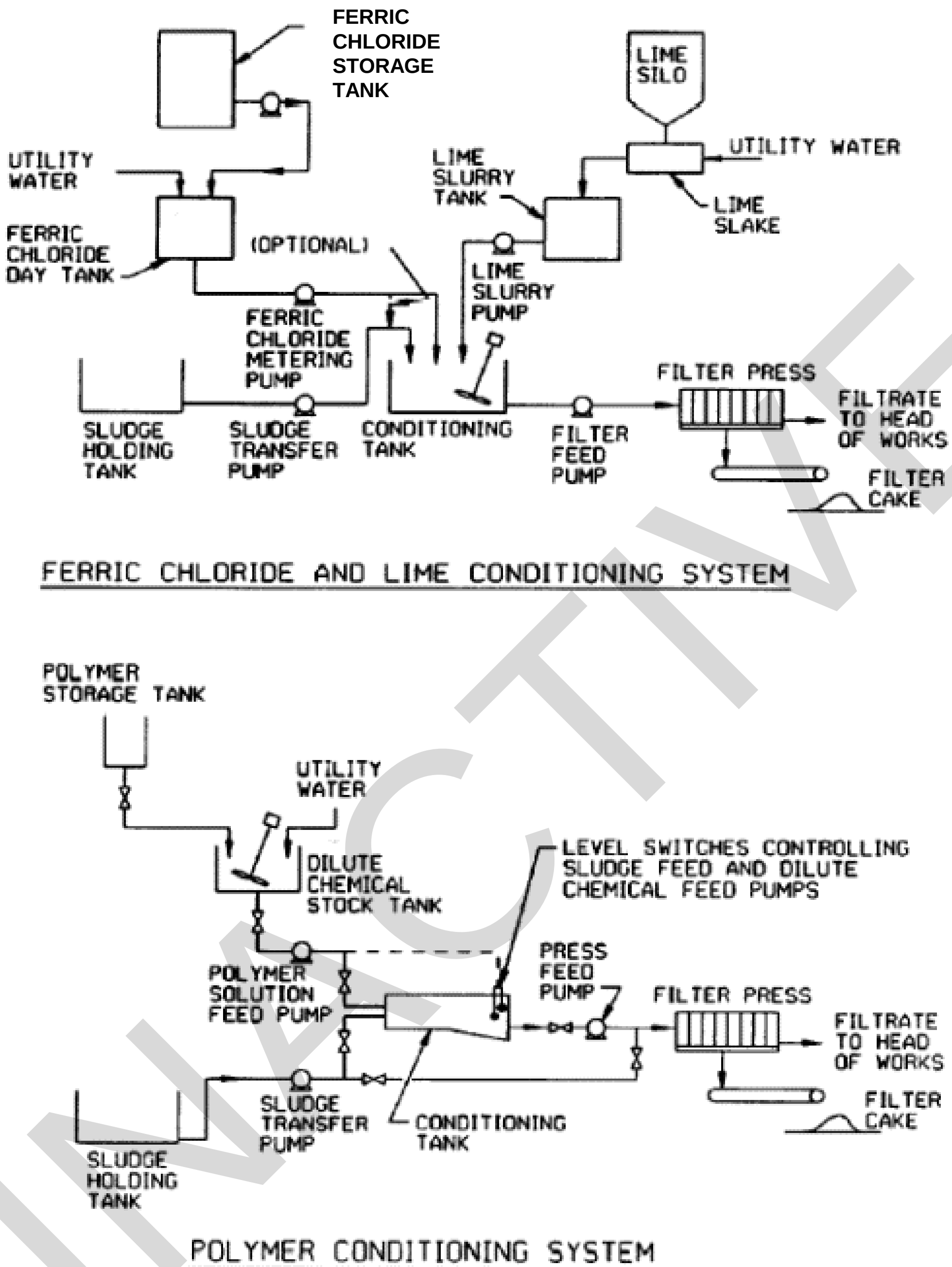


Figure 2-6. Schematics of typical ferric chloride and lime and polymer conditioning systems (WPCF 1983 and WEF 1992).

b. A summary of using polymers for various sludge applications is presented in Tables 2-4 and 2-5. Because of the numerous types of polymers that are commercially available, specific polymer dosages are not shown; however, as a general rule the application is less than 0.5 g/kg (10 lb/ton).

c. Dry polymers are typically available in powder, granular, microbead, and flake forms. These polymers have high amounts of active solids, usually ranging from 90 to 95%. The shelf life is usually several years; however, cool, dry storage is required because exposure to moisture tends to cake the polymer and make it unusable. Most dry polymers are difficult to dissolve and require special equipment such as an eductor or other prewetting device before they are delivered to the polymer solution mixing tank. The solution should be mixed slowly, until the polymer is dissolved and then mixed or aged according to manufacturers specifications because undissolved polymer can cause clogging of pipes, pumps, and filter media. Once polymers are in the dilute form, they are typically only usable and stable for 24 hours.

d. Liquid polymers are generally available in low to medium molecular weight, with active solids ranging from 10 to 50%. Typical shelf lives range from 2 months to 1 year. This type of polymer should be protected from large temperature variations during storage. When using higher viscosity liquid polymers, an adequate pump should be used to transfer the polymer from the storage tanks to the mixing tanks. A wet dispersal unit or static mixer should be used to disperse liquid polymers into the water.

e. The forms and characteristics of the polymers can greatly affect how they react with sludge. Because characteristics differ from one sludge to another, the selection of the correct polymer requires treatability testing to determine the correct type as well as the optimum chemical dosage. A description of treatability testing procedures and requirements is presented in Paragraph 2-6.

f. Preconditioning handling facilities include polymer storage, preparation, and feed systems. A detailed description of the polymer storage and preparation systems is provided in Subparagraph 2-4.6.1.

g. Because polymer dosages are generally quite small, the concentrated polymer needs to be diluted to be fed into the unit. Once the polymer is prepared, it is typically introduced into the sludge feed stream through an in-line system that continuously feeds the polymer to the press with the sludge, rather than as a batch. This can be accomplished by either continuous pumping of sludge into a small tank and addition of chemicals or by directly injecting the conditioning chemical into the sludge on its way to the filter press. If the former method is used, deleterious effects may be noted if storage and agitation are prolonged. A minimal retention time of 10 minutes at a moderate degree of mixing (i.e., 75 rpm) is typically used (WEF 1992). A typical polymer conditioning system is shown in Figure 2-6.

2-4.4.5.3 **Filter Aids**. In addition to ferric chloride and lime, other types of inorganic materials have occasionally been used to condition sludge or act as a filter aid or filter media precoat. The filter aid or body feed is added to slurries, particularly those containing slimy or gelatinous solids, to provide structural integrity and porosity to the sludge. This facilitates additional drainage when the sludge is compressed during the filtration cycle. The use of filter media precoat is discussed in detail in Subparagraph 2-4.6.2. Although using these materials may reduce the overall dosages of other conditioning chemicals, the cost and volume increase may not be warranted versus the increase in the dewatering results.

2-4.5 **Filter Press Major Equipment Components**. The major components of the filter press are the frame, plates, filter cloth, hydraulic plate closing mechanism, and plate shifting mechanism. A schematic showing the major components of the recessed filter press system is shown in Figure 2-7.

2-4.5.1 **Structural Frame**. The structural frame of a recessed filter press consists of a fixed end, a moving end, and plate support systems (EPA 1986). The fixed end anchors one end of the filter press and plate support bars. The moving end anchors the opposite end of the press and houses the plate closing mechanism. The plate support bars span between these two ends and carry the filter press plates.

Two typical configurations of the plate support system are a side bar or an overhead bar. A diagram of each of these is shown in Figure 2-7. The side bar configuration consists of two side bars that provide support at each side of the plate at a point slightly above the center of each plate. The overhead bar configuration consists of two overhead bars and two lower tie bars. The plates in the overhead assembly are attached to a support beam and carriage assembly at the center of each plate. The side bar frame is normally used for presses with plates up to 1200 mm (48 inches) and with pressures up to 1550 kPa (225 psi). Overhead frames are used for larger plates (i.e., 1500 mm [60 inch] plates and up) or pressures greater than 1550 kPa (225 psi), such as in the variable-volume presses. The advantage of the side bar support system is that it allows for easy removal of individual plates directly from the press, whereas the advantage of the overhead type support allows easier observation between individual plates. Problems or disadvantages associated with the side bar support system are jamming of the plate shifting mechanism and access to plates during sludge cake discharging operations. However, the initial cost for this type of system is less than the overhead bar assembly.

2-4.5.2 **Filter Press Plates**. Filter press plates are available in several types, construction, dimensions, and materials (WEF 1992). The most common type, recessed plates, are fabricated with a constant recess (or depths) and area on adjacent plates in which the constant volume filter cake forms. To provide additional support and prevent deflection of the plates in the recessed area, the plates normally are constructed with stay bosses within them. The stay bosses have the same overall thickness as the perimeter of the plate. The number and size of the stay bosses primarily depend on the dimensions and structural material of the plate.

2-4.5.2.1 Filter press plates range in size (i.e., 600 to 2100 mm [24 to 84 inches]) and can be round, square, or rectangular. Depending on the plate design and the desired cake thickness, the recessed area can also range from 25 to 50 mm (1 to 2 inches) in thickness, with 32 mm (1.25 inches) being typical. Plates are typically constructed with a center feed port, with filtrate ports located at the corners of the recessed area. Although corner feed plates, which use one or more corner ports for sludge feed, may be required for specialty applications, these types of plates are typically avoided because foreign material tends to plug the passages from the corner port to the chamber area. The surfaces of the perimeter of the plate and stay bosses are flat to provide a proper seal. The surfaces of the recessed plate area are constructed with rows of grooves to provide support for the filter cloth and allow paths of filtrate drainage. The construction of the variable-volume plate filter press is similar to that of the fixed-volume press, with the addition of a polypropylene or elastomeric diaphragm attached to the face of the plate.

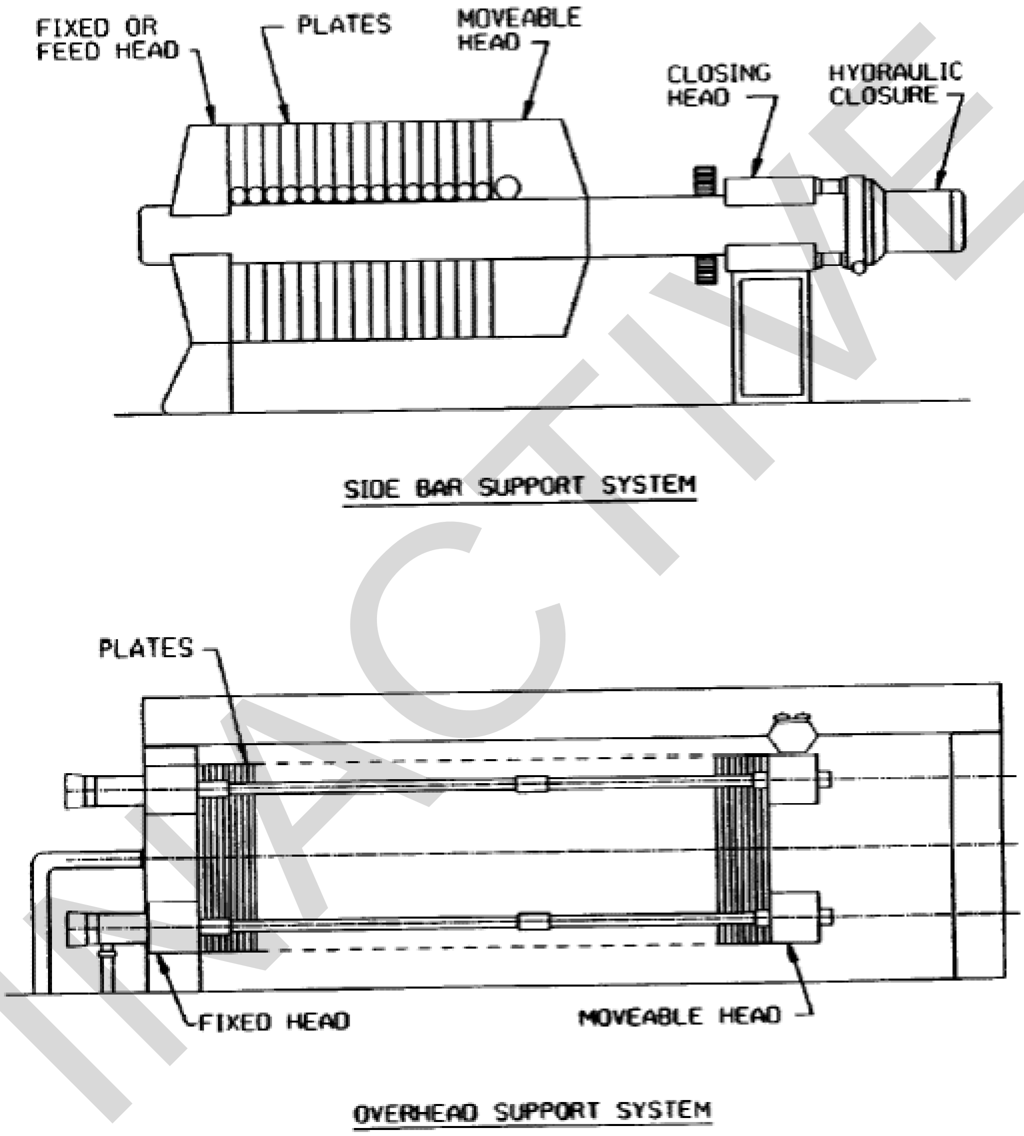


Figure 2-7. Schematic side views of recessed plate and filter frame filter presses (EPA 1988).

2-4.5.2.2 Filter media can be installed on fixed-volume filter press plates with or without gaskets. In non-gasketed plates, the filter media are draped over the entire plate and held in place by hooking grommets located at the top of media over clothdogs on the top of the plates. For this design, the filter media provide the seal between adjacent plates when they are closed. A reinforcing strip of heavier media is typically sewn on the periphery of the filter media used on non-gasketed plates to improve sealing properties and to better protect the media from the wear and tear of the plate rims repeatedly hitting and compressing this area. In general, non-gasketed filter designs leak filtrate, resulting in wet and sometimes malodorous operating conditions. Because of these conditions, non-gasketed systems are typically equipped with drip trays to collect and keep the leaking filtrate from the sludge cake storage receptacles or handling equipment located beneath the filter press.

2-4.5.2.3 In gasketed plate designs, the filter media are typically held in place by resilient caulking material imbedded in a groove running around and just inside the inner periphery of the plate rim. Liquid-tight sealing is provided by gaskets, normally O-ring type, installed in a groove in the sealing faces of the rim and in grooves around the filtrate ports.

2-4.5.2.4 The primary advantages of gasketed plates as compared with non-gasketed plates are their ability to keep liquid fully contained in the filter, and their typically longer media life and lower replacement cost because of the lack of wear in the rim area where adjacent plates come in contact. However, the disadvantages with gasketed plates are their slightly higher cost to manufacture, owing to machining of gasketing and caulking grooves, and the slightly longer time required to change their media.

2-4.5.2.5 Filter press plate construction materials are described further in Subparagraph 4-8.1.2. A summary of typical filter press plate sizes and weights is presented in Table 2-8.

2-4.5.3 **Filter Media**. Filter media (cloth) are available in several types of materials, weaves, and permeabilities. Primarily, select the filter media to optimize cake dryness and filterability of the sludge. Secondarily, durability, ease of cake release, blinding, chemical resistance, and characteristics of the sludge, such as the size of solids in the sludge, are important. The durability of the filter media can be affected by both materials and construction, whereas cake release can be affected by both weave and cleanliness. In addition to the filter media characteristics, the precoat system (Subparagraph 2-4.6.2) may be used to ease the release of the sludge cake, or a filter media washing (water or acid) system (Subparagraph 2-4.6.3) may be used for filter cleaning. The construction materials, construction factors, and selection of filter media are described in detail in Subparagraph 2-8.1.1.3.

Table 2-8. Typical filter press plate sizes and weights.

Plate size (mm)	Plate filtration area per chamber (m^2)	Plate chamber capacity (m^3)		Press dimensions and weights (based on 32-mm cake thickness)						
		25-mm (1-in.) thick cake	32-mm (1.25-in.) thick cake	Number of chambers	Length (mm)	Width (mm)	Height (mm)	Weight (kg)		
								Polypropylene plate	Rubber plate	Cast iron plate
500	0.288	0.0039	0.0048	20 40	2200 3850	1250	1500	1210 1700	1900 2760	2240 1760
630	0.484	0.006	0.0075	20 40	2800 4080	1350	1500	1470 2260	2300 3520	2804 4153
800	0.889	0.0112	0.0135	20 60	3440 6000	1700	1550	2570 3420	4020 7620	4760 9760
1000	1.51	0.0192	0.0224	30 90	4660 8620	2000	1500	5060 7130	8490 17,200	11,870 27,100
1200	2.1	0.0284	0.035	50 100	6610 8210	2200	1800	11,350 14,150	18,700 28,700	27,060 45,260
1500	3.5	0.045	0.056	60 120	7980 12,640	2600	1850	16,600 22,260	30,000 49,000	45,160 78,780
2000	5.66	0.0865	0.104	150	17,430	3400	2135	NR	200,000	NR

NR = not reported
Source: Rushton (1982)
Conversions: 1 mm = 0.039 in.; 1 m^2 = 10.8 ft^2; 1 m^3 = 35.3 ft^3; 1 kg =2.2 lb.

2-4.5.4 **Closing Mechanism**. The closing mechanism either hydraulically or electromechanically closes the plates and maintains the force to hold the plates constant during the filter cycle period. The hydraulic closing mechanism can either be manually operated by a jack or automatically controlled by a hydraulic ram and power pack. The electromechanical mechanism typically consists of a twin or single screw and electric gear motor. These systems can be equipped with automatic controls to maintain a constant closing force to compensate for varying sludge feed pressure increases, compression of the filter cloth and plates, and expansion and contraction of construction materials with temperature changes.

2-4.5.5 **Plate Shifter**. Plates can be shifted manually or automatically to remove the sludge cake after the filter cycle is complete. The typical shifting mechanism is a semiautomatic or automatic device that works on the principle of an endless chain or reciprocating bar. These mechanisms involve pawls attached to a chain or bar that engage with the plate at the end of the plate pack and slide this plate along the plate support to a distance of 2 to 3 feet, allowing the sludge cake to be discharged. This process continues for each successive plate until all the plates have been separated and the filter cake is removed.

2-4.5.6 **Optional Equipment**. Optional equipment that is typically provided to ensure safe and successful performance includes safety guards, light curtains, drip trays, and cake-breaking cables or bars.

2-4.5.6.1 **Safety Guards**. A fixed guard is one type of safety feature for smaller presses where it is possible to designate operating and non-operating sides of the press. Fixed guards typically consist of a metal screen mounted on the non-operating side of the press. The primary function of this device is to prevent access to the plate stack while the press is opening or closing. However, for larger presses (i.e., with plates greater than 1220 mm [48 inches]), it may be necessary to have access to both sides of the plate stack; therefore, the fixed guards become impractical. For these applications, a safety light curtain should be employed.

In addition to the fixed safety guards, splash curtains can be used to prevent access to the plates during operation. Splash curtains are normally temporary structures that encapsulate the press during the fill cycle or during power washing of the filter media and plate, or contain high-pressure leakage. Although this can be used as a temporary safety device, its primary function is housekeeping.

2-4.5.6.2 **Light Curtains**. The light curtain is optional but is the most commonly used safety device. A bank of photo cells, on alternative ends of the press, project a continuous light curtain when automatically activated by the closing or plate shifting mechanism. If the light curtain is interrupted or broken, the closing or plate shifting is stopped immediately. The ultimate function of this feature is to prevent workers who are removing or separating plates or foreign objects from being caught in the press.

Safety light curtains are commercially available in both the visible spectrum and infrared. An advantage to the visible spectrum curtain is that there is no question about whether it is operating. If, however, an infrared curtain is used, a beacon-type or visual light indicator should also be used to provide positive assurance that the curtain is operating when the plate mechanism is opening or closing. Typically, the horizontal bank for a light curtain extends from about 0.6 m (2 feet) above the operating floor to about 1.5 m (5 feet) above the floor, which is the area where an operator might accidentally get a hand or arm caught between moving plates. However, light curtains are available that range from the floor upward to the maximum height of the press to ensure additional operator protection.

2-4.5.6.3 **Drip Trays and Bombay Doors**. Drip trays and bombay doors are optional, but important, housekeeping features that can be mounted below the filter press to collect drainage. This drainage may consist of residual filtrate discharged at the end of the filtration cycle, leakage from the plates during the filtration cycle, and washdown used in general maintenance and cleaning. Drip trays typically consist of hinged single leaf or double leaf trays sloped to a launder located on one or both sides and parallel to the length of the press for drainage. Before the cake is discharged, the drip trays must be manually slid to one end of the press or removed to prevent them from interfering with the process of emptying the press.

An automatic equivalent of drip trays that is often used to collect this drainage is "bombay doors." Bombay doors typically consist of two doors that are automatically opened and closed by a hydraulic cylinder when the press is opened and closed. These doors are closed under and parallel to the length of the press. In the open position, these doors hang vertically and parallel to the sides of the press. The primary advantage of the bombay doors over the drip trays is they are automated and require less labor-.

2-4.5.6.4 **Cake Breakers**. Cake breakers are an essential design option that break the sludge into smaller particles for further treatment and disposal. The design of the cake breakers is based on the structural properties of the dewatered cake and desired particle size. Typically, cake breakers consist of wires, bars, or cables located beneath the filter. The cake breakers are typically aligned parallel to the length of the press and spaced at a distance of 300 to 600 mm (12 to 24 inches) apart.

2-4.6 **Filter Press Accessories and Auxiliary Systems**. Accessories and auxiliary systems used to support the filter press include the following: filter press feed (sludge transport) and prefilling, chemical conditioning, filter media precoating, filter cloth (water and acid) washing, filtrate and sludge cake handling, and supplying compressed air. Detailed descriptions of the types of pumps required for liquid sludge transport and filtrate and sludge cake handling are presented in Paragraphs 2-4.3 and 2-4.8 through 2-4.10, respectively. Therefore, the information presented in this paragraph will only describe chemical feed, precoatings, filter media wash, and compressed air systems.

2-4.6.1 **Chemical Feed Systems**. Chemical feed systems for filter presses typically consist of conditioning, precoating, and acid wash systems. Chemical feed systems for the precoating and the acid wash systems will be described in detail in Subparagraphs 2-4.6.2 and 2-4.6.3, respectively.

The following subparagraphs present an overview of the conditioning chemical feed systems for lime, ferric chloride, or polymer preparation, and chemical feed control systems. Guidelines selecting and using specific conditioning chemicals are presented in detail in Subparagraph 2-4.4.5. Detailed descriptions of these conditioning chemical feed systems are presented in EPA (1987), WPCF (1983), and WEF (1992).

2-4.6.1.1 **Lime Feed Systems**. Lime handling equipment typically used for filter presses use either a quick lime (CaO) or hydrated lime $Ca(OH)_2$. Both forms are typically available in 36- and 45-kg (80- and 100-pound) multiwalled paper bags and in bulk. Quick lime in bulk is typically used for large presses (i.e., greater than 114 kg/hr [250 lb/hr] or 900 to 1800 kg/day [1 to 2 tons per day]) because it is more economical to use than hydrated lime.

a. Quick lime (CaO) is commonly available in three grades: 88 to 96% CaO, 75 to 88% CaO, and 50 to 75% CaO. To use quick lime, a calcium hydroxide slurry must be prepared using water. This process, called slaking, generates heat and, thus, special equipment is required. In general, only quick lime that is highly reactive and quick slaking should be used for conditioning. A slurry ranging up to 25% by weight can be prepared by slaking, although a maximum of 10% or less is typical. Special consideration must also be given to storing the quick lime in a dry area because even moisture in the air may cause it to react and become unusable.

b. Hydrated lime is much easier to handle than quick lime because it does not require slaking, it can be easily mixed with water (without generation of excess heat), and it does not require any special storage conditions. However, it is more expensive and less available than quick lime.

c. Lime handling systems typically include storage and processing equipment, lime slurry and day tanks equipped with mechanical mixers, and feed pumps to transfer the slurry from the day tank to the conditioning system. The feed pumps used for transferring the lime slurry should be capable of handling concentrations ranging from 5 to 25% solids (WPCF 1983). Diaphragm-type and plunger-type meter pumps and progressive cavity pumps are typically used. Potential scaling in transfer lines and equipment should be prevented.

2-4.6.1.2 **Ferric Chloride Feed Systems**. Ferric chloride handling equipment typically consists of a bulk storage tank, a dilution tank, and feed pumps to transfer the dilute ferric chloride solution to the sludge conditioning system. Ferric chloride can be stored for long periods without deterioration. It is typically stored in aboveground tanks constructed of resistant plastic or in lined steel tanks. At temperatures lower than 0 degrees C (32 degrees F), ferric chloride solutions can crystallize. Therefore, tanks must be stored indoors or heated. Because of the corrosive nature of ferric chloride, only components made of special materials must be used, including epoxy, rubber, ceramic, PVC, and vinyl. Provisions should also be taken to avoid direct skin contact with ferric chloride.

Ferric chloride is usually fed to filter press conditioning systems in a solution ranging between 10 and 20%. Although ferric chloride is typically available in commercial strengths between 38 and 42%, direct addition of commercial strength ferric chloride to sludge may liberate heat and cause splatter. In addition, the costs would be high. The feed pumps need to be capable of handling ferric chloride solution concentrations ranging from 10 to 42% (WPCF 1983). For this application, diaphragm-type metering pumps, chemical gear-type pumps, and progressive cavity pumps are typically used.

2-4.6.1.3 **Polymer Feed Systems**. As described in Subparagraph 2-4.4.5, the polymers typically used in filter presses are dry and liquid polymers. A brief discussion of feed systems for these types of polymers will be presented in the subparagraphs that follow. Typically, the dry polymer systems are used because they are more economical than the liquid polymer systems, although some facilities are built with both types to add versatility. More detailed information on polymer feed and preparation systems, in addition to feed systems for other polymer types (i.e., emulsion, gel, Mannich polymers), is presented in the publication *Design of Municipal Wastewater Treatment Plants—Manual of Practice No. 8* (WEF 1992).

a. **Dry Polymer Feed Systems**. Dry polymers are typically available in 22-kg (50-lb) double-walled paper bags or polyethylene bags. Dry polymers can also be supplied in 820-kg (1800-lb) bags or in bulk shipments. However, this is not usually desirable because dry polymers should be stored in a dry, cool, low-humidity area and usually have a shelf life of only 15 to 30 days. Because dust may develop when the bags are emptied, the storage and polymer mixing area should be well ventilated, and proper eye protection and respirator equipment should be available.

(1) The dry polymer preparation and feed equipment typically consists of a dry feed or an eductor or dispenser, mixing tank and mixer, feed tank, and supporting solution and chemical feed metering pumps. The solution preparation system can be either manual or automatic.

(2) The dry polymer is dispensed into the solution preparation system by hand or volumetric feeder (i.e., screw or vibrating-type) to an eductor. The eductor is used to prewet the dry polymer before adding it to the water in the solution mixing tank. The working solution is then mixed and aged from 30 minutes to 2 hours. A variable-speed mixer, with a maximum speed not to exceed 500 rpm, should be used. The aged polymer is then pumped or transported to a polymer solution feed tank (day tank). This tank should be adequately sized to hold a 24-hour supply of polymer. From the day tank, the polymer is then dispensed into the sludge stream by metering pumps. The metering pumps should be positive displacement pumps that have a variable-speed controller that can be adjusted to the sludge flow. In general, diaphragm-type pumps are used for applications of 6.3 L/s (100 gpm) and lower; and progressive cavity, gear, or lobe pumps are used for applications greater than 6.3 L/s (100 gpm). In most applications, the polymer is further diluted with water and is either injected into the sludge through an in-line entry point or added and mixed in a sludge conditioning tank. If dilution water is used, the dilution system should be equipped with a flow meter, such as a rotameter, and control valves for flow adjustment. The tanks, piping, and valves for this type of polymer system are typically constructed of PVC and fiberglass. Any metal that may come in contact with the polymer solution should be stainless steel.

b. **Liquid Polymer Feed Systems**. Liquid polymers are typically available in 20-L (5 gallon) pails, 210-L (55-gallon) drums, 950-L (250-gallon) bins, or by bulk in 18.9-kL (5000 gallon) tank trucks. Liquid polymer should be stored in heated areas equipped with adequate ventilation because it can generate harmful fumes and unpleasant odors. The shelf life of liquid polymers is typically from 2 months to 1 year. Tanks used for bulk storage are typically steel tanks lined with a polymer-resistant coating or fiberglass tanks with a storage capacity of 150% of tank truck capacity or 15 to 30 days' anticipated use. Refer to EM 1110-1-4008 for material compatibility charts.

Depending on the quantity of liquid polymer required and the form of delivery used, liquid feed systems range from large polymer solution preparation systems to compact blending systems. The only difference between large polymer systems and dry polymer systems is that the dry polymer working solution doesn’t have to be prepared. Liquid polymer solutions are prepared by manually or automatically dispensing the liquid polymer and water into a tank. The dosage of liquid polymer into the tank is controlled with a variable-speed metering pump. From the tank, the liquid polymer solution is dispensed along with the sludge feed stream into a conditioning mixing tank or directly injected and further diluted by water prior to in-line mixing with the sludge feed stream. In addition to using the liquid polymer system as a stand-alone conditioning process, this type of system can also be combined with the dry polymer feed system.

Compact liquid polymer blending systems typically use polymer delivered in 210-L (55-gallon) drums or even smaller containers. These systems are typically simple to use, plug-in systems that consist of the polymer storage device (i.e., drum), a metering pump, a small detention and aging chamber, and a dilution water meter such as a rotameter. These units maximize solution preparation by slow-mixing and aging in the detention chamber.

2-4.6.1.4 **Chemical Feed Control Systems**. The control components and types of automatic controls required for chemical feed systems are specific to the individual filter press. Typically, types of controls may include high-low level sensors in the storage and feed preparation tanks, automatic or manual dosage input controllers, metering pump controllers, manual on/off switch controllers, and loss of flow sensors. These controls may be equipped with either light alarms or audible alarms. Chemical feed systems may be controlled from separate control panels or integrated into a single control panel that provides overall control for the entire sludge dewatering system. However, either of these control systems should be interlocked with the sludge feed system to stop adding chemicals if the sludge feed is discontinued or vice versa. Additional details on specific types and elements of control systems are provided in Paragraph 2-4.7.

2-4.6.2 **Filter Precoat Systems**. Precoat systems are an option that can be used to aid in releasing the sludge cake from the filter media and to alleviate premature blinding of the media from residual particles. The precoating process involves pumping a slurry of ash or similar substance to the filter press to provide a thin coating (e.g., 1.6 to 2.5 mm [1/16 to 3/32 inch]) on the filter media before the press is filled with sludge. The precoat system is most useful for sludges with high biological content or industrial waste sludges because they have a tendency to stick to the filtration media. It is also useful for high pressure filter presses (i.e., 1550 kPa [225 psi]) because of problems with cake release and filtration media blinding, regardless of the sludge feed characteristics, because of the "extrusion" effect of solids into the filter media caused by the high pressure (WEF 1983). A precoat may reduce the overall cycle times and labor required because removing the residual materials adhering to the filter media will be easier. In addition, the precoat material can protect the media from mechanical damage caused by sharp particles contained within the slurry. The precoat system is primarily used in the fixed-volume recessed filter plate press because the cake release for the variable-volume recess filter plate press is assisted by a mechanical device that pulls the filter media down between the plates. Both wet and dry feed precoat systems are typically used. Figure 2-8 gives schematics of these two systems.

2-4.6.2.1 The dry system shown in Figure 2-8 has typically been used in the past for larger presses that operate continuously, but it is rarely used today. In the dry system, water from the filtrate storage tank is circulated by the precoat pump through the filter press and then returned to the storage tank. While the water continues to circulate and after the press has been entirely filled with water and all air evacuated, a predetermined amount of dry precoat material is transferred from storage to the precoat tank. The filtrate water circulating directly to the press is then diverted through the precoat tank, which consists of a series of baffles, and forms a slurry with the precoat material. This slurry is then circulated through the filter press to coat the filter media. The filtrate water being passed through the precoat tank is circulated at a high rate to ensure uniform and even precoating. The precoat process typically lasts from 3 to 5 minutes.

2-4.6.2.2 The wet material precoat system shown in Figure 2-8 is more common. The precoat is prepared before it is introduced into the press by a batch or continuous mixing operation. The way the press is filled with the wet precoat system is similar to that for the dry material system. However, after the press is filled with filtration water, the premixed precoat is pumped to the filter press and distributed uniformly throughout the filter media.

2-4.6.2.3 Precoat materials commonly used include fly ash, incinerator ash, diatomaceous earth, cement kiln dust, buffing dust, coal, or coke fines. Typical precoat materials requirements range from 0.2 to 0.5 kg/m^2 (5 to 4 10 lb/100 sq ft), with a typical design criteria of 0.4 kg/m^2 (7.5 lb/100 sq ft) (WPCF 1983). The pumping system should be designed to complete the filling process in 3 to 5 minutes at a minimum rate of 0.2 to 0.3 L/m^2•s (0.3 to 0.5 gpm/sq ft). The filtrate storage area is also sized to have a working volume of one and one-half to twice the capacity of the filter press.

2-4.6.2.4 Overall, the precoat system is an option that may require that equipment and operation and maintenance costs be economically evaluated versus additional filter cycle time, frequency of cleaning and washing required, and wear and replacement of filter media.

2-4.6.3 **Wash Systems**. Filter media wash systems are an integral part of the filter press operation. Filter media wash systems are used, as required, following the filtration cycle to remove residual sludge cake, liquid feed sludge from the feed core (if core blowing is not used), and solids and grease buildup on and around the filter media to allow subsequent uninhibited drainage. The removal of these materials is essential to prevent filter media blinding and to maintain atmospheric pressure between the filter media and filtrate to alleviate back-pressure buildup. Two types of filter wash systems are typically used: water and acid. A combination of these can be used where scale builds up from lime conditioning. In other applications, such as those involving polymers for conditioning, only water wash systems may be required.

2-4.6.3.1 **Water Wash Systems**. The surface of the filter media should be washed with water frequently, typically as often as once every 8 to 10 cycles, to prevent residual solid buildup (WPCF 1983). The common water wash systems are either manual or automatic. The manual spray wash system typically consists of a hydraulic reservoir, a high-pressure wash pump operating up to 13.8 MPa (2000 psig), and a hand-held wand for directing the spray. The operator directs spray to the areas of observed buildups; this is very labor-intensive.

Automatic spray wash systems are an option. These are typically included with the plate shifter mechanism to wash the entire filter media system. They usually require high-pressure water pump boosters to elevate the pressure of the tap water. Although the capital cost is much higher than the portable spray-wash system, the labor requirements are significantly lower, and the system allows more thorough cleaning of the entire filter media.

The designer should consider adding strainers to remove solids from the washwater to reduce plugging of the spray system and a mist suppression and control device to avoid corrosion and maintenance problems.

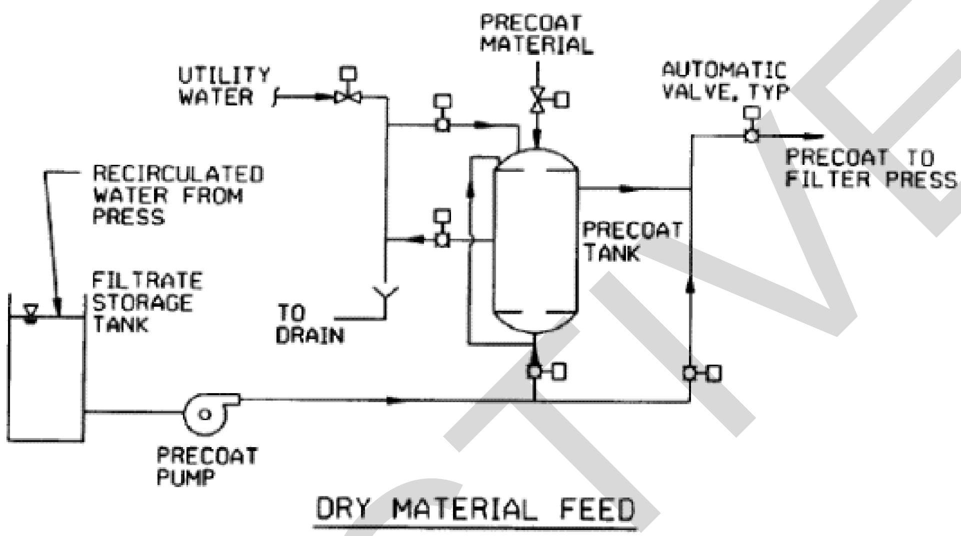


Figure 2-8. Schematics of dry and wet material feed precoat systems.

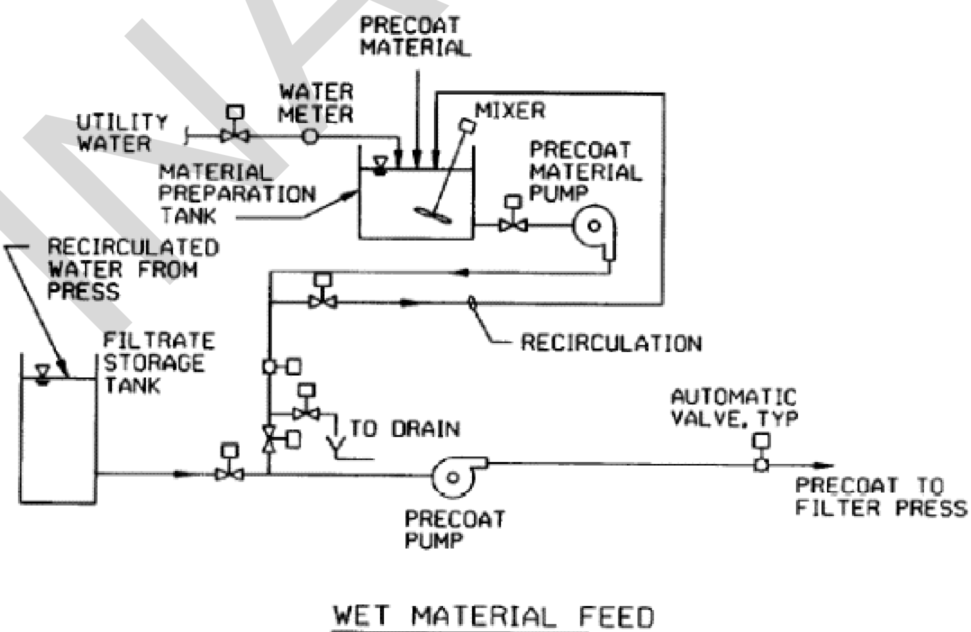


Figure 2-8 (cont'd). Schematics of dry and wet material feed precoat systems.

2-4.6.3.2 **Acid Wash Systems**. Acid washing is primarily used when sludge is conditioned with lime. It is essentially used for larger or continuously operating dewatering systems; however, its technical and economical feasibility should be evaluated for small or intermittently operated systems. The acid wash is typically an internal washing system that uses a dilute hydrochloric acid solution to remove lime scale buildup on the filter media by pumping and circulating the dilute acid throughout the closed press. Typically, continuously operating presses are acid washed at least every 30 to 40 cycles or as often as once a week (WPCF 1983).

Equipment for this system usually includes a bulk acid storage tank, acid transfer pump, water metering system, dilute acid washwater storage tank, acid wash pump, and associated valves and piping. The concentrated acid should be transferred directly from the storage container to the acid wash solution dilution tank by an acid-resistant (non-metallic) pump, such as a drum pump if the acid is shipped directly in small containers. The dilute acid storage tank should be of sufficient capacity to fill the press and allow for circulation. Typically, the capacity of the dilute acid storage tank should be approximately 1.5 times the capacity of the press (e.g., 70 L/m^3 [0.5 gallon per cubic foot] of press). A low-pressure (e.g., 140 to 210 kPa [20 to 30 psi] maximum) and acid-resistant pump should be used to transfer and recirculate the dilute acid. Piping and plumbing should be provided to isolate the press from the sludge stream and allow the acid wash to recirculate to the storage tank where the spent acid solution can be drained. A throttling valve installed in the return line to the acid tank is often required to ensure complete top-to-bottom press filling and washing of the filter-media. A schematic of a typical acid wash system is shown in Figure 2-9.

Typically, a 38% concentration hydrochloric acid wash that is delivered in carboy containers (barrels), by tank truck, or in tank car shipments, is used. A final solution strength of 5% up to a maximum of 25% is typically used.

2-4.6.4 **Compressed Air Systems**. Compressed air is required for several functions and types of equipment within the filter press system, including opening and closing the press for pneumatically operated, hydraulically controlled units, core and air blowdown, plate shifting, inflation of diaphragms in variable-volume filter press systems, operation of pneumatic controls, and operation of sludge feed pumps that have air diaphragms. Although air requirements will be specific to each press, normally multiple air compressors are required, with air filters and silencers to remove moisture and oil condensates, air aftercoolers, air receivers, and associated valves and accessories, such as pressure gauges and automatic and manual drains.

Although specific to each application, two grades of air may typically be required for a filter press: plant grade air and instrument grade air. Instrument grade air will be dry, and moisture- and oil-free. This type of air will normally be required for equipment such as pneumatic controls. Plant air typically is unfiltered air used for core and air blowdown or for inflating diaphragms in variable-volume units. To supply these two grades of air, a dual air supply system may be used in conjunction with a primary compressed air supply. The side of this dual system that supplies the instrument grade air would typically be equipped with an air receiver, air filters, air coolers, air dryer, and associated valves and pressure gauges. The plant air side of this system would typically consist of an air receiver and associated valves and pressure gauges. The type and quality of air required for specific equipment may be best determined by manufacturer's and equipment supplier's recommendations.

To properly size the air compressors in the design, the capacity of the air compressor versus the air receiving tanks must be evaluated. For example, for batch applications requiring small amounts of air, a small-capacity air compressor and large capacity air receiving tank may be better than a system with an air compressor and receiving tank of equal capacity because maintenance and operation will be easier and the initial costs will be lower. However, if the system requires continuous operation or larger quantities of air, a larger capacity compressor and equally sized air receiving tank may be best because less work will be required from the air compressor.

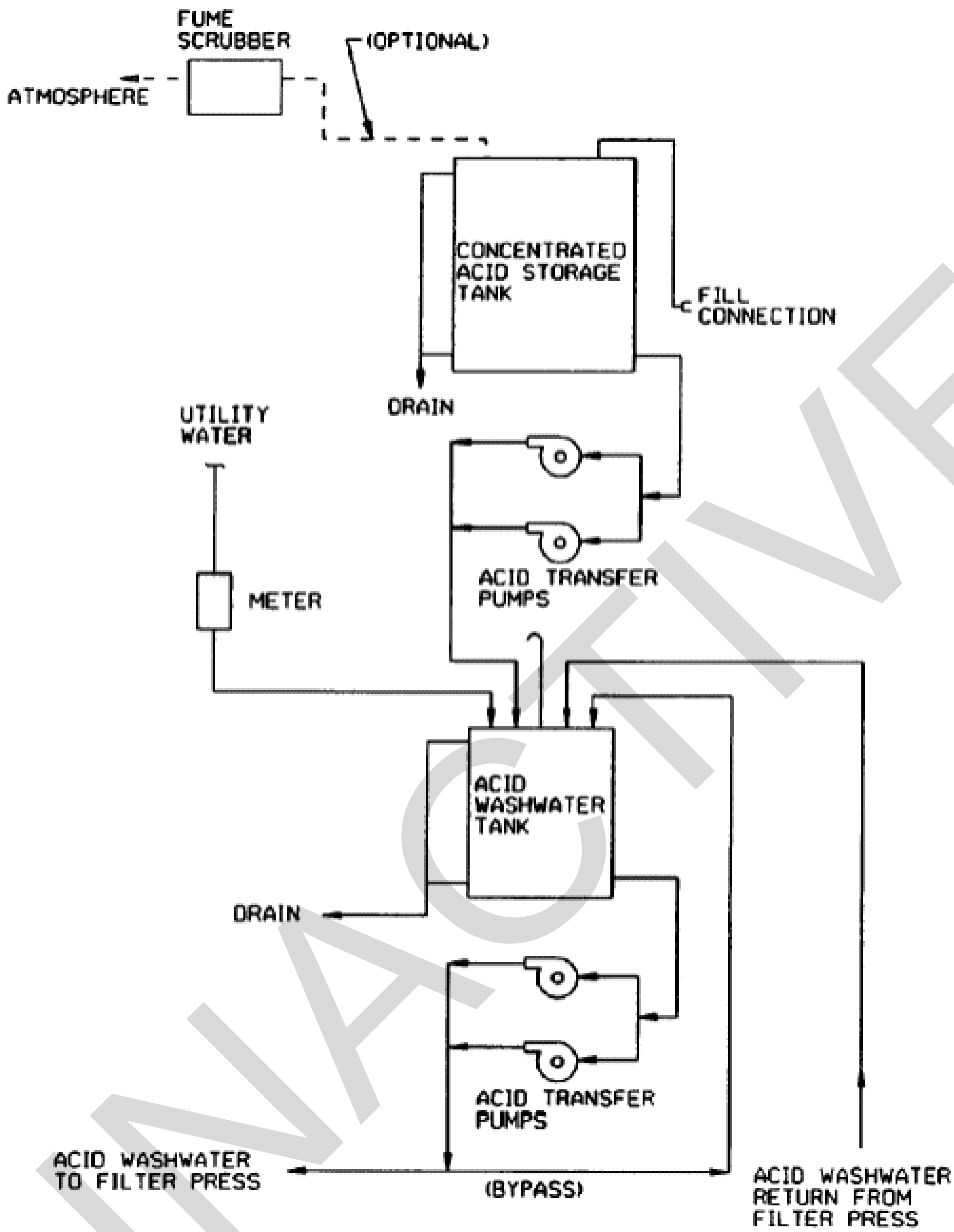


Figure 2-9. Schematic of typical filter media acid wash system.

2-4.7 **Filter Press Control and Instrumentation**. The controls for the plate and frame presses may be manual, semiautomatic, or fully automatic. Depending on the degree of control and instrumentation automation, labor requirements can vary dramatically.

2-4.7.1 **General**. Control systems for filter presses can range from full manual control to fully automated control. The appropriate control system is primarily selected on the basis of the size of the dewatering system, the stability of operating conditions, the complexity of the system, and the capability of personnel required to run the system. In general, manual control (i.e., manual valves or local push-button controls) would be appropriate for small installations and presses that do not require additional systems such as conditioning. Typically, industrial processes fit this category while wastewater sludge treatment rarely fits. For wastewater applications, control systems generally fall into one of three categories: remote manual, semiautomatic, and fully automatic.

2-4.7.1.1 **Remote Manual Systems**. These typically work as follows:

- All system functions are controlled by an operator from a centrally located panel.
- All operating elements, such as valves and pumps in the filter press and associated support systems, are individually opened, closed, started, and stopped by manipulation of switches located at the central control panel.

The control panel for this remote system typically includes operating switches for each element and indicator lights showing their status, an alarm telling when the filter cycle is complete, and an indicator and an annunciator to sound an alarm under specific conditions. This panel may also be equipped with color coded interconnecting lines with arrows to guide the operator in the proper sequence of actions to be taken.

In addition to the features described above, the remote manual system is also equipped with features such as safety light curtains and interlocks that cause the system to automatically stop if specific conditions are not met. Detailed descriptions of the safety light curtain and interlocking systems are presented in Subparagraph 2-4.7.2.3.

2-4.7.1.2 **Semiautomatic Systems**. A semiautomatic control system typically consists of subcycles within the dewatering process that can be manually started or stopped, such as the prefill and precoat, start filtration or feed, core blowing, sludge cake discharge, and filter media wash cycles. This control system consists of an alarm that is given at the end of each subcycle to alert the operator that the next subcycle can be initiated. This type of system will normally include a graphic representation of the system with status indicators for all operating components.

This type of system typically contains one central control panel and distributed local control panels, or subpanels within the central panel to control the subcycles. The control of the subcycle is typically initiated by an automatic switch located on or within the local panel or subpanel. As with the remote manual system, safety and interlocking features are also provided. In addition to interfacing of central and local remote panels, control panels and controls should be interfaced and coordinated with other remote control systems, as required, such as a Supervisory Control and Data Acquisition (SCADA) system, annunciators, etc., that may be used in for monitoring process variables throughout the complete water or wastewater treatment cycle.

As a minimum, the system control panel should include "start" buttons for operating the subsystems; selector switches to shift from primary to a redundant operating unit (i.e., pumps); a feed pressure recorder; level indicators for all tanks and bins used throughout the system; and alarm indicators for cycle completion, tank/bin low or high levels, and equipment malfunction. In addition to these components, auxiliary control and record-keeping instruments at large presses could include noting and recording sludge concentration, noting cycle start time and project cycle time, instantaneous cycle feed rate and totalizer, cake and filtrate concentration status, and total operating hours for major operating components to aid maintenance.

2-4.7.1.3 **Fully Automatic Systems**. Fully automatic systems are the same as semiautomatic systems, except the complete operation, from the prefill through the end of the filtration cycle, is begun through a single "start cycle" push button. Although this system is automatically controlled during the filtration cycle, it is normally equipped with selector switches for control of subcycles within the filtration cycle.

2-4.7.2 **Common Control Elements**. Three important elements that should be incorporated into any control system are feed pressure recording, filtrate flow measurement, and safety and interlocking systems.

2-4.7.2.1 **Feed Pressure Recording Systems**. Feed pressure monitoring throughout the filtration cycle is one of the best ways of seeing how well the system is operating. As described in Paragraph 2-2, the pressure trace during the filtration cycle normally generates an "S" curve. Deviations noted when comparing the current cycle with previous cycles may indicate a problem. This can be monitored by a strip recorder placed within or adjacent to the system control panel.

2-4.7.2.2 **Filtrate Measurement Systems**. In typical presses, a combination of feed terminal pressure and reduction in filtrate flow to a predetermined level is used to indicate a complete filtration cycle. The filtrate flow is normally measured in a weir tank, equipped with an alarm switch, which is further described in Paragraph 2-4.10.1, that signals when the flow drops to a predetermined level. The feed terminal pressure is normally measured by a pressure switch. Once either the specified minimum flow rate or terminal pressure is achieved, the sludge feed system is shut off.

2-4.7.2.3 **Safety and Interlocking Systems**. Safety and interlocking systems are essential for all filter press installations. For this discussion, safety systems will include only those that, when engaged, interrupt service, such as a safety light curtain. Interlocking systems prevent or start a sequential step of the process unless a specific condition is met, such as the filter press not opening if the feed pressure is greater than zero.

a. **Safety Systems**. The primary safety system used in filter presses is a safety light curtain. Safety light curtains consist of a bank of photo cells on alternative ends of the press that, when activated, form a continuous light curtain during closing or plate shifting. If the light curtain is interrupted, the work is stopped immediately. The light curtain, therefore, acts as an interlock when the plate is closed, opened, or shifted.

The light curtain should also be wired for "fail safe" operation to ensure that beam misalignment or failed wiring causes the system to de-energize the safety relay and stop the filter press. If the light curtain causes the plate closing or shifting mechanism to trip, the system should only be reactivated by use of a lanyard, a local push-button control, or from a centrally located control panel. However, the reactivation device should be located far enough away from the filter to ensure the area is clear before it is restarted. Once the filter is pressurized, the light curtain interlocking is bypassed to allow automatic maintenance of the hydraulic closure pressure.

b. **Interlock Systems**. Several types of interlocking systems are typically used in filter presses. These range from devices that prevent the start of the filtration cycle if adequate hydraulic pressure does not exist to hold the filter closed to those preventing discharge of the sludge cake if the cake receptacle is not in place. The most commonly used interlocking devices include those for starting the filtration cycle and filter opening, and those for drip trays and bunker covers, conveyors, and sludge cake receptacle systems.

(1) The start cycle interlock should prevent the sludge feed from being pumped to the filter system if adequate hydraulic pressure does not exist to keep the plates tightly in place. This type of interlock is not only desirable for housecleaning but also for safety.

(2) The open filter interlock should ensure that the hydraulic pressure holding the filter closed cannot be released if the pressure within the sludge feed system is greater than zero. This type of system is desirable to avoid excessive housecleaning and to provide safe operation. This interlock is essential for feed systems that possess pressure vessel surge tanks or equalizer tanks.

(3) The drip tray and bunker cover interlock should be used to provide proof that the drip tray or bunker covers are open before the filter cake is discharged. This system is normally designed using limit switches that monitor both the hydraulic pressure applied to the press closing mechanism and the position of the trays and covers. This interlock will not allow the press to be opened unless the trays and covers are opened. This avoids inadvertent discharge of sludge cake that may cause problems and damage to the trays and covers.

(4) The conveying interlock is only used when a conveyor is used in the sludge cake disposal process. Typically, this type of system will be interlocked with another sequential treatment process step (i.e., incineration) or to a bunker or receptacle used for storage prior to ultimate disposal. In general, the following controls should apply to all conveyor installations:

- All conveyors should be equipped with motion switches.
- Startup of the conveyor system should be in sequential order, based on proven startup of upstream conveyors or sequential treatment processes.
- Failure of a downstream conveyors or sequential treatment processes should cause immediate shutdown of upstream conveyors.

- Failure of upstream conveyors should cause sequential shutdown of down-stream conveyors or sequential treatment processes. This should be timed based to ensure that the previous load on the downstream side has been conveyed or processed.

(5) The sludge cake receptacle interlock should ensure that the sludge cake receptacle (i.e., dumpster or truck) is in place before the sludge cake is discharged. This is essential when the filter operator cannot see the receptacle. For this type of system, a manual push-button could be used. Electric eye devices or load cells could also be employed.

2-4.7.3 **Specific Control Elements**. The filter press and supporting systems can be equipped with several types of control elements, depending on the degree of control desired. The types of specific control elements for a filter press system may include sensors, meters, interlocks, controllers, control valves, and recorders. Further information for these types of control elements are presented in WEF (1992).

2-4.8 **Sludge Cake Handling and Storage**.

2-4.8.1 **Sludge Cake Handling**. Sludge cakes are typically handled either by dumping them directly into a bunker below the unit for storage or by dumping them onto a conveyor for subsequent processing or storage. The specific cake handling method used primarily depends on the ultimate disposal method. For example, if an offsite disposal method such as landfilling or incineration is to be used, the sludge may be deposited directly into a storage container or truck.

Storage containers typically used for smaller presses are extended platforms equipped with drum or roll-off box chutes and appropriately sized storage containers. For example, for smaller presses (i.e., 18 to 24 inches [470 and 630 mm]) a drum platform chute may be better than the roll-off platform or direct discharge into trucks, whereas the roll-off platform and chute may be better for the 0.7-m^3 (25-cubic yard) roll-off box. When using direct discharge into trucks, the filter press may need to be elevated, adequate space should be allowed for the trucks or containers to be loaded and unloaded, and an ample number of trucks should be available for the anticipated volume of sludge generated.

For further onsite treatment, such as sludge cake drying and incineration, or remote loading for offsite disposal, two potential sludge cake handling methods using conveyor systems could be used. The first method provides storage directly below the press and a conveying system that leads to the onsite treatment device. The second method includes a conveying system from the press to an intermediate storage facility between the press and onsite treatment device. The accumulated sludge in intermediate storage would be subsequently metered to the onsite treatment device. Typical sludge conveying systems are further described in Subparagraph 2-4.9.1. For additional information on thermal processing methods (i.e., sludge drying and incineration), equipment, and design criteria, refer to WEF (1992).

2-4.8.2 **Sludge Cake Storage**. The overall size and use of cake storage devices is based on the frequency and quantity of sludge cake generated and the ultimate disposal method. For example, for smaller applications, material may be directly discharged to a drum or dumpster. However, for larger applications, the material may be discharged to a roll-off box that can be directly loaded onto a truck for offsite disposal or discharged onto a conveyor for further treatment. Typical types and sizes of disposal receptacles range from chute disposal systems equipped with 210-L (55-gallon) drums to 0.7-m^3 (25-cubic yard) roll-off boxes that can loaded directly onto trucks for further disposal.

Design considerations for the storage of sludge cake include both discharge into and removal from storage containers. Sludge cake has thixotropic characteristics that can change the material from a firm cake into gelatinous discrete masses that, if allowed to settle, will recompact with time. Therefore, the overall characteristics of the cake that is removed from storage is typically different from the sludge cake discharged into storage. A design concern with any type of cake handling and storage is bridging, or buildup of sludge cake, which prevents removal of the cake. To avoid bridging, sludge cake storage bins should be constructed with steep side walls (greater than 5 vertical to 1 horizontal). In addition, if further processing or treatment is required, a "live bottom" (i.e., conveyor or screw auger) should be used over the full bottom length of the bin. For this application, a chain and flight conveyor mechanism or gauged helical screws with a minimum clearance to the outside of the bin should be used to minimize bridging effects. A variable-speed control device should also be used in conjunction with the live-bottom mechanism to achieve the desired loading rate to subsequent process or treatment units.

In addition to designing for discharge and removal of sludge cake from storage containers, housekeeping should also be considered in the design of sludge cake discharge systems. Housekeeping includes the use of optional features and equipment to reduce the amount of liquid sludge and potential for "splashing" or "slopping" upon sludge cake discharge from the press to the storage receptacle or transport equipment. To reduce the amount of liquid leakage into the sludge storage receptacle during the filtration cycle, optional equipment such as drip trays and bombay doors could be used, as described in Subparagraph 2-4.5.6.3. To reduce the amount of liquid sludge present before sludge cake discharge, optional features could be used, such as air or core blowing, as described in Subparagraph 2-4.3.4. In addition to options available before sludge discharge, sludge cake handling equipment, such as drum platforms and chutes for smaller presses and direct disposal chutes into roll-off boxes or directly onto conveyor systems for larger presses, as described in Subparagraph 2-4.8.1, could also be used.

2-4.8.3 **Standby Capabilities**. A critical factor that should not be overlooked is the standby capability of the sludge dewatering system. The standby system is an auxiliary sludge cake handling capability. This equipment is necessary in the event of a breakdown of the primary cake handling or disposal equipment. Although most multiple-unit filter press sludge dewatering systems are equipped with adequate dual auxiliary sludge conditioning, pumping, and filter press backup capability, standby capability for sludge cake handling is sometimes overlooked in the design. If a conveyor or live-bottom (conveying) storage bin breaks down, a "bottleneck" may result and the shut down the dewatering system. Although most sludge handling equipment, such as conveyors, are reliable and the cost of dual or additional equipment may be considered unwarranted, the consequences of a shutdown of the dewatering system can be substantial. Therefore, additional handling equipment or provisions for an alternative handling or disposal option, such as an alternative conveyor that leads to a temporary storage container or trucks or direct discharge into storage receptacles, should be considered.

2-4.9 **Sludge Cake Transport**. Sludge cake is normally transported at the treatment facility by conveyor belts. However, other systems, such as augers and pumps, can also be used. In all cases when selecting a sludge cake transport system, the designer must consider minimizing agitation to reduce changing the thixotropic or plastic characteristics of the sludge, odor control, and housekeeping, such as spillage.

The subparagraphs that follow provide an overview of design considerations for conveyor, auger, and pumping systems for sludge cake transport. More detailed information is presented in *Design of Municipal Wastewater Treatment Plants--Manual of Practice No. 8* (WEF 1992).

2-4.9.1 **Conveyor Systems**. Conveyor systems are most commonly used to transport sludge cake for filter presses. Located beneath the filter press, conveyors can transport the discharged sludge cake to a storage hopper, to a truck loading facility, or to an additional onsite disposal or treatment process (i.e., incineration). Conveying systems may involve horizontal, inclined, or cross-collection transfer. For horizontal conveyor transfer, a flat conveyor belt located beneath the filter press that is equipped with side skirts or troughs is used. A narrow feed chute from the press discharge to the conveyor should be used to direct the sludge cake to the belt discharge point.

2-4.9.1.1 The inclined belt transfer involves conveyor belts equipped with cleats or corrugations to ensure that the cake is moved without slipping or rolling. Potential problems with this type of conveyor include inadequate scraping and cleaning of the belt. Inclined drag flight (chain) conveyors can also be used; however, these conveyors can be a potential maintenance problem because of wear to chain and flights and cleaning requirements.

2-4.9.1.2 The cross-collection conveyor can be either horizontal or inclined.

2-4.9.1.3 Cake conveyor systems are typically a major housekeeping concern. The conveyor design should consider minimizing transfer points to avoid the accumulation of sludge. The design of the conveyor system should also provide additional rollers for those areas where the sludge drops onto the conveyor.

2-4.9.2 **Auger Systems**. Augers can move dewatered sludge horizontally, on an incline, or vertically. These systems move dewatered sludge by the pushing action of a helical blade attached to a center shaft. The blade and shaft of the auger are mounted in a U-shaped trough or enclosed in a tubular housing. A drive mechanism turns the center shaft, which is supported by end bearings and intermediate bearings as necessary to reduce shaft deflection.

Standard augers are most useful for moving dewatered sludge horizontally over relatively short distances. The length of auger systems in most wastewater treatment facilities is limited to 9 to 12 m (30 to 40 feet), although longer augers are possible. Inclined augers require different design criteria than horizontal augers and are less efficient. The capacity of an inclined auger is reduced approximately 2% for each degree of incline over 10 degrees.

Design considerations for auger systems are similar to those for belt conveyors. Characteristics, volume, and variability of the sludge are important design considerations. A major advantage of an auger system over a belt conveyor is that the auger can be completely enclosed to control odors and reduce housekeeping requirements.

2-4.9.3 **Pumping Systems**. Only two types of pumps, progressive cavity and hydraulically driven reciprocating piston pumps, have been used with limited success to transport sludge cake in lieu of belt conveyors and augers. Advantages of pumps include control of odors, spills, and noise. However, pumps usually require more energy than conveyor systems. Head losses for most sludge cake pumping systems are high and often range from 1.4 to 6.9 MPa (200 to 1000 psig), depending upon the length, diameter, and configuration of the discharge piping.

Progressive cavity pumps have been used with limited success to pump sludge cake, and these pumps should be limited to pumping wet sludge cakes with solids concentrations of approximately 15% or less. Hydraulically driven reciprocating piston pumps were developed from concrete pumping technology and have also been successfully used to pump sludge cake. The principal advantage of these pumps over other pumps is that they can move sludge cakes with a wider range of plasticities. Additional descriptions of these two types of pumps is also presented in Paragraph 4.3.

2-4.10 **Filtrate and Cake Waste Management**.

2-4.10.1 **Filtrate Management**. The filtrate management system is an important part of monitoring the effectiveness of the filtration cycle. The minimum filtrate flow rate is typically used in combination with a terminal pressure to determine the end of the filtration cycle. The filtrate flow rate is normally slightly less than the feed rate of sludge to the press. The filtrate typically has a low solids content because of the removal of solids in the press, and it has biological oxygen demand (BOD) and chemical oxygen demand (COD) concentrations. For HTRW sites, the filtrate may contain contaminant concentrations that are similar to or lower than that of the sludge feed The quality and rate of filtrate flow should also be monitored throughout the filtration cycle for changes that indicate required conditioning adjustments or suggest filter media blinding.

Filtrate is typically discharged to an overflow tank to prevent solids from escaping in the event of media failure. The filtrate tank is typically equipped with an overflow weir (i.e., V-notch weir) and level sensors to indicate when a stable minimal flow rate has been achieved. As described previously, this minimum flow rate is often used in combination with maximum termination pressure as the indicator to end the filtration cycle.

For presses not treating HTRW, stored filtrate is typically used as makeup water for the precoat or prefilling systems, returned to primary treatment processes, or transferred to subsequent treatment processes prior to disposal. However, for HTRW applications, because the filtrate has the potential to still contain contaminants, it is typically only returned to primary treatment processes or transferred to subsequent treatment processes prior to disposal and not recycled for makeup water for the filter press.

2-4.10.2 **Disposal of Sludge Cake**. Common methods of disposing of HTRW or industrial sludge cake include disposal in landfills and incineration. Other options for sludge not treated for HTRW and certain industrial sludge include disposal on agricultural and non-agricultural land. The method of sludge disposal depends on the type of sludge treatment provided and the chemical characteristics of the sludge after treatment.

2-4.10.2.1 **Landfills**. Landfilling is a sludge disposal practice in which sludge is deposited in a dedicated area, alone or with solid waste, and buried beneath a soil cover. Sludge disposal in solid waste landfills must comply with the minimum requirements in 40 CFR 258 and any additional state regulations that are more restrictive. Sludge that is defined as hazardous waste under 40 CFR 261 may be disposed of in RCRA-permitted landfills. Prior to disposal, the sludge must be treated to meet the requirements specified in 40 CFR 268.

2-4.10.2.2 **Incineration**. Incineration is a disposal practice that destroys the organic pollutants and reduces the volume of sludge. Incineration takes place in a closed device using a controlled flame.

The advantage of using an incinerator to dispose of sludge is that the volume of sludge requiring final disposal in a landfill is greatly reduced. The disadvantages of incineration include high capital and operation and maintenance costs.

New incinerators must meet the New Source Performance Standards (40 CFR 60, Subpart O) promulgated under the *Clean Air Act*. If the sludge is defined as hazardous under 40 CFR 261, the incinerator must meet the requirements of 40 CFR 264, Subpart O. Residual ash from the incineration of sludge that is a listed hazardous waste remains a hazardous waste until it is delisted, and it must be disposed of as a hazardous waste.

2-4.10.2.3 **Sludge Application to Agricultural Lands**. The sludge cake from domestic sources is often applied to agricultural land to improve the condition and nutrient content of the soil for agricultural crops. However, this disposal method is not an option for sludge generated from HTRW waste.

2-4.10.2.4 **Sludge Application to Dedicated Land**. The objective of sludge disposal from domestic sources on non-agricultural land is to employ the land as a treatment system. The soil will bind metals and soil microorganisms, sunlight, and oxidation will destroy organic matter. Frequently, the dedicated land disposal site has a cover crop that is not in any food chain to reduce the potential for runoff or leaching of the pollutants to surface or ground water.

Sludge that is listed as a hazardous waste under 40 CFR 261 or that is derived from a listed hazardous waste could not be disposed in this manner unless the sludge was delisted in accordance with 40 CFR 260. Requirements for land disposal of sludge that may be a hazardous waste should be coordinated with Federal and state regulatory agencies.

2-5 **LEGAL REQUIREMENTS AND PERMITS**. Federal and state legal requirements must be addressed if the plate and frame filter press is selected as the method to dewater the sludge. Applicable Federal and state laws and regulations generally address treatment and disposal of sludge from the filter press. Federal regulations are authorized under several statutes. State regulations are generally similar to Federal regulatory requirements, but may vary among the states. Although other laws may apply to the use of a plate and frame filter press, the most applicable Federal laws are the *Clean Water Act* (CWA), *Resource Conservation and Recovery Act* (RCRA), and *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), as amended by the *Superfund Amendments and Reauthorization Act of 1986* (SARA). A summary of these laws and their implementing regulations to the plate and frame filter press operations are discussed in the following paragraphs.

2-5.1 ***Clean Water Act* (CWA).** The CWA was passed by Congress in 1972 and was amended by the CWA of 1977. Section 405 of the CWA required the United States Environmental Protection Agency (EPA) to develop regulations for the use and disposal of sewage sludge. These criteria are included in regulations co-promulgated under Subtitle D of RCRA (Solid Waste Disposal facilities) and Section 405(d) of the CWA and are found in 40 CFR 257 and 40 CFR 503.

2-5.2 ***Resource Conservation and Recovery Act* (RCRA).** RCRA and the regulations that implement it are applicable to the plate and frame filter press if the filter press is used for dewatering a hazardous waste as defined under Subtitle C of RCRA and 40 CFR 261. RCRA is also applicable if the residual cake from the filter press is a hazardous waste as defined under these laws and regulations.

Federal regulations that address hazardous wastes are located in 40 CFR 260 through 40 CFR 270. The requirements in these regulations should be coordinated with Federal and state regulatory agencies.

In addition to these regulations addressing requirements for the sludge generated from hazardous waste, the regulations also address exclusions to permitting for treatability studies if performed in accordance with requirements provided in 40 CFR 261.

2-5.3 ***Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) as Amended by the *Superfund Amendments and Reauthorization Act of 1986* (SARA).** The primary purpose of CERCLA/SARA is to address past disposal of hazardous wastes. Portions of the law that address past disposal of hazardous wastes are not applicable to the operation of a plate and frame filter press. Title III of SARA established a program that requires facilities, including wastewater treatment plants, to notify state and local officials if the facility has hazardous substances in excess of specified threshold amounts (40 CFR 355 and 40 CFR 370). Hazardous substances and hazardous chemicals that could be used in the operation of the filter press include acids, caustics, and possibly sludge conditioners, depending upon the chemicals selected.

2-5.4 **State Regulations**. State and local regulations and ordinances will also impact the design and operation of the filter press. The EPA frequently delegates authority to the individual states to implement portions of the CWA and RCRA. When the state has received authority to implement an EPA program, it must promulgate regulations that are at least as restrictive as the Federal regulations. States may also promulgate regulations that are more restrictive than the Federal regulations.

States and local government agencies may also adopt regulations and ordinances addressing building codes and safety features that must be incorporated into the design of the filter press. These regulations may address such issues as handrails and guards, first aid equipment, lighting, and ventilation. State and local regulatory requirements will vary among the states and should be addressed during the design of the plate and frame filter press.

2-6 **TREATABILITY STUDIES**. Treatability testing evaluates design parameters and the potential effectiveness of the filter press. This testing may begin at the bench-scale level and proceed to pilot-scale or full-scale testing. However, if pilot-scale testing is not feasible, the design can be developed from the bench-scale data.

2-6.1 **Types of Treatability Testing**. The types of tests that can be conducted include basic filterability tests and tests to optimize chemical conditioning.

2-6.1.1 **Basic Filterability Testing**. Basic filterability testing evaluates the filtering properties of the sludge and determines the ease of separating the water phase from the solid phase (EPA 1987, WEF 1992). Two basic parameters that can be used to provide design information on final solids concentration are specific resistance and capillary suction time (CST). The specific resistance testing can be used as a basic guide in estimating the solids yield and cake solids. CST tests can also be used to evaluate whether the sludge can be easily dewatered; however, they are primarily used to evaluate the effectiveness of sludge conditioning.

2-6.1.2 **Conditioning Tests**. Optimizing chemical dosages is not only important to the dryness of the cake, but it also affects the solids capture rate and solids disposal costs. Several types of tests can evaluate the effectiveness of a single conditioning chemical or group of conditioning chemicals. Standard test procedures include jar tests, CST tests, Buchner funnel tests, and pilot-scale and on-line testing. Although chemical dosages should be initially evaluated, they should also be reevaluated periodically because of changes in sludge characteristics.

2-6.2 **Test Procedures**. Test procedures that can be used for both basic filterability testing or conditioning testing include jar tests, CST tests, specific resistivity tests, and pilot and on-line tests.

2-6.2.1 **Jar Testing**. Jar testing, the simplest type of conditioning testing, is often used for the preliminary evaluation of the type and estimated quantity of conditioners required. Jar testing involves the visually observing the size of sludge floc produced when various types and quantities of different types or combinations of conditioning chemicals are mixed with samples. This type of testing can be used to screen or eliminate different types of chemical conditioners and determine the effects of different dosages of a specific conditioner. A description of the jar testing procedure is outlined in *Design Manual—Dewatering Municipal Wastewater Sludge* (EPA 1987).

2-6.2.2 **Capillary Suction Time Testing**. The capillary suction time (CST) test involves measuring the time to move a volume of filtrate over a specified distance as a result of the capillary suction pressure of dry filter paper. The CST test provides information regarding the ease of separating the water portion from the solids portion of sludge. This type of testing is most effectively used during the selection of the optimum conditioner dosages during on-line tests. The CST is typically defined in units of time (seconds). For, example, the typical range of CST for unconditioned organic wastewater sludge is 100 to 200 seconds (EPA 1987). In general, to dewater this type of sludge in a filter press, a CST of 10 seconds or less is required. A detailed theoretical description of this method and its procedures are presented in *Design Manual—Dewatering Municipal Wastewater Sludge* (EPA 1987).

2-6.2.3 **Specific Resistance Testing**. Specific resistance testing has been widely used and investigated as a way to evaluate the effectiveness of filterability. Specific resistance is typically defined in units of tetrameters (10^{12} m) per kilograms (Tm/kg). The specific resistance for raw wastewater typically ranges from 10 to 100 Tm/kg (1.5 x 10^{13} to 15 x 10^{13} ft/lb) (EPA 1987). Generally, the specific resistance can be adjusted by a factor of 100 to 1000 (e.g., 0.1 to 1.0 Tm/kg [1.5 x 10^{11} to 15 x 10^{11} ft/lb]) with proper conditioning. A lower specific resistance indicates increased dewaterability. This testing can be done by calculating the specific resistance from Buchner funnel testing or by measuring the specific resistance directly with specific resistance test meters.

The Buchner funnel test is a method commonly used for predicting the specific resistance of sludge. A detailed theoretical description of this testing and its procedures are provided in *Design Manual—Dewatering Municipal Wastewater Sludge* (EPA 1987).

2-6.2.4 **Pilot-Scale and On-Line Testing**. Based on the results of jar tests or the other tests previously described, pilot-scale testing or on-line testing can be done to evaluate different conditioners and to determine their optimum dosage based on actual thickening or dewatering performance. During pilot-scale and on-line tests, actual samples of the raw sludge feed, conditioned sludge, thickened or filter cake discharge, and filtrate or supernatant are collected and analyzed. On the basis of these test results, an economic analysis may also be conducted as part of the final evaluation of the optimum dosage. In addition to evaluating and optimizing conditioning agents, pilot-scale and on-line testing can be used to determine filter press operating conditions, such as optimal filtration cycle times and pressures (i.e., feed, compression, extraction), required filtration area, and the need for filter media precoat and filter aids.

Pilot-scale testing is commercially available from several filter or filter press manufacturers that have bench-scale equipment (i.e., cylinders or plate unit) and trailer mounted equipment that can simulate actual operating conditions.

In addition to pilot-scale testing, on-line testing to verify optimal operating conditions should be done after the filter press is installed. During this testing, conditioning dosages may be further optimized, and actual dewatering operation conditions (such as cycle times) and equipment selections (such as the filter media or the need for precoating or filter media washing) may be further refined.

2-7 **SIZING CRITERIA**. The sizing of the major components of the filter press and accessories and auxiliary systems primarily depends on the specific flow rate and type of sludge generated and its associated characteristics. In addition to the sludge characteristics, the mode of operation, such as the overall size of the required sludge dewatering systems and whether the sludge dewatering system requires continuous batch operation or is operated in a periodic batch mode, will also affect the sizing of major components. An example of a continuous batch mode operation is a municipal wastewater treatment system that requires several sludge dewatering cycles per day and continuous operation over a 5- to 7-day period per week because of continuous flow or wastewater being treated. An example of a periodic batch operation system is an application where only limited amounts of sludge are generated over an extended period or where a batch waste treatment system is only used periodically for sludge dewatering. The specific type and size of equipment should be capable of processing the sludge to a form suitable for its ultimate disposal.

The "Ten States Standards," *Recommended Standards for Wastewater Facilities*, provided by the Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers, contains minimum requirements for sludge processing using mechanical dewatering equipment, such as the plate and frame filter press system, that can be applied to HTRW applications and are summarized in this paragraph for reference (GLUMRB 1990). In addition to the sludge processing requirements, the "Ten States Standards" also provide guidelines for wastewater treatment, including the design of influent piping systems, treatment processes, and discharge. Although these are industry accepted guidelines, the requirements summarized below may not be applicable in every case and additional "site-specific" requirements may also need to be addressed. In addition to the information that follows in this paragraph, a summary of design calculations is presented in Chapter 3, and design examples that illustrate use of these calculations and the following sizing criteria are presented in Chapter 5.

2-7.1 **Concentration Related**. Several preliminary steps should be completed to ensure adequate sizing. The first step in the initial design phases is doing a mass balance around process units that generate sludge. This step will only provide a basis for the anticipated volume of solids that should be used for equipment sizing. The next step should confirm the anticipated quantities of sludge generated following conditioning and treatability testing because the sludge volume may increase following the addition of conditioning chemicals such as lime.

2-7.2 **Flow Related**. Several flow related factors that affect sizing criteria should be considered. Flow related factors can be categorized into two separate categories: peak and minimum flows and equipment concerns.

2-7.2.1 **Peak and Minimum Flows**. Because the filter press is a batch operation, the sizing of the filter press and associated supporting system is primarily based on an average daily flow of liquid sludge and the percent concentration of solids in the sludge feed. To compensate for peak flows, storage may be required prior to the dewatering system as described in Subparagraph 2-7.2.2. Because the process is a batch operation, storage should also be provided for low flows to ensure an adequate amount of sludge is present to complete the sludge dewatering cycle.

2-7.2.2 **Equipment Concerns**. Flow related equipment concerns associated with sizing criteria include those related to sludge pumping, piping, and storage. The following paragraphs provide recommended requirements from the "Ten States Standards" (GLUMRB 1990).

2-7.2.2.1 **Sludge Pumping**. A detailed discussion of sludge transport (i.e., pumps) equipment is presented in Paragraph 2-4.4 of this chapter. The following minimum sizing criteria and requirements should be considered for sludge pumps.

a. **Capacity**. The volumetric capacity for the sludge pumps will be based primarily on the filter press size or required length of the associated filtration (filling) cycle period. The sludge pumps should be adequately but not excessively sized and should be equipped to handle varying capacities and pressures through the filter press cycle.

b. **Number of Units**. Duplicate units or standby units should be provided for each type of sludge transfer pump used. The duplicate units should be sized with sufficient capacity to handle peak flows with the largest unit out of service.

c. **Type**. A positive displacement pump, such as a diaphragm, progressive cavity, or piston-type pump, should be used for this sludge dewatering application. A general application guide is presented in Table 2-7.

d. **Minimum and Maximum Head**. The minimum head will be based on the specific application required. In general, a minimum positive head of 610 mm (24 inches) should be provided at the suction side of the pump, and a maximum suction lift should not exceed 10 feet for plunger-type pumps. An additional safety factor of 10 to 25% should be applied to the dynamic pressure to reduce the effects caused by the thixotropic characteristics of the sludge.

e. **Sampling Facilities**. Unless additional provisions are required, sampling valves should be provided at the sludge pumps. The sampling valves should be quick closing valves of at least 1½ inches that terminate at a suitably sized sampling sink or floor drain.

2-7.2.2.2 **Sludge Piping**. The following minimum sizing criteria and requirements should be considered for sludge piping (GLUMRB 1990):

a. **Size**. Sludge withdrawal piping should have a minimum diameter of 150 mm (6 inches). Minimum diameters for pump discharge lines should be 100 mm (4 inches) for facilities treating less than 22 L/s (350 gpm) and 200 mm (8 inches) for facilities treating more than 45 L/s (700 gpm). Short and straight runs are preferred, and sharp bends and high points should be avoided. Although not recommended, if less than 100-mm (4-inch) piping is used, additional cleanouts should be provided and no sharp bends should be present.

b. **Head**. The available head for gravity withdrawal should be at least 7.5 kPa (30 inches) or greater as necessary to maintain a 0.9-m/s (3-fps) velocity in the withdrawal pipe.

c. **Slopes**. Gravity piping should be laid on uniform grade and alignment. The slope for gravity piping should not be less than 3% for sludge with greater than 2% solids and should not be less than 2% for sludge with less than 2% solids.

d. **Flushing**. Blank flanges and valves should also be provided for draining, flushing, and cleanout.

e. **Freeze Protection**. All sludge piping should be adequately protected to prevent freezing.

2-7.3 **Operation Related**. Sizing criteria can be related to both operation and maintenance labor requirements and equipment requirements.

2-7.3.1 **Operation and Labor Requirements**. Operation and labor requirements are important considerations in sizing equipment because the plate and frame filter press pressure system operates in a batch mode. The effects of operation and labor requirements on sizing equipment can best be demonstrated by the following examples. First, if one 8-hour operating shift is desired rather than two shifts, then the dewatering equipment for the former case would be larger unless multiple units were used. Second, if the operation is based on a 5-day work week instead of a 7-day week, the dewatering equipment would need to be sized to store a portion of the additional sludge generated or have a filter capacity greater than the daily sludge volume capacity generated. Typically, it is assumed the filter press will only be operated during one shift operating 8 hours per day in a 5-day work week.

2-7.3.2 **Equipment Requirements**. Sizing criteria are also applied to the equipment associated with the plate and frame filter press and supporting systems, such as chemical handling (i.e., conditioning) and storage.

2-7.3.2.1 **Sludge Processing Units**. The following are general requirements that should be considered in sizing and designing the sludge processing units (GLUMRB 1990).

a. **General Provisions**. Service should be maintained so that sludge may be dewatered without accumulating beyond the storage capacity. Multiple units with a capacity to dewater the design sludge flow with the largest capacity unit out of service should be available, or facilities should be available to store the sludge from at least 4 days of operation, unless other standby dewatering facilities are available.

b. **Ventilation**. Adequate ventilation for the dewatering area should be provided to avoid nuisance odors or hazardous fumes. Additional provisions for ventilation are described in Subparagraph 2-9.8.2.

c. **Chemical Handling Systems**. Facilities used for chemical handling should be automated as much as possible to limit personnel exposure from manual operations. In addition, facilities that generate dust, such as lime mixing facilities, should be enclosed to prevent escape of dust.

2-7.3.2.2 **Sludge Storage**. The following general requirements should be considered for either liquid sludge or sludge cake storage units (GLUMRB 1990).

a. **General Provisions**. Appropriate storage should be provided for both liquid and dried sludge.

b. **Storage Capacity**. A storage facility capable of storing 4 days' production volume should be provided unless other standby dewatering facilities are available.

2-7.4 **Cycle Time**. Cycle time also plays a major role in the sizing of equipment. The cycle time not only consists of the time required for the filtration cycle, but also includes the time required for cake discharge and other operations, such as filter media washing. Cycle time primarily depends on the filtration period and degree of desired cake dryness. Typical cycle times for sludge dewatering in various fixed-volume and variable-volume filter presses are presented in Tables 2-4 and 2-5, respectively. Based on the anticipated sludge loading divided by the cycle time and operations and labor requirements, the sludge volume and optimum number and size of filter presses required can be determined. An example of this determination is presented in Chapter 5.

2-8 CONSTRUCTION MATERIALS AND INSTALLATION CONSIDERATIONS.

2-8.1 Construction Materials.

2-8.1.1 Filter Press Components.

2-8.1.1.1 **Structural Frame**. The structural frame is typically made of carbon steel. It should be designed to provide a completely integrated structure sufficient to support the entire weight of the filter plates and withstand the operating pressures. Coatings and materials should also be selected to minimize corrosion. The structural frame should be installed as discussed in Paragraph 2-8.2.

2-8.1.1.2 **Plate Materials**. Selecting the construction material for filter plates depends on several factors. The key factors that should be considered are mass and strength. Because mass and strength of materials are interrelated, the design should consider tradeoffs between greater mass/less strength and less mass/greater strength.

a. The mass of the plate can affect the following items: ease of handling during installation, cleaning, inspection, and changing filter cloth; cost and overall weight of the press; and additional structural costs for the building that houses the press. Although the current press may not require the heavier filter press plates, it can be beneficial to include provisions in the initial building design to handle heavier plates for the future.

b. Strength is an important aspect because of the high operating pressure. Operating pressures can run from 690 to 1550 kPa (100 to 225 psi), and the potentially uneven force distribution that may occur during the filter cycle can increase the pressure that must be considered. Uneven distribution can deflect and deform the plates, cause blowout, and increase filter wear. Overall these effects increase as plate sizes increase. To compensate for these, plates of lower strength are typically constructed with larger stay bosses, which reduce cake volume between plates. This reduced volume leads to a larger number of plates required, added structural frame length, and additional building space to achieve a given volume using plate materials of lesser strength.

c. Fixed-volume filter press plates are commonly available in polypropylene, gray cast iron, ductile iron, and epoxy- or rubber-coated steel. Variable-volume press plates are also commonly available in polypropylene, ductile iron, and steel, and are equipped with an elastomeric diaphragm typically constructed of polypropylene. Polypropylene plates are the most common because of their excellent chemical or corrosion resistance, their lighter weight, which eases handling, and their low initial cost. Plates constructed of polypropylene are typically found in all sludge presses for pressures of 1550 kPa (225 psi) and below at temperatures less than 90 degrees C (200 degrees F). Above these conditions, glass filled polypropylene or nylon plates are recommended. Although the strength of polypropylene plates is less than those made from iron and steel, plate thickness and additional stay bosses can be used to compensate for their lower strength. Cast iron and ductile iron plates are the most durable materials because of their strength and chemical and corrosion resistance. However, they are more costly and weigh considerably more than the polypropylene plates. Epoxy-coated and rubber-coated steel plates offer lower initial costs than the iron plates and have moderate strength, weight, and chemical resistance. However, these plates are susceptible to corrosion and chemical resistance if the epoxy coating is not maintained or the rubber covering cracks.

2-8.1.1.3 **Filter Media**. The initial selection of filter media is one of the most important equipment variables in filter press applications. Durability, ease of cake release, minimum blinding, and chemical resistance are all important. The designer must evaluate materials of construction, permeability, and overall construction and weave. If properly installed and maintained, the life expectancy of a filter media is between 1000 and 4000 cycles (WPCF 1983). In most cases, the initial selection filter media will be based on manufacturer's experiences with similar applications.

a. Filter media are available in several materials and different permeabilities. The most commonly used materials are polypropylene, polyester, and nylon, with, polypropylene being the most common because of its durability and resistance to ferric chloride and lime conditioning chemicals and acid solutions used to wash filter media. It is, however, limited to operations below 90 degrees C (200 degrees F). Polyester is slightly more durable than other material because of its low stretching ability; however, it is expensive. Nylon is typically only used where conditioning and media washing (i.e., acid wash solution) require no chemicals.

b. The overall construction and weave are also important aspects of the filter media. The media construction typically consists of either monofilament, multifilament, or spun fibers. Filter media constructed of multifilament fiber warp, monofilament fiber weave, or satin design weave are typically used because of their smooth surface characteristics, which help improve cake release properties and reduce media blinding. Calendaring is an optional method used to increase the smoothness of the filter media by heat pressing or ironing them to provide a finish that increases cake release.

c. Permeability is a measurement of the openness of the weave as determined by air flow through a given area of media at a given pressure drop. The typical permeabilities range from 1.5 to 2.4 L/s (3 to 5 scfm) as measured on the Frazier Scale, which measures the amount of air that passes through a wetted cloth at differential pressure of 1 atmosphere. The permeability of the filter cloth may change through use because it becomes impregnated with solids, swells, and its weave becomes distorted. Although permeability affects the initial stage of filter cake formation, once the filter cake begins to form, the filter cake itself serves as the filter medium and is relatively independent of the filter media (cloth). Media blinding and cake release are also important aspects of permeability.

d. In addition to general construction aspects, stay bosses are added and the plate perimeter is often reinforced to improve wear of the media. This reinforcement typically consists of an additional layer of media, impregnation with a coating, or insertion of a different material. However, if reinforcement is used, the thickness at all locations should be uniform to alleviate the potential of plate deflection or blowouts.

e. The attachment of the cloth to the plates is also an important aspect of filter media construction. The non-gasketed type of filter media are placed on the faces of the plate and fastened through grommets located around the perimeter with ties to the filter media on the opposite side of the plate. A sewn loop is typically attached to the top edge of the filter media through which a rod is inserted to provide uniform support of the filter media across the press.

f. Filter media can also be attached to the plates using a gasket at the perimeter of the recessed area. The advantage of the gasketed filter media plate is less leakage than the non-gasketed plate because of the seal created around the recessed chamber and filtration ports.

2-8.1.2 **Filter Press Accessories and Auxiliary Systems**. The following subparagraphs provide an overview of construction materials for filter press accessories and auxiliary systems. Additional information is presented in WEF (1992).

2-8.1.2.1 **Chemical Feed Systems**. Chemical feed systems associated with filter presses primarily are those related to sludge conditioning, such as lime, ferric chloride, and polymers. Scaling and corrosion are the primary design concerns for construction materials for facilities handling conditioning chemicals, such as lime and ferric chloride.

a. Although not corrosive, lime slurry tends to cake and line piping systems with calcium carbonate scale. To reduce maintenance of the facilities, the distance from the lime slurry day tank to the sludge conditioning tank should be minimized and flexible hose with quick disconnects should be utilized for piping. Most materials that are standard for industry, such as carbon steel, are suitable for tanks and piping handling lime slurry.

b. Because the ferric chloride solution may range in pH from 3 to 5, appropriate materials should be considered. For storage tanks, suitable materials of construction include most plastics, fiberglass with vinyl or polyester resin material, titanium, and rubber-lined steel. For piping and equipment, suitable materials include chlorinated polyvinyl chloride (CPVC), polyvinyl chloride (PVC), polypropylene, hypalon, and neoprene.

c. Polymers are not corrosive, therefore, suitable construction materials include PVC, fiberglass reinforced plastic (FRP), and stainless steel.

2-8.1.2.2 **Other Auxiliary Systems**. Other auxiliary equipment with specific material construction considerations includes sludge storage, sludge conditioning, precoat, and filter media wash systems.

a. Both liquid and cake sludges need to be stored. Suitable materials for liquid-sludge storage tanks are typically carbon steel with a coating system compatible with the sludge's chemical characteristics for smaller tanks, and concrete for very large tanks. Tank equipment, such as mixers, should be constructed of corrosion-resistant material, such as PVC, polyethylene (PE), or stainless steel. Construction materials for sludge cake storage receptacles, such as hoppers, typically include carbon steel with a coating system compatible with the sludge's characteristics. Refer to EM 1110-1-4008 for material compatibility.

b. Sludge conditioning equipment primarily includes a storage tank and mixer, in addition to feed systems for the conditioning chemical. Materials of construction for conditioning chemicals such as lime, ferric chloride, and polymers are discussed in Subparagraph 2-8.1.2.1. Suitable materials for sludge conditioning tanks may include FRP and coated steel.

c. Precoat equipment typically includes a precoat tank and mixer, pump, and chemical feed system. Because of the abrasive nature of material used as precoat, such as diatomaceous earth, suitable construction materials typical for the precoat tank and chemical feed system are limited. A coating system that is compatible with the sludge's characteristics and stainless steel are best, although plastic may be suitable to a lesser extent. Suitable materials for the precoat pump are described in Subparagraph 2-4.3.2.

d. Filter media wash systems typically used for filter presses include both water and acid. No specific materials are required for the water wash system, although polypropylene, polyethylene, and FRP are suitable. Because the acid wash system typically involves the use of diluted hydrochloric acid, corrosion-resistant materials such as FRP and rubber-lined steel are suitable for tanks, and PVC is suitable for piping.

2-8.1.2.3 **Sludge Pumps and Piping**. An overview of construction materials for pumps used for sludge feed is presented in Subparagraph 2-4.3.2. Materials suitable for sludge piping for filter presses typically include PVC, carbon steel, and stainless steel (WEF 1992). However, only carbon steel and stainless steel are recommended for operating pressures greater than 690 kPa (100 psi).

2-8.1.3 **Corrosion Protection**. Corrosion protection is also an important design consideration because of the frequent use of washing systems (water and acid) and because of the use of corrosive conditioning chemicals, such as ferric chloride. Therefore, the use of corrosion-resistant materials and coatings should be considered for the press and supporting systems, such as the chemical handling systems used for bulk storage, and feed and associated equipment, such as piping systems. Several areas located within the filter press system may be subject to potential corrosion problems. The primary concern is the area directly around the filter press because of the use of high-pressure water to wash filter media. This may require that the area around the press be constructed with corrosion-resistant materials, such as ceramic tile for floor and wall coverings.

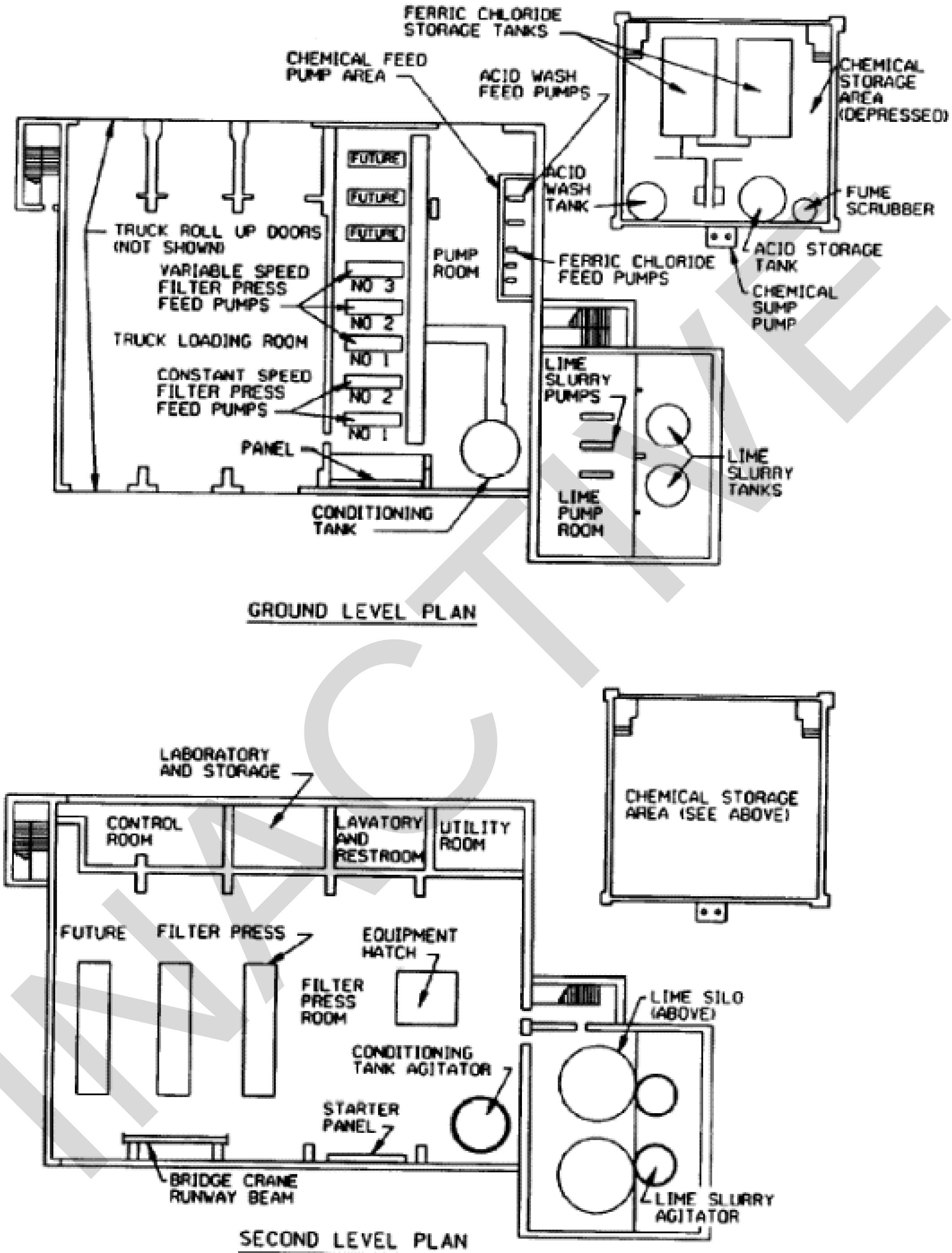
2-8.2 **Installation Requirements**. The filter press and supporting systems should be located in a covered building to avoid exposure to severe weather that could affect sludge characteristics and the overall success of the dewatering process.

2-8.2.1 The structural load imposed on the building foundation from the filter press can be substantial. If installed properly, the press should only exert load in the vertical direction, with all horizontal load being maintained within its structural frame. The press should also be aligned properly to keep the structural frame from warping and keep anchor bolts from twisting.

2-8.2.2 Layout and access to the filter press are important design aspects because of the weight and size of the press and the use and interrelationship of several support systems (WEF 1992). A typical layout and building cross section for a multiple-unit filter press dewatering system are shown in Figures 2-10 and 2-11, respectively. A typical layout for a single press dewatering system is also presented in Figure 2-12. The size of the press and the required clearance space govern the overall space required. A minimum of 1.2 to 1.8 m (4 to 6 feet) should be allowed around the ends of the press, and a typical clearance of 1.8 to 2.5 m (6 to 8 feet) is required between presses. Storage space should be sufficient to allow room for spare filter plates, filter media, and other spare parts. Height clearance for removal of plates should also be considered and depends on the size of the plates, and on frame size and construction. An elevated platform is often placed on one side of the press to allow operators to inspect the system and to assist in sludge cake release, as required. The other side should remain open to allow for equipment access. If multiple presses are used, a common platform should be located between the presses.

2-8.2.3 The building layout should also be designed to allow for installation and removal of equipment. Layout design considerations include adequately sized openings to allow passage of major equipment components such as the fixed and moving end and plate support bars. An additional consideration is the installation of an overhead bridge crane, monorail, or hoist rated to carry the heaviest individual press component during installation, repair, and removal. Typical filter press installations are also provided on a second story or are elevated to allow direct disposal of cake into storage receptacles or trucks.

2-8.2.4 If truck-loading facilities are used in the disposal processes, facilities should be designed with ample clearance and sized for a variety of vehicles. The minimum clearance should be 4.2 m (13.5 feet). If possible, one-way traffic or drive-through traffic is preferred to driveways that require trucks to back in and out.



NOTE: ABOVE FIGURE BASED ON SCHEMATIC SHOWN IN FIGURE A-5. SEE FIGURE A-11 FOR BUILDING CROSS SECTION.

SOURCE: WPCF 1983.

Figure 2-10. Typical floor plan layout filter press dewatering system.

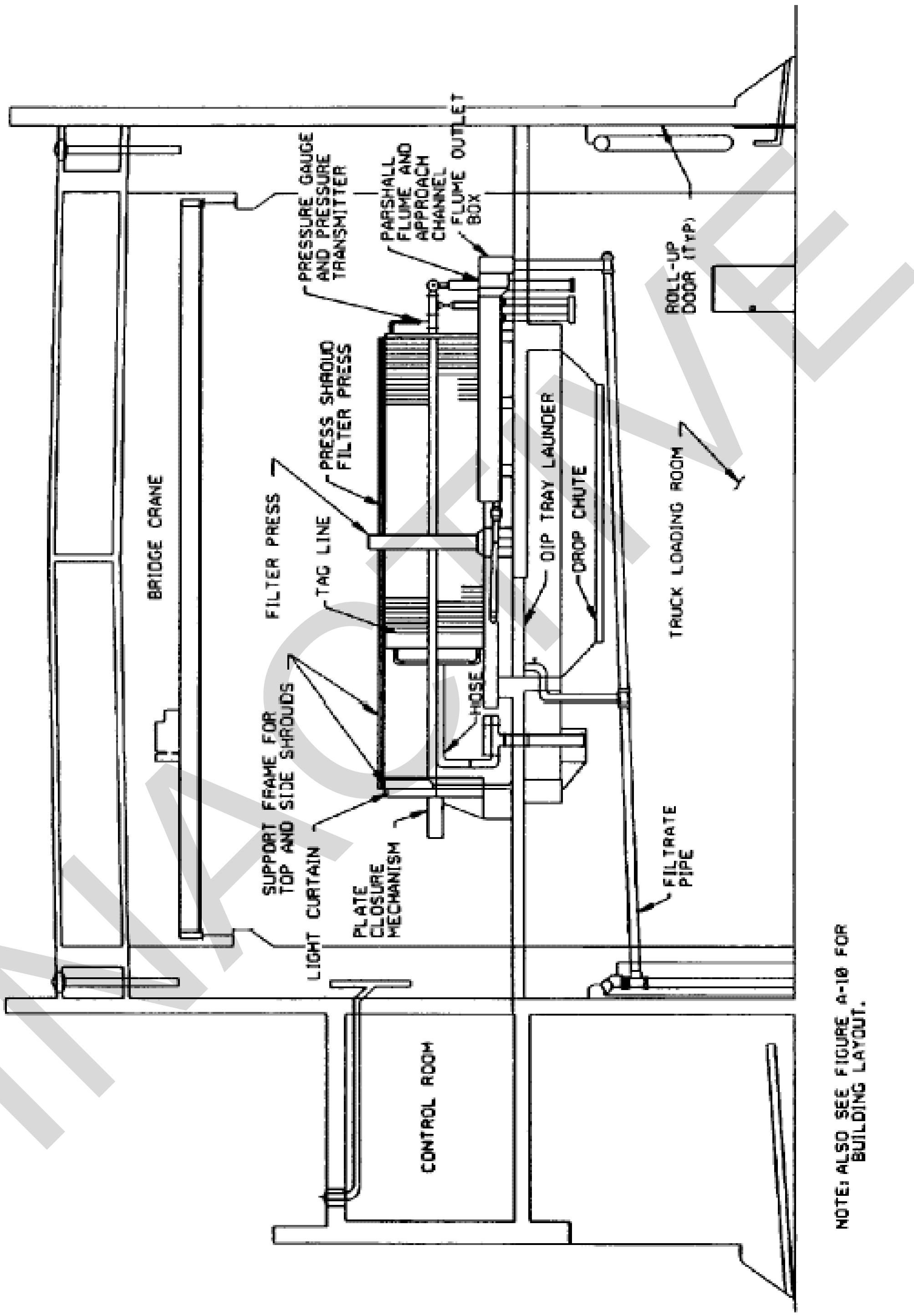


Figure 2-11. Typical building cross section filter press dewatering system (WPCF 1983).

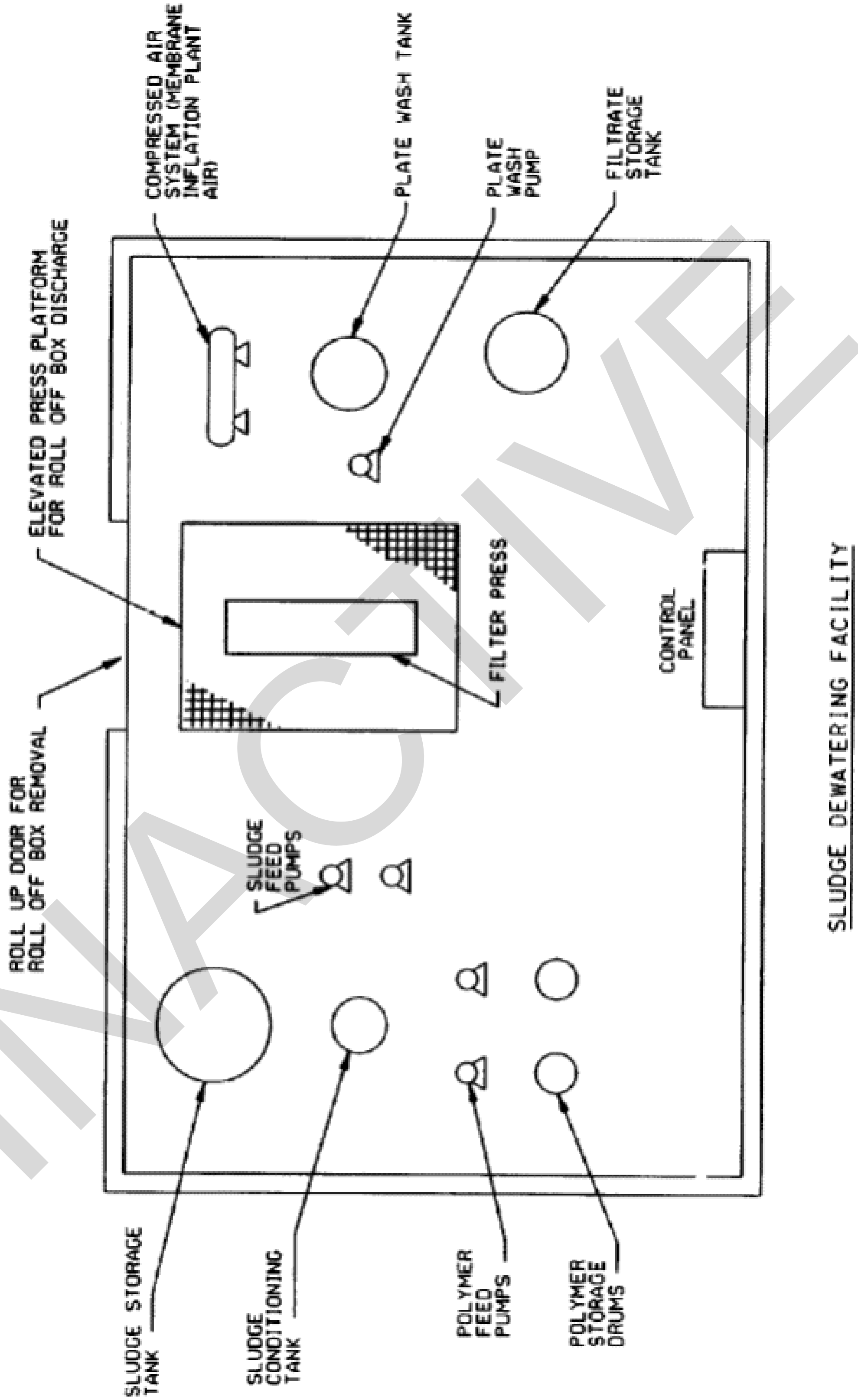


Figure 2-12. Floor plan single filter press dewatering system.

2-9 **OPERATION AND MAINTENANCE**. This paragraph summarizes typical operation and maintenance requirements for plate and frame filter press systems. In addition, a summary of common operational problems and associated remedial measures or process interferences is presented.

2-9.1 **Process Interferences**. Design or operational shortcomings can create process interferences. Although these interferences do not occur frequently, this paragraph provides a discussion of the most common ones, resultant problems, and potential solutions. Process interferences for filter presses can be categorized into the following areas of concern: equipment quality problems, operational problems and concerns, process integration, and auxiliary system selection. A summary of the most common design and operational shortcomings and potential remedial measures is presented in Table 2-9.

2-9.1.1 **Equipment Quality Problems**. Major equipment problems include plate deflection, filter cloth wear, and stay boss deterioration.

2-9.1.1.1 **Plate Deflection**. Plate deflection can be caused by several factors, including high differential pressure across the filter plates, residual sludge buildup on plates, and uneven sludge distribution and cake formation. To reduce the high pressure across the filter plates, the operating pressures may be reduced to lower sludge filling pressure (i.e., 690 kPa [100 psi]). Although some applications require higher pressures to achieve desired dewatering results (i.e., 1550 kPa [225 psi]), most do not. For example, a lower pressure unit (i.e., 690 kPa [100 psi]) may give the same results as a higher pressure unit (i.e., 1550 kPa [225 psi]) for a non-compressible sludge, such as metals hydroxide sludge. A more detailed explanation of appropriate pressure applications is further given in Tables 2-4 and 2-5. To reduce sludge buildup on plates, they should be washed more frequently. Remedial measures for uneven sludge distribution and cake formation are described in Subparagraph 2-9.1.2.3.

Plate deflection problems are more common with polypropylene than cast iron plates. For example, the life expectancy of a polypropylene plate that is larger than 48 inches square is approximately 5 to 7 years as compared with ductile iron plates, which have been known to be in operation more than 35 years without breaking (EPA 1986).

2-9.1.1.2 **Filter Cloth Wear**. Wear of filter media in areas around the stay bosses and the perimeter of the plates is a frequent problem. As described previously, stay bosses are raised areas on the filter plate that provide additional support and reduce the potential of deflection. As the pressure increases during the filter cycle, these stay bosses and perimeter areas of the plate press against one another. However, during this process, minor deflection may occur that causes a rubbing action and excessive wear to the filter media.

Table 2-9. Most common design and operational shortcomings of filter press installations.

Shortcomings	Resultant Problems	Solution
Improper conditioning chemicals utilized.	Blinding of filter cloth and poor cake release.	Switch conditioning chemicals or dosages.
Insufficient filter cloth washing.	Blinding of filter cloth, poor cake release, longer cycle time required, wetter cake.	Increase frequency of washing.
Inability to transport dewatered cake from dewatering building.	Cake buildup and spillage onto the floor.	Install cake breakers; redesign angle of screw conveyors or belt conveyors to 15 degrees maximum angle. Alternatively, use a heavy-duty flight conveyor.
Improper filter cloth media specified.	Poor cake discharge; Difficult to clean.	Change media.
Inadequate facilities when dewatering a digested sludge with a very fine floc.	Poor cake release.	(1) Try two-stage compression "pumping" cycle with first stage at low pressure to build up dewatered sludge on the filter media before increasing to the second-stage higher operating pressure. (2) If this fails, vary conditioning or install precoat storage and feed facilities.
Feed sludge is too dilute for efficient filter press operation.	Long cycle time and reduced capacity.	Thicken sludge before feeding to filter press.
Sludge feed at only one end of large filter press.	Unequal sludge distribution within the press.	Use equalizing tank or additional pump to feed at opposite end of press.
Source: EPA (1982)		

Remedial measures for this problem include the use of reinforcement, such as an extra layer of material, or use of a different type of material, or the use of stainless steel covers that fit directly over the cloth media and stay boss. However, if the former method is used, care should be taken to ensure that the additional layer of thickness is equal to that around the perimeter of the plate to ensure proper sealing and to minimize the potential for plate deflection.

2-9.1.1.3 **Stay Boss Deterioration**. Stay bosses deteriorate from excessive wear caused by plate deflection. This wear increases the flexing of the plate and ultimately breaks the plate. Therefore, stay bosses should be regularly inspected for deterioration and repaired as required. Stay boss deterioration can also be minimized by following the remedial measures listed for plate deflection in Subparagraph 2-9.1.1.1.

2-9.1.2 **Operations Concerns**. Nonuniform sludge feed distribution, improper sludge conditioning, poor cake release, inoperable safety curtains, inability to estimate the completion of the filter cycle, and lime scaling are all common operational problems. Although these problems may be interrelated with the equipment design, they can also be caused by changes in operations.

2-9.1.2.1 **Sludge Feed Distribution**. Non-uniform feed distribution can cause a pressure differential between plates that results in plate deflection, plate breakage, and excessive wear to the filter media and stay bosses. The primary causes of the non-uniform feed distribution are sludge pump stallout, prefiltration of sludge at the feed end of the press, cloth blinding, and poorly conditioned sludge.

a. The prefiltration problem typically occurs in presses with a large number of plates (i.e., 80 or more) or when air is trapped in the press. The effects of prefiltration include the formation of sludge cake in the initial chambers of the press or prefiltering before all downstream chambers are filled. To remedy this problem, the press can either be prefilled with water prior to starting the sludge filtering cycle and then rapidly filled with sludge, or the sludge can be fed into both ends of the press simultaneously.

b. Blinding of the filter media is another major cause of unequal sludge distribution. Remedial measures to eliminate media blinding include modifying the sludge feed rate, changing to a different type of filter media, and optimizing the uniformity of the sludge feed by proper storage and blending. The release of liquid sludge from the feed core during sludge cake discharge can also result in cloth blinding. This problem may be remedied by using the core blowing option to remove this material prior to cake discharge.

c. Poorly conditioned sludge may also cause non-uniform feed distribution. Improper sludge conditioning and associated remedial measures are described below.

2-9.1.2.2 **Leakage**. During normal operation, there will typically be a small amount of leakage between the filter plates. Generally, with continued solids buildup, the leakage will be reduced. However, excessive leakage can occur because of low hydraulic pressure, wrinkles or holes in the filter media, and filter cake buildup in surface joints.

Remedial measures to minimize or stop leakage are increasing the sludge feed pressure, replacing the filter media, and cleaning or removing sludge cake buildup from surface joints. In addition to these measures, plates with gasketed filter media can be used.

2-9.1.2.3 **Improper Sludge Conditioning**. Several factors may cause improper sludge conditioning, including under-dosing or overdosing with conditioning chemicals or inadequate mixing. To remedy this, the conditioned sludge should be evaluated frequently. Paragraph 2-6 describes in detail sludge conditioning tests.

2-9.1.2.4 **Poor Cake Release**. Poor cake release can be caused by worn or improper filter media, lack of precoating of filter media, or poorly conditioned sludge. The effects of poor cake release result in increased cycle time, increased frequency of filter media washing, and potential filter media damage.

a. There are several remedial measures that can reduce these effects. If the filter media are worn, they should be replaced. If, however, poor cake release still occurs, then a filter media of different construction material, permeability rating, or surface finish may be required.

b. Poor cake release may also result from "too wet or sticky" sludge cake. Use a precoat for this situation. Precoat systems are described in Subparagraph 2-4.6.2.

c. Poorly conditioned sludge may also cause poor cake release. Sludge conditioning should be optimized by doing tests, such as the CST or Buchner funnel test, on the feed sludge and by making the proper chemical dosage adjustments.

2-9.1.2.5 **Slow Filtration Rates**. Many types of sludge (i.e., activated sludge) may have slower filtration rates, longer cycle times, or lower solids content, even with conditioning because of their inherent dewatering characteristics. However, if filtration rates are slower than anticipated and a wet sludge cake is produced, filter media blinding may be indicated. To alleviate this, wash the filter media.

2-9.1.2.6 **Cloudy Filtrates**. At the beginning of the filtration, the filtrate is typically cloudy, unless a precoat or filter aid is used. However, if cloudiness persists, it may mean that the system pressure is too high or fluctuating too much, that the filter media are torn, or that the sludge is poorly conditioned. To remedy these conditions, a lower pressure should be used, the filter media should be replaced, or the conditioning requirement should be adjusted.

2-9.1.2.7 **Determination of Dewatering Cycle Completion**. Because the operator cannot watch the sludge cake form, the end of the filter cycle is typically based on experience from previous runs and, to some extent, on the elapsed cycle time when the filtrate flow has been reduced to a minimum. Because operation of the press involves the interrelationship of several process variables, the successful use of either timing method requires experience with sludge characteristics, conditioning, and press performance. During the dewatering process, these parameters should be monitored to determine if adjustments to conditioning dosages or cycle times are required.

2-9.1.2.8 **Lime Scaling**. Using lime in the sludge conditioning process can cause scaling in the sludge feed piping, on the filter media, and on the filter plates. If scale is allowed to accumulate, the cycle time may be increased, throughput may be reduced, cake release may be a problem, cake dryness may be reduced, and the filter media may be blinded.

Remedial measures to minimize lime scaling are using an acid wash system to periodically remove the scale buildup or changing the conditioning chemicals from lime to polymers. Although polymers may work well in some applications, testing should be done to ensure that dewatering is adequate.

2-9.1.2.9 **Light Curtain Reliability**. The light curtain is designed to protect operators from injury when the closing or plate shifting mechanism is operating. However, equipment corrosion, electrical failure, or faulty alignment of the transmitter and receiver could stop the light curtain from functioning. Because this is a safety device, it must be kept in proper working order and should be checked routinely as part of the operation and maintenance procedures.

2-9.1.3 **Process Integration**. Filter presses experience few process integration problems compared with other treatments or processes. Filter presses can handle nearly all types and mixtures of sludge and operating criteria can be modified because of their batch operation. One problem, however, is non-uniform sludge feed. Although the filter press system can accommodate a variety of sludges, to be most efficient, the sludge feed should be blended and conditioned to maintain the sludge's continuity throughout the filtration cycle.

2-9.1.4 **Auxiliary Systems**. The problems with auxiliary systems include corrosion of pneumatic cylinders and excessive misting from filter media washing systems.

2-9.1.4.1 **Pneumatic Cylinder Corrosion**. Pneumatic cylinder corrosion and ultimate failure can be caused by high moisture levels in compressed air supplied to the filter press. This problem can be resolved by adding drying equipment to the compressed air system.

2-9.1.4.2 **Excessive Misting**. Excessive misting during filter media washing can result in corrosion and failure of mechanical devices, instrumentation, and electrical devices. Remedial measures to reduce or eliminate this problem include using brush assemblies or spray curtains to contain the mist.

2-9.2 **Storage Requirements**. Paragraph 2-4.2 provides considerations for liquid sludge storage, Paragraph 2-4.8 provides considerations for sludge cake storage, and Subparagraph 2-7.3.2.2 provides storage sizing requirements for both liquid sludge and sludge cake.

2-9.3 **Utility Requirements**. Although utility requirements will be specific to the individual facility, a summary of typical requirements for filter presses and supporting equipment is discussed in the following subparagraphs.

2-9.3.1 **Power**. Although power requirements are specific to both the system and equipment used, the typical filter press requires 480 volts, three-phase, 60 Hz power at. This power is typically supplied to a single power distribution system that sends the power to individual motors and equipment requiring the 480 volt/three-phase/60 Hz supplies and to control power transformers that supply power to all other components of the system having lower power requirements (i.e., 120 volt/one-phase/60 Hz).

2-9.3.2 **Emergency Power**. Because the operation of the filter press system is primarily a batch operation, the need for emergency power depends on the overall treatment system and related process system. Therefore, the need for emergency power should be evaluated on the basis on the entire treatment scheme and not just on for the dewatering system.

2-9.3.3 **Air**. Air is typically required for instrument controls (i.e., pneumatic controls), sludge feed pumps (i.e., air diaphragm sludge pump), for core or air manifold blowing, and for inflation of diaphragms for the variable-volume filter press. Air is typically supplied at 690 kPa (100 psi) from the air compressor and should be dry and oil free. If higher pressures are required, an air receiver tank and a pressure regulator should be used in together with the air compressor. Additional design considerations for air compressors and associated equipment are presented in Paragraph 2-4.8.

2-9.3.4 **Water**. Auxiliary water may be required for filter press operations, such as chemical conditioning and preparing an acid wash solution, washing filter media, and inflating the diaphragms for the variable-volume filter press. Specific requirements, rates, and pressures at which auxiliary water will need to be supplied will be specific to both application and equipment. A backflow preventor should be required for all utility water sources to stop cross-contamination of clean water from sludge sources.

2-9.4 **System Startup**. System startup procedures and sequences of operation will vary, depending upon the filter press application and type of equipment used. For example, if the filter press requires sludge conditioning before startup of the pumps that transfer sludge to the conditioning mixing tank, the conditioning chemical should be prepared so that it can be added simultaneously with the raw sludge. In addition to auxiliary systems, the filter press equipment will also have a specific sequence of operation. Typical sequences of operation for fixed-volume and variable-volume filter press systems are described in Subparagraphs 2-9.5.1 and 2-9.5.2, respectively. However, for specific types of equipment used, the manufacturers' or equipment suppliers' startup procedures should be followed and incorporated with the use of other equipment.

2-9.5 **Sequence of Operation**. The paragraphs that follow present typical sequences of operation for both fixed-volume and variable-volume plate and frame filter press systems. The sequences of operations provided are based on the assumptions given for each of the systems described below. The sequence of operation used for actual presses will be based on the type of filter press used and associated supporting systems, such as conditioning, precoating, core blowing and air blowing manifolds, and filter media wash (i.e., water wash or acid wash).

2-9.5.1 **Fixed-Volume Press Operation**. A typical sequence of operation for a fixed-volume plate and frame filter press system is presented below. For the sequence described, it is assumed that the system is semiautomatically controlled and that the press operator has manual control over or override control over several functions of the filtration cycle. It is also assumed that this system is equipped with a variable flow rate/pressure feed pumping system, a filter media precoat system, a core and air blowing manifold system, and both water and acid wash filter media systems. The typical operation sequence is as follows.

2-9.5.1.1 The closure (i.e., hydraulic or electromechanical) device is engaged, closing all the chambers of the press.

2-9.5.1.2 The press is prefilled with water, and the filter media precoat system is engaged. The precoat cycle is then allowed to operate for a minimum of three passes.

2-9.5.1.3 Following the precoat cycle, while a constant pressure is maintained within the press, the sludge feed pump system is started and allowed to fill the press at the specified high flow rate and low pressure.

2-9.5.1.4 After the initial fill period is completed, the pumping system flow rates and pressures should be inversely stepped or adjusted (e.g., flow rate should be decreased and pressure should be increased) until the terminal pressure, minimal filtrate flow, or cycle time is achieved.

2-9.5.1.5 After the filtration cycle is completed, the feed pump system should be shut off, and compressed air should be blown through the feed core and filtrate manifold to remove any remaining liquids.

2-9.5.1.6 The closure device is then opened, and plate shifting and sludge cake discharge is initiated.

2-9.5.1.7 Following sludge cake removal, and as required, the plate and filter media water wash operation is initiated. The water wash consists of the following sequence:

- Start the wash water pumping system.
- Open the filter press.
- Shift and wash one plate at a time.
- After the last plate has been washed, turn off the wash water pumping system.

After completing the water wash, and as required, the filter media are washed in acid. The acid wash consists of the following sequence:

- Close the press and ensure all valves not related to the acid wash system are in the closed position.
- Open the outlet valve to the acid recirculation tank and the valve to the acid feed pump system.
- Start the acid feed pump and allow the chambers of the press to fill. Allow the pump to continue to run and recirculate the acid while occasionally inspecting the press for leakage.

- After completing several recirculation cycles, turn the acid pump off. After the acid pump is turned off, follow with an air blowing cycle, similar to that described for the normal sludge filtration cycle, to purge acid from the filter press.
- Close all acid feed and recirculation valves.
- Open all normal press operation valves.

2-9.5.2 **Variable-Volume Press Operation**. A typical sequence of operation for a variable-volume plate and frame filter press is described below. For this sequence of operation, it is assumed that the variable-volume press system is fully automatic and equipped with a core blowing system and a fully automatic wash system that allows a high-pressure water wash on both sides of the filter media. The typical automatic operation sequence is as follows:

2-9.5.2.1 The closure device is engaged, closing all the chambers of the press.

2-9.5.2.2 The feed pump is started, and the feed is introduced at the initial specified fill flow rate and pressure.

2-9.5.2.3 After the initial fill cycle is completed, high-pressure water is pumped into the diaphragms at the minimum specified pressure, causing the diaphragms to expand and the sludge to dewater to its appropriate dryness.

2-9.5.2.4 After the sludge is dewatered to the appropriate dryness, the feed pump is stopped and compressed air is blown through the feed pipe and filtrate manifold to remove any remaining liquids. The water in the diaphragms is also removed, and the diaphragms are returned to their original position.

2-9.5.2.5 The hydraulic closure device is then depressurized and the filter plates are separated, allowing the sludge cake to discharge.

2-9.5.2.6 Following sludge cake removal, the filter media are washed on both sides, if required, and then returned to its original position.

2-9.6 **Maintenance Requirements**. Maintenance for filter presses includes measures to keep normal operation on track, such as cleaning and lubrication, and preventive maintenance, such as periodic inspections and replacement of worn equipment. A summary of typical parameters and schedule of normal and preventative maintenance is presented in Table 2-10.

Table 2-10. Typical parameters and schedule for normal and preventive maintenance for filter press equipment.

General Category	Item	Daily	Weekly	Monthly	Annually
Plate and	Check for cloth holes or cloths out of	X			

Cloth	caulking grooves				
	Replace gaskets that have cuts, abraded areas, or separations (if applicable)	X			
	Clean sealing areas of excessive solids buildup	X			
	Wash cloths with either water or acid or both		X		
	Replace cloths and gaskets				X
Hydraulics	Inspect for leakage	X			
	Check for correct clamping pressure	X			
	Check for correct relief valve setting		X		
	Check oil level in hydraulic reservoir		X		
	Replace oil in hydraulic reservoir				X
	Clean oil filter element			X	
	Replace oil filter element				X
Pneumatics	Bleed water traps to plant water to press and feed pumps	X			
	Clean, or replace, air filter elements • Hydraulic Cabinet • Shifter • Feed Pump		X	X X	
	Clean Exhaust Silencers • Hydraulic Cabinet • Feed Pump		X	X	
	Clean Plate Shift or Guide Rods			X	
* More frequent filter medial washing with water may be required.					

2-9.6.1 **Cleaning**. Equipment should be cleaned for general housekeeping as well as for maintaining it in proper operating conditions.

2-9.6.1.1 **Filter Plates and Filter Media Cleaning**. Cleaning of filter plates and filter media is an important aspect of maintaining filter press performance, as well as preventing damage to equipment. During the filter cycle, sludge particles remain on the filter media owing to repeated use or because of poor cake release and eventually become imbedded in the cloth, causing blinding. Blinding results in poorer sludge cake quality and longer cycle times because a less effective area is available for filtrate to exit. Blinding can also result in plate damage from deflection caused by unequal filter cake formation and unequal pressure distribution.

As described previously in Subparagraph 2-4.6.3, two types of filter plate and media washing systems can be used, depending on the specific filter press application. Filter media water washing systems are described in detail in Subparagraph 2-4.6.3.1. The frequency can be based on experience and the operator can occasionally check the media for buildup of residual cake deposits and monitor the cumulative filtrate flow versus time intervals that occur over the normal filtration cycle.

Acid washing, as described in Subparagraph 2-4.6.3.2, is used primarily for filter presses that include chemical conditioning with lime. This type of washing is used to free impregnated solids, such as lime scale buildup, that cause a decrease in the filter loading rate and an increase of the filtration cycle time.

2-9.6.1.2 **Other Cleaning Considerations**. In addition to plate and filters, the hydraulics and pneumatics also need to be clean. Elements that may require periodic cleaning or replacement include oil and air filters. A summary of periodic cleaning requirements is presented in Table 2-10. In addition to these items, additional recommendations for periodic cleaning are provided by manufacturer's specifications.

2-9.6.1.3 **Additional Housecleaning Design Considerations**. A major component that requires housecleaning is the sludge cake handling system. For example, the cake handling system may consist of a conveyor that may bounce and roll and cause sludge to splatter or cling and accumulate at each transfer point. A cake breaker may also contribute to these effects. To remedy this situation, the number of transfer points and distances of drop should be minimized. Other remedies include the use of flexible chutes and skirt boards. V-shaped or rounded drip trays that are wider than the conveying system can also be installed beneath the conveyer to collect wash down water and allow it to drain. Additional housekeeping design considerations for direct disposal of sludge cake into storage receptacles are also presented in Subparagraph 2-4.8.2.

2-9.6.2 **Lubrication**. All moving parts that are subject to wear should be lubricated. As shown in Table 2-10, several areas of the filter press require normal preventative maintenance and lubrication. For the specific applications, the press manufacturer's specifications should be followed. Accessible grease fittings should be provided for grease-type bearings and those bearings should be provided with relief ports to prevent buildup of pressure that may damage them or their seals. The oil reservoir should also be liberally sized, properly vented, and have an overflow opening to prevent overfilling.

In addition to lubricating the filter press equipment, supporting equipment such as air compressors should be periodically lubricated. For the frequency of maintenance and specific lubrication details, the specific manufacturer's details should be followed.

2-9.6.3 **Inspections**. In addition to cleaning and lubrication, periodic inspections are also an important aspect of preventative maintenance. Inspections of the plates and filter media can find torn filter media at the stay bosses or perimeter of the plates, stay boss deformation, or plate warping that may indicate uneven pressure distribution or plate deflection. These effects may eventually break the plate.

In addition to inspections for adverse wear, inspections for normal maintenance should also be done. A summary of typical parameters and schedules for periodic inspections for filter press equipment are presented in Table 2-10.

2-9.7 **Safety Considerations**. Inadvertent operation of the machinery while it is being serviced is a primary hazard. Operation practices and precautions should be used to prevent accidents.

2-9.7.1 **Safety Features**. The most common safety features on filter presses are fixed guards and light curtains, which prevent injury by preventing access while plates are being shifted. Detailed descriptions of these features are presented in Subparagraphs 2-4.5.6.1 and 2-4.5.6.2, respectively.

2-9.7.2 **Other Safety Considerations**. Other areas of safety concern include protection from over-pressurization, proper chemical storage and handling, and adequate ventilation. Additional information on these safety considerations are presented in EPA (1986), WPCF (1983), and WEF (1992).

2-9.8 **Heating and Ventilation**.

2-9.8.1 **Heating**. Heating requirements are a typical part of building design and depend on site conditions (WPCF 1983). In general, the area around the press should be heated to prevent any freezing. The temperature should be kept as constant as possible because temperature can affect sludge dewatering characteristics. In addition to adversely affecting the sludge, temperature can also affect the filter press equipment. For example, in installations where rubber-coated steel plates are used, the filter press and plate storage area should be maintained above 4 degrees C (40 degrees F) to prevent thermal contraction and resulting damage.

2-9.8.2 **Ventilation**. The area of the filter press should be properly ventilated for operator comfort, odor reduction, and protection from fumes (WEF 1992). The area where the sludge is conditioned is the primary concern because odors and fumes are generated there. For example, when sludge is conditioned with lime and ferric chloride, the pH rises and significant amounts of ammonia may be generated and released in the conditioning tank and filter press. The minimum ventilation rate should be six air changes per hour for summer and three air changes per hour for winter (EPA 1986). Fumes may also be emitted when the press is opened. Therefore, covering and ventilating the area around the conditioning tank and filter press should be considered. More detailed information on the design considerations for ventilation systems is presented in WEF (1992).

2-10 **DESIGN AND CONSTRUCTION PACKAGE**. The design and construction package for the filter press sludge dewatering system should include a design analysis, drawings and plans, and project specifications (can be generated from guide specifications). This design and construction package can be used as a stand-alone or integrated into an overall HTRW treatment plant design and construction package. The paragraphs that follow provide a brief overview of the elements of the design analysis, drawings, and guide specifications. In addition to the information provided below, a description of general types of design calculations required is presented in Chapter 3 and a checklist of design documents and associated elements is presented in Chapter 4.

2-10.1 **Design Analysis**. The design analysis should be conducted in accordance with ER 1110-345-700. For filter press applications, the design analyses should include, but not be limited to, items such as:

2-10.1.1 A tabular summary or description, or both, of the characteristics of the untreated sludge and desired sludge cake characteristics including:

2-10.1.1.1 Influent characteristics (i.e., flow rate, influent solids concentration, pertinent chemical characteristics).

2-10.1.1.2 Conditioning requirements (i.e., chemical dosages).

2-10.1.1.3 Desired performance requirements (i.e., percent solids in sludge cake) and a description of the methods used for disposal of waste streams.

2-10.1.2 A tabular summary and description of the filter press and the auxiliary systems used with the press (i.e., filter media washing systems) and supporting systems (i.e., sludge feed systems, etc.). This information should include:

2-10.1.2.1 A brief description of each component and its relation to other components within the dewatering system.

2-10.1.2.2 Number of each component required, type, designation (number), and size or capacity.

2-10.1.2.3 Design demand and related design criteria (i.e., pressures, pumping requirements, etc.).

2-10.1.3 A description of controls, instrumentation, and proposed operating sequence. This description should not only address how the dewatering equipment will be interfaced within the dewatering system, but also should address how the dewatering system is interfaced with the treatment processes that generate the sludge and other related processes.

2-10.1.4 All calculations necessary to support the sludge generation capacity, equipment sizing, and chemical dosages, for example.

2-10.1.5 Examples of manufacturer's literature for the supplied equipment.

2-10.2 **Drawings and Details for Bidding and Construction**. Design drawings should be provided for all dewatering systems and equipment described in the design analysis in sufficient detail to permit construction. The design drawings should include provisions for indicating interfacing with other treatment processes. Drawings that should be provided and coordinated with other treatment process drawings include the following:

2-10.2.1 A site plan showing the major components of the dewatering system and their relationship to existing facilities.

2-10.2.2 A flow schematic diagram or diagrams showing process flow, solids handling, and chemical feed systems, for example.

2-10.2.3 A building layout, including a floor plan showing equipment layout and piping with tentative sizes.

2-10.2.4 A cross section through each building showing pertinent elevations and pipe locations.

2-10.2.5 A complete equipment layout that includes all major equipment components, auxiliary and supporting systems, and required piping, valves, meters, and pumps.

2-10.2.6 A complete control system layout that includes all major equipment components, auxiliary and supporting systems, and required piping, valves, meters, and pumps.

2-10.2.7 A diagram of utility routing and requirements.

2-10.3 **Project Specifications**. Project specifications should be prepared based on the standard guide specification CEGS 11360. The guide specifications should be adapted to each specific application. Therefore, as required, the standard guide specification should be edited to include both general and technical specifications for major equipment, auxiliary and supporting systems, accessories, special material or installation requirements, and any references to related specifications.

CHAPTER 3

DESIGN CALCULATIONS

3-1 **INTRODUCTION**. This chapter describes the general types of calculations that may be required for filter press applications. Based on the specific type of sludge being dewatered, sludge dewatering conditions, and the specific type of equipment and accessories used, additional calculations may be required. Although the calculations that are described refer primarily to filter presses, several of these calculations depend on, or should be used in conjunction with, other calculations that should be used in the development of the design for the entire treatment process or treatment facility. Design examples illustrating the use of several of these calculations are presented in Chapter 5.

3-2 **PURPOSE**. Filter press design calculations primarily provide design criteria for sizing equipment for editing guide specifications and developing construction drawings. Based on the preliminary selection of equipment, additional calculations can also determine parameters such as utility requirements and supporting mechanical and electrical distribution systems.

3-3 **DESIGN BASIS AND DATA SOURCES**. Several types of data sources can be used for the basis of the design calculations. Typical sources of data include pre-engineering design reports and treatability studies, standard reference materials, and other sources such as telephone conversations. Any source of data or basis used for the design calculations should be identified and referenced appropriately in the design analysis.

3-3.1 **Pre-engineering Design and Treatability Studies**. Pre-engineering design reports and treatability studies (i.e., laboratory, bench-scale or pilot scale testing, or all three) are typically used as the basis of the design calculations. Before doing the filter press design calculations, the following specific parameters should be identified, if possible, from these sources:

- Sludge flow rates and solids concentration from each process generating sludge.
- A representative or composite density or specific gravity of the wet sludge feed stream or streams.
- A determination of sludge conditioning chemical dosages required, usually based on a weight percent of dried sludge solids.
- Minimum dry solids allowed in the cake by percent weight of wet sludge feed.
- A representative or composite density or specific gravity of the wet sludge cake.
- A determination of the sludge cake thickness.
- A determination of the filtrate solids content.
- A determination of operating time (i.e., 8 hour/day).

- Total cycle time, which includes all time required for sludge filtration, cake discharge, and all other related time requirements (i.e., core blow).

Each data source used should be clearly identified within the design calculation and properly referenced with the date, title, or other pertinent information that will identify the data source and its validity.

3-3.2 **Reference Materials**. Data and information from reference materials, other than data from pre-engineering design and treatability studies, can be also used for filter press design calculations. Reference materials consist of applicable codes, standards, textbooks, standard tables, and manufacturers' catalogs and examples of manufacturers' literature. Each source used should be properly referenced with the date, title, issue, or other pertinent information.

3-3.3 **Telephone Conversations Records**. In addition to reference and design data from the design analysis report, telephone conversations to equipment suppliers and manufacturers and regulatory agencies may also be used for the design calculations.

3-4 **COMPOSITION AND CONCENTRATION DEPENDENT CALCULATIONS**. Composition and concentration calculations provide the design basis for sizing the filter press equipment and for related operation requirements. These types of calculations can be categorized as pretreatment calculations and process calculations.

3-4.1 **Pretreatment Calculations**. Pretreatment calculations include those that are required to provide the initial basis for sizing equipment and process conditions, such as calculating mass balance and determining the required filter press volume.

3-4.1.1 **Mass Balance Calculations**. The mass balance calculations should be based on previously determined hydraulic flow rates and solids concentrations for each sludge generating stream to determine the total mass flow rate of sludge to be dewatered. This calculation is based on the mass balance equation:

Mass out = Mass in.

The "mass out" term refers to the total solids to be removed by dewatering. This term is determined from the "mass in" term, that is determined by the summation of mass flow rates from each sludge generating unit as determined from multiplying the sludge flow rate by solids concentration from each unit. The sludge generating units may consist of clarifiers or biological treatment units, for example. To aid in these calculations, a flow schematic showing both hydraulic flow rates, solid concentrations, and mass flow rates to and from each process unit should be developed.

Based on the calculation of total daily mass of sludge generated , other process calculations can determine the filter press volume and related sludge storage, chemical feed systems, and other filter press accessories.

3-4.1.2 **Filter Press Volume**. Based on the calculation of the "mass out" term of the mass balance equation, the volumetric filter press capacity can be determined by the following equation:

> Cake volume produced per day = [(weight sludge dried solids per day) x (1 + fraction of conditioning chemical(s))] / [(% cake solids content) x (wet sludge cake density)]

Based on this volumetric calculation and the previously determined parameters, the filter press can be sized based on the following calculation:

> Filter press volume capacity per cycle = [(cake volume produced per day) x (hour per cycle)] / [operating period (hour per day)]

Based on this capacity, a filter press should be selected from manufacturers' information. The filter press selected and the accessories required can then be used to determine utility requirements and subsequent sizing of other equipment.

3-4.2 **Process Calculations**. Process calculations include those that determine design criteria and sizing of storage containers, chemical feed systems, and accessories.

3-4.2.1 **Storage Calculations**. Several types of storage containers may be required for filter presses, including tanks for storage of sludge, sludge conditioning, filter precoat, filter media wash, acid wash, and sludge cake storage.

In general the sizing of these storage containers is either based on the amount of detention required, or the frequency, duration, and quantity of material required for the normal filter press operation.

3-4.2.1.1 **Sludge Storage**. The amount of storage required for the raw sludge is very site specific and depends on requirements for equalizing flow and on sludge characteristics, in addition to retention in a treatment process tank. A general rule provided by the "Ten States Standards" is that a minimum of 4 days of storage shall be provided for mechanical dewatering facilities unless other standby wet sludge facilities are available (GLUMRB 1990). In general, the sludge storage capacity can be calculated by the following equation:

> Sludge storage volume requirement = (Volume of sludge produced per day) x (Number of days required for storage)

3-4.2.1.2 **Sludge Conditioning Storage**. The size of the sludge conditioning tank will be based on the amount of sludge to be processed and the conditioning chemicals required. In general, vertical, cylindrical tanks equipped with a mixer and high and lower level indication will be used for this. Based on the quantities of sludge and conditioning chemicals required, a working volume should be calculated by the following equation:

> Working volume of tank per cycle = (Volume of raw sludge per cycle + Volume of conditioning chemicals required per cycle)

Based on this working volume, the diameter and working height of the tank should be determined. As a final step in determining the total height required for the sludge storage container, height allowances should be provided in both the top and bottom of this storage container to allow for high and low level indicators, as well as providing adequate freeboard to reduce the potential for overfilling, excess volume for moderate and vigorous mixing, and any anticipated excess storage volume.

3-4.2.1.3 **Precoat Storage**. If required, the filter media will be precoated before the filtration cycle and a storage tank must be provided. As a general rule of thumb, the tank for the precoat system should be approximately one and one-half times the volumetric capacity of the filter press.

3-4.2.1.4 **Filter Media Wash Storage**. The size of the filter media wash tank should be based on the filter media washing requirements (duration and frequency) of the specific filter press. The total volume required should be equal to the working capacity of the tank calculated in Subparagraph 3-4.2.1.2.

3-4.2.1.5 **Acid Wash Storage**. The size of the acid wash storage depends on the acid wash requirements (frequency and duration) of the specific application. The calculation of the working capacity and total size required should follow the method described in Subparagraph 3-4.2.1.2.

3-4.2.1.6 **Sludge Cake Storage**. The size of the sludge cake storage is very application specific and will be based on the method of disposal or frequency of disposal. For example, for an intermittently operated filter press unit, such as a unit that is operated only once a week, only weekly up to monthly storage should be provided. However, for continuously operated filter presses, such as those working several cycles per day, the minimum storage capacity should be determined on the basis of the daily sludge cake volume produced, with additional allowances for up to several days of storage for contingencies related to transportation. Additional storage considerations are also presented in Paragraph 2-4.8.

3-4.2.2 **Chemical Feed Systems**. Chemical feed systems for filter presses may include those required for sludge conditioning, filter media precoating, and filter media acid washing.

3-4.2.2.1 **Conditioning Chemicals Feed Systems**. The chemical feed dosages for each type of conditioning chemical required is determined from treatability studies, and are usually expressed as a percentage of the sludge on a dry weight basis. Based on the mass flow rate of sludge to be generated and the percent of chemical dosage required, the chemical dosage required can be determined from the following equation:

Chemical dosage per day = [Mass flow rate of sludge (weight per day)] x [Percent of chemical required based on sludge dried solids]

In addition to the daily dosage requirements, the storage requirements can be determined based on the daily dosage, concentration of chemical purity if less than 100%, and typical desired storage period. Typically, a 30-day storage period is required for conditioning chemical storage. The chemical feed system's storage requirements can be calculated by the following equation:

Chemical storage requirement = [(Daily dosage) x (storage period)] / [chemical purity]

Additional calculations are required for the conditioning chemical feed systems, including the pure chemical feed system, chemical feed solution preparation and mixing tanks, and solution metering systems. Because these requirements and related calculations are specific to the types of conditioning chemicals for each filter press, no specific calculations are provided in this chapter. However, a discussion of chemical feed systems is presented in Subparagraph 2-4.6.1.

3-4.2.2.2 **Filter Media Precoat Feed System**. For filter press applications, pure precoat material storage and feed, precoat preparation (tank storage), and precoat slurry feed need to be calculated. Because the type of precoat material and dosage required is specific to each filter press, no calculations for precoat material feed systems are provided in this chapter. However a discussion of precoat systems is provided in Subparagraph 2-4.6.2. In addition, a discussion of calculating precoat preparation and storage is presented in Subparagraph 3-4.2.1.3, and calculations required for pump sizing can follow the general guidelines provided in Paragraph 3-5.

3-4.2.2.3 **Acid Filter Media Wash Systems**. For the acid filter media wash system, calculations include sizing the supplied acid storage tank, supplied acid feed pumps, acid wash dilution tank, and acid wash feed pumps. The specific requirements for the components of this system depend on the specific requirements of the filter press (i.e., frequency and duration) in addition to the purity of the acid supplied; therefore, no specific calculations are described in this paragraph. However, a description of design considerations for acid wash systems is provided in Subparagraph 2-4.6.3.2. In general, the tank calculations for this system should follow the method presented in Subparagraph 3-4.2.1.5, and the pump calculations should follow the method presented in Paragraph 3-5.

3-4.2.3 **Additional Accessories**. Additional accessories, including pumps and air compressors, will require design calculations. The calculations required for pumps are discussed in this chapter in Paragraph 3-5 and air requirements and air compressors are discussed in Paragraph 3-7.4.

3-5 **FLOW-DEPENDENT CALCULATIONS**. Flow-dependent calculations are primarily required for pumps and piping distribution systems used within the filter press application. The typical pumps are those required for sludge feeding, the chemical conditioning feed pump, the precoat feed pump, and the filter media water wash and acid wash pumps. Although different types of pumps may be required, the basic calculations for sizing these pumps are similar and include determining the volumetric capacity and pressure requirements.

Calculate the volumetric capacity on the basis of the frequency, duration, and overall quantity required for each specific application. The total pressure requirement is calculated based on the total head requirements of the system, which includes the summation of both the static and dynamic heads within the system. An additional safety factor of 10 to 25% should be added to the dynamic pressure to reduce the effects caused by the thixotropic characteristics of the sludge.

3-6 **EQUALIZATION REQUIREMENTS AND VARIATION ALLOWANCES**. The objective of sludge flow equalization and variation allowances is to provide sludge that contains similar characteristics for each filtration cycle.

3-6.1 **Maximum Conditions**. The design and equalization requirements and variation allowance for maximum conditions can be handled in several different ways. However, these approaches are specific to an application and typically do not require calculations. The first method would be to size the equipment and associated system based on an average of 30 consecutive days of sustained flow and solids loading. In general, this method would cause oversizing of equipment typically required. However, if this approach uses several presses to process the sludge generated at the maximum flow conditions, the number of presses operating during an average flow condition could be reduced to handle only the average flow.

A second approach consists of basing the design on the average flow of an average operating day and providing adequate storage for maximum flow conditions, then processing the additional sludge with increased operating periods. To illustrate this approach, assume the daily average flow was typically processed within 8 hours. To process the sludge during maximum flow, an additional operating shift could be used to process the sludge until average conditions resumed.

3-6.2 **Minimum Conditions**. Although typically the design of the filter press is based on maximum or average requirements, and no calculations are based on minimum flow conditions, the minimum flow condition should be considered. However, several possible approaches can be used to address minimum flow conditions: providing storage until enough sludge is generated to complete average flow filtration cycle; reducing the number of filtration cycles over a typical operation period; using a blanking plate to cut down the volume of sludge being dewatered if a single filter press is being used; or cutting down on the number of units used if a multiple press system is used.

3-7 **SUPPORT UTILITY REQUIREMENTS**. Based on the initial selection of equipment, requirements for ventilation, power, water, air, telephone, and other utilities can be calculated. Although some of these calculations may be determined as requirements for the entire treatment facility, incremental calculations may be required that apply specifically to equipment or facilities required for filter press applications.

3-7.1 **Special Ventilation Systems**. Typically heating, ventilation, and air conditioning calculations are done for the entire treatment facility and are not specifically for the filter press. Under normal conditions, as described in Subparagraph 2-9.8.2, the minimum ventilation rate of six air changes per hour for summer ventilation and three air changes per hour for winter ventilation should be applied. However, for specific areas, such as those where dust (i.e., lime conditioning) or odor (i.e., ammonia) are possible, additional ventilation and calculations may be required.

3-7.2 **Power Requirements**. Several types of calculations for power requirements can be used in the design of a filter press, including a normal load and lead protection analysis, a ground fault current analysis, and lighting analysis. These types of calculations are usually performed as part of the electrical calculations for the entire treatment facility. Because these calculations are specific to an application and equipment, only a description follows.

The normal load and load protection analysis consists of determining electrical loads for the filter press and associated components, such as pumps and controls. Once the load analysis is completed, a load protection analysis is then conducted to ensure the proper design and placement of circuit transformers for the over-current protection of individual components. The ground fault current analysis also determines the rated listing for individual component.

In addition to direct power requirements, lighting calculations are typically provided with power calculations. However, the lighting requirements are typically provided with the entire treatment facility's general lighting calculations, unless special light requirements for platforms, mezzanines, or catwalks are required.

3-7.3 **Water Requirements**. Filter presses require water for fire protection as well as potable water. Water requirements for fire protection are typically calculated for the entire treatment facility. Potable water requirements are based on frequency, duration, and quantity required for each specific system within the filter press. Typical requirements for potable water are dilution water for conditioner preparation, water to prepare precoat slurry if filtrate water cannot be reused, water for the filter media wash, and dilution water for filter media acid wash. Based on the specific requirements for each of these uses, the quantity of potable water required and associated distribution systems will be calculated.

3-7.4 **Air Requirements**. In general, air requirements are calculated on the basis of the frequency, duration, quality, and pressure of air required for several functions within filter press applications, including pneumatics operating the press, such as hydraulic press opening/closing and plate shifting, in addition to accessories such as air operated pumps, core and air blowing systems, inflation systems for diaphragms for variable-volume filter presses, and pneumatically operated controls. Typically, two types of air quality are required: instrument air and plant air. The instrument air is typically passed through an air cooler and air dryer to produce a dry, quality air required for pneumatically operated controls. Although two types of air are required, only one air compressor system is typically necessary. Therefore, calculations for the air system include those for sizing the air compressors and those for sizing air distributions systems. Because the specific calculations are equipment specific, only a description of calculations that may be required are presented in this chapter.

The air compressor system is typically sized on the basis of calculation of the sum of the air requirements and the highest pressure required. The air is then sent to the air distribution system via of pressure regulators.

Additional calculations for the distribution systems include those required for sizing storage receivers, air dryers, and distribution piping. These calculations are primarily based on the specific air requirements for each individual demand.

3-7.5 **Telephone Line Requirements**. Telephone lines for remote alarms are typically not designed specifically for filter presses. The specific requirements are typically determined for the site conditions, and specific control outputs requiring remote alarms are specified within the guide specification along with other controls requiring remote alarms within the treatment facility.

3-7.6 **Other Utility Requirements**. Other utilities that may be required for filter presses include natural gas. Natural gas may be used indirectly for general heating, sludge drying, and sludge incineration. Natural gas needs for a filter press are primarily determined in conjunction with the requirement of the entire treatment facility. Typically, quantity and pressure required, and sizing of the specific distribution systems are calculated.

3-8 **ADDITIONAL REQUIREMENTS**. In addition to the process, mechanical, and electric calculations, additional design calculations may be required for a filter press. For example, architectural requirements such as determining aisle space, equipment clearances, and storage space; structural requirements for the filter press, supporting accessories, and chemical storage; operation and maintenance provisions; and health and safety requirements need to be calculated. However, these calculations are application-specific.

CHAPTER 4

CHECKLIST FOR DESIGN DOCUMENTS

4-1 DESIGN ANALYSIS

4-1.1 Process Description

4-1.1.1 **Sludge Characteristics**
4-1.1.2 **Conditioning Requirements**
4-1.1.3 **Performance Requirements**
4-1.1.4 **Description of Equipment and Controls**

4-1.2 Calculations

4-1.2.1 **Solids Management Calculations**
4-1.2.2 **Equipment Sizing**
4-1.2.3 **Conditioning Feed**

4-1.3 Records

4-1.3.1 **Correspondence**
4-1.3.2 **Manufacturers Literature**
4-1.3.3 **Environmental Criteria**

4-2 PLANS

4-2.1 Process Flow Diagrams (Liquid and Solid)

4-2.2 Equipment Layout Plan

4-2.3 Piping and Plumbing Plans, Sections, and Details

4-2.4 Process and Instrumentation Diagrams (Control Schematics)

4-2.5 Connection Details

4-2.6 Coordination with other Disciplines

4-2.6.1 **General Plans (Drawing Index, Legend and General Notes, Abbreviations)**
4-2.6.2 **Structural Plans (Concrete Slab and Foundation Plans)**
4-2.6.3 **Architectural Plans (Interior and Exterior Elevations)**
4-2.6.4 **Mechanical Plans (Hydraulic Profiles of Liquids and Solids, HVAC Plans and Details)**
4-2.6.5 **Electric Plans (Line Diagrams, Power and Control Plans)**

4-3 **GUIDE SPECIFICATIONS**

4-3.1 **Equipment Sizing (Based on Design Analysis Calculations)**

4-3.2 **Filter Press Components**

4-3.3 **Accessories (Coordinate with Other Guide Specifications)**

4-3.3.1 **Sludge Pumps Specifications**
4-3.3.2 **Sludge Storage/Handling Specifications**
4-3.3.3 **Chemical Feed Systems Specifications**
4-3.3.4 **Compressed Air (Plumbing) Specifications**

4-3.4 **Special Material Requirements (Coordinate with All Guide Specifications)**

4-3.5 **Related Specifications**

4-3.5.1 **Electric Work Specifications**
4-3.5.2 **Plumbing and Piping Specifications**
4-3.5.3 **Installation (Concrete and Welding) Specifications**

4-4 **OPERATION AND MAINTENANCE MANUALS**

4-4.1 **O&M Procedures**

4-4.1.1 **Startup Procedures**
4-4.1.2 **Operating Procedures**
4-4.1.3 **Shutdown Procedures**

4-4.2 **Specifications and Plans**

4-4.2.1 **Equipment Specifications (Manufacturer's Name, Model Number, Description of Operating Functions)**
4-4.2.2 **Equipment Plans (Piping, Valve, Wiring, and Control Layouts)**

4-4.3 **Equipment Catalogs**

4-4.3.1 **Descriptive Data (Bulletins and Cut Sheets)**
4-4.3.2 **Parts List (Required and Spare)**

4-4.4 **Service Requirements**

4-4.4.1 **Utility Requirements (Air, Electric, Water)**
4-4.4.2 **Maintenance Instructions (Routine Procedures, Breakdowns and Repairs)**
4-4.4.3 **Troubleshooting Guide**

CHAPTER 5

DESIGN EXAMPLES

5-1 **DESIGN APPROACH FOR PLATE AND FRAME FILTER PRESS APPLICATIONS**. Following is a typical approach for designing a plate and frame filter press and supporting systems for sludge dewatering, as well as basic information that is required.

5-1.1 Develop sludge characteristics and perform a mass balance based on the design flow rate around each treatment process generating sludge. From this analysis the following information should be obtained:

- Design flow rate of sludge generated per day.
- Sludge solids concentration.
- Whether the sludge requires pretreatment or is stabilized.

5-1.2 Determine the method of ultimate sludge cake disposal and associated requirements. From this, the following information should be obtained:

- Maximum allowable moisture content of the sludge cake.
- Design criteria from the concerned regulatory agencies, including any contaminant-specific disposal criteria.

5-1.3 Evaluate existing or proposed treatment site conditions, such as space, and determine how this will interface with existing or proposed treatment units.

5-1.4 Determine the need or type of conditioning required for proper dewatering. For plate and frame filter presses, this typically includes bench scale or pilot scale testing to establish the type and dosages of chemical conditioning required, mixing requirements, and reaction period.

5-1.5 Develop design data for selecting dewatering equipment. From this process, the following information should be obtained:

- Operational period.
- Filter press solids-loading rate.
- Cycle time.

5-1.6 Obtain manufacturers' catalogs and equipment selection guides.

5-1.7 Evaluate operational characteristics of the equipment, including energy requirements, specialized maintenance requirements, performance reliability, and simplicity of operation.

5-1.8 Prepare equipment design layout (i.e., engineering drawing and details) and design analysis. The design analysis should include a detailed description of the dewatering process and supporting calculations.

5-1.9 Prepare project equipment specifications from guide specifications.

5-2 **DESIGN EXAMPLES**. Following are three examples that follow the design approach described in Paragraph 5-1 of this chapter and design calculations presented in Chapter 3. The design criteria presented in these three examples are primarily based on information presented in Paragraph 2-4 and other referenced paragraphs of Chapter 2.

5-2.1 **Design Example Number 1**. This is a design example with supporting calculations for sizing a sludge-dewatering system.

5-2.2 **Assumptions**. The following assumptions and criteria are used for the design of the sludge-dewatering system.

5-2.2.1 The characteristics of the sludge stream are given below.

- Assumed type of sludge: chemical/biological
- Design liquid sludge flow = 37,850 L/d (10,000 gpd)
- Concentration of solids = 2%
- Specific gravity of feed = 1.0

5-2.2.2 The minimum dry solids allowed in the sludge cake will be 30% by weight.

5-2.2.3 A fixed-volume recessed plate filter press will be used for this example. Typical ranges of design criteria for this type of filter press are presented in Paragraphs 2-3 and 2-4.

5-2.2.4 This example assumes that treatability testing has been done and the following design data were obtained.

5-2.2.4.1 **Sludge Cake Characteristics**.

- Cake thickness = 32 mm (1.25 inch)
- Wet cake density = 1280 kg/m^3 (80 lb/ft^3)

5-2.2.4.2 **Optimum Chemical Conditioning**.

- Lime dosage (CaO) = 10% by weight of dried solids
- Ferric chloride dosage ($FeCl_3$) = 5% by weight of dried solids

5-2.2.4.3 **Dewatering Equipment Requirements**.

- Operating time = 8 hours/day, 5 days/week
- Cycle time (variable flow/pressure system)

Feed	=	30 min (1800 sec) at 172 kPa (25 psig)
Feed	=	30 min (1800 sec) at 345 kPa (50 psig)
Feed	=	30 min (1800 sec) at 517 kPa (75 psig)
Feed	=	1 min (60 sec) at 690 kPa (100 psig)
Cake discharge	=	29 min (1740 sec)
Total	=	120 min (7200 sec) or 4 cycles/day

5-2.2.5 The filter press system will be housed inside a building that shall include the sludge storage tanks, sludge transport equipment (i.e., pumps), chemical conditioning tanks, chemical feed equipment, chemical storage, plate and frame filter press assembly, and filtrate and sludge cake management systems.

5-2.2.6 The number of filter press units will be selected such that 100% of the design liquid sludge flow rate is filtered when the largest single unit is out of service as described in Subparagraph 2-7.3.2.1. This example will also assume that the maximum filtration capacity shall be 125% of the design capacity when all units are in operation. Any additional specific optional features or supporting systems (i.e., precoating, air blowing, and filter media wash systems) and associated sizing requirements will be determined once the filter press has been selected.

5-2.3 **Design Calculations**.

5-2.3.1 **Determine Required Filter Volume**.

5-2.3.1.1 Compute total daily sludge solids generation rate.

Daily sludge solids generation rate = [(37,850 L/d) x (0.02) x (1.0) x (1 kg/L)] = 760 kg/d (1670 lb/d) dry solids

5-2.3.1.2 Compute total dry solids processed per day of filter operation.

Total dry solids dewatered = sludge + lime + ferric chloride

Sludge solids = [760 kg/d x 7 d/wk] / [5 d/wk (operation)] = 1064 kg/d

Lime (CaO) = 1064 kg/d x (0.10) = 106 kg/d

Ferric chloride = 1064 kg/d x (0.05) = 53 kg/d

Total dry solids per day = 1223 kg/d ~1230 kg/d (2700 lb/d)

5-2.3.1.3 Compute filter volume required per cycle.

Filter volume per cycle = [1230 kg/d] / [(4 cycle/d) x (1280 kg/m^3) x (0.30)] = 0.8 m^3 (29 ft^3) of sludge/cycle

5-2.3.2 **Selection of Efficient Filter Unit**.

5-2.3.2.1 **Determine the Pressure Filter Sizes Available**. From the manufacturers' catalogs, determine the sizes of various filter units. Tabulate the filter area available with and without the single largest unit. See Table 5-1.

5-2.3.2.2 **Select Proper Filter Press Unit**. The most efficient and manageable filter press unit assembly is the one that has the fewest operating units and provides nearly 100% operating capacity when one unit is out of service, and about 25% extra capacity when all units are in operation. Based on this method, the proper unit selection from Table 5-1 would be Unit F. This selection has a total of four units, including three operating units and one standby unit. This assembly will provide 105% of the design daily requirement when one unit is not operating, and 140% of the design daily dewatering capacity when the standby unit is in operation. Although Unit D required the same number of units and has the same overall operating capacities, this selection is the maximum capacity of this size unit and would not allow for additional future capacity, if necessary. A typical schematic layout of the filter press units and supporting equipment is presented in Figure 5-1.

Table 5-1. Selection chart of recessed fixed-volume plate and frame filter press units.

Unit I.D.	Filter Size (mm)[1]	No. of Chambers	Volume of Each Unit (m^3)	Minimum Units Required	Total Volume with Minimum Units (m^3)	Total Units with one Standby	Total Volume with One Standby Unit (m^3)	Volume without standby Unit (%)[2]	Volume with standby Unit (%)[3]
A	470	27	0.11	8	0.88	9	0.99	110	124
B	470(max)	40	0.20	5	1.0	6	1.2	125	150
C	630	27	0.23	4	0.92	5	1.15	115	144
D	630(max)	30	0.28	3	0.84	4	1.12	105	140
E	800	16	0.23	4	0.92	5	1.15	115	144
F	800	20	0.28	3	0.84	4	1.12	105	140
G	800(max)	40	0.57	2	1.14	3	1.71	143	214

Conversions: 1 m^3= 35.3 ft^3, 1 inch= 25 mm.
[1] Data compiled from actual manufacturer's data.
[2] Total volume without standby unit/actual volume required.
[3] Total volume with one standby unit/actual volume required.

Although the method presented provides a direct approach to selecting the optimal the size and number of required presses, an economic and technical evaluation of several alternatives that achieve the minimum requirements should be considered prior to the final selection of the appropriate filter size and number of associated units.

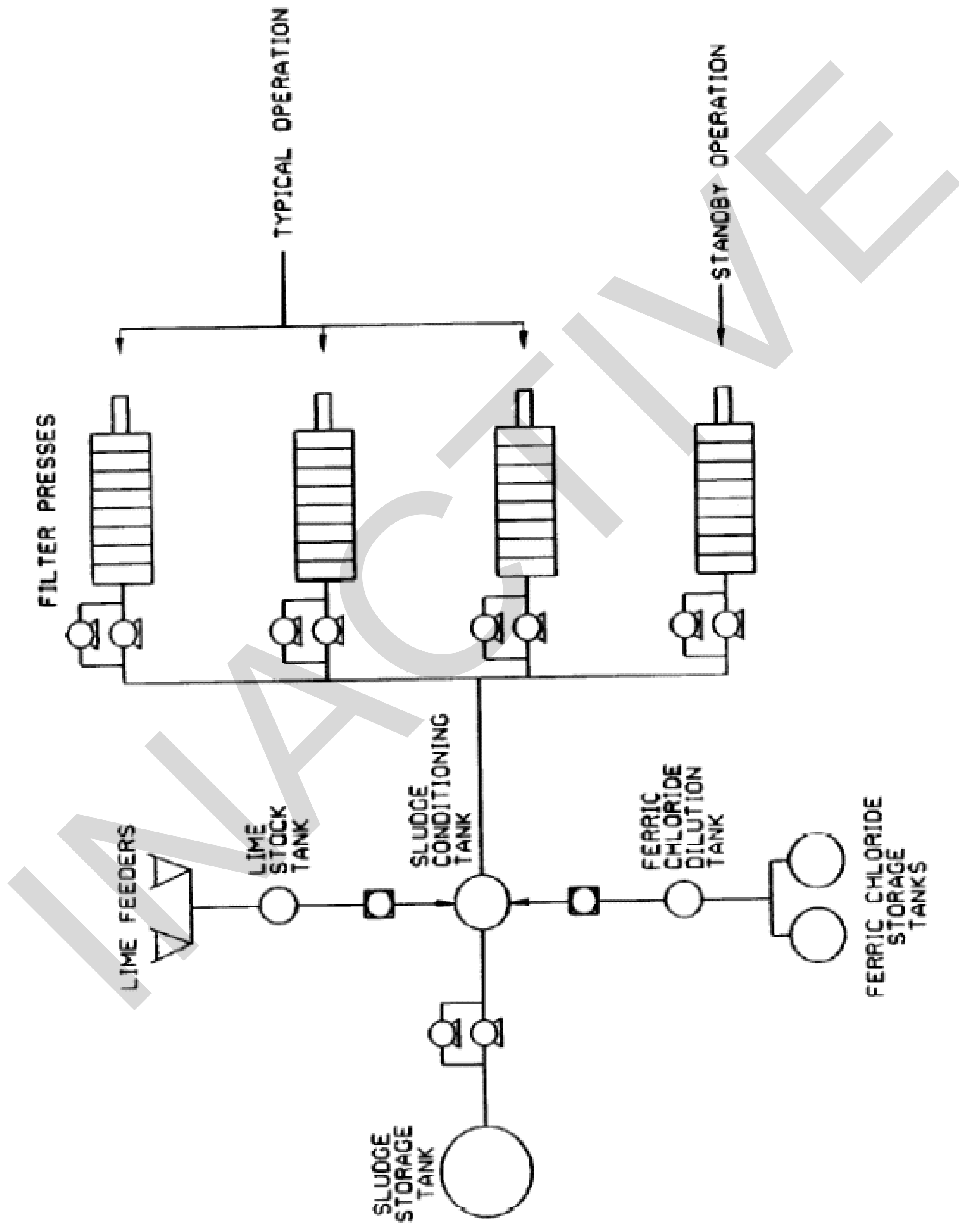


Figure 5-1. Schematic for sludge dewatering process design example no. 1.

5-2.3.2.3 **Supporting Systems**. Based on the specific filter press selected, requirements for sizing supporting systems such as precoating, air blowing, and media washing systems, along with utility requirements, will be determined from the information provided in Paragraph 2-4 and from equipment manufacturers or suppliers. However, for this example these requirements will not be further defined.

5-2.3.3 **Sludge Storage, Conditioning, and Feed Systems.**

5-2.3.3.1 **Development of System Components**. The flow scheme, shown in Figure 5-1, involves sludge storage, conditioning, and feed systems. The associated assumptions related to the design criteria presented below are primarily based on information given in Paragraph 2-4.

a. A sludge storage tank will be located upstream of the sludge conditioning system.

b. A dry lime storage and mixing system will be used downstream of the sludge storage tank. This system will have the capacity to store a 30-day supply of hydrated lime, which will be provided in 45-kg (100-pound) bags of 96% purity. A hydrated bagged lime system was selected because of the low quantity of lime required, as described in Subparagraph 2-4.6.1. The dry lime will be fed in the required amount into a dilution tank by two volumetric feeders. A 10% slurry of calcium hydroxide ($CaOH_2$) by weight will be mixed prior to being metered into the conditioning tank.

c. A ferric chloride storage and mixing system will be used downstream of the sludge storage tank. This system will have the capacity to store a 30-day supply of 40% ferric chloride solution. The ferric chloride will be diluted to obtain a 10% solution prior to being metered into the conditioning tank.

d. A sludge transfer system will be used to pump the sludge from the sludge storage tank to the conditioning tank. If required, the sludge will pass through an in-line grinder prior to the sludge transfer pumping system. This in-line grinder will improve sludge mixing and flow characteristics and protect downstream pumping and dewatering equipment.

e. The conditioning system will consist of a conditioning tank to which the sludge and conditioning chemicals are added and assumed to be completely mixed. The conditioned sludge will then be pumped to the filter press units.

f. The feed pump system will consist of pumps with the capacity to deliver the sludge to the filter press at the following pressure stepping conditions, as described in Subparagraph 2-4.3.1—30 minutes (1800 seconds) at 172 kPa (25 psig), 30 minutes (1800 seconds) at 345 kPa (50 psig), 30 minutes (1800 seconds) at 517 kPa (75 psig), and 1 minute (60 seconds) at 690 kPa (100 psig).

5-2.3.3.2 **Compute the Size of Sludge Storage Required**. Assume sludge must be stored for 4 days (GLUMRB 1990).

Volume of sludge to be stored = 37,850 L/d x 4 days = 151,400 L (40,000 gallons)

Therefore, a storage tank or tanks should be selected with a capacity of 152,000 L or 152 m^3 (40,000 gallons) from manufacturers' catalogs (40,000 gallons is the largest size tank that can be shipped from factories).

5-2.3.3.3 **Compute the Size of Lime Storage Facility Required.** Provide 30 days or 1 month of storage. Assume approximately 4.33 weeks/month.

Lime required per 8-h day = 106 kg/d

Lime required per month = 106 kg/d x 5 d/wk x 4.33 wk/mo = 2300 kg/mo (5070 lb/mo)

a. Assume use of hydrated lime at 96% purity.

For 30 day storage quantity of hydrated lime required = [(2300 kg/mo)/0.96] x [74(MW of $Ca(OH)_2$)/56(MW of CaO)] = 3170 kg/mo (7160 lb/mo)

Number of bags of hydrated lime needed per month= (3170 kg/mo)/(45 kg/bag) = 71 bags/mo

Therefore, storage should be provided for 80 bags.

b. The capacity of the hydrated lime feed hopper should be large enough to contain 1 day's supply of lime.

Bags needed per day = [71 bags/mo] / [(5 d/wk) x (4.33 wk/mo)]= 4 bags/day

Based of the bulk density of hydrated lime of 480 kg/m^3 (30 lb/ft^3) and allowing provisions for two hoppers to hold two bags of hydrated lime each.

Volume required for each hopper = [(2 bags) x (45 kg/bag)] / [480 kg/m^3] = 0.2 m^3 (7 ft^3)

Therefore, each hopper should have a minimum capacity of 0.2 m^3 (7 ft^3) and will feed lime into a mixing tank where a 10% by weight lime slurry will be prepared prior to being metered into the sludge conditioning tank.

5-2.3.3.4 **Compute the Size of the Ferric Chloride Storage Facility Required**. Provide 30 days or 1 month of storage at operating condition.

Ferric chloride required per 8-h day = 53 kg/d

Ferric chloride required per month = 53 kg/d x 5 d/wk x 4.33 wk/mo = 1150 kg/mo (2530 lb/mo)

Assume use of ferric chloride at 40% purity with a density of 1.45 kg/L (12 lb/gal).

For 30-d storage quantity of ferric chloride required = [(1150 kg/mo) / (0.40 x 1.45 kg/L] = 1990 L/mo (530 gal/mo)

Therefore, minimum storage should be provided for 2000 L or 2 m^3 (550 gallons).

5-2.3.3.5 **Compute Size of the Sludge Pump Used Before the Conditioning Tank.** Assume that the conditioning tank is connected to all the filter processes, and that all the operating filters are fed at one time.

Total sludge pumped per operating day = (37,850 L/d x 7 d/wk)/(5 d/wk operating) = 53,000 L/d = (14,000 gal/d)

Pumping rate per cycle (filling time 100 min [6000 s]) = [53,000 L/d]/[(4 cycle/day) x (6000 s/cycle)] = 2.2 L/s (35 gpm)

Therefore, the total minimum required pumping capacity is 2.2 L/s (35 gpm). For this application a minimum of two pumps should be provided, one operating pump and one standby pump. To size these pumps, the system's hydraulic (static and dynamic) head requirements would need to be determined. This would be based on specific system requirements, in addition to a safety factor of 10 to 25%, as described in Subparagraph 2-7.2.2.1, to overcome any effects from the sludge such as its thixotropic properties. Knowing the pump capacity and head, the designer should use manufacturers' catalogs and select the appropriate pump.

5-2.3.3.6 **Compute the Size of the Conditioning Tank**. Assume use of an in-line conditioning tank with a 10-minute (600-second) detention and mixing time.

Volume required for conditioning tank = 2.2 L/s x 600 s = 1320 L (350 gallons)

Therefore, a conditioning tank should be selected with a minimum capacity of 1320 L or 1.32 m^3 (350 gallons). This conditioning tank should also be equipped with a mixer and level switches to control the operation of the sludge and dilute conditioning chemical metering pumps.

5-2.3.3.7 **Compute the Size of the Sludge Feed Pumps to the Filter Presses**. Each filter press will be equipped with one operating sludge feed pump and one standby pump. The total quantity of conditioned sludge plus chemical solution to the filter presses follows:

Sludge quantity = 53,000 L/d

Water in lime at 10% solution =[106 kg/d] / [(0.1 x 1 kg/L)] = 1060 L/d

Water in ferric chloride at 10% solution =[53 kg/d] / [(0.1 x 1 kg/L)] = 530 L/d

Total quantity to be pumped =[53,000 + 1060 + 530] L/d = 54,590 L/d ~ 54,600 L/d (14,440 gal/d)

Pumping rate for each pump when 3 filter units are operating = [54,600 L/s] / [(3 pumps) x (4 cycles/day) x (6000 s/cycle)] = 0.76 L/s (12 gpm)

Therefore, the total minimum pumping capacity for each operating and standby pump is 0.76 L/s (12 gpm) at a filter press pressure of 690 kPa (100 psig) (maximum pressure condition specified). However, prior to selecting the appropriate pump, any additional system head losses, in addition to safety factors, should be determined and combined with the required filter press pressure to determine the overall head requirements. Once this is done, manufacturers' catalogs should be obtained and an appropriate pump selected.

5-2.3.4 **Sludge Cake**.

5-2.3.3.1 **Compute the Total Sludge Dry Cake Solids**. The filter cake contains sludge solid, lime, and ferric chloride. This example will assume that 100% of the condition chemicals are incorporated into the sludge cake and that the dewatering facility provides 98% solids capture.

Sludge solids in cake = 0.98 x 1060 kg/d = 1039 kg/d

Lime solids in cake = 1.00 x 106 kg/d = 106 kg/d

Ferric chloride in cake = 1.00 x 53 kg/d = 120 kg/d

Total dry solids in sludge cake = 1198 kg/d ~ 1200 kg/d (2640 lb/d)

5-2.3.3.2 **Compute the Volume of Sludge Cake and Required Storage**. The wet sludge cake has a bulk density of 1,280 kg/m^3 (80 lb/ft^3). This example will assume that the sludge will be discharged directly into a hopper for direct dumping into transport trucks for offsite disposal and a 4-day volume of sludge cake storage will be provided (GLUMRB 1900).

- Volume of the sludge cake generated each day:

[(1200 kg/d)] / [(1280 kg/m^3) x (0.30)] = 3.1 m^3/d (110 ft^3/d)

- Volume of sludge cake storage required per press:

[(3.1 m^3/d) x (4 d)] / [3 filter press] = 4.1 m^3/press

Therefore, the volume of the storage receptacle for each of the three operating presses will be 4.1 m^3 (150 ft^3).

5-2.3.5 **Filtrate Quality**. The filtrate generated in the sludge-dewatering process shall be discharged into a sump with a 1-day capacity of filtrate or combined with other treatment process overflow streams. A portion of this filtrate may then be either used in the filter dewatering process for sub-cycles, such as filter media precoating, or returned to the headworks of the treatment process with the remaining filtrate.

5-2.3.5.1 **Compute Volume of Filtrate**.

Filtrate volume = 53,000 L/d – [(3.1 m^3/d) x (1000 L/m^3)]= 49,900 L/d

Water in lime solution = 1060 L/d

Water in ferric chloride solution = 530 L/d

Total of return flow = 51,490 L/d ~ 51,500 L/d (13,600 gpd)

(Note that in addition to the items listed above, the addition of process water used in the dewatering system, such as water needed for filter media washing, will need to be considered. However, these quantities are specific to the dewatering equipment selected and are not included for this example.)

5-2.3.5.2 **Compute Total Solids in the Return Flow**.

Total solids in conditioned sludge	=	1230 kg/d
Total solids in sludge cake	=	1200 kg/d
Difference total solids in return flow	=	30 kg/d (~70 lb/d)

Therefore, the sump for this example should be sized to store 51,500 L or 51.5 m^3 (13,600 gallons) based on 1 day of storage.

5-2.3.6 **Design Details**. A diagram of the design of the filter press assembly is presented in Figure 5-1.

5-3 **DESIGN EXAMPLE NUMBER 2**. This paragraph provides a design example and supporting calculations for sizing a sludge-dewatering system.

5-3.1 **Assumptions**. The following assumptions and criteria are used for the design of the sludge-dewatering system:

5-3.1.1 The characteristics of the sludge stream are given below:

- Assumed type of sludge: biological
- Design daily liquid sludge flow = 80,000 L/day (21,100 gpd)
- Concentration of solids = 5%
- Specific gravity of feed = 1.0

5-3.1.2 The minimum dry solids allowed in the sludge cake will be 25 % by weight.

5-3.1.3 A variable-volume recessed plate filter press will be used for this example. Typical ranges of design criteria for this type of filter press are presented in Paragraphs 2-3 and 2-4.

5-3.1.4 This example will assume that treatability testing has been done and the following design data were obtained:

5-3.1.4.1 **Sludge Cake Characteristics**.

- Cake thickness = 32 mm (1.25 inch)
- Wet cake density = 1120 kg/m^3 (70 lb/ft^3)

5-3.1.4.2 **Optimum Chemical Conditioning**.

- Lime dosage (CaO) = 5 % of dried solids by weight
- Organic polymer = 2 % of dried solids by weight

5-3.1.4.3 **Dewatering Equipment Requirements**.

- Operating time = 8 h/d, 5 d/wk
- Cycle time
  - Feed = 20 min (1200 s) at 345 kPa (50 psig)
  - Compression = 15 min (900 s) at 1550 kPa (225 psig)
  - Cake discharge = 25 min (1500 s)
  - Total = 60 min (3600 s) or 8 cycles/d

5-3.1.5 The filter press system will be housed inside a building that shall include the sludge storage tanks, sludge transport equipment (i.e., pumps), chemical conditioning tanks, chemical feed equipment, chemical storage, plate and frame filter press assembly, and filtrate removal and sludge cake management systems.

5-3.1.6 The number of filter press units will be selected such that 100% of the design liquid sludge flow rate is filtered when the largest single unit is out of service as described in Subparagraph 2-7.3.2.1. This example will also assume that the maximum filtration capacity shall be 125% of the design capacity when all units are in operation. Any additional specific optional features or supporting systems (i.e., precoating, air blowing, and filter media wash systems) and associated sizing requirements will be determined once the filter press has been selected.

5-3.2 **Design Calculations**.

5-3.2.1 **Determine Required Filter Volume.**

5-3.2.1.1 **Compute Total Daily Sludge Solids Generation Rate**.

Daily sludge solids generation rate = [(80,000 L/d) x (0.05) x (1.0) x (1 kg/L)] = 4000 kg/d (8800 lb/d) dry solids

5-3.2.1.2 **Compute Total Dry Solids Processed per Day of Filter Operation**.

Total dry solids dewatered = sludge + lime + polymer

Sludge solids = [4000 kg/d x 7 d/wk]/[5 d/wk (operation)]= 5600 kg/d

Lime (CaO) = 5600 kg/d x (0.05) = 280 kg/d

Polymer = 5600 kg/d x (0.02) = 112 kg/d

Total dry solids per day = 5992 kg/d ~6000 kg/d (13,200 lb/d)

5-3.2.1.3 **Compute filter volume required per cycle**.

Filter volume per cycle = [6000 kg/d] / [(8 cycle/d) x (1120 kg/m^3) x (0.25)] = 2.7 m^3 (95 ft^3) of sludge/cycle

5-3.2.2 **Selection of Efficient Filter Press Unit**.

5-3.2.2.1 **Determine the Pressure Filter Sizes Available**. Examine the manufacturers' catalogs to determine the sizes of various filter units. Tabulate the filter area available with and without the single largest unit. See Table 5-2.

5-3.2.2.2 **Select Proper Filter Press Unit**. The most efficient and manageable filter unit assembly is the one that has the fewest operating units and provides nearly 100% operating capacity when one unit is out of service, and about 25% extra capacity when all units are in operation. Based on this method, the proper unit selected from Table 5-2 would be Item D. This selection has a total of five units, including four operating units and one standby unit. This assembly will provide 104% of the design daily requirement when one unit is not operating, and about 133% of the design daily dewatering capacity when the standby unit is in operation. Although Item C has the same number of units and has the same overall operating capacities, this selection is the maximum capacity of this size unit and would not allow for additional future capacity, if necessary. A typical schematic layout of the filter press units and supporting equipment is presented in Figure 5-2.

Although the method presented provides a direct approach for selecting the optimal size and number of required presses, an economic and technical evaluation of several alternatives that achieve the minimum requirements should be considered prior to the final selection. For example, by comparing different alternatives in Table 5-2, Item C and Item D are both similar for the number of units and operating capacities. However, although Item C is at its maximum size, it has some additional capacity (i.e., 105%) and would less expensive than Item D and may be suitable if no additional capacity is required.

5-3.2.2.3 **Supporting Systems**. Based on the specific filter press selected, requirements for sizing supporting systems such as precoating, air blowing, and media washing systems, along with utility requirements, will be determined from the information provided in Paragraph 2-4 and from equipment manufacturers or suppliers. However, for this example these requirements will not be further defined.

Table 5-2. Selection chart of recessed variable-volume plate and frame filter press units.

Unit I.D.	Filter Size (mm)[1]	No. of Chambers	Volume of Each Unit (ft^3)	Minimum Units Required	Total Volume with Minimum Units (ft^3)	Total Units with one Standby	Total Volume with One Standby Unit (ft^3)	Volume without standby Unit (%)[2]	Volume with standby Unit (%)[3]
A	630 (max)	33	0.28	10	2.8	11	3.1	104	115
B	800 (min)	16	0.23	12	2.8	13	3.0	104	111
C	800 (max)	53	0.71	4	2.8	5	3.6	104	133
D	1000 (min)	31	0.71	4	2.8	5	3.6	104	133
E	1000 (max)	62	1.42	2	2.8	3	4.3	104	159
F	1200 (min)	62	2.12	2	4.2	3	6.4	156	237

Conversions: 1 m^3= 35.3 ft^3, 1 inch= 25.4 mm.
[1] Data compiled from actual manufacturer's data.
[2] Total volume without standby unit/actual volume required.
[3] Total volume with one standby unit/actual volume required.

5-3.2.3 **Sludge Storage, Conditioning, and Feed Systems**.

5-3.2.3.1 **Development of System Components**. The flow scheme in Figure 5-2 shows sludge storage, conditioning, and feed systems. The associated assumptions related to the design criteria presented below are based on information given in Paragraph 2-4.

a. A sludge storage tank will be located upstream of the sludge conditioning system.

b. A dry lime storage and mixing system will be used downstream of the sludge storage tank. This system will have the capacity to store a 30-day supply of hydrated lime, that will be provided in 45-kg (100-pound) bags. The dry lime will be fed in the required amount into a dilution tank by two volumetric feeders. A hydrated bagged lime system was selected because of the low quantity of lime required, as described in Subparagraph 2-4.6.1. A 10% slurry of calcium hydroxide ($CaOH_2$) by weight will then be mixed and metered into the conditioning tank.

c. A dry polymer storage and mixing system will be used downstream of the sludge storage tank. This system will have the capacity to store a 30-day supply of dry polymer supplied in 22-kg (50-pound) bags. The dry polymer will be fed in the required amount into a dilution tank by two volumetric feeders. A 5% solution will then be mixed prior to being metered into the conditioning tank.

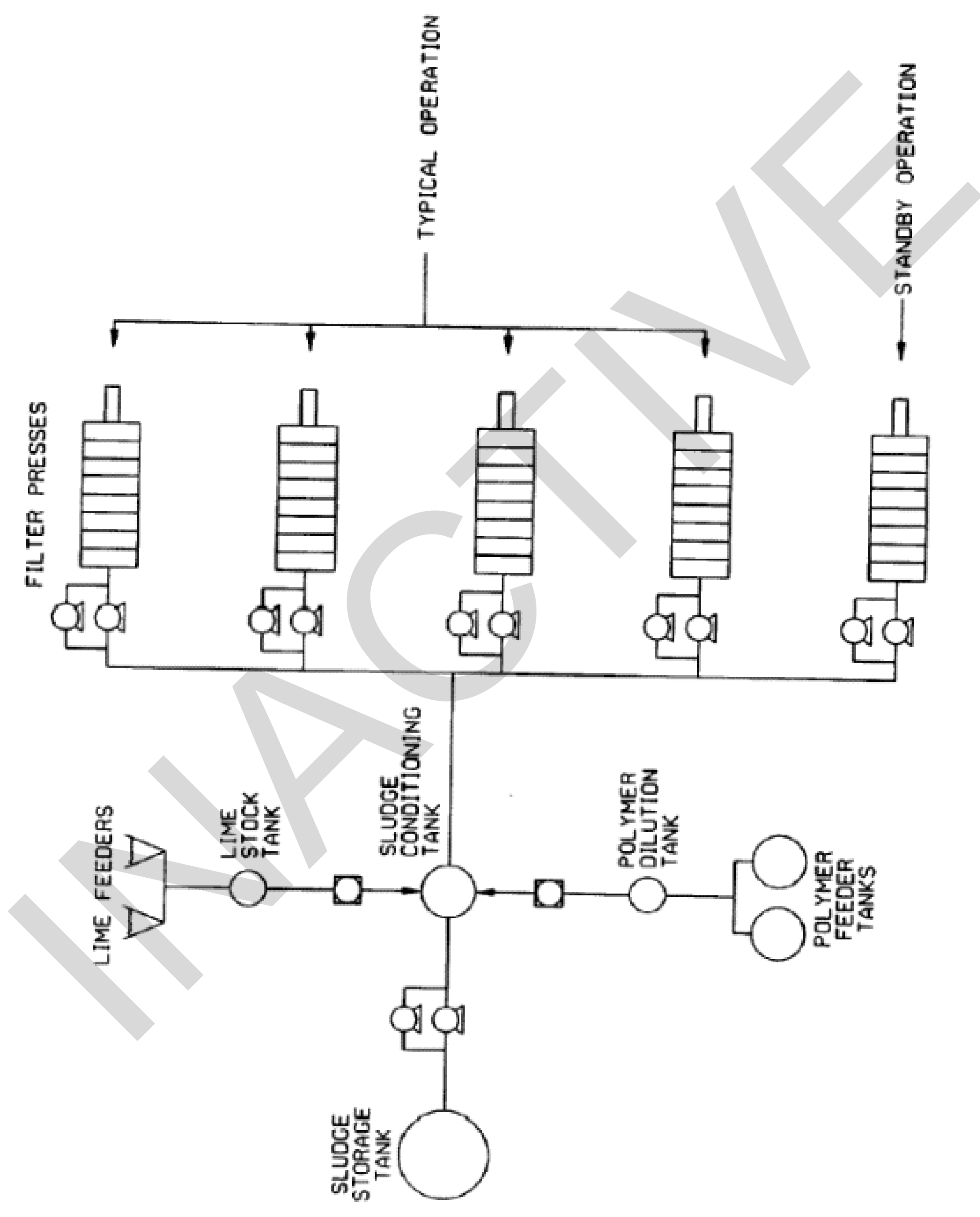


Figure 5-2. Schematic for sludge dewatering process design example no. 2.

d. A sludge transfer system will be used to pump the sludge from the sludge storage tank to the conditioning tank. If required, the sludge will be passed through an in-line grinder before it reaches the sludge transfer pumping system. This in-line grinder will improve sludge mixing and flow characteristics and protect downstream pumping and dewatering equipment.

e. The conditioning system will consist of a conditioning tank to which the sludge and conditioning chemicals are added and are assumed to be completely mixed. The conditioned sludge will then be pumped to the filter press units.

f. The feed pumps will have the capacity to deliver the sludge to the filter press at the design pressure of 345 kPa (50 psig) for 20 minutes (1200 seconds). After completion of the feed cycle, the compression cycle will proceed by pumping water at 1550 kPa (225 psig) for 15 minutes (900 seconds) behind the filter press diaphragms for inflation.

5-3.2.3.2 **Compute the Size of Sludge Storage Required**. Assume that the sludge must be stored for 4 days (GLUMRB 1990).

Volume of sludge to be stored = 80,000 L/d x 4 day = 320,000 L (84,400 gallons)

Therefore, a storage tank or tanks should be selected with a capacity of 320,000 L or 320 m^3 (85,000 gallons) from manufacturers' catalogs.

5-3.2.3.3 **Compute the Size of Lime Storage Facility Required**. Provide 30 days or 1 month storage and assume 4.33 weeks/month and the use of hydrated lime at 90% purity.

Lime required per 8 h day = 280 kg/d (620 lb/d)

Lime required per month = 280 kg/d x 5 d/wk x 4.33 wk/mo = 6100 kg/mo (13,430 lb/mo)

For 30 day storage quantity of hydrated lime required = [(6100 kg/mo)/0.9] x [74 (MW of $Ca(OH)_2$)/56 (MW of CaO)] = 8960 kg/mo (19,740 lb/mo)

Number of bags of hydrated lime needed per month = (8960 kg/mo)/(45 kg/bag) = 199 bags/mo

Therefore, storage should be provided for 200 bags. The capacity of the hydrated lime feed hopper should be large enough to contain one day's supply of lime.

Number of bags needed per day = [199 bags/mo] / [(5 d/wk) x (4.33 wk/mo) = 10 bags/day

Based on the bulk density of hydrated lime of 480 kg/m^3 (30 lb/ft^3) and allowing provision for two hoppers to hold 5 bags of hydrated lime each,

Volume required for each hopper = [(5 bags) x (45 kg/bag)] / [480 kg/m^3] = 0.47 m^3 (17 ft^3)

Therefore, each hopper should have a minimum capacity of 0.5 m^3 (17 ft^3) and will feed lime into a mixing tank where, a 10% lime slurry by weight will be prepared prior to being metered into the sludge conditioning tank.

5-3.2.3.4 **Compute the Size of the Polymer Storage Facility Required**. Provide 30 days or 1 month storage.

Polymer required per 8-h day = 112 kg/d (250 lb/d)

Polymer required per month = 112 kg/d x 5 d/wk x 4.33 wk/mo = 2425 kg/mo (5420 lb/mo)

Number of bags of polymer needed per month = (2425 kg/mo) / (22 kg/bag) = 110 bags/mo

Therefore, storage should be provided for 110 bags. The capacity of the polymer feed hopper should be large enough to contain 1 day's supply of polymer.

Number of bags needed per day = (112 kg/d) / (22 kg/bag) = 5 bags

The bulk density of the polymer is assumed to be 320 kg/m^3 (20 lb/ft^3) and the daily supply will be stored in two hoppers.

Volume required for each hopper = [112 kg/d)] / [2 x 320 kg/m^3] = 0.2 m^3 (7 ft^3)

Therefore, each hopper should have a minimum capacity of 0.2 m^3 (7 ft^3) and will feed polymer to a mixing tank for preparation of the 5% solution prior to being metered into the sludge conditioning tank.

5-3.2.3.5 **Compute Size of the sludge Pump Used Before the Conditioning Tank**. Assume the conditioning tank is connected to all of the filter processes, and all the operating filters are fed at one time.

Total sludge pumped per operating day = (80,000 L/d x 7 d/wk) / (5 d/wk operating) = 112,000 L/d

Pumping rate per cycle (filling time 20 min [1200 s]) = [112,000 L/d] / [(8 cycle/day) x (1200 s/cycle)] = 12 L/s (185 gpm)

Therefore, the total minimum required pumping capacity is 12 L/s (185 gpm). For this application, at least two pumps should be provided, one operating pump and one standby pump. To size these pumps, the system hydraulic (static and dynamic) head requirements would need to be determined, as would an additional safety factor of 10 to 25%, as described in Subparagraph 2-7.2.2.1, to overcome any effects from the sludge such as its thixotropic properties. Using the pump capacity and head, the designer should obtained manufacturers' catalogs and select the appropriate pump.

5-3.2.3.6 **Compute the Size of the Conditioning Tank**. Assume use of an in-line conditioning tank with a 10-minute (600-second) retention and mixing time.

Volume required for conditioning tank = 12 L/s x 600 s = 7200 L (1900 gallons)

Therefore, a conditioning tank should be selected with a 7200 L or 7.2 m^3 (1900 gallon) working capacity. This conditioning tank should also be equipped with a mixer and level switches to control the operation of the sludge and conditioning chemical metering pumps.

5-3.2.3.7 **Compute the Size of the Sludge Feed Pumps to the Filter Presses**. Each filter press will be equipped with one sludge operating feed pump and one standby pump. The total quantity of conditioned sludge plus chemical solution to the filter presses follows:

Sludge quantity = 112,000 L/d (29,540 gpd)

Water in lime at 10% solution = [280 kg/d] / [(0.1 x 1 kg/L)] = 2800 L/d (740 gpd)

Water in polymer at 5% solution = [112 kg/d] / [(0.05 x 1 kg/L)] = 2240 L/d (600 gpd)

Total quantity to be pumped = (112,000 + 2800 + 2240) L/d = 117,040 L/d (30,880 gpd)

Pumping rate for each pump when 4 filter units are operating = [117,040 L/d]/[(4 pumps) x (8 cycles/day) x (1200 s/cycle)] = 3 L/s (50 gpm)

Therefore, the total required pumping capacity for each operating and standby pump is 3 L/s (50 gpm) at a filter press pressure of 345 kPa (50 psig). However, prior to selection of the appropriate pump, any additional system head losses, plus safety factor requirements, should be determined and combined with the required filter press pressure to determine the overall head requirements. Once this is determined, manufacturers' catalogs should be obtained and an appropriate pump selected.

5-3.2.4 **Sludge Cake.**

5-3.2.4.1 **Compute the Total Sludge Cake Solids**. The filter cake contains sludge solid, lime, and polymers. This example will assume that 75% of the conditioning chemicals are incorporated into the sludge cake and that the dewatering facility provides 95% solids capture.

Sludge solids in cake = 0.95 x 5600 kg/d = 5320 kg/d

Lime solids in cake = 0.75 x 280 kg/d = 210 kg/d

Polymer solids in cake = 0.75 x 112 kg/d = 84 kg/d

Total dry solids in sludge cake = 5620 kg/d (12,370 lb/d)

5-3.2.4.2 **Compute the Volume of Sludge Cake and Required Storage**. The sludge cake has a bulk density of 1120 kg/m^3 (70 lb/ft^3). This example will assume that the sludge will be discharged directly into a hopper for direct dumping into transport trucks for offsite disposal, and 4 days of sludge cake storage will be provided.

Volume of the sludge cake generated on a daily basis = [(5620 kg/d)] / [(1120 kg/m^3) x (0.25)] = 20 m^3 (710 ft^3/d)

Volume of sludge cake storage required per press = [(20 m^3/d) x (4 d)]/[4 filter press] = 20 m^3/press

Therefore, the volume of the storage receptacle for each of the four operating presses will be 20 m^3 (710 ft^3).

5-3.2.5 **Filtrate Quality**. The filtrate generated in the sludge-dewatering process shall be discharged into a sump with a 1-day capacity of filtrate or combined with other treatment process overflow streams. A portion of this filtrate may then be either used in the filter dewatering process for sub-cycles, such as filter media precoating, or returned to the headworks of the treatment process with the remaining filtrate.

5-3.2.5.1 **Compute Volume of Filtrate.**

Filtrate volume = 112,000 L/d – [(20 m^3/d) x (1000 L/m^3)] = 92,000 L/d

Water in lime solution = 2800 L/d

Water in polymer solution = 2240 L/d

Total of return flow = 97,040 L/d (25,600 gpd) or 1.1 L/s (18 gpm)

(Note that in addition to the items listed above, additional process water used in the dewatering system, such as water needed for filter media washing, cake extraction, and diaphragm losses, will need to be considered. However, these quantities are specific to the dewatering equipment selected and are not included for this example.)

5-3.2.5.2 **Compute Total Solids in the Return Flow.**

Total solids in conditioned sludge = 5990 kg/d

Total solids in sludge cake = 5620 kg/d

Difference total solids in return flow = 370 kg/d (815 lb/d)

Therefore, the sump for this example should be sized to store 97,100 L or 97 m^3 (25,600 gallons) based on 1 day of storage.

5-3.2.6 **Design Details**. A diagram of the design of the filter press assembly is presented in Figure 5-2.

5-4 **DESIGN EXAMPLE NUMBER 3**. This paragraph provides a preliminary design example assuming that both chemical (metal hydroxide) and biological sludge are generated from a contaminated water source. This example is limited to the selection of the press. Once the press is selected, the calculations for supporting equipment can be done, as demonstrated in Examples no. 1 and 2.

5-4.1 **Assumptions**. The following assumptions and criteria are used for the design of the sludge-dewatering system.

5-4.1.1 The characteristics of ground water to be treated are as follows.

5-4.1.1.1 Assumed type of ground water contamination is landfill leachate containing heavy metals (i.e., chromium) and organics (i.e., volatiles and semivolatiles). Specific influent characteristics:

Chromium (hexavalent) = 10 mg/L (required effluent 0.02 mg/L)

BOD_5 = 900 mg/L (required effluent 30 mg/L)

COD = 1,600 mg/L

5-4.1.1.2 Design influent flow is 6.3 L/s (100 gpm).

5-4.1.2 This example assumes that the contaminated ground water is first treated to remove the metals by a reduction, flocculation, and clarification process, which generates a metal hydroxide sludge. Following metals removal, the ground water is then treated to remove organics contamination by an activated sludge process, which generates biological sludge. The two separate sludge streams are then sent to separate filter presses. Fixed-volume recessed plate filter presses will be used.

5-4.1.3 This example assumes that treatability testing has been done and the following data were obtained.

5-4.1.3.1 **Metal Hydroxide Sludge**.

a. **Sludge Feed Characteristics.**

Concentration of solids = 1%

Solids production = 70 mg/L

Specific gravity = 1.0

b. **Sludge Cake Characteristics**.

Cake thickness = 32 mm (1.25 inches)

Wet cake density = 1200 kg/m^3 (75 lb/ft^3)

Minimum solids = 30%

c. **Optimum Chemical Conditioning**.

Polymer = 1% of dried solids by weight

5-4.1.3.2 **Biological Sludge**.

a. **Sludge Feed Characteristics**.

Concentration of solids = 2%

Liquid sludge stream (includes influent and recycle streams) = 10,900 L/d (2 gpm)

Specific gravity = 1.0

b. **Sludge Cake Characteristics**.

Cake thickness = 32 mm (1.25 inches)

Wet cake density = 1120 kg/m^3 (70 lb/ft^3)

Minimum solids = 30%

c. **Optimum Chemical Conditioning**.

Lime (CaO) = 30 % of dried solids by weight

5-4.1.4 Fixed-volume recessed plate filter presses will be used for this example. Typical ranges of design criteria for this type of filter press are presented in Paragraphs 2-3 and 2-4. For each type of sludge the following filter press information applies (see Table 2-4).

5-4.1.4.1 **Metal Hydroxide Sludge**.

Cycle time	=	240 minutes (maximum 4 cycles per day)
Operating pressure	=	690 or 1550 kPa (100 or 225 psi)

5-4.1.4.2 **Biological Sludge (Assume Industrial Type)**.

Cycle time	=	240 minutes (maximum 4 cycles per day)
Operating pressure	=	1550 kPa (225 psi)

5-4.2 **Design Calculations**.

5-4.2.1 **Determine Required Filter Volume**.

5-4.2.1.1 **Metal Hydroxide Sludge**.

a. Compute total daily sludge solids generation rate. Determine the daily solids flow rate:

[(Influent flow rate) x (total solids to be removed)] = [(6.3 L/s) x (70 mg/L)] x [(10^{-6} kg/mg) x (86,400 s/d)] = 38 kg/d (84 lb/d) dry solids

Total sludge flow rate is as follows:

[(Solids flow rate)/(Solids in Feed)] / [Density of Sludge] = [(38 kg/d)/(0.01)] / [1 kg/L] = 3800 L/d (1000 gal/d)

b. Compute total dry solids processed per day of filter operation.

Sludge solids = [38 kg/d x 7 d/wk] / [5 d/wk (operation)] = 53 kg/d

Polymer = [168 kg/d x 0.02] = 1 kg/d

Total dry solids per day (sludge + polymer) = 54 kg/d (120 lb/day)

c. Compute filter volume required per cycle (assume a minimum of one cycle each day).

Filter volume per cycle = [54 kg/d] / [(1 cycle/d) x (1200 kg/m^3) x (0.30)] = 0.15 m^3 (5.3 ft^3) of sludge/cycle

5-4.2.1.2 **Biological Sludge**.

a. Compute total daily sludge solids generation rate.

Total sludge flow rate = 10,900 L/d

b. Determine the daily solids flow rate.

[(Influent sludge flow rate) x (solids in feed)] = {(10,900 L/d) x [(0.02) x 1 kg/L]} = 220 kg/d (480 lb/d) dry solids

c. Compute total dry solids processed per day of filter operation.

Sludge solids = [220 kg/d x 7 d/wk] / [5 d/wk (operation period)] = 308 kg/d

Lime = [308 kg/d x 0.30] = 92 kg/d

Total dry solids per day = sludge + lime = 400 kg/d (880 lb/day)

d. Compute filter volume required per cycle (assume a minimum of 1 cycle to be performed each day).

Filter volume per cycle = [400 kg/d] / [(1 cycle/d) x (1120 kg/m^3) x (0.30)] = 1.2 m^3 (42 ft^3) of sludge/cycle

This is a rather large press for only one cycle per day; therefore, assume at least two cycles per day. The filter press volume required would then be reduced by half to 0.6 m^3 (21 cubic feet).

5-4.2.2 **Selection of Efficient Filter Press Unit**.

5-4.2.2.1 **Determine the Filter Press Sizes Available**. From the manufacturer's catalogs, determine the sizes of various filter press units. Using as the basis that the most efficient and manageable filter press unit assembly is the one that has the fewest operating units and provides nearly 100% operating capacity when one unit is out of service, and about 25% extra capacity when all units are in operation, tabulate the filter area available with and without the single largest unit for both sludge streams.

a. **Metal Hydroxide Sludge**. Based on this method, the proper unit to select from information complied in Table 5-3 would be Item B. This selection has a total of two units, including one operating unit and one standby unit. This assembly will provide 133% of the design daily requirement when one unit is not operating, and about 267% of the design daily dewatering capacity when the standby unit is in operation.

b. **Alternative Approaches**. Because of the small amount of metal hydroxide sludge generated, two potential alternatives for providing redundancy could be used. The first approach would be to only provide redundancy for the biological sludge stream and use the standby press for both sludge streams, or just providing two presses. Another approach would be to obtain only the two presses required for the biological sludge. Use one press as the primary press for the sludge and use the other as the primary press for the metal hydroxide sludge (using a blanking plate to reduce the volume) and as a standby press for the biological sludge stream. Using either of these approaches would be a more economical way to satisfy the requirements.

c. **Additional Calculations**. Based on the information presented above, additional calculations should be performed for sludge storage, conditioning, feed systems, sludge cake storage, and filtrate storage. These types calculations should follow the example calculations shown in Examples no. 1 and 2. In addition to these calculations, based on the specific filter press selected, requirements for sizing supporting systems, such as precoating, air blowing, and media washing, along with utility requirements, will be determined from the information provided in Paragraph 2-4 and from equipment manufacturers or suppliers.

Table 5-3. Selection chart of recessed fixed-volume plate and frame filter press units.

Unit I.D.	Filter Size (mm)[1]	No. of Chambers	Volume of Each Unit (m^3)	Minimum Units Required	Total Volume with Minimum Units (m^3)	Total Units with one Standby	Total Volume with One Standby Unit (m^3)	Volume without standby Unit (%)[2]	Volume with standby Unit (%)[3]
A	470	27	0.11	2	0.22	3	0.33	74	220
B	470(max)	40	0.20	1	0.2	2	0.4	133	266
C	630	27	0.23	1	0.23	2	0.46	153	306
D	630(max)	30	0.28	1	0.28	2	0.56	187	373
E	800	16	0.23	1	0.23	2	0.46	153	306
F	800	20	0.28	1	0.28	2	0.56	187	373
G	800(max)	49	0.71	1	0.71	2	1.42	473	947

Conversions: 1 m^3= 35.3 ft^3, 1 inch= 25 mm.
[1] Data compiled from actual manufacturer's data.
[2] Total volume without standby unit/actual volume required.
[3] Total volume with one standby unit/actual volume required.

Table 5-4. Selection chart of recessed fixed-volume plate and frame filter press units.

Unit I.D.	Filter Size (mm)[1]	No. of Chambers	Volume of Each Unit (m^3)	Minimum Units Required	Total Volume with Minimum Units (m^3)	Total Units with one Standby	Total Volume with One Standby Unit (m^3)	Volume without standby Unit (%)[2]	Volume with standby Unit (%)[3]
A	470	27	0.11	6	0.66	7	0.77	110	128
B	470(max)	40	0.20	3	0.6	4	0.8	100	133
C	630	27	0.23	3	0.69	4	0.92	115	153
D	630(max)	30	0.28	3	0.84	4	1.12	140	186
E	800	16	0.23	3	0.69	4	0.92	115	153
F	800	29	0.42	2	0.84	3	1.26	140	210
G	800(max)	49	0.71	1	0.71	2	1.42	118	237

Conversions: 1 m^3= 35.3 ft^3, 1 inch= 25 mm.
[1] Data compiled from actual manufacturer's data.
[2] Total volume without standby unit/actual volume required.
[3] Total volume with one standby unit/actual volume required.

APPENDIX A

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