SECTION VI

REVIEW OF SLUDGE DEWATERING TECHNIQUES

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Introduction

Dewatering is a physical (mechanical) unit operation used to reduce the moisture content of sludge so that it can be handled and/or processed as a semi-solid instead of as a liquid.

Devices commonly used for dewatering include:

- Rotary Vacuum Filters
- Centrifuges
- Drying Beds
- Lagoons
- Filter Presses
- Continuous Belt Filter Presses (CBFP'S)
- Thermal Drying

Drying beds, lagoons and thermal drying were not considered suitable dewatering methods for this particular application, and therefore are not discussed in detail in this section. Both drying beds and lagoons require a fair amount of suitable acreage for proper installation and operation. Such acreage is not available nearby the treatment facility. This would not only have an impact on land acquisition costs, but on transportation and handling costs. Thermal drying was not considered suitable on the basis of its high energy input requirements. In addition, the use of the dried AMD sludge as a supplemental fuel in the thermal process is precluded due to its inert nature.

Following is a detailed description of those dewatering devices considered capable of achieving the AMD sludge disposal objectives. However, the final selection will be based on the economic evaluation performed in Section VII of this report.

A. Rotary Vacuum Filtration

1. Conventional

Rotary vacuum filtration basically consists of a cylindrical drum covered with a filter media which rotates partially submerged in a vat of sludge. The physical mechanisms which take place during vacuum filtration may be divided into three phases (see Figure VI-1).

The first phase, which refers to the cake pick-up or form phase, occurs when a segment of the drum rotates into the sludge. Vacuum is applied to that segment, filtrate is drawn through the media and discharged. Concurrently, sludge solids are deposited on the media to form a partially dewatered cake. As the sludge cake increases in thickness, its resistance to the passage of filtrate increases.

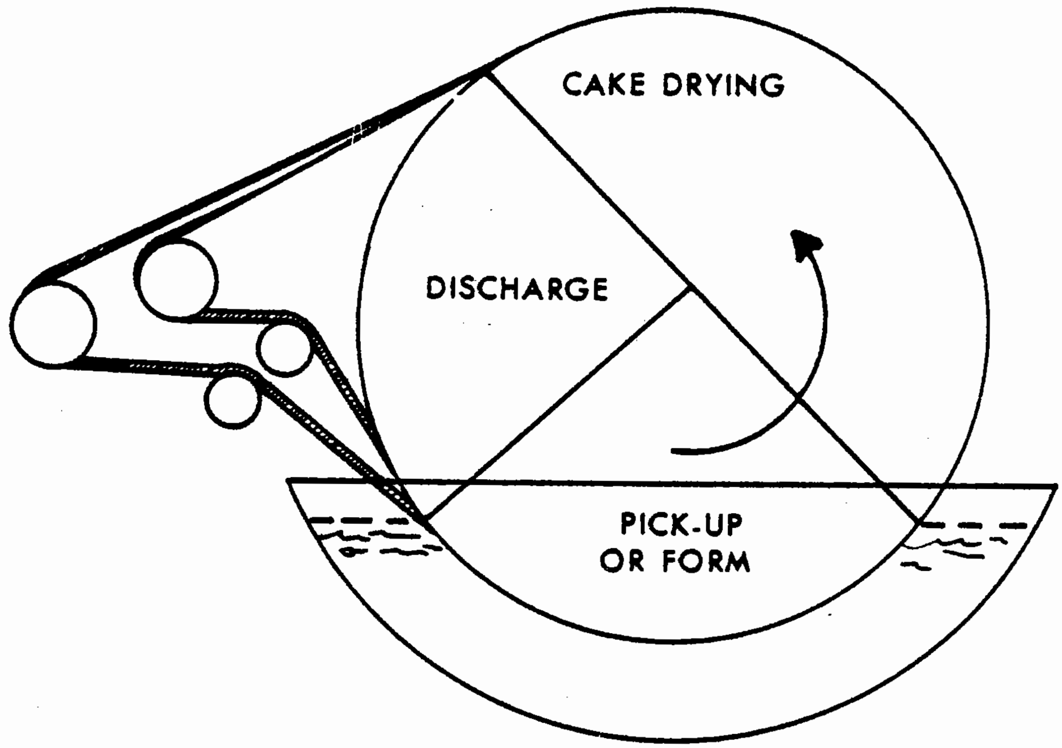

FIGURE VI-1 OPERATING ZONES OF A VACUUM FILTER

The second phase, cake drying, occurs during that time the drum segment leaves the sludge and before the cake is removed. As the drum leaves the sludge, the cake is still under vacuum and additional moisture within the cake is drawn out.

The third phase, cake discharge, occurs after an acceptable cake dryness has been achieved and without vacuum.

All of the above described operations are continuous in nature such that all three phases occur simultaneously on different portions of the drum.

There are basically three types of rotary vacuum filters. These filters, described below, differ primarily in the type covering used and the cake discharge mechanism employed.

The drum filter, shown in Figure VI-2, was the original type unit employed in water and wastewater plants. Here, the filter media does not leave the drum which resulted in inadequate cake discharge and frequent belt washing. Use of this type unit has been virtually eliminated with the advent of the following two vacuum filtration units.

A coil vacuum filter, shown in Figure VI-3, uses two layers of stainless steel coils arranged in cordury fashion around the drum. After the cake drying phase, the two layers of springs leave the drum and separate from each other. As a result of this separation, the cake is lifted off the lower layer of springs and discharged from the upper layer. The coils are then washed and reapplied to the drum. As would be expected, sludge with a large percentage of fine particles and resistant to flocculation, dewater poorly on coil filters.

The belt-type vacuum filter, as shown in Figure VI-4, was introduced primarily to permit continuous washing of the filter media and thereby overcome plugging of the media by fines. As the filter media leaves the drum surface at the end of the cake drying phase it passes over a small discharge roll which facilitates cake discharge. These filters normally utilize a small diameter curved bar between the point where the belt leaves the drum and the discharge roll. This bar aids in maintaining belt stability and improves cake discharge.

2. Precoat

Precoat vacuum filtration is similar to conventional vacuum filtration with the exception of the application of a precoat prior to filtration. The precoat is normally diatomite, the siliceous skeletal remains of single cell aquatic plant life called diatoms. These diatoms form a permeable coating on the filter allowing filtrate to pass through easily while trapping sludge solids. Use of a precoat produces filtrate of very high quality.

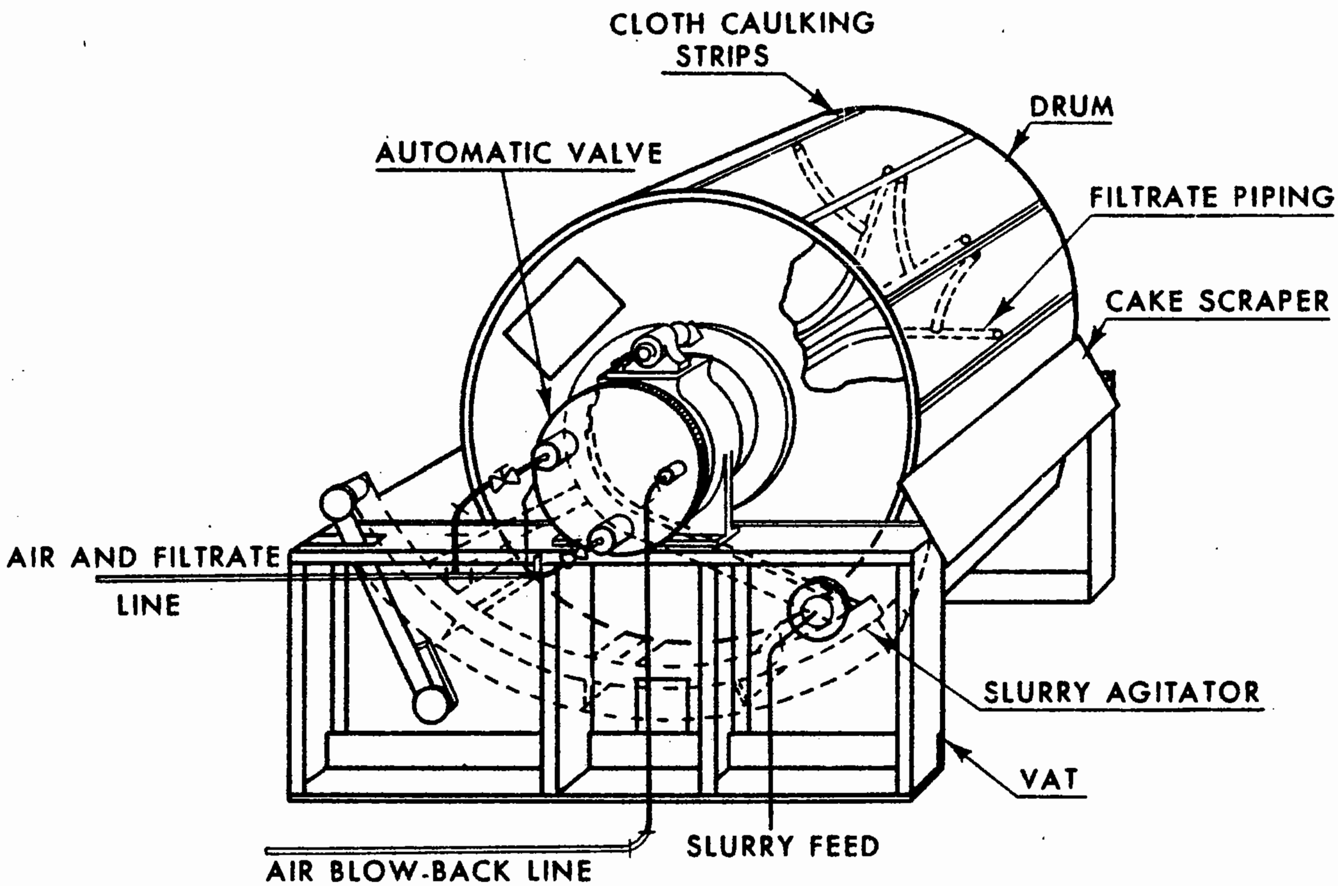

FIGURE VI-2 CUTAWAY VIEW OF A ROTARY DRUM VACUUM FILTER

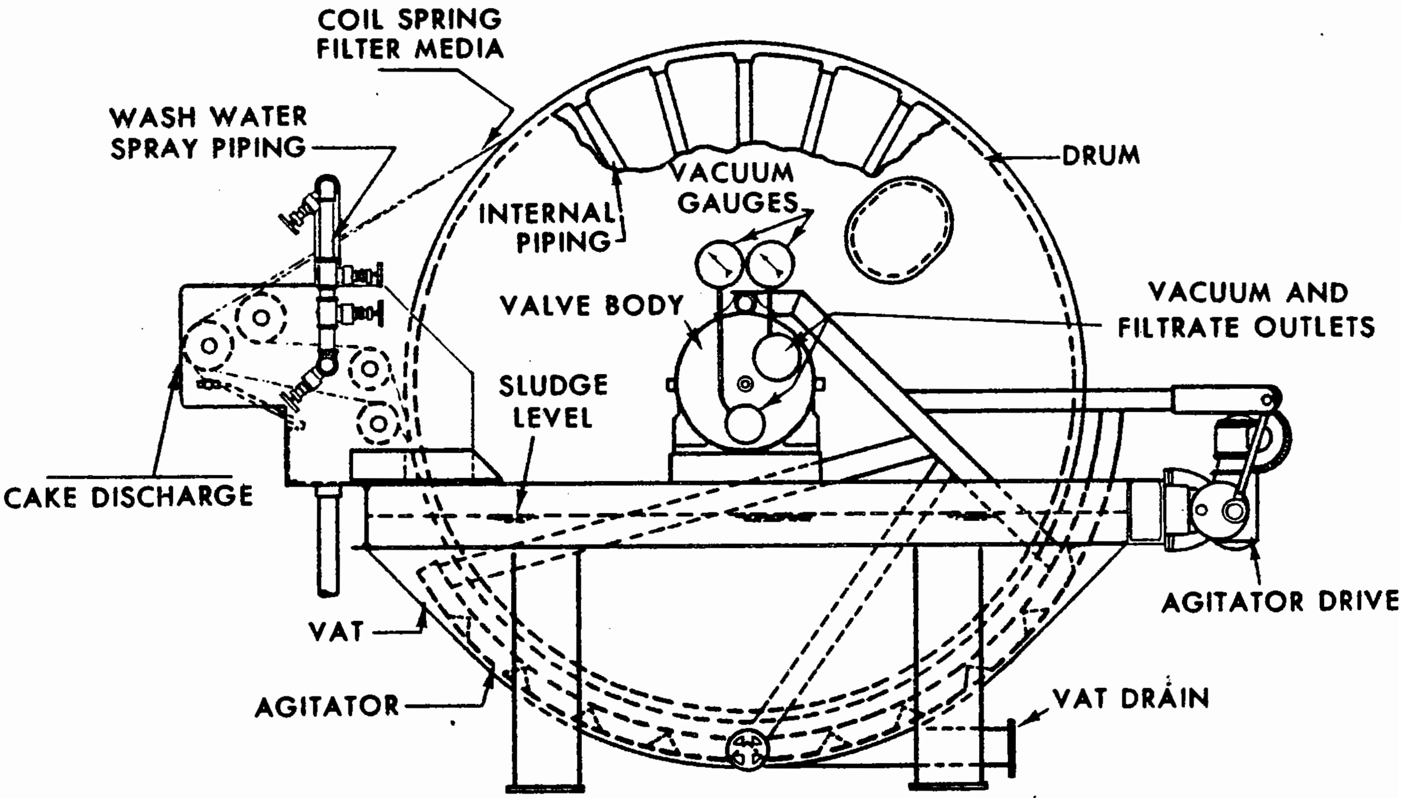

FIGURE VI-3 CROSS SECTION OF A COIL FILTER

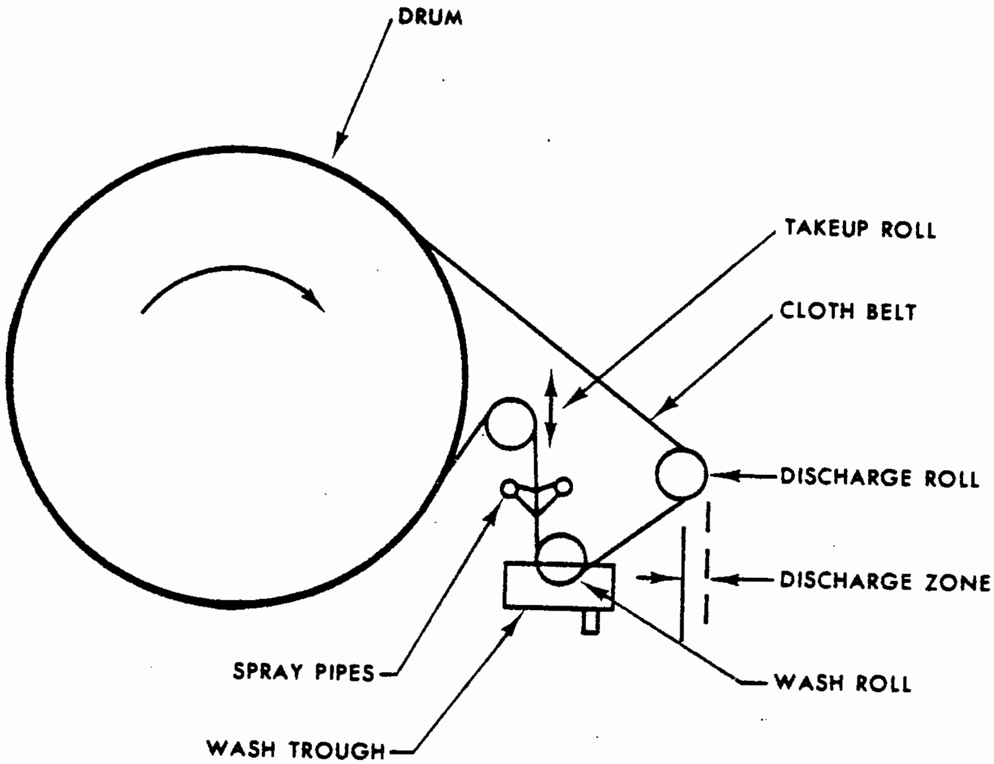

FIGURE VI-4 CROSS SECTION OF A BELT FILTER

Prior to filtration, the rotary drum is immersed in a slurry of precoat and an increasingly thick cake of diatomite is formed on the drum as the fluid is drawn through the media and solids deposited. After sufficient thickness is attained, the precoat cake is shaved smooth and the dewatering operation begun.

Precoat vacuum filtration may also be divided into three phases with the first two being indentical to those previously described. However, the third phase, cake discharge, begins when the cake has reached an acceptable dryness. The cake is usually removed before cracking occurs, as cracking tends to damage the precoat. During cake discharge, cake and a few thousandths of an inch of precoat are cut away by means of a continuously advancing knife. This fresh precoat surface is then rotated into the sludge to begin the dewatering cycle again.

The rotary vacuum filter for many years had been the standard used throughout the industry for dewatering sludges. While many of the earlier operational problems such as poor cake pick-up and release and high maintenance requirements have been somewhat improved in recent years by chemical conditioning methodology and mechanical innovations, two universal deterrents have prevented its continued widespread usage. These are:

a. The high energy and maintenance costs associated with operating a vacuum system.

b. The inability to produce as dry a cake as some of the more advanced technology currently available.

3. Vacuum Filter Operation

Filter cake formation is accomplished first by blinding of the media with the large particles and is followed by a packing of the pores near the filter media with the fine particles. Chemical conditioning of the sludge changes the size distribution of the sludge by coagulating the majority of small particles. This reduces resistance and improves filtrate clarity. Therefore, the size distribution of the sludge to be dewatered and the filter media specified have a significant impact on the extent to which a vacuum filter can dewater a sludge.

Increased filter yield can be realized by increasing the vacuum due to the compressible nature of sludge. However, these benefits can be offset by higher power costs experienced in providing that vacuum.

Increased drum submergence rate increases the time for cake pick-up and usually results in higher cake yields but at the expense of a wetter cake. Generally, drum submergence is kept between 15 and 25 percent to allow for adequate drying time to keep cake moisture content to a minimum.

Figure VI-5 shows a complete rotary vacuum filtration system depicting the essential auxiliary equipment normally supplied. Principal equipment includes a vacuum pump, filtrate receiver and pump, sludge pumping system, and in most applications, sludge conditioning apparatus. Each filter system is normally supplied with one vacuum pump and filtrate receiver. This receiver, which is interposed between the filter drum and vacuum pump, functions to separate air from the liquid and acts as a reservoir for the filtrate pump. Filtrate pumps must be sized to carry away that water separated out in the receiver.

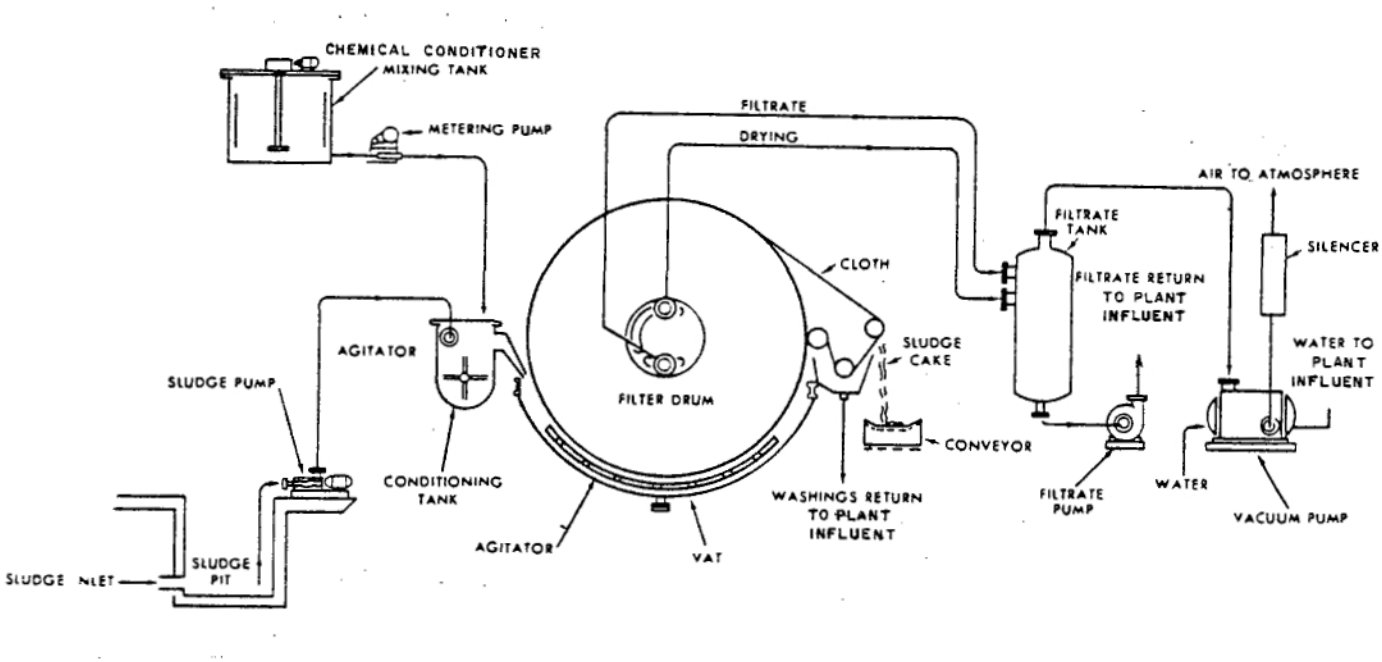

FIGURE VI-5 ROTARY VACUUM FILTER SYSTEM

B. Continuous Belt Filter Presses (CBFP)

1. First Generation CBFP

The continuous belt filter press was originally developed and in subsequent years, modified and improved in West Germany. Installation of the latest and best models in the United States have only recently experienced popularity. These systems were developed in an attempt to overcome the sludge pick-up problem occasionally experienced with rotary vacuum filtration. A combination of sludge conditioning, gravity dewatering and pressure dewatering is utilized to increase the solids content of the sludge.

With all units, the infeed sludge is mixed will polymer (or other chemicals) and placed onto a moving porous belt or screen. Dewatering occurs as the sludge moves through a series of rollers which squeeze the sludge to the belt or squeeze the sludge between two belts much like an old washing machine wringer. The cake formed is then discharged from the belt by a scraper mechanism.

Figure VI-6 illustrates the original concept in continuous belt filter presses. There are basically three processing zones which occur along the length of the unit. These are: the initial drainage zone, which is analogous to the action of a drying bed; the press zone which involves application of pressure; and a shear zone in which shear is applied to the partially dewatered cake. Shearing action is accomplished by positioning the support rollers of the filter belt and the pressure rollers of the pressure belt in such a way that the belts and the sludge between them describe an S-shape curve. This condition creates a parallel displacement of the belts relative to each other due to the difference in radius.

2. Second Generation CBFP

In an attempt to improve the dewatering capabilities of the original CBFP's second generation was developed which incorporated a continuous mechanical thickening device in the initial stage (see Figure VI-7). This thickening device is where the sludge is flocculated to promote rapid and complete cake formation. As a result, these units are capable of using a coarse mesh, relatively open weave, filter medium for improved gravity drainage.

3. Third Generation CBFP

Attempting to improve the dewatering capabilities of these units still further, a third generation of CBFP's have since been developed and are currently available from several manufacturers. These units employ additional medium and/or high pressure sections and variations in cake shearing mechanisms. These third generation units are capable of achieving dry cake solids equivalent to those attained by pressure filters.

The use of chemicals to condition the sludge prior to dewatering of the sludge is a necessary step regardless of what type CBFP is selected. Proper sludge conditioning results in flocculation of the small particles into larger particles of sufficient size and strength to bridge the openings in the filter media and thus be retained on the belt.

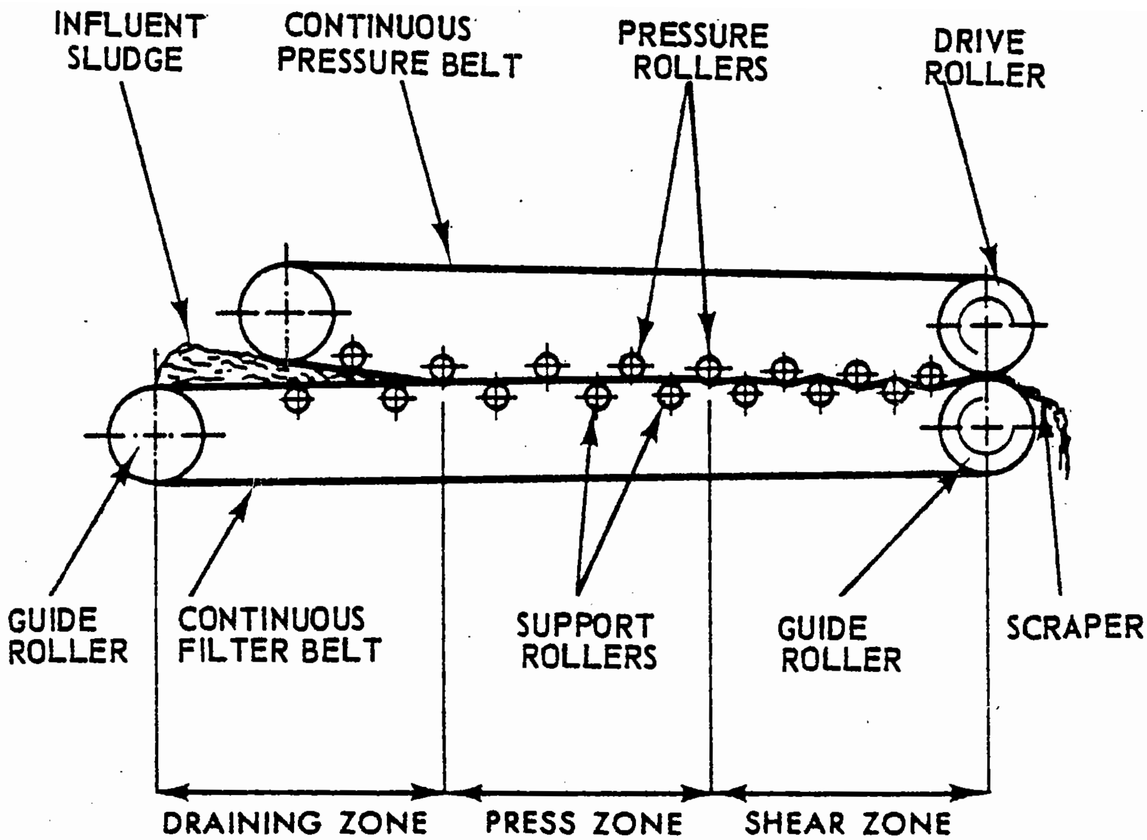

FIGURE VI-6 BELT PRESSURE FILTER

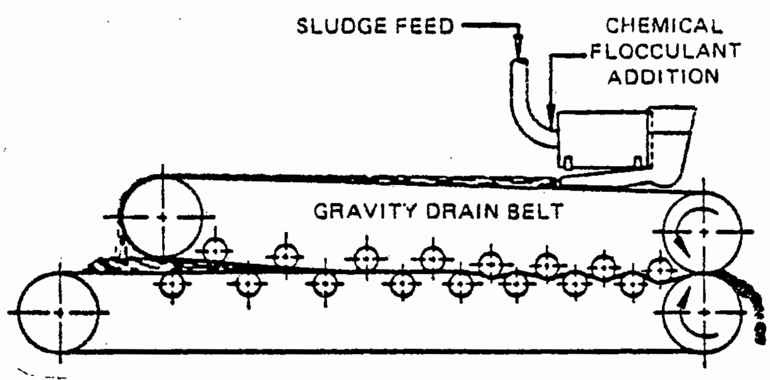

FIGURE VI-7 SECOND GENERATION: CONTINUOUS BELT FILTER PRESS

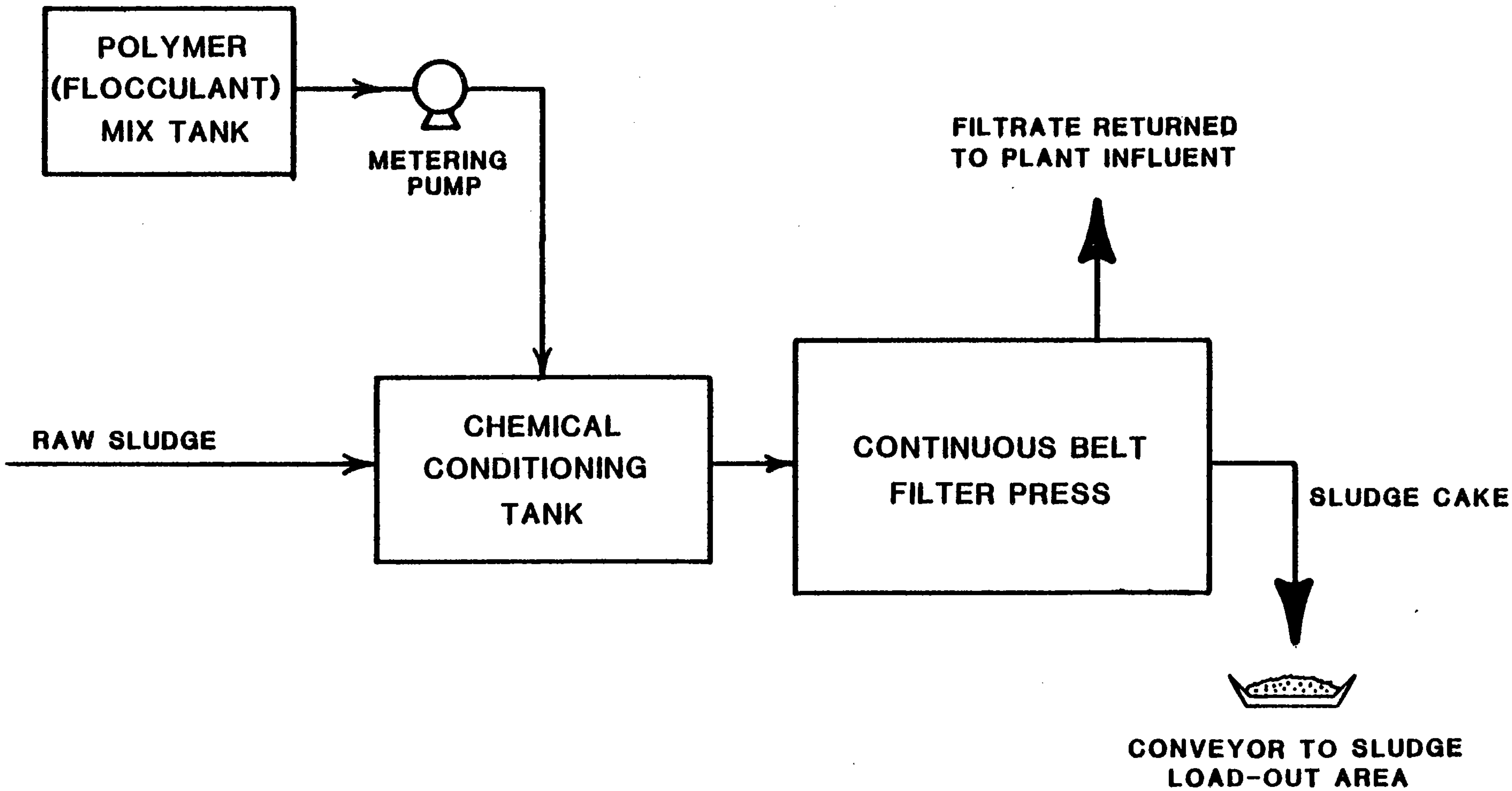

FIGURE VI - 8

CONTINUOUS BELT FILTER PRESS SYSTEM

A brief description of several currently available third generation CBFP's and their respective processing sequences follow.

Infilco Degremont Floc-Press

This two stage unit shown in Figure VI-9 originated in France and features a horizontal belt gravity drainage area followed by a press section. The partially dewatered cake is then sandwiched between the lower belt and a rubber pressure belt. As the cake leaves this pressure section, it is removed from the belt by either a flexible scraper or doctor blade and discharged onto a conveyor for removal.

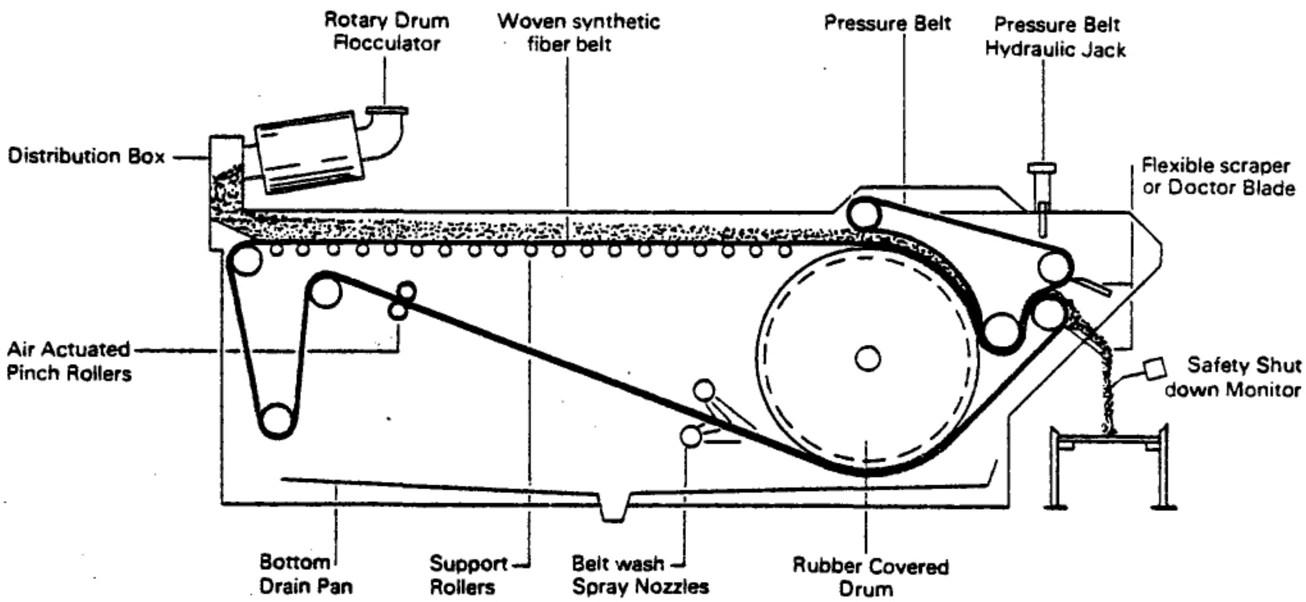

FIGURE VI-9 INFILCO DEGREMONT FLOC-PRESS

Komline Sanderson Unimat GM2H-7

This unit which is designed to achieve maximum cake dryness and throughput, consists of four stages (see Figure VI-10):

a. Gravity Drainage or Thickening Stage
b. Mild Pressure Stage
c. Medium Pressure Stage
d. High Pressure Stage

In the initial stage, gravity drainage occurs on a continuous belt of pockets formed by folding a rectangular piece of filter media. After this initial gravity drainage (thickening) the sludge is transferred to a different belt which passes over another drainage tray before being transferred to yet another belt where a small amount of pressure is applied via small diameter rollers. The sludge is then subjected to a slightly greater pressure before entering the medium pressure stage. While passing over the medium pressure rolls, which are adjustable for pressure optimization, the cake sandwiched between the belts is flexed from one side to the other. Each of the larger drums have smaller diameter rolls which apply pressure as the sandwich passes over the drum.

The sludge cake then enters the high pressure stage where pressure is applied by upright belts similiar in configuration to two Caterpiller tractor tracks butting together. These units are available without the high pressure section for those applications where very high dry cake solids is not essential.

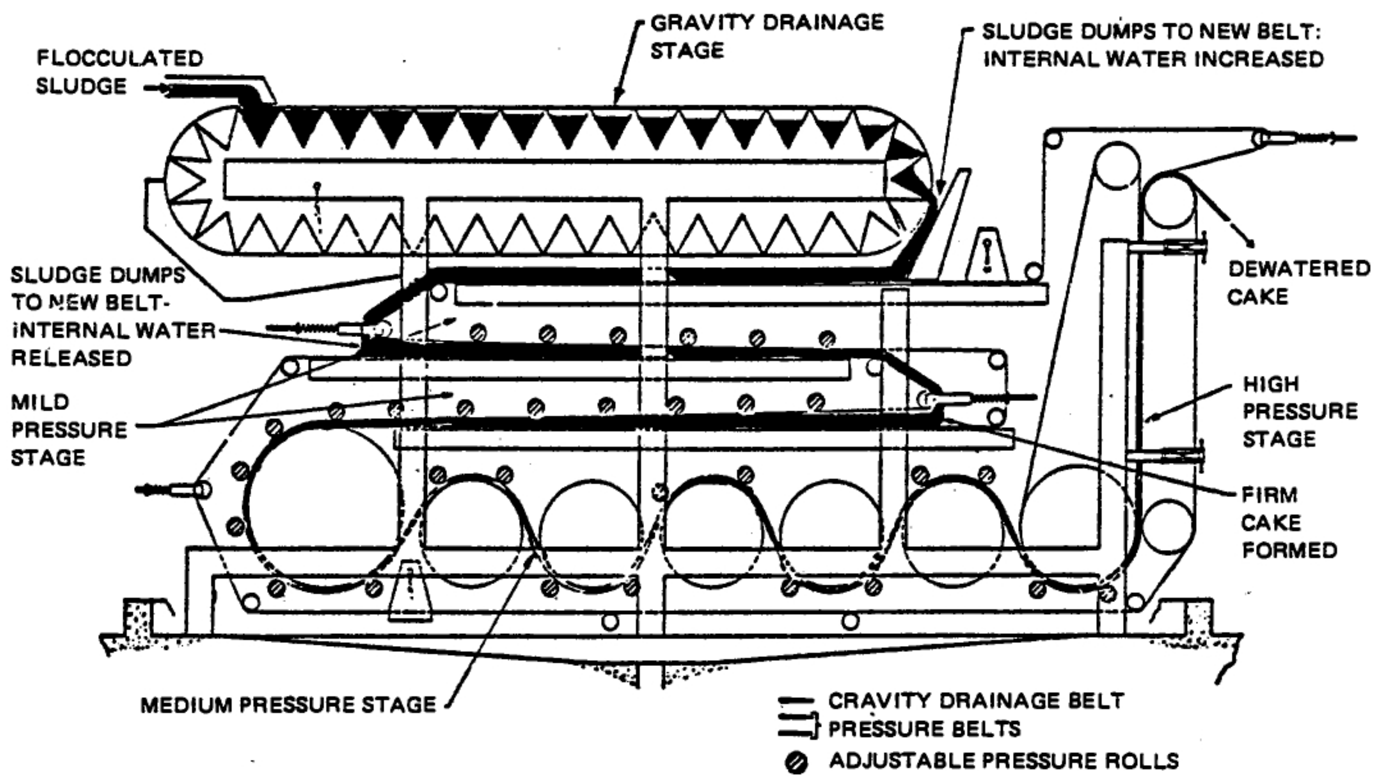

FIGURE VI-10 KOMLINE SANDERSON UNIMAT GM_2H-7

Parkson Magnum Press

The Magnum Press, shown in Figure VI-11, is a device of Swedish origin which is manufactured and sold in the United States by the Parkson Corporation of Ft. Lauderdale, Florida. This unit can best be described as having three distinct stages, the first of which is a unique gravity drainage system. In addition to the normal dewatering which occurs by gravity to a properly conditioned sludge, the sludge can either be subjected to a light pressure by rollers and/or be continuously turned by plows (both optional).

After gravity drainage, the sludge is then sandwiched between two belts in a low pressure stage where perforated press rolls of decreasing diameter subject the sludge to increasing pressure in the last or high pressure stage, the sludge cake is subjected to very high pressures applied by a series of 1 inch wide flat belts that press the screens against a perforated roll uniformly from side to side. The pressure in this stage is adjustable through the use of hydraulic cylinders.

Although there are several other units available in the United States, each employ the same basic principal and vary only in belt configuration and the number and magnitude of pressure stages.

Continuous belt filter presses are fast replacing the use of rotary vacuum filters as the industry standard due to significantly lower power costs and improved performance. A schematic showing a typical CBFP installation is shown in Figure VI-8.

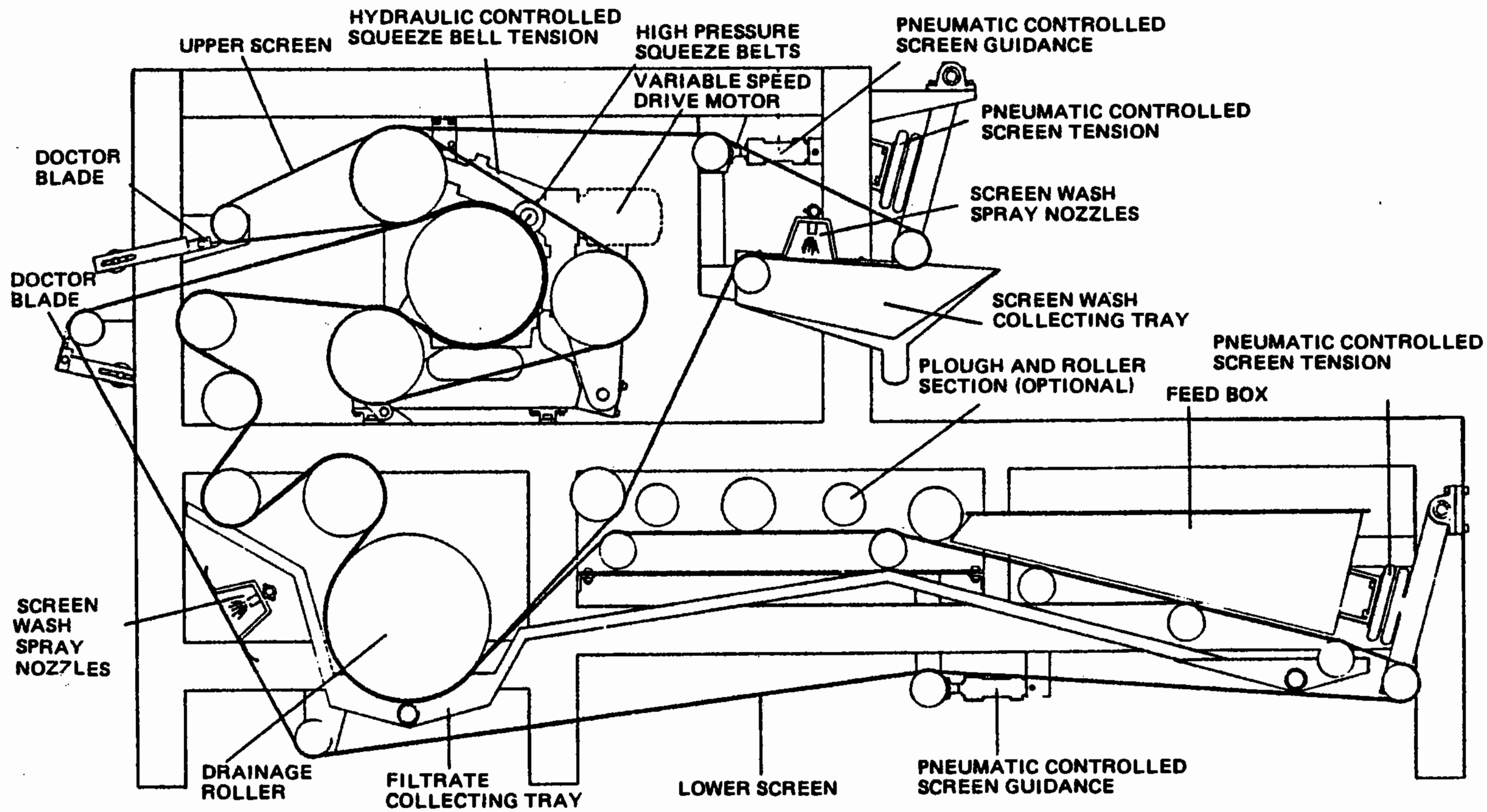

FIGURE VI-11 CROSS SECTION OF A PARKSON MAGNUM PRESS

C. Pressure Filtration

Of the several types of pressure filters available, the most widely used consists of a series of vertical plates held ridgedly in a frame which are pressed together between a fixed and moving end (see Figure VI-12). Mounted on the face of each individual plate is a filter cloth to support and contain the cake produced.

Pressure filters do not produce a cake by pressing and squeezing. Instead, sludge is fed into the press "batch mode" through feed holes in trays along the length of the press. Pressures up to 225 PSI (16 kg/cm^2) are applied to the sludge causing water to pass through the cloth while the solids are retained forming a cake on the surface of the filter cloth. Sludge feed is stopped when the chambers between the trays are completely filled. Drainage ports are provided at the bottom of each chamber where the filtrate is collected, taken to the end of the press and discharged.

The dewatering phase is complete when the flow of filtrate through the filter cloth nears zero. At this point, the sludge feed pump is stopped and any back pressure in the piping released. Each plate is then turned over the gap between the plates and the moving end to allow for cake removal. Filter cake usually drops below onto a conveyor for further removal.

After each plate has released its cake, the plates are pushed back together and the dewatering cycle restarted.

A cutaway view depicting several of the filter presses internal components is shown in Figure VI-13.

In most applications, filter presses require a precoat materialto aid in solids retention on the cloth and cake release. Preliminary laboratory results performed on a typical AMD sludge from the Carl A. White Water Reclamation Plant, indicate that good solids recovery and cake removal can be achieved without the use of a precoat.

Because of the pressures which may be applied by filter presses for the removal of water (5,000 to 20,000 times the force of gravity) cake solids produced are generally 10 to 20 percent drier, than those obtained by rotary vacuum filters under similar operating conditions.

Recently, a pressure filter employing flexible rubber diaphrams between its chambers has been introduced. As noted in Figure VI-14, which illustrates the operating principals, the feed slurry enters the top of the chamber between the filter cloths and gradually fills the chamber. After a cake is formed, the diaphram is expanded by water under pressures to 250 lbs./in.^{2} (17.6 kg/cm^2) which squeezes and dewaters the cake. The filter plates are then automatically opened and the cake discharged. Prior to the beginning of another pressing cycle, the filter cloths are washed.

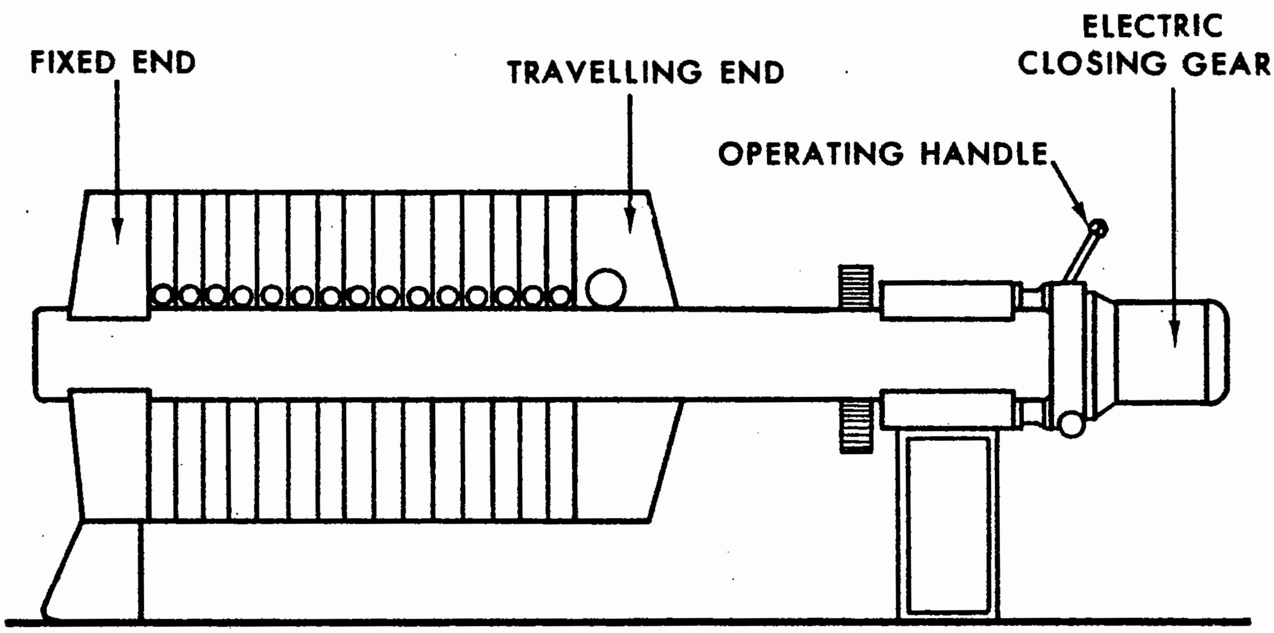

FIGURE VI-12 SIDE VIEW OF A FILTER PRESS

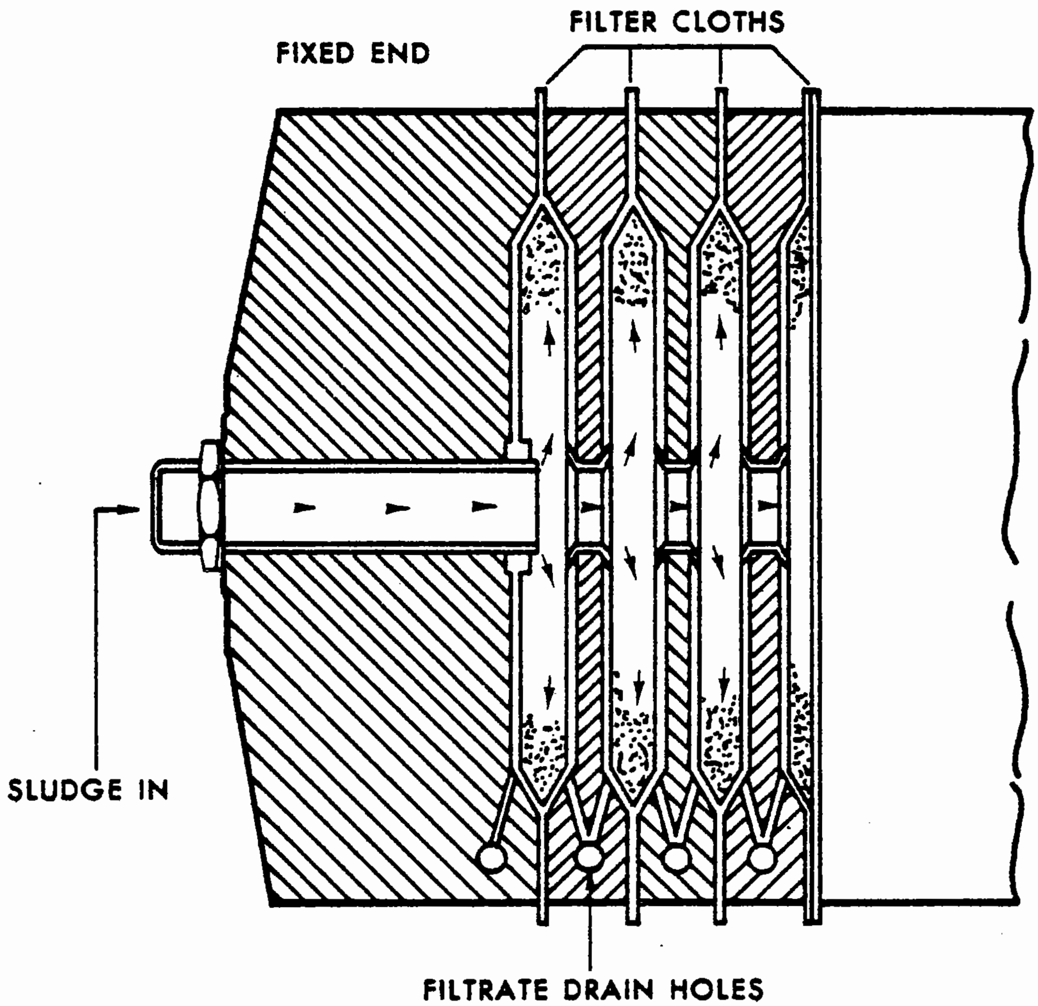

FIGURE VI-13 CUTAWAY VIEW OF OF A FILTER PRESS

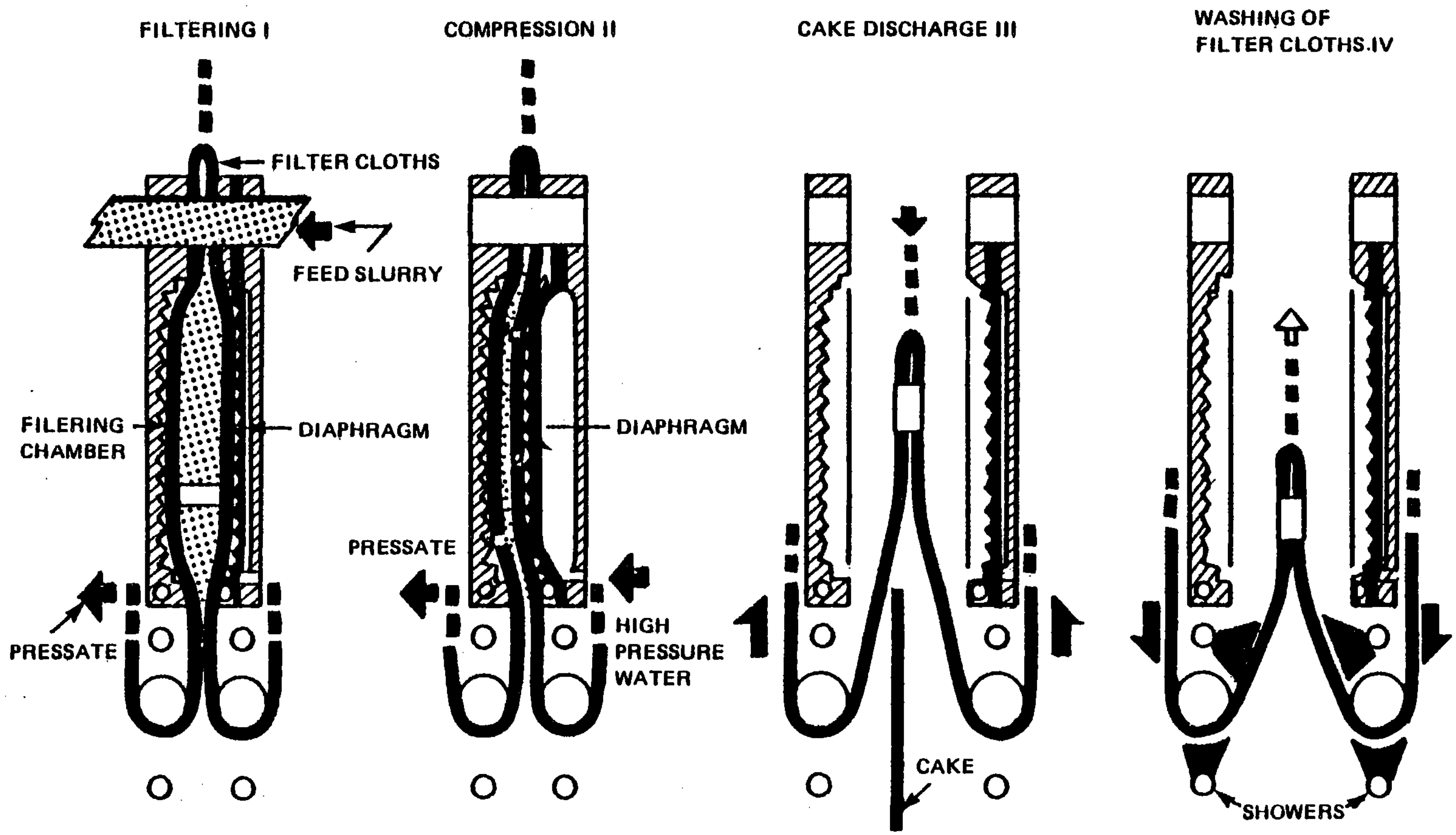

FIGURE VI-14 LASTA DIAPHRAGM PRESSURE FILTER

This press is reported to achieve shorter cycle times than conventional presses because of the improved control of the relationship between cake formation and pressure build-up. However, pricing figures available indicate that these units will be priced about eight times the price of a conventional filter press.

Widespread use of filter presses throughout the industry has not been experienced due to several operational limitations such as frequent filter cloth maintenance and manual operation of various dewatering sequences each contributing to excessive operational costs. In recent years, these shortcomings have been overcome. with the advent of suitable monofilament filter media and increased mechanization.

The main advantage to using a filter press for sludge dewatering is in the reduced sludge disposal costs associated with producing a drier cake solids. However, a detailed cost analysis should be performed to determine if these savings are sufficient to offset its high capital cost.

A schematic of a pressure filtration system incorporating precoat and chemical conditioning units is shown in Figure VI-15.

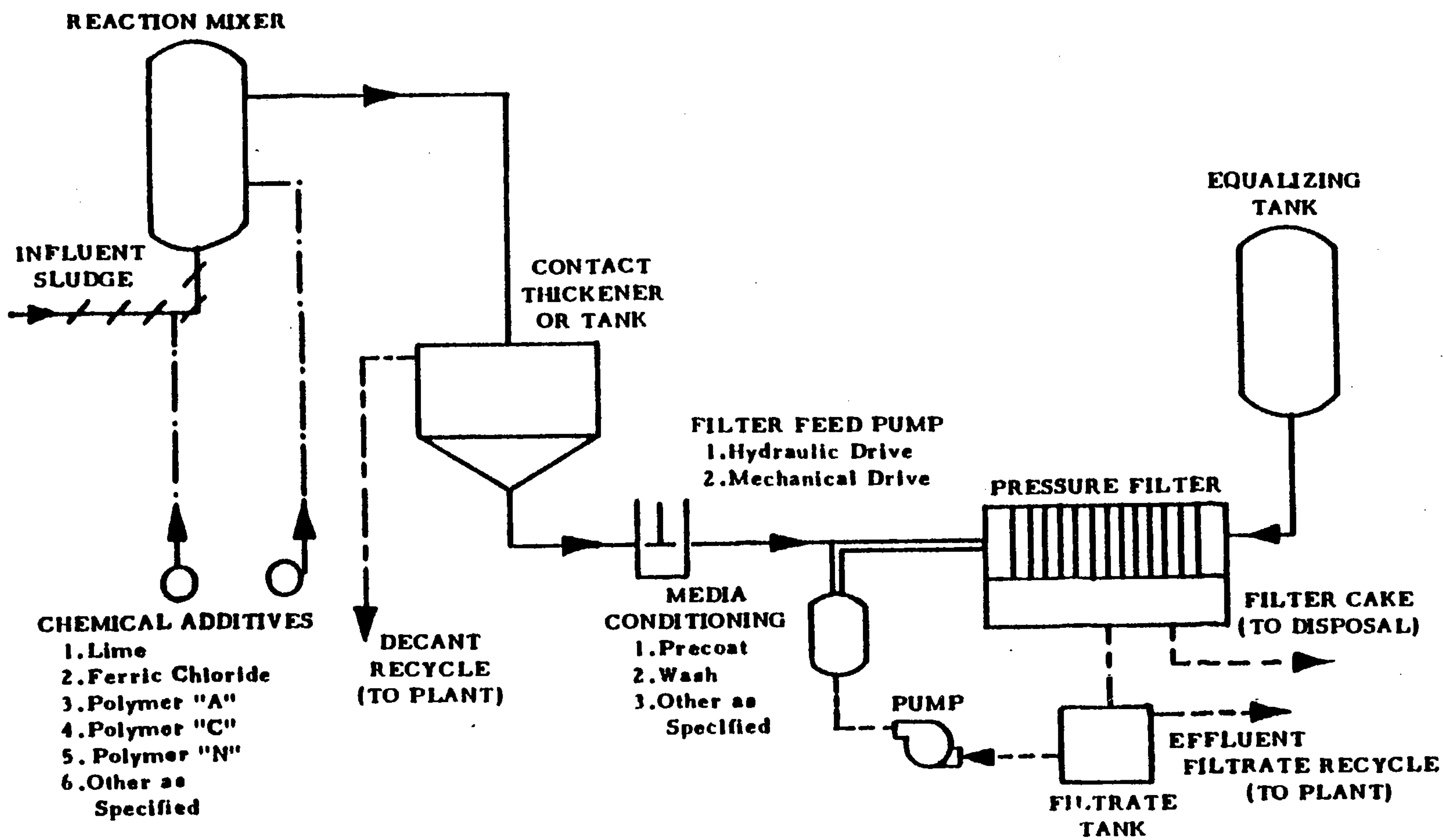

FIGURE VI-15 PRESSURE FILTRATION SYSTEM

D. Centrifugation

General

A centrifuge is essentially a sedimentation device in which the solids - liquid separation is enhanced by the use of centrifugal force. This is accomplished by rotating the liquid at high speeds to subject the sludge to increased gravitational forces.

There are basically three types of centrifuges available for sludge dewatering.

1. Continuous Solid Bowl Centrifuge. This centrifuge consists of two principal elements: a rotating bowl which is the settling vessel; and a conveyor which discharges the settled solids (see Figure VI-16). The rotating bowl is supported between two sets of bearings and includes a conical section at one end. This section, which is not submerged, forms the dewatering beach or drainage deck. Sludge enters the rotating bowl through a stationary feed pipe extending into the hollow shaft of the rotating screw conveyor and is distributed through ports into a pool within the bowl. As the bowl rotates, centrifugal force causes the slurry to form an annular pool, the depth of which is determined by the effluent fluent weirs.

The rotating screw conveyor continuously moves the sludge solids across the bowl, up the beaching incline to outlet ports and then to a discharge hopper for ultimate removal.

As the liquid sludge flows through the bowl towards the overflow weirs, progressively finer solids are forced to the rotating bowls wall. The water (centrate) drains from the solids and back into the pool. The centrate is then discharged through ports at the end where the effluent weirs are located.

Most solid bowl centrifuges are of the "countercurrent" type employing a countercurrent flow of liquid and solids. Recently a "concurrent" centrifuge has been introduced in which the incoming sludge is carried by the feed pipe to the end of the bowl opposite the discharge (see Figure VI-17). As a result, settled solids are not disturbed by the incoming feed. Turbulence is reduced substantially as both the solids and liquid pass through the bowl in smooth parallel flow patterns. Because solids are conveyed over the entire length of the bowl before discharge, better compaction is achieved providing drier cake solids and reduced polymer demand.

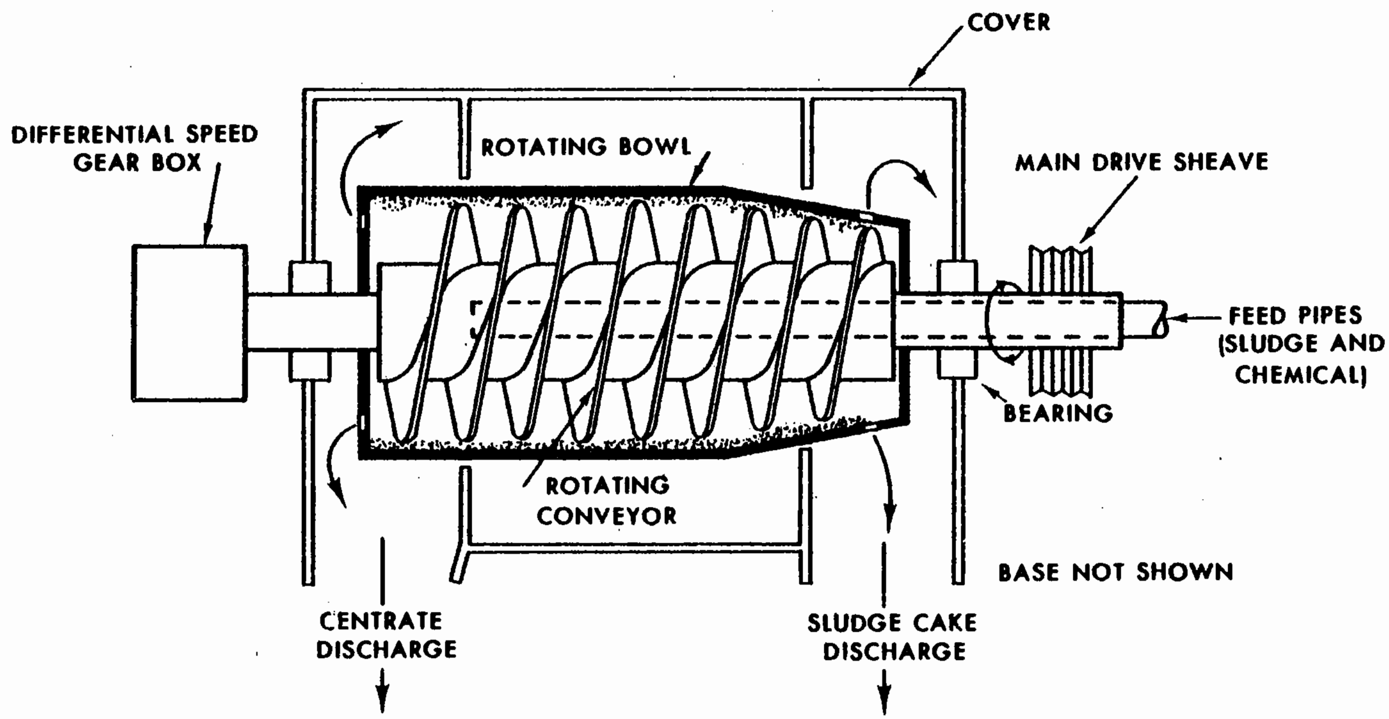

FIGURE VI-16 CONTINOUS COUNTERCURRENT SOLID BOWL CENTRIFUGE

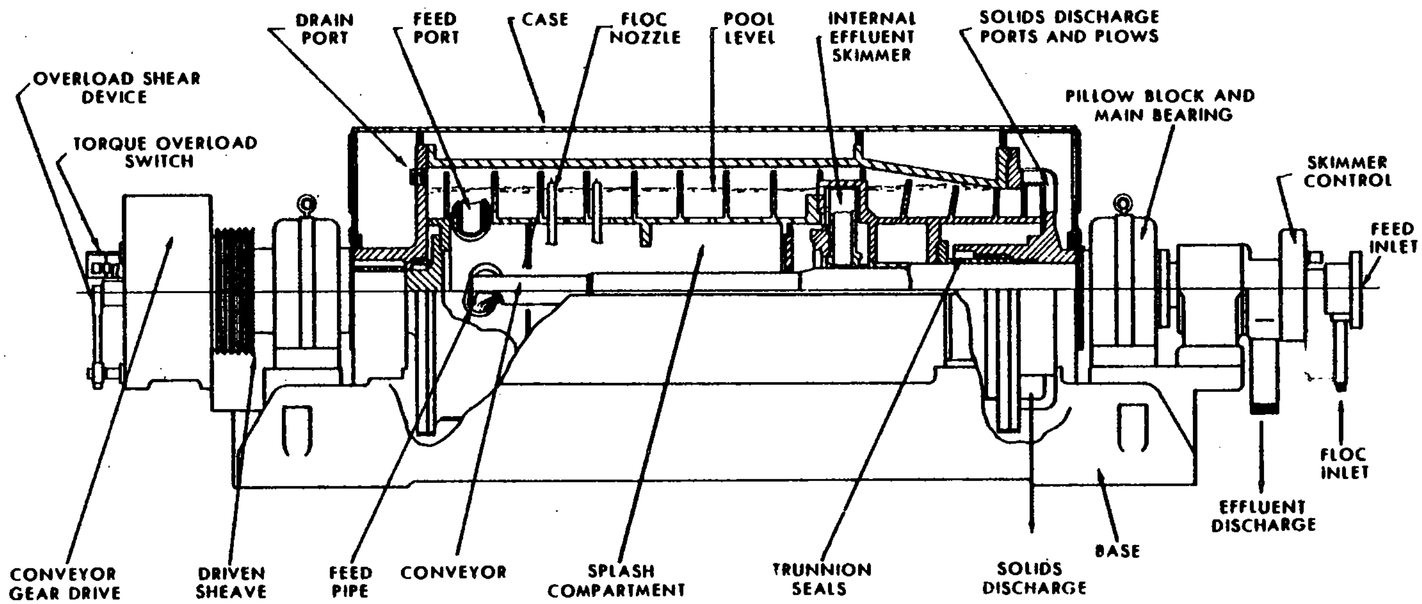

FIGURE VI-17 CROSS SECTION OF CONCURRENT FLOW SOLID-BOWL CENTRIFUGE

2. Basket Centrifuge. The basket or imperforated bowl-knife discharge unit, as shown in Figure VI-18, is a batch dewatering unit introduced primarily for use as a partial dewatering device for small operations.

Sludge is charged into the basket forming an annular ring as the unit rotates around its vertical axis. Cake continually builds up within the basket as the liquid (centrate) is displaced over a baffle or weir at the top of the unit. When the solids concentration of the centrate reaches an undesirable level, the centrifuge is stopped, the unit decelerates, and a skimmer enters the bowl to remove the remaining liquid. A knife is then moved into the bowl to cut out the cake which falls out the open bottom for removal. Although the batch operating mode of this type unit does limit its adaptability to large scale operations, it is capable of producing higher solids recovery than continuous devices without chemical addition because of minimum disturbance of the depositing solids.

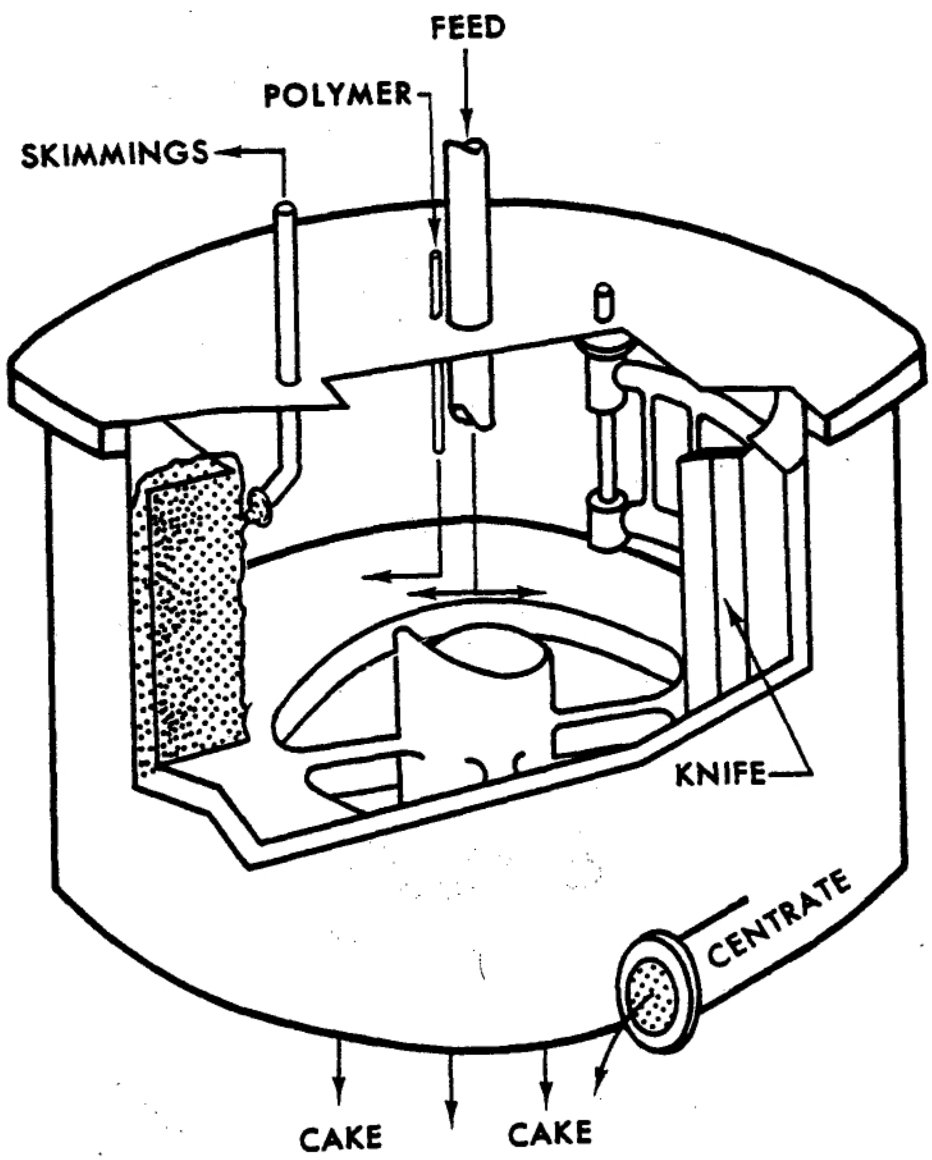

FIGURE VI-18 SCHEMATIC OF A BASKET CENTRIFUGE

3. Disc Centrifuge. The disc centrifuge, shown in Figure VI-19, is a continuous flow variation of the previously described basket centrifuge. The incoming sludge is distributed between a multitude of narrow channels formed by stacked conical discs. Sludge solids have only a short distance to settle which rather limits this units application to those sludges containing small, low density particles. Solids are collected and continuously discharged through fairly small orifices in the bowl wall (0.05 to 0.10 inches). These orifice openings impose the upper limit as to the size solids which can be handled by this type unit. Without adequate screening prior to centrifugation, this centrifuge is prone to orifice plugging resulting in prohibitive maintenance costs.

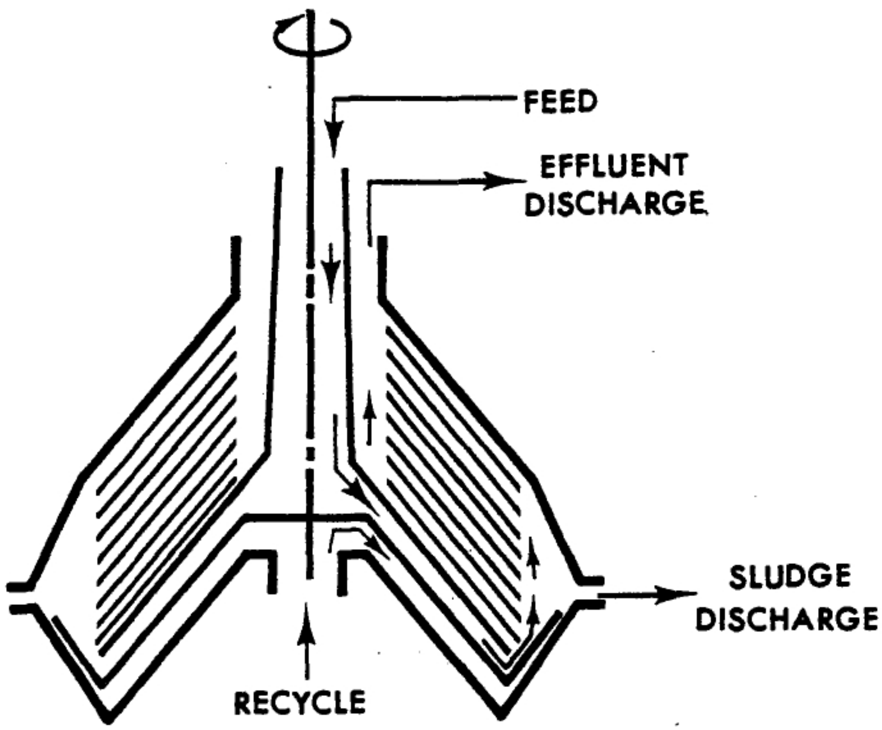

FIGURE VI-19 DISC TYPE CENTRIFUGE

In past years, attempts to gain widespread acceptance of the centrifuge throughout the industry had been plagued by two problems:

a. Erosion of those surfaces exposed to high speed impingement of abrasive materials resulting in excessive maintenance costs.

b. Inability to provide a reasonably clear centrate and avoiding serious fines recirculation. In effect, solids capture was inadequate.

Recently, improvements to the basic unit as well as developments in wastewater technology have had a significant impact in gaining increased acceptance in the industry. These are as follows:

a. Development and use of high molecular weight, shear resistant polymers.

b. Use of lower rotational speeds to achieve higher solids capture and minimize recirculation of solids without high polymer dosages. This low rotational speed also reduces wear and tear on the rotating parts.

c. Use of tungsten carbon construction to minimize abrasion wear.

d. Adjustable speed differential between the bowl and the sludge removal conveyor for increased system flexibility.

e. Use of larger bowls with smaller diameters.

f. Availability of units capable of handling large sludge dewatering needs which provide for economy of scale.

4. <u>Centrifuge-Operation</u>

Machine variables which affect centrifuge performance are as follows:

Bowl Design

a) Length/Diameter Ratio - For a given bowl diameter, increasing the length/diameter ratio increases the settling time and surface area. Although an increase in the diameter will increase settling time, lower centrifugal forces result which offset potential advantages.

b) Bowl Angle - Providing a steeper bowl discharge angle will increase the length of the clarifying zone and in addition, increase centrifugal forces.

c) Flow Pattern - Using a concurrent flow pattern in lieu of the more widely used countercurrent flow pattern has a decreasing effect on the magnitude of turbulence developed in the bowl.

Bowl Speed - Increasing bowl speed increases centrifugal forces and favors increased clarification. However, cake discharge becomes more difficult and abrasion problems are intensified.

Pool Depth - Within limits, as pool depth increases, retention time increases thereby improving clarification. However, providing too great a pool depth may prevent some sludge solids from reaching the sediment zone prior to being discharged. At too shallow a depth some sludge solids may tend to redisperse as a result of the moving conveyor.

Conveyor Design - Conveyors are normally designed and/or adjusted to produce minimum turbulence within the pool while providing adequate sludge removal capacity. As conveyor speeds are reduced, the rate of abrasive wear is decreased. While increasing conveyor speed may produce drier cake solids, abrasion problems would only intensify.

Sludge Feed Rate - Clearly one of the most important operating variables is sludge feed rate. As the sludge volume per unit time increases for a given centrifuge, there is generally a decrease in solid recovery. As a result of this increase of fines in the centrate, the cake solids produced are usually drier.

Figure VI-20 shows a typical centrifuge installation. Progressive cavity pumps are usually used for sludge feed pumps since a constant feed rate is essential. Not shown, is a cyclone separator generally incorporated into those systems encountering a gritty sludge.

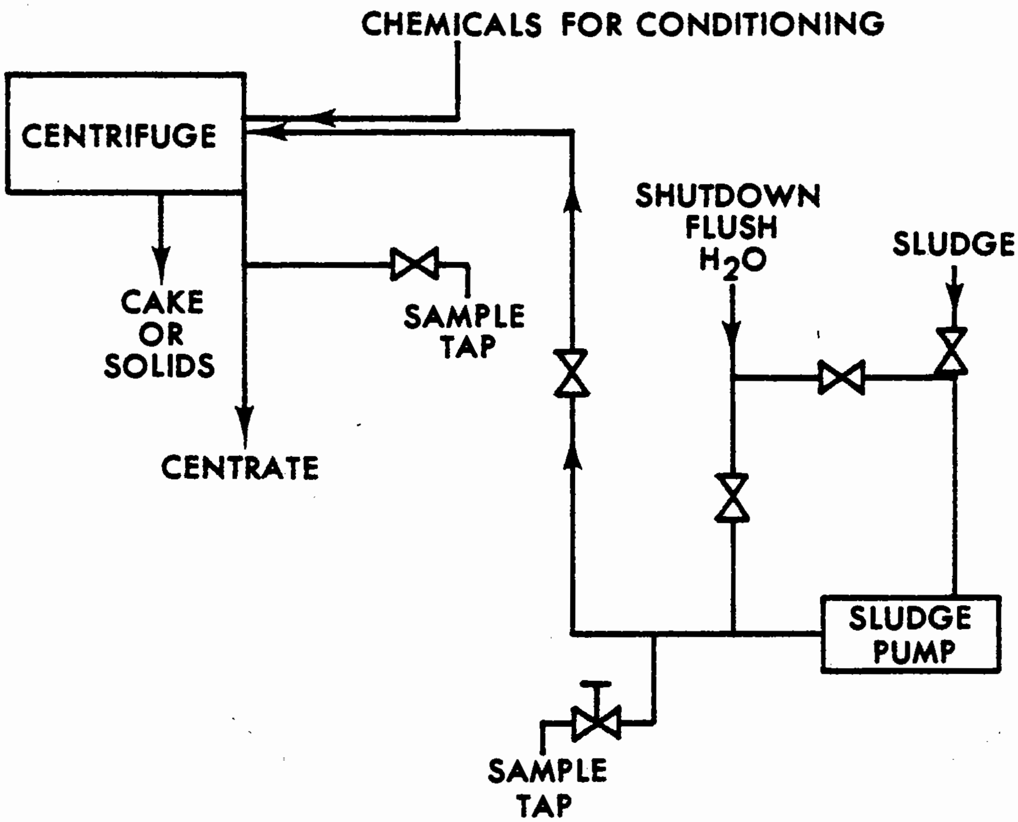

FIGURE VI-20 CENTRIFUGE DEWATERING SYSTEM