WATER / WASTEWATER DEWATERING WITH THE MEMBRANE FILTRATION TECHNIQUE

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ABSTRACT

In the United States, as well as most industrialized areas of the world, there is an increasing requirement for today's industrial and municipal water / wastewater treatment systems to produce drier and firmer cake solids for either composting, land-filling, land-applying, or combustion processes. New and old wastewater treatment processes are faced with increased capacity needs as well as a variety of constraints for their disposal processes. A horizontal plate filter press dewatering system utilizing the membrane (diaphragm) filtration technique will provide solutions to meet the demands and constraints of today's and the future's water / wastewater treatment requirements. This paper will briefly describe the benefits / advantages as well as possible future requirements of the horizontal membrane filter press. Also, known case studies of existing applications will be discussed supporting this type of dewatering process.

INTRODUCTION

Industrial and municipal water / wastewater treatment systems are characterized by extreme complexity. Technology can vary depending on such factors as the specific application, economics, environmental regulations and concerns, and available resources. Often these and other concerns make engineering and management decisions difficult as well as considering emerging new technologies in meeting the needs of today's and the future's water / wastewater treatment goals.

In most industrial and municipal wastewater treatment systems, the final "product" produced by the treatment process requires dewatering - physical separation of the solids fraction for final disposal and the liquid fraction for recycling to the beginning of the treatment process or for further treatment processing. In this final dewatering process, the membrane (diaphragm)* filtration technique can be one of the most important steps in the overall treatment process by providing higher cake solids, better transportable filter cakes, and lower disposal costs as well as overall improved economics.

* NOTE: For reason of clarification, the term membrane should not be confused with submicron mediums – "membranes" utilized in reverse osmosis, microfiltration, or ultrafiltration applications. The word "membrane" has been distinctly used in the filter press industry but the word "diaphragm" is a better choice of words when considering the broad spectrum of treatment processes and techniques. However, in this report the words will be interchanged for convenience purposes.

Historically, there have been many dewatering techniques and systems utilized for solid / liquid separation. A few of the various types of systems include belt presses, centrifuges, rotary drum vacuum filters, tube filters, rotary screw presses, sand filters, automatic vertical presses, and horizontal plate filter presses. Horizontal plate filter presses include fixed volume recessed chamber plate filter presses and variable volume membrane plate filter presses. These various types of systems can be further subdivided into continuous or batch type processes. For the last twenty years in North America, horizontal membrane plate filter presses have been a slow emerging choice for dewatering applications. This is mainly due to the following issues: lack of knowledge in the industry considering the membrane filtration technique as an emerging technology, higher initial capital costs compared to other dewatering systems, variously reported commissioning problems concerning failures of membrane plates, malfunction of initial start up operations, and the general attitude of "not wanting to be the first to try something new," but more than willing to be second in line. It should be noted the membrane filtration technique has been well accepted as the primary choice for dewatering applications in the European community due to stricter regulations and a general higher consciousness for environmental concerns.

There have been several excellent papers presented on the comparison of different dewatering techniques and option considerations. Also available are articles on the development and U. S. market acceptance of the horizontal plate membrane filter press system. (Refs. 3, 4, 5, 6, 7, 8)

As the horizontal plate filter press has been traditionally categorized as a non-continuous batch type system requiring various degrees of labor attention, there has been a recent trend for complete automation (labor-free) and continuous operation that is threatening the horizontal filter press as a logical choice for dewatering applications. However, applying the membrane filtration technique can allow the opportunity for future advancements to meet the needs of the growing trend for "automatic–continuous" batch processes. Several new trends with filtration technology and equipment were presented at the Achema Exhibition-Congress in Frankfurt, Germany, held May 22-27, 2000.

MEMBRANE (DIAPHRAGM) FILTRATION TECHNIQUE

Horizontal plate filter presses have been utilized for over the last (150) one hundred fifty years for dewatering such slurries as municipal wastewater sludge and clay / kaolin mixtures for the production of ceramic tableware. (Ref. 9) To become familiar with the membrane filtration technique is to understand its predecessor and still today's most popular filter press application

choice in the U.S. - the filtration technique utilizing polypropylene fixed volume recessed chamber filter plates.

RECESSED CHAMBER FILTER PRESSES

The fixed volume recessed chamber filter press utilizes a series of horizontally arranged vertical filter plates. Polypropylene filter plates have been selected as the primary choice for the last (30) thirty years due to chemical resistance, weight, and cost compared to coated cast iron or ductile iron filter plates. Each filter plate, mainly fitted with a polypropylene woven cloth, has a fixed chamber depth and filtration area in providing a fixed volume capacity. The filter press also consists of a cast iron or steel skeleton to support the filter plates/cloths and the closure mechanism to provide the necessary closing force on the sealing areas of the plates to counteract the applied force created by the filtration cycle. The formation of the cake in each chamber is applied by the hydrodynamic dewatering principle. The slurry is fed into the chambers allowing the suspended particles (solids) to form on the filter cloth and continue to cake up until a solid cake thickness is formed in the chamber. The liquid (filtrate) flows through the cake / cloth and is discharged through the discharge outlets. The filtration cycle is complete when the minimum specific filtration efficiency has been reached. Typical terminal filtration pressure is 100 psig as well as up to 225 psig. When the filtration cycle is complete, a filter cake wash cycle may be applied before discharging the filter cake from the chambers. (Refs. 10, 11)

MEMBRANE (DIAPHRAGM) RECESSED CHAMBER FILTER PRESSES

The variable volume membrane filter press utilizes a series of horizontally arranged filter plates as well. The membrane plate is basically a recessed chamber plate with two inflatable diaphragms attached to the core body plate. The diaphragms can be supplied welded to the core body plate or in a detachable, replaceable diaphragm design. (Exhibits 1 & 2) The diaphragms can be inflated (pressurized) with compressed air or water to squeeze additional moisture from the formed filter cake. The inflation step will vary the volume of the filter plate system capacity from its pre-squeezed fixed volume. Typical terminal filtration pressures can be up to 100 psig while most terminal squeeze pressures are up to 225 psig. The plates can be supplied in an “all” membrane plate arrangement or alternately arranged with standard recessed chamber filter plates. When combining membrane and chamber plates, the advantages of the membrane filtration technique are maintained. In addition, the investment costs for the membrane plate package can be reduced by approximately 30 to 40 %. (Refs. 10, 11)

EXHIBIT 1

Filter Plate Cross-section

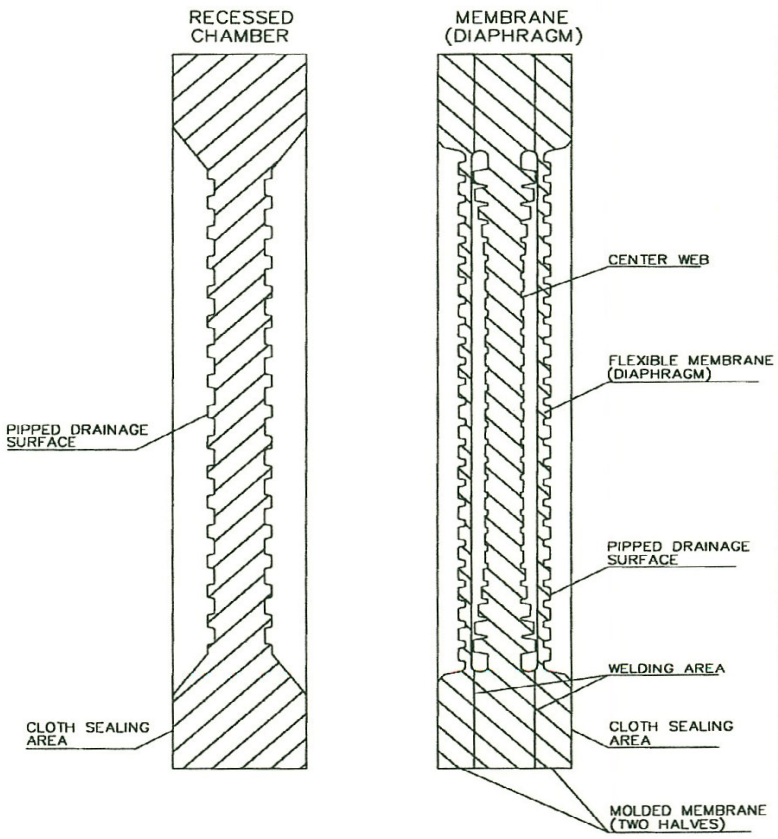
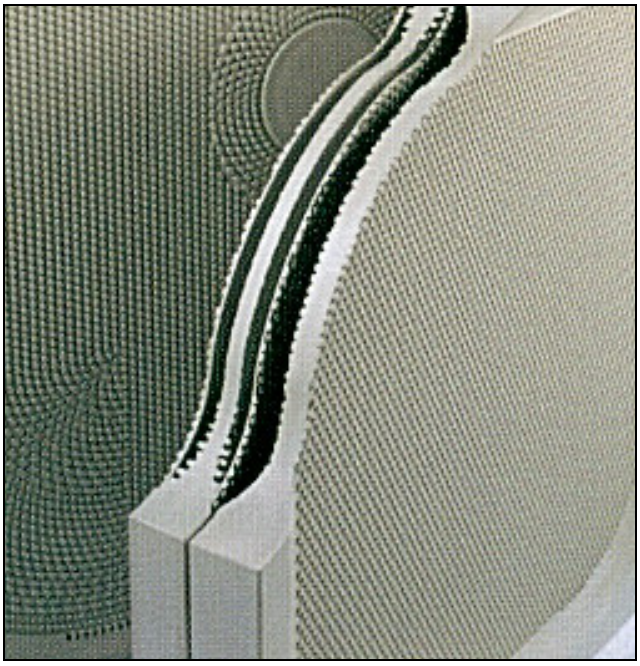


EXHIBIT 2

Mixed Pack Membrane Plate System



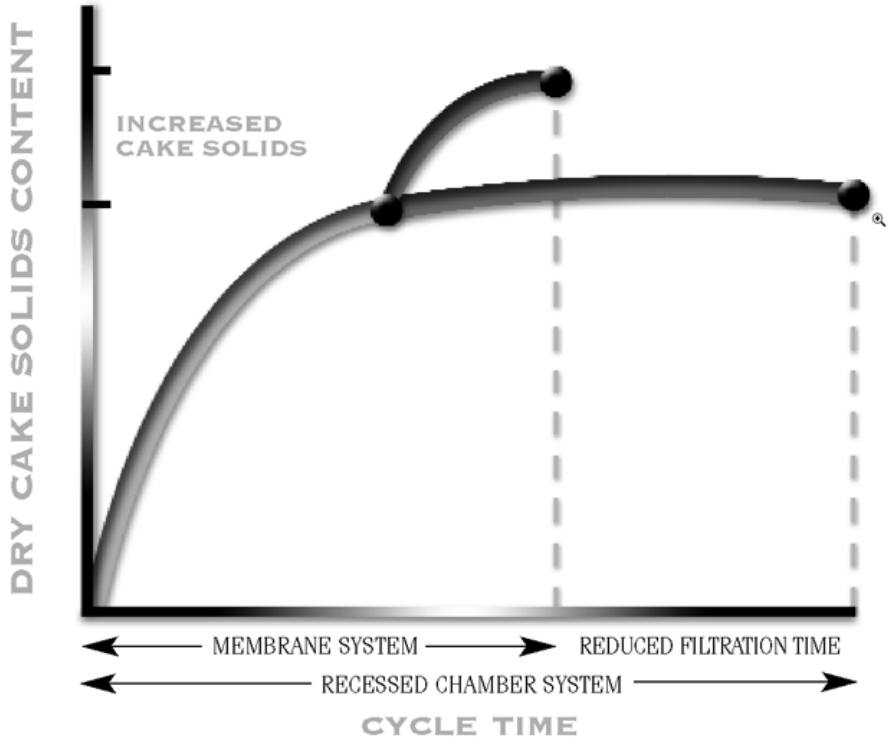
MEMBRANE FILTRATION TECHNIQUE

When the final selection of a chosen filter press filtration system requires the filtered cake to be of the highest degree of dryness and meet certain criteria for shear strength, the membrane filtration technique will outperform any currently utilized filter plate system.

The two types of filtration techniques – fixed volume recessed chamber and variable volume membrane filter plates differ only in one important point - the final filter cake is a result of the mechanical squeeze step of the membrane plates. (Exhibit 3) In a conventional recessed chamber filter press, the cake is built up in layers until the chamber is completely filled with solids. As the cake thickness increases, the less the cake becomes permeable, leading to a decline in the discharge flow rate. Intense compressible products reduce the cake permeability causing long filtration cycles and lower yields. Approximately 70-80% of the batch is filtered in the first 50% of the cycle time. If the filter plate system is opened before the filtration cycle has reached its minimum specific filtration efficiency, the result will be a wet, sloppy, egg-shelled filter cake. (Refs. 10, 11)

EXHIBIT 3

Membrane Plate System versus Recessed Chamber Plate System



The significant advantage of the membrane filter plate technique is that the filtration phase is conducted in only the efficient phase of the cycle. The unproductive phase of the hydrodynamic filtration cycle is replaced by squeezing (pressurizing) the diaphragm when the filtration cycle is still in an efficient point in the cycle. The filtration (feed) step is completed and the diaphragms are pressurized to squeeze additional liquid from the filter cake.

BENEFITS OF THE MEMBRANE FILTRATION TECHNIQUE

When considering the final step of an industrial or municipal water / wastewater treatment process, the membrane filtration technique will provide the highest degree of flexibility for the available disposal processes - composting, landfilling, land-applying, or combustion.

Higher and Firmer Cake Solids

When squeezing the filter cake, the porosity of the filter cake decreases, so that additional dewatering occurs. With the recessed chamber filter plate technique, the cake next to the cloth is drier than in the center due to uneven distribution of pressures when the two half cakes form into one filter cake. The membrane squeezing technique will result in a drier overall cake with solids content from 25 to 100% greater than the fixed volume recessed chamber filter press.

Each disposal process listed above possesses criteria for the maximum dry cake solids requirement. The advantage of the membrane filtration technique is that the final cake solids can be adjusted and optimized based upon the requirements of the disposal processes. Composting will require a certain dryness requirement of the cake to properly mix with wood chips or other organic material. Land-applying may require a certain degree of dryness to be used as a fertilizer or as a fill material in land reclamation projects. Land application is an accepted approach for its beneficial use of sludge but there are increased concerns regarding potential hazardous products leaching into our water supplies and / or food chain. (Ref. 5) Landfilling will require filtration systems that provide the highest cake solids possible due to increased tipping fees, reduction of landfill availability, and future requirements for higher cake solids (> 40 %). Combustion (incineration) processes will need higher BTU-rated filter cakes to provide better sludge combustion systems due to growing public concerns over air emissions and ash residue, as well as tightening regulations. (Ref. 5)

The membrane squeeze step causes a more even spread of the applied pressure so that a homogeneous porosity is created within the cake. The average grade of dewatering is profoundly higher with the membrane filtration technique compared to the conventional dewatering technique with fixed volume recessed chamber filter plates. As a result, a firmer filter cake is formed leading to higher cake compression strength. This is critical for transportation and landfilling requirements.

Reduced Cycle Times Lead to Increased Production

The membrane filtration technique will provide the maximum specific filter efficiency of any type of filter plate system. Reduced cycle times compared to the recessed chamber filtration technique lead to increased production. The combination of higher cake solids and reduced cycle times will increase production yields. Due to increased production yields, the size and capacity of the filter press and the amount of labor required can be reduced.

Reduction of Chemical Conditioning Requirements

Most slurries produced from water / wastewater treatment processes exhibit very poor settling and filtering characteristics requiring chemical conditioning. Chemical conditioning with filter presses is mainly accomplished with inorganic chemicals (ferric chloride / lime), organic chemicals (polymers), or a combination of ferric chloride / polymer. Solids compressibility

theory has proven that most solids are pseudoelastic and compress better when thinner. (Ref. 12) The membrane filtration technique will provide the ability to vary the cake thickness, increase solids content, and increase production yields, as well as minimize chemical conditioning requirements. It has been proven that thin cakes are desirable to produce dry cakes and increase production yields. (Ref. 13) With fixed volume recessed chamber filter plates, the chemical conditioning must provide efficient dewatering even when the cake thickness and pressure increases in the chamber, or a wet sloppy filter cake will result. The advantage of the membrane filtration technique is that the mechanical squeeze step replaces the stage in the cycle when the filtration efficiency has decreased due to the reduced permeability of the cake. As a result, the chemical conditioning requirements can be reduced because additional dewatering is a function of the mechanical squeeze step.

Excellent Cake Washing Capability

Cake washing is utilized to displace the liquid fraction in the cake with another liquid (mainly water) or to remove impurities from the formed cake that contain soluble impurities. In water / wastewater treatment applications, washing, if required, is utilized to displace a valuable liquid from the waste solid product. The membrane filtration technique provides a uniform, homogeneous filter cake that will provide optimum wash efficiency in terms of displacement / impurity removal and wash water consumption.

CASE STUDIES

The following case studies support the benefits of the membrane filtration technique for water / wastewater treatment processes that require solid / liquid dewatering.

Case 1

In 1990, a California municipal water / wastewater treatment plant was reaching the limits of acceptable bio-solids in their settling lagoons. The plant is treating the region's complete wastewater inflow as well as backwash flow from the local water treatment plant. After treatment, the bio-solids are transferred into various lagoons for settling. The municipality required a dewatering process that would provide filter cakes suitable for their own composting facility or for sale of the filter cakes to a private composting facility. This required a dewatering process to produce dry and firm cakes from anaerobic sludge that has very poor settling and filtering characteristics. Since polymer was the only accepted conditioning agent, a pilot study with horizontal recessed chamber and membrane filter plate techniques was conducted. The pilot study recommended a membrane filter press with a thin cake recess (30mm) to squeeze the highly compressible bio-sludge into the highest possible dry cake. The membrane filtration technique was also found to provide adequate cake release which required occasional filter cloth washing when an under-conditioned batch was inadvertently made.

A 1500mm x 1500mm membrane filter press was installed in 1992 with KLINKAU "Empty Chamber" (Ref. 14) replaceable membrane filter plate system. The replaceable "empty chamber" filter plate system was selected due to potential problems with a polymer-conditioned sludge and underfilling of the chambers leading to overstretching of the membrane plate. The municipality has reported no filter plate damage or failure since the commissioning of the dewatering system. The membrane filtration technique has provided flexibility in optimizing the necessary cake solids required for the composting process. The membrane filter press has met the goals of the

project for cake solids, cake release, and production yield. Table 1 below presents data from the project.

TABLE 1

CALIFORNIA MUNICIPALITY SLUDGE DEWATERING

PILOT STUDY RESULTS					
Plate System	Cakes Solids (%)	Cycle Time (min.)	Polymer Dosage (#/ton)	Pressure (psig)	Acceptable
Recessed	< 20	165	20	225	No
Membrane	29	105	15.5	100 (feed) 225 (squeeze)	Yes
AVERAGE MONTHLY RESULTS					
Membrane	27	110	13.1	100 (feed) 225 (squeeze)	Yes

Case 2

A Pennsylvania steel mill had installed a 1500mm x 1500mm fixed volume recessed chamber filter press to dewater the sludge generated from their pickling operation. The treatment process produced 20% slurry to be dewatered in the filter press. Due to the high solids loading and the fast filtering characteristics of the sludge, the filter press produced "dough-like" filter cakes that were labor intensive to remove from the filter cloth. The filter cakes are currently disposed on a company- owned landfill at another location. The wet, "dough-like" filter cakes posed two transportation problems; water leakage from the container and the thixotropic nature of the cakes caused troublesome dumping maneuvers. The steel mill faced the future closure of the company-owned landfill and increased costs to dispose at a public landfill. A KLINKAU membrane filter plate system was installed to replace the fixed volume recessed chamber filter plate system. The membrane filter plate system has continuously produced dry, firm cakes that completely fall from the chamber into the container. Table 2 below presents data from the project.

TABLE 2

PENNSYLVANIA STEEL MILL WASTEWATER DEWATERING

Plate System	Chambers	Capacity (ft^3)	Pressure (psig)	Cake Solids (%)	Cake Density (#/ft^3)	Lbs. / Dry Solids/ Cycle
Recessed	62	120	90	45	75	4050
Membrane	54	95 (post squeeze)	50 (feed) 100 (squeeze)	65	85	5250

Case 3

A municipal water / wastewater treatment plant in Bad Segeberg, Germany, was faced with increased capacity prompting the decision to install a duplicate recessed chamber filter press. Instead, the plant installed a KLINKAU membrane filter plate system in the existing filter press. The key benefit is that additional cycles are accomplished in the same period of time resulting in increased throughput. The additional benefit of higher cake solids will meet the future requirements of the European community for landfill disposal. The installation has been operating 24 hours a day since 1989 with consistent and excellent results. (Ref. 8) Table 3 below presents data from the project.

TABLE 3

BAD SEGEBERG, GERMANY, MUNICIPAL SLUDGE DEWATERING

Plate System	Cycle Time (min.)	Cycles / day	Pressure (psig)	Cake Solids (%)
Recessed	240	4-5	225	33-37
Membrane	140	7-8	100 (feed) 225 (squeeze)	44

FUTURE OPPORTUNITIES FOR MEMBRANE FILTRATION

There is a growing trend with industrial and municipal water / wastewater treatment processes to become an automatic-continuous operation combining previously separate processes into combined processes. In Europe, there are several installations involving filter presses that are utilizing the membrane filtration technique to achieve higher cake solids with the use of high-pressure membrane plates (rated up to 450-psig-squeeze pressure). The combination of a high pressure (> 225 psig) membrane filter press with highly automated subsystems (filter plate vibrator, filter cloth spreader, and cake scraping devices) has met the demands for an automatic-continuous batch process.

An additional method is the combination of dewatering and drying steps in a membrane filter press. This patented technology utilizes a modified filter press, hot water / steam source, and a vacuum system. (Ref. 15) The key advantage is that the filter cake solids can be dried mechanically to any desired level by the thermal / vacuum drying process without the necessity of cake discharge, de-lumping / handling, and transport to a separate drying system. (Ref. 16)

These types of automatic-continuous batch “combo” methods will further enhance the selection of the horizontal filter press utilizing the membrane filtration technique in meeting the growing needs of today’s and the future’s water / wastewater treatment processes.

SUMMARY

The membrane filtration technique has been proven as a logical choice for water / wastewater treatment dewatering applications. The key benefits of a membrane filter press are high solids cake, reduced cycle times, reduced chemical conditioning requirements, increased cake wash capability, and overall better process flexibility compared to other dewatering processes. Additionally, the membrane filtration technique can provide future benefits concerning process automation, continuous operation, and combo dewatering/drying methods.

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