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Revision Memo

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New Design Practice


Documents

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SCOPE

This section covers dewatering equipment for oily and biological sludges generated in ExxonMobil manufacturing plants. In most cases the sludges with significant water contents are generated from the removal of suspended oil and solids in wastewater treatment plants. The practice was not intended to cover tank cleaning or bottom sludges, but this practice may help identify dewatering equipment for these applications. Dewatering of slop oils and slop oil emulsions is not included in this practice. This section will cover typical equipment used at refineries and chemical plants, including gravity/pressure belt presses, rotary vacuum filter drums (also referred to as rotary drum thickeners), centrifuges and recessed plate filter presses. Thermal drying is covered in [DP XX-C2](#) and may also be included as part of a waste handling train. Incinerators, cokers and cement kilns are typically not part of the environmental waste treatment area of responsibility, although pretreatment for these processes should be included in dewatering equipment selection. Pretreatment for incinerators, cokers and cement kilns is covered in general in [Section XX-A](#) Guidelines and Considerations for Managing Solid and Liquid wastes. Gravity thickening, covered in [DP XX-A2](#), of high water content sludges is typically employed prior to mechanical dewatering of biological and oily sludges from wastewater treatment plants. This design practice provides technical considerations for preparation of a duty specification for mechanical dewatering equipment and systems. It is not intended to provide information to allow design of these facilities. The technical information provided to help prepare a duty specification would apply whether the facilities will be purchased or leased.

REFERENCES

DESIGN PRACTICES/GUIDES

- [DP XX-A](#) Guidelines and Considerations for Managing Solid and Liquid Wastes
- [DP Section XX-A2](#) Gravity Sludge Thickeners
- [DP XX-A9](#) Water/Wastewater Chemical Feed Systems
- [DP XX-C2](#) Thermal Treatment

Section DG 11-8-1 Gravity Belt Filter Press System, Dec. 1997, Exxon Water and Wastewater Design Guide (TMEE 080)

OTHER REFERENCES

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3. Mitchell, A. O., EE.10E.86, Dewatering, and Recovering Oil from, Wastewater Treatment Sludges with Mechanical Equipment, January, 1986
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5. Water Environment Federation, "Operation and Maintenance of Sludge Dewatering Systems, Manual of Practice No. OM-8, 1987
6. Water Environment Federation, " Basic Maintenance of Belt Filter Presses," copyright 1997
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11. R. S. Gurak & R. W. Scharrow, Centrifuge Pilot Test on Montreal Oily Sludge, 82-03-10, R 41372, March 1982
12. Water Environment Federation, "Sludge Conditioning", Manual of Practice No. FD-14, 1988
13. Water Environment Research Foundation, "Thickening and Dewatering Processes: How to Evaluate and Implement an Automation Package", Project 98-REM-3, Final Report, 2001
14. American Public Health Assoc., et. al, "Standard Methods for the Examination of Water and Wastewater," 20th Edition, 1998

DEFINITIONS

Dewatering - Dewatering is the removal of water from a sludge, usually by mechanical means, to achieve a greater volume reduction than that achieved by thickeners. The product of the dewatering is usually in the range of about 10-30% percent dry solids.

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Thermal treatment unit – The piece of equipment in which moisture and hydrocarbons are removed by heat transfer and evaporation.

Drying – The removal of water from a material by evaporation. In a broader sense, it can include removal of water and hydrocarbon from a material.

Moisture Content – The weight loss from a sludge or soil sample dried to 103 - 105 deg C per Standard Methods for the Examination of Water and Wastewater, 17th ed., Method 2540. This includes water and some light hydrocarbons.

Paint Filter Test - A lab test to determine if a dewatered sludge will release additional water during transportation to the disposal facility. Dewatered sludge may require lime addition, or another additive, to ensure the free water is bound to the sludge cake.

Solids Capture- The percent of feed solids remaining with the dewatered sludge cake, usually 80-90%. Some of the feed solids are lost into the separated water filtrate, usually less than 20%. For example, if a thickened biox sludge with a 3% solids is dewatered to a 20% solids at a 85% solids capture efficiency, the separated water would contain approximately 5,200 mg/L of suspended solids. This is the reason why the separated water needs to be returned to the biox system.

Solids Content – The mass of solids remaining from a sludge or soil sample dried to 103 - 105 deg C per Standard Methods for the Examination of Water and Wastewater, 20th ed., Method 2540. The solids include inert solids and hydrocarbons (oil) that do not volatilize at 103 - 105 deg C. Sometimes the solids content is referred to as dry solids content.

Sludge – The accumulated semi-liquid suspension of settled solids deposited in tanks or basins from raw or treated water or wastewaters.

Stabilization - Stabilization is the addition of chemicals, such as lime, diatomaceous earth, fly ash or silicates, which change the consistency of a sludge from liquid to solid. It can be used as an alternative to dewatering, depending on the nature of the sludge and the ultimate disposal method used. The sludge must be fluid enough to mix well with the chemical, but dry enough to prevent excessive chemical use. Stabilization is sometimes used following dewatering to pass the 'paint filter test', used in the U.S.A. to determine if a sludge will drain liquid during transport.

Thickening - Thickening is a process which aims to increase the solids content of a dilute slurry by removing some of the water content by gravitational means. It is commonly used to concentrate biological solids or filter backwash solids where the free water content is greater than 95%, and is usually placed upstream of dewatering processes. The thickened sludge is usually pumpable by conventional means and has most of the characteristics of a liquid. Thickening is not always needed.

Total Suspended Solids - Total suspended solids (TSS) is the amount of suspended matter removed by a filter paper (which is dried at 217°F (103°C) per unit volume of sludge. TSS is expressed as mg/L. TSS does not include dissolved salts, usually reported as TDS, total dissolved solids. Total solids (TS) = TSS + TDS. For the purposes of sludge dewatering, TSS in terms of percentages is the important measure of dewatering effectiveness, but this term is sometimes abbreviated as %solids.

BACKGROUND

GENERAL

Mechanical sludge dewatering is the process used to remove a significant amount of the water from sludges generated in wastewater treatment units or tankage. Mechanical sludge dewatering is done prior to transportation offsite for disposal, or prior to further reduction in sludge volume through thermal treatment. In many locations, mechanical dewatering units are preceded by gravity thickeners, with the solid effluent stream routed to transport units (roll off containers) for offsite disposal, or to further reduction in sludge volume via thermal treatment. Dewatering is done primarily to decrease the operating costs of direct sludge disposal or conversion and disposal. Mechanical dewatering is only one component of the wastewater solids treatment process and must be integrated with the wastewater treatment system so that both the liquid and solids treatment units are optimized and total costs are minimized. Offsite disposal of sludges to third party facilities is done at only those sites that have been reviewed and approved by ExxonMobil personnel. More information on management of wastes is provided in the 'Responsible Waste Management Practices Manual', Vol.2, May 2003.

It is important to recognize that a chemical feed system is part of the mechanical dewatering process. Examples include polyelectrolyte dewatering chemicals or body feed such as lime slurry or diatomaceous earth for a recessed plate pressure filtration. Chemical feed and metering systems need to be factored into the facility basis and identified either in a separate duty specification or included with the dewatering equipment duty specification. The cost of chemicals needs to be factored into project basis.

ExxonMobil experience with mechanical sludge dewatering equipment is summarized in [Table 1](#). A typical flow plan for how the mechanical dewatering equipment is used in a manufacturing plant is provided in [Figure 1](#).

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REASONS FOR USING MECHANICAL SLUDGE DEWATERING

Sludges from wastewater treatment equipment have a large percentage of water, usually 90+ %. For biological treatment sludge from a typical activated sludge unit, the percentage is typically 98-99% water from the clarifier underflow. The volumes of watery sludge are very large, and either reuse or disposal would be prohibitively expensive without dewatering. The most important approach to sludge management is to look at the entire sludge generation/pumping/dewatering/disposal system to optimize how the sludge is handled, reused, or disposed of. Frequently the key factor in defining the preferred dewatering equipment is what solids % is acceptable for pumping or for final disposal. A life-cycle cost analysis should be made to determine whether the dewatering is performed with plant personnel or outsourced to a contractor, since operating costs for chemicals and equipment maintenance is significant for any dewatering equipment. For wastewater treatment sludges that will be transported and disposed of offsite, consideration should be given to mechanical dewatering followed by thermal drying to minimize the volume. For sludges that will be reused in existing process units, such as cokers, thickening and limited mechanical dewatering are needed to keep the sludge pumpable and only to the concentration needed to meet the coker sludge handling capacity.

TYPES OF MECHANICAL SLUDGE DEWATERING EQUIPMENT

BELT PRESSES

Belt filter presses are the most prevalent type of dewatering equipment for wastewater treatment applications. They use single or double moving belts to continuously dewater sludges through several stages of dewatering. All belt press filtration processes include the 3 operational stages shown in [Figure 2](#) : 1- Chemical conditioning of the feed, 2- gravity drainage to a non-fluid consistency, and 3- final dewatering through shear and compression of the drained sludge. A wide variety of mechanical configurations are available from the different manufacturers, but the overall system and operation are similar. Both moderate pressure (30psi or 200kPA) and high pressure options (75 psi, 520kPA) are available, depending upon the degree of dewatering performance needed. A flocculant, usually an organic polyelectrolyte or 'polymer' is mixed with the sludge prior to feeding it to the belt press. Free water drains from this conditioned sludge in the gravity section, and then the sludge moves on between 2 filter belts, which move around a series of rollers at a constant speed. The belts convey the sludge, allow water filtrate drainage, and progressively compress the sludge. The 2 filter belts separate at the end of the press where a scraper blade is used to remove the dewatered cake from the belts. The water filtrate and the spray wash water, used to keep the belts clean, are then pumped to the upstream section of the wastewater treatment (WWT) system, usually at the API separator or the flotation unit.

Belt press performance is measured by percent solids of the dewatered sludge cake, percent solids capture, the solids and hydraulic loading rates (per section of belt width), and the required flocculent chemical dosage. Several machine characteristics influence belt performance, including belt speed, tension, and the type of belt used for the particular sludge. Little oil separation or recovery from oily sludges should be expected, since the sludges are dewatered under low pressure in the belt presses. Belt presses need a sloped paved foundation and diked area to ensure that small amounts of the sludge that fall off the belts are captured and can conveniently be returned to the front end of the feed or to the WWT system. At a minimum, a canopy or roof needs to be over the entire belt press operation and foundation. For sludges with significant odor potential, a more complete enclosure around the belt press with off gas exhaust and perhaps treatment may be required. Careful consideration of the design of these enclosures needs to be made to ensure access can be made safely and efficiently for maintenance and belt adjustments during operation.

For manufacturing plants, the belt press is used primarily for dewatering biological waste sludge and dilute oily waste sludges from flotation units. The typical concentration of these sludges is 3-5% solids after thickening pretreatment, and the belt press will produce a cake sludge of 18-22% solids.

ROTARY VACUUM FILTERS

Rotary vacuum filters, sometimes called rotary vacuum drums, rotary screen thickeners or rotary drum thickeners have been used in municipal wastewater bio-sludge dewatering facilities for many years. The application of this equipment to some refinery sludges has been successful, and can offer advantages if used solely for dewatering sludges to a concentration that allows the sludge to be fed to a coker, or used as a thickener prior to third party treatment and disposal. The equipment functions similar to gravity belt presses in that the free water from the chemical conditioned sludge drains under a vacuum through a porous screen/filter while the sludge is retained on the filter. Variable speed units operate between 5-20 rpm. The sludge is moved along the screen continuously by an internal screw or angled flights, and exits through a discharge chute. A diagram of the process is shown in [Figure 3](#).

The only ExxonMobil application is at Baton Rouge Refinery, where the rotary drum is used as a thickener for biox sludge, concentrating the clarifier bottoms from about 1wt% solids to 5wt% for further dewatering using a gravity belt filter press. Typical applications in refineries or other manufacturing plants are to use the rotary drum downstream of a gravity thickener, concentrating the sludge from 3% to 10%. Rotary drum thickeners can be considered instead of gravity thickeners if the sludge dewatering requirements are met.

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CENTRIFUGES

Centrifuges are the second most frequently used dewatering devices in the industry for wastewater treatment sludges. The most applicable type is the solid bowl, which provides a continuous discharge of sludge cake. For application to refinery oily wastes, see Reference No. 10 for detailed information on all types of centrifuges. For wastewater treatment sludges, work done in pilot tests showed that no significant free oil recovery can be expected with 3 phase centrifuges, so only 2 phase solid bowl or decanter type units are recommended for consideration. A diagram of the system is shown in [Figure 4](#).

There are no generally accepted guidelines for sizing the centrifuges. Literature reports and vendors suggest that the hydraulic loading can be estimated by having a minimum of one minute residence time in the centrifuge pool. This time is only a guideline since an excessive residence time may cause dewatering to the extent that the sludge will not be easily removed from the unit. Also, different vendor configurations may require different pool volumes. A minimum pool depth for effective dewatering and sludge removal is 2 inches. If sludge flow rates are significant, then pilot testing is recommended to define performance and sizing optimization. In some cases, choosing standard size equipment, that has been pre-engineered, will be the lowest capital cost alternative, rather than fine tuning a custom design for the specific sludge loading rates.

RECESSED PLATE FILTER PRESSES

Recessed plate filters are also called plate and frame filter presses and pressure plate filters. Recessed plate filters operate by removing water from the liquid feed slurry by pressure filtration at about 100-225 psi (690-1550 kPa). The sludge is pumped into the space between filter plates, pressure is applied to the plates, and the cake remains trapped within the filter plates. The filtrate liquid is removed and returned back to the wastewater treatment plant. The plates on the press are opened to allow the filter cakes to drop downward into a roll-off box container, completing the pressing cycle in a semi batch mode. The plates and filter undergo a brief wash cycle, then are returned to service mode with the feed sludge being pumped into the plates on the press. Some experience has shown these plate filter presses are very effective in pond sludge dewatering.

CHOOSING A DEWATERING SYSTEM

GENERAL

The most effective way to choose a dewatering system is to understand how the sludge will be generated and stored, its characteristics (% solids, oil and water) and the required effluent conditions and characteristics for final disposition. If the sludge will be taken to an offsite landfill, the system design should consider minimizing the volume to the extent that the costs of volume reduction are less than the transportation and disposal (tipping fee) costs. For ExxonMobil, an approach that has the potential to save capital costs and operation/maintenance is to contract with a third party waste management firm to provide sludge handling and dewatering onsite, rather than to own and operate the dewatering equipment. If the sludge can be used in the delayed coker, fluid coker or Flexicoker, then the sludge needs to be pumpable, and minimizing the volume may not be appropriate to the lowest possible water content.

PRETREATMENT /STORAGE

Most wastewater treatment sludges are concentrated first to minimize the size and cost of the mechanical dewatering equipment. However, the need for pretreatment should be based on overall cost-effectiveness, not just volume reduction. A pretreatment and storage unit option is a gravity thickener (refer to [DP XX-A2](#)). The thickener acts to store and dewater the sludges by 50-75 %, allowing down time or maintenance on the mechanical dewatering equipment. For example biox sludge, which is the largest volume sludge generated in a wastewater treatment plant, is typically 1% solids and 99% water. A gravity thickener concentrates it to 3% solids, 97% water, or 2/3 reduction in water content. The bottoms from the thickener can go to a gravity belt filter press for dewatering to a 20% solids cake. An alternative that should be considered is a centrifuge or GBFP on the biox clarifier bottoms. This strategy would take the 1% solids biosludge to about 10% solids directly with a centrifuge, allowing for a more continuous sludge handling system and avoiding the thickener. The end product sludge may still meet requirements for disposal, and may remain a pumpable sludge for pumping to the coker. Also, the option of taking the biosludge directly, unthickened, to the GBFP should be considered. The design of the unit would need to reflect the dilute sludge of 1% solids to avoid spillage off of the belt. This option may be an economic one, that avoids the cost of a thickener, but increases the size of the GBFP. Hence, an economic comparison of with/ without a thickener should be made, factoring the size/cost of GBFP and sparing philosophy on the entire sludge handling train.

All wastewater sludges and dewatering equipment require some sort of chemical conditioning system, using polyelectrolytes or other coagulant aids. Refer to DP XX-A9 for information on types of systems and design bases for facilities.

ODOR/AIR EMISSION CONTROL

Oily sludges and those from biological treatment systems can be odorous if stored in open units. Some governments require that oily sludges only be handled in closed units, which favors centrifuges and rotary drum vacuum filters and thermal dryers.

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Chemical conditioning with lime or hydrogen peroxide may be needed to avoid odors during dewatering operations with belt presses and recessed plate pressure filters. Emission and odor control, using proper ventilation, should be factored into the design of buildings that house the mechanical dewatering equipment and sludge cake roll-off containers.

POST TREATMENT

Some sort of post treatment of mechanically dewatered sludges may be economic, depending upon the final recycling or disposal needs. If transportation and disposal costs are high, then thermal drying (DPXX-C2) may be appropriate to reduce the volume and water content of the sludges to the maximum extent. For example, the sludge cake from a belt filter press or centrifuge still contains over 75% water. Steam dryers can be used to reduce the water content to less than 5 % (95% solids content). Contracting of this type of service may be appropriate for reducing capital costs of owned equipment.

BENCH OR PILOT TESTING

Bench or pilot testing is recommended prior to specifying a mechanical dewatering process. Testing is typically performed by the contractor who will be providing the service or by the thermal treatment unit vendor. Pilot testing can be used to determine the sludge heat transfer coefficient or "U" factor to size the thermal treatment unit. If thermal treatment is being used to meet Universal Treatment Standards or other hydrocarbon removal limits, bench testing is used to determine the temperature that must be achieved to meet this standard. Pilot testing can also determine if the sludge goes through a sticky phase during drying and whether or not recycle is needed to prevent sludge sticking. The vendor should be questioned regarding the type of testing they recommend, how much sample is needed and what will be determined based on the testing.

SAFETY ISSUES /INDUSTRIAL HYGIENE

GENERAL

There are some safety considerations that need to be factored into the design of mechanical sludge dewatering equipment. A list is given below:

- Sludge dewatering equipment has rotating or moving parts. Proper shields, screens or other protective equipment need to be included to protect personnel from contacting these moving parts. Consult appropriate design and global practices for rotating and mechanical equipment.
- Equipment is sometimes located in a building for winter operation and protection from storm events. Appropriate ventilation is needed to ensure a safe environment for personnel and minimization of nuisance odors. A roof with an open sider is often acceptable, particularly in warm climates.
- Appropriate safety equipment and practices need to be put in place for chemical conditioning equipment.
- Where oily sludge are dewatered, vapor space above the sludge roll-off boxes should be periodically tested to ensure a safe working area.

MECHANICAL SLUDGE DEWATERING SELECTION & DUTY SPECIFICATION PREPARATION

CHOOSING A MECHANICAL DEWATERING SYSTEM

Choosing the appropriate dewatering equipment for an application is simplified if the dewatering service is contracted to a third party vendor or contracting firm with a performance based contract. If equipment is to be owned or the contractors plans for facilities are reviewed, the plant's owners representative can consult [Table 2](#) to understand the advantages and disadvantages of the dewatering equipment.

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FACILITY SIZING BASIS ESTIMATION

Estimating the size of mechanical sludge dewatering equipment is complicated by the variety of designs of the equipment vendors. Several references, literature, experience data, and pilot test results have been summarized and are included in

[Table 3](#). This table can be used for guidance purposes, but the final facility basis will need to be provided by the vendor, including process performance guarantees. In most cases, where dewatering occurs 12-24 hours per day, two 100% dewatering units should be provided. For large capacity applications, three 50% units can be economic. Every effort should be made to specify standard size units, thus avoid custom design and engineering costs. Where large scale facilities are contemplated or costs of sludge handling and dewatering are high, pilot testing of the units is strongly recommended, using feed sources from other EM manufacturing plants for the testing.

DUTY SPECIFICATION PREPARATION

The duty specification should provide the contractor with the information needed to design a mechanical sludge dewatering system that will fit the needs of the job. [Table 4](#) provides a list of items that should be covered in the duty specification. It is oriented to a contracted services type of arrangement, but could also be used for purchased facilities. Duty specifications for purchased facilities can disregard sections covering contractor progress reports, processing charges and personnel resumes.

DESIGN CONSIDERATIONS

A brief list of considerations that should be factored into the facility basis or design specification are provided below:

Mechanical Sludge Dewatering--Design Considerations

- All units need to be covered from stormwater and weather impacts; in many cases, particularly in cold climates, units need to be inside buildings with proper ventilation.
- Winterization of sludge lines and equipment needs to be considered.
- Area for equipment needs to consider maintenance access and clearance for truck loading facilities.
- Truck loading facilities and driveway should be set up to minimize trucks need for back-up and turn-around; consider one way operation.
- For most units, strainers need to be placed upstream of the units to protect them from large and small objects; this is particularly important for high speed centrifuges.

TYPICAL VENDOR QUESTIONNAIRE INFO

Vendors are more responsive to requests for quotations and can provide better service to identifying the appropriate equipment for the job if they have key pieces of information. An example table of information needed prior to contacting the vendor is provided in [Table 5](#).