

Evaluation of the Technology Alternatives for Controlling Fugitive Emissions from Sludge Dewatering Operations

HEALTH AND ENVIRONMENTAL SCIENCES
API PUBLICATION NUMBER 4566
OCTOBER 1992

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005



Evaluation of the Technology Alternatives for Controlling Fugitive Emissions from Sludge Dewatering Operations

Health and Environmental Sciences Department

PUBLICATION NUMBER 4566

OCTOBER 1992

PREPARED UNDER CONTRACT BY:

IT CORPORATION

4425 W. AIRPORT FREEWAY, SUITE 350

IRVING, TEXAS

**American
Petroleum
Institute**



FOREWORD

API PUBLICATIONS NECESSARILY ADDRESS PROBLEMS OF A GENERAL NATURE. WITH RESPECT TO PARTICULAR CIRCUMSTANCES, LOCAL, STATE, AND FEDERAL LAWS AND REGULATIONS SHOULD BE REVIEWED.

API IS NOT UNDERTAKING TO MEET THE DUTIES OF EMPLOYERS, MANUFACTURERS, OR SUPPLIERS TO WARN AND PROPERLY TRAIN AND EQUIP THEIR EMPLOYEES, AND OTHERS EXPOSED, CONCERNING HEALTH AND SAFETY RISKS AND PRECAUTIONS, NOR UNDERTAKING THEIR OBLIGATIONS UNDER LOCAL, STATE, OR FEDERAL LAWS.

NOTHING CONTAINED IN ANY API PUBLICATION IS TO BE CONSTRUED AS GRANTING ANY RIGHT, BY IMPLICATION OR OTHERWISE, FOR THE MANUFACTURE, SALE, OR USE OF ANY METHOD, APPARATUS, OR PRODUCT COVERED BY LETTERS PATENT. NEITHER SHOULD ANYTHING CONTAINED IN THE PUBLICATION BE CONSTRUED AS INSURING ANYONE AGAINST LIABILITY FOR INFRINGEMENT OF LETTERS PATENT.

Copyright © 1992 American Petroleum Institute

ACKNOWLEDGMENTS

THE FOLLOWING PEOPLE ARE RECOGNIZED FOR THEIR CONTRIBUTIONS OF TIME AND EXPERTISE DURING THIS STUDY AND IN THE PREPARATION OF THIS REPORT:

API STAFF CONTACT(S)

Paul Martino, Health and Environmental Sciences Department

MEMBERS OF THE WASTE AIR EMISSIONS WORKGROUP

Doreen F. Connaughton, Amoco Research Center

Reza Eshragi, BP America R & D

Mark C. Luce, Chevron Research & Technology Company

Kenneth H. Ludlum, Texaco Inc.

Howard Shiel, Exxon Research & Engineering Company

ABSTRACT

Sludge dewatering, in some form, is a common method to reduce waste in oil refineries in the United States. The purpose of this study was to gather existing information on air emissions from dewatering operations and to identify economically and technically feasible air pollution control equipment. Based on previous studies, (PEI Associates, Inc., 1987, 1990) sludge dewatering operations are a source of air emissions, namely, volatile organic compounds (VOCs). Refineries in the United States were contacted and surveyed about their sludge dewatering operations, including operating parameters and air emissions data. In addition, various air pollution control equipment types were reviewed to determine the economic and technological feasibility of using the equipment to control emissions from dewatering operations. Costs for controlling VOC emissions from sludge dewatering were compared for various control equipment and operating parameters.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
EXECUTIVE SUMMARY	ES-1
1. INTRODUCTION	1-1
2. SUMMARY OF SLUDGE DEWATERING OPERATIONS	2-1
3. SURVEY PROCEDURES AND RESULTS	3-1
4. TECHNICAL FEASIBILITY OF AIR POLLUTION CONTROL EQUIPMENT ..	4-1
5. ECONOMIC FEASIBILITY OF AIR POLLUTION CONTROL DEVICES	5-1
6. CONCLUSIONS AND RECOMMENDATIONS	6-1
REFERENCES	R-1
APPENDIX A DEWATERING SURVEY FORM	A-1
APPENDIX B DETAILED COST ESTIMATES OF POLLUTION CONTROL EQUIPMENT	B-1

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
2-1. Sludge dewatering process.	2-2
2-2. Belt filter press.	2-3
2-3. Horizontal scroll centrifuge.	2-5
2-4. Plate and frame filter press.	2-6
2-5. Rotary vacuum filter.	2-8
3-1. Comparison of Average Feed Flow Rate to Dewatering Method.	3-3
4-1. Scrubber.	4-5
4-2. Fixed-bed carbon adsorber system.	4-7
4-3. Direct-flame fume incinerator.	4-10
4-4. Catalytic incinerator.	4-11

LIST OF TABLES

<u>Table</u>	<u>Page</u>
3-1. Summary of Survey Results.	3-2
3-2. Summary of Operating Data - Dewatering with Belt Filter Press.	3-4
3-3. Summary of Operating Data - Dewatering with Plate and Frame Filter.	3-5
3-4. Summary of Operating Data - Dewatering with a Centrifuge.	3-6
3-5. Summary of Operating Data - Dewatering with Vacuum Filtration.	3-7
3-6. Summary of Air Emission Data.	3-8
4-1. Technical Feasibility of Controlling Emissions from Sludge Dewatering Operations.	4-3
5-1. Cost to Control Emissions From Low Air Flow Operations.	5-2
5-2. Cost to Control Emissions From High Air Flow Operations.	5-3

EXECUTIVE SUMMARY

The American Petroleum Institute (API) initiated a study to evaluate technology alternatives for controlling fugitive emissions from sludge dewatering operations. This study discusses the types of methods used by refineries and the technical and economic feasibility of controlling emissions from sludge dewatering operations.

Sludge dewatering is a common method to reduce waste in oil refineries. Of the 184 refineries in the United States, many conduct some form of dewatering. The sludge is dewatered through the use of a belt filter press, plate and frame filter, centrifuge, or vacuum filtration system. Based on previous studies, sludge dewatering operations are a source of air emissions, namely, volatile organic compounds (VOCs).

On March 7, 1990, the EPA promulgated a national emission standard for benzene waste operations (40 CFR 61, subpart FF). This standard imposed restrictions on benzene-containing waste and wastewater streams for petroleum refineries that generated at least 10 Megagrams per year (22,000 lb/yr) of benzene in waste streams (40 CFR 61.342). Under these regulations, dewatering operations are required to meet the standards for tanks (40 CFR 61.343). These standards include "install[ing] a closed-vent system that routes all organic vapors . . . to a control device." This regulation was finalized on January 7, 1993, after being stayed and amended.

The purpose of this study was to gather existing information on air emissions from dewatering operations and to identify economically and technically feasible air pollution control equipment that could be installed to meet the requirements of 40 CFR 61, subpart FF.

U.S. refinery personnel were contacted and surveyed about their sludge dewatering operations, including operating parameters, emissions control equipment and air emissions data. In addition, various air pollution control equipment types were reviewed and vendors contacted to determine the economic and technological feasibility of using the equipment to control

emissions from dewatering operations. Costs for controlling VOC emissions from sludge dewatering were compared for various control equipment and operating parameters.

SURVEY RESULTS

Of the 85 refineries contacted, 40 responded with *specific* dewatering methods. The following summarizes the dewatering information of those who responded:

- 16 use plate and frame filtration;
- 11 use a belt filter press;
- 12 use a centrifuge; and
- 1 uses a vacuum filter.

Of those who responded, ten provided air emissions data and/or information on the use of an air pollution control device. VOC emissions from a refinery with no control equipment were 16.1 lb/hr; for refineries with controls, emissions ranged from not detected to 0.14 lb/hr. These emissions usually contained benzene, toluene, and xylene.

FEASIBILITY OF AIR POLLUTION CONTROL TECHNOLOGY

The five most common methods of controlling emissions with air pollution control equipment are condensers, scrubbers, flares, carbon adsorbers, and incinerators. The technical feasibility of each type of control equipment depends on the air flow, volatile organic compound (VOC) concentration, and nature of the specific VOCs.

Table 1 summarizes the technical feasibility of each of the above control methods as they apply to controlling emissions from sludge dewatering operations. This table shows that carbon adsorption and incineration are the most technically feasible methods of control.

Table 1. Technical Feasibility of Controlling Emissions from Sludge Dewatering Operations

Control Method	Advantages	Disadvantages
Condensers	◦ Simple ◦ Flexible ◦ Low cost ◦ Can recover VOCs	◦ Low efficiency ◦ High maintenance ◦ Unsuitable for low concentration streams ◦ Difficult to achieve 95% efficiency
Scrubbers	◦ Low cost ◦ Easy to operate	◦ Unsuitable for VOCs insoluble in aqueous contact solutions ◦ Difficult to achieve 95% efficiency
Flare	◦ High destruction efficiency ◦ Easy to operate	◦ Unable to effectively burn high air flow/dilute VOC streams without excessive fuel use
Carbon Adsorber	◦ Suitable for low concentration streams ◦ Suitable for high air flow streams ◦ High capture efficiency (90%) ◦ Potential recycle of VOC contaminant	◦ High start-up and operating cost ◦ High humidity decreases efficiency ◦ Design problems with VOC mixtures
Incineration	◦ Suitable for low concentration streams ◦ Suitable for high air flow streams ◦ High destruction efficiency (+90%) ◦ Destruction of VOC contaminant	◦ High start-up, maintenance, and operating costs

Based on data provided by equipment vendors, refineries, and reference books, the economic and technical feasibility of various pollution control technologies were determined. Capital and annual costs for two air emissions scenarios were calculated.

The economic feasibility was compared in terms of cost per ton of VOC controlled for the following types of control equipment: condenser, scrubber, flare, regenerative carbon adsorber, carbon canister, thermal incinerator, and catalytic incinerator. Tables 2 and 3 show the pollution control costs.

CONCLUSIONS

Two types of pollution control equipment reviewed by IT appeared economically and technically effective to control VOC emissions: the regenerative carbon adsorption system and catalytic incinerator. Both controls can achieve VOC removal efficiencies of 95% when operated properly. Several refineries surveyed control VOC emissions with carbon adsorbers, and one controlled emissions with a catalytic incinerator.

Table 2. Cost to Control Emissions from Low Air Flow Operations

Air flow (acfm): 1,000
 VOC loading (lb/hr): 10
 Operating schedule (hr/yr): 3,000

	Condenser	Scrubber	Carbon		Flare	Incinerator	
			Regenera- tive	Canister		Thermal	Catalytic
Equipment Cost	\$1,064,000	\$10,300	\$79,000	NA	\$60,800	\$104,000	\$149,000
Installation Cost	\$160,000	\$7,300	\$48,300	NA	\$46,935	\$25,000	\$36,000
Total Capital Cost	\$1,224,000	\$17,600	\$127,300	NA	\$107,735	\$129,000	\$185,000
Annual Cost	\$387,700	\$30,128	\$29,000	\$189,000	\$240,000	\$44,500	\$54,000
Removal Efficiency (%)	60	60	95	95	98	95	95
Tons VOC Removed	9	9	14.25	14.25	14.7	14.25	14.25
\$/ton VOC Removed	\$43,078	\$3,348	\$2,028	\$13,262	\$16,311	\$3,124	\$3,793

NA - Not applicable.

Table 3. Control of Emissions from High Air Flow Operations

Air flow (acfm): 10,000
 VOC loading (lb/hr): 10
 Operating schedule (hr/yr): 8,760

	Condenser	Scrubber	Regenera- tive Carbon	Flare	Incinerator	
					Thermal	Catalytic
Equipment Cost	\$10,140,000	\$52,000	\$263,500	\$690,000	\$275,000	\$220,000
Installation Cost	\$1,520,000	\$39,000	\$161,000	\$531,400	\$64,000	\$50,000
Total Capital Cost	\$11,660,000	\$91,000	\$424,500	\$1,221,400	\$339,000	\$270,000
Annual Cost	\$6,115,700	\$470,900	\$95,800	\$6,267,750	\$199,000	\$117,000
Removal Efficiency (%)	60	60	95	98	95	95
Tons VOC Removed	26	26	41.6	42.9	41.6	41.6
\$/ton VOC Removed	\$232,712	\$17,918	\$2,297	\$146,020	\$4,787	\$2,818

ES-6

Section 1

INTRODUCTION

Sludge dewatering is a common method to reduce waste in oil refineries. Many of the almost 200 refineries in the United States conduct some form of dewatering. Based on previous studies (PEI Associates, Inc., 1987, 1990), sludge dewatering operations are a source of air emissions, namely, volatile organic compounds (VOCs).

On March 7, 1990, the EPA promulgated a national emission standard for benzene waste operations (40 CFR 61, subpart FF). This standard imposed restrictions on benzene containing waste and wastewater streams for petroleum refineries that generated at least 10 Megagrams per year (22,000 lb/yr) of benzene in these streams (40 CFR 61.342). Under these regulations, dewatering operations are required to meet the standards for tanks (40 CFR 61.343). These standards include "install[ing] a closed-vent system that routes all organic vapors . . . to a control device." This regulation was finalized on January 7, 1993, after being stayed and amended.

The purpose of this study was to gather any existing information on air emissions from dewatering operations and to identify economically and technically feasible air pollution control equipment that can be installed to meet the requirements of 40 CFR 61, subpart FF.

Refineries in the United States were contacted and surveyed about their sludge dewatering operations, including operating parameters, emissions control equipment, and air emissions data. In addition, various air pollution control equipment types were reviewed and vendors contacted to determine the economic and technological feasibility of using the equipment to control emissions from dewatering operations. Section 2 of this report summarizes the nature of sludge dewatering operations. Section 3 details the survey and accompanying results. Section 4 presents the technological feasibility of air pollution control equipment. Section 5 presents an economic analysis of air pollution control equipment. Section 6 contains conclusions and recommendations.

Section 2

SUMMARY OF SLUDGE DEWATERING OPERATIONS

Sludge dewatering can occur by using several methods. The four most common methods used among refineries are: belt press filtration, centrifuge, plate and frame filtration, and vacuum filtration. Figure 2-1 shows an overview of a sludge dewatering process.

Refineries dewater sludge to reduce the volume of solid waste required for further treatment and disposal. The sludges most typically dewatered at refineries are: API separator sludge, Dissolved Air Flotation (DAF) float, and biological sludge (Ponder and Bishop, 1990). Both API separator sludge and DAF float are "listed" by the U.S. Environmental Protection Agency as hazardous wastes (K048 and K051, respectively). Typically, API separator sludge is the consistency of asphalt mastic and consists of approximately 50 percent solids, and heavy hydrocarbons, with high concentrations of toluene, benzene, and heptane. DAF float is lighter than water, has a high hydrocarbon concentration, and is low in solid, generally 10-15 percent. DAF float generally contains benzene, toluene, and xylene. Biological sludge is not a listed hazardous waste and is usually dewatered separately from the API separator sludge and the DAF float.

2.1 BELT PRESS FILTRATION

The belt press filtration method (belt filter press) is commonly used among the refineries (Ponder and Bishop, 1990). This filtration process is used to continuously dewater sludge by filtering it between two revolving belts. Figure 2-2 shows a typical belt filter press.

An advantage of the belt filter press is its ability to dewater sludge streams with a high throughput on a continuous basis. Belt filter presses require no filter precoat, therefore eliminating the need for the disposal of additional contaminated materials. However, polymers are often added to the feed stream as a flocculent to aid filtration.

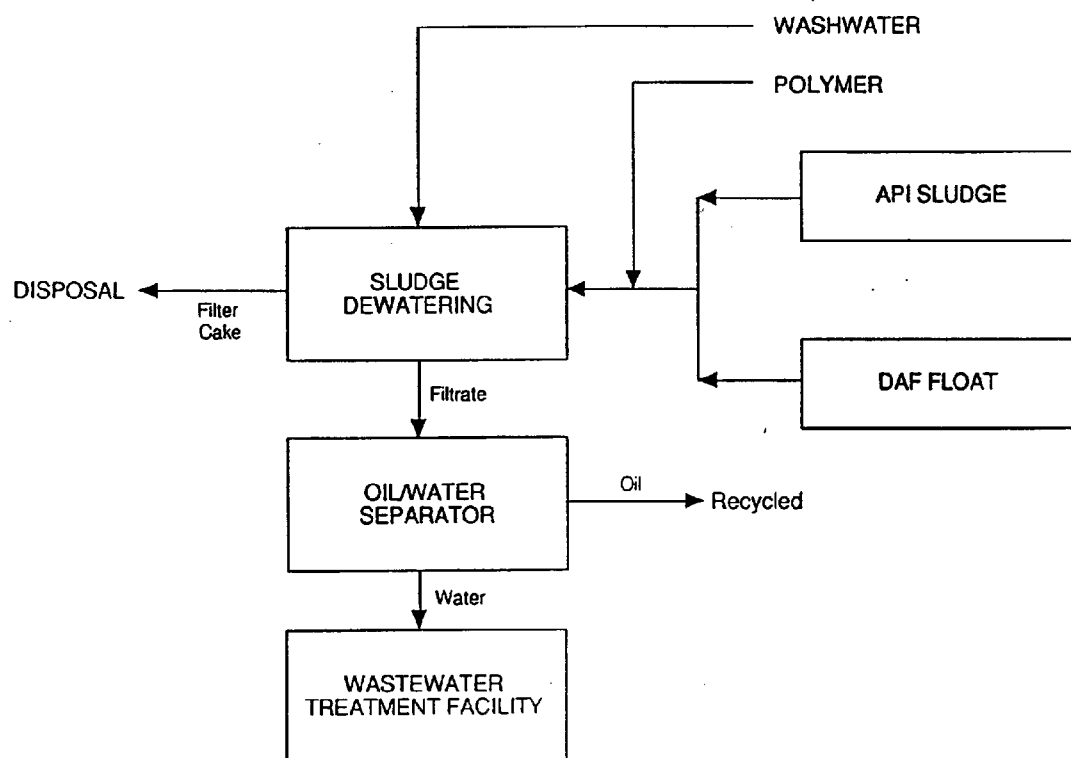


Figure 2-1. Sludge dewatering process.

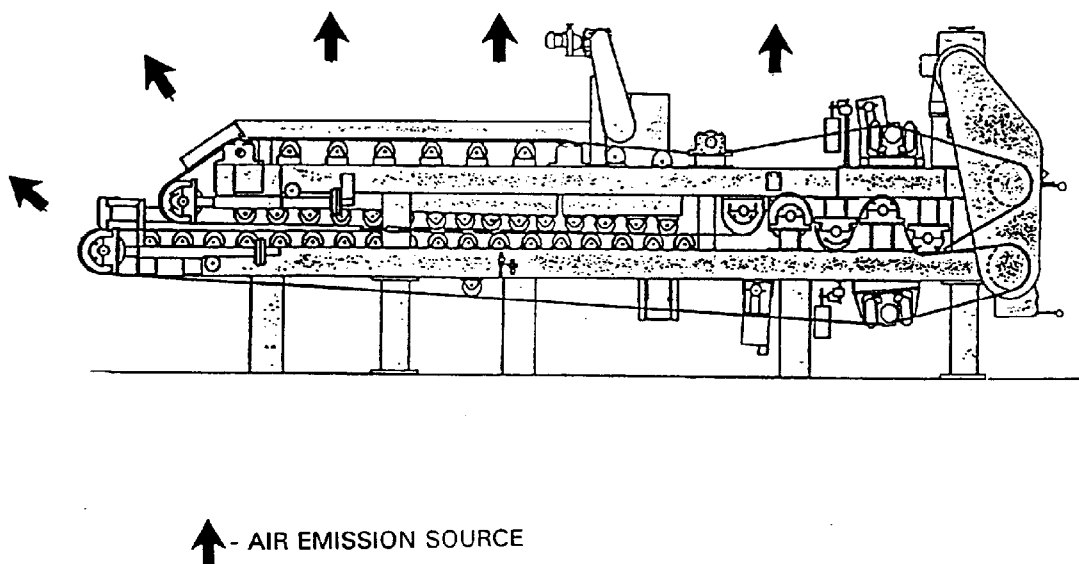


Figure 2-2. Belt filter press.

Belt filter presses emit a large amount of volatile organic compounds (VOCs) during dewatering (10 to 20 lb/hr)(Ponder and Bishop, 1990). Sludge is usually fed into a belt filter press at elevated temperatures, which increase the potential for VOC releases. In addition, the pressing of the sludge in the open belt press allows for a greater surface area for the release of VOCs. Figure 2-2 shows the areas of VOC emissions.

2.2 CENTRIFUGE

The centrifuge device causes dewatering by using a centrifugal, or spinning, force to induce sedimentation. A centrifuge basically slings out the solids. A rotating bowl functions as the settling tank. The centrifuge method is not widely used by refineries because of high maintenance costs and problems associated with separating suspended solids (Ponder and Bishop, 1990). Figure 2-3 shows an example of a horizontal scroll centrifuge.

Centrifuges require a high amount of maintenance. A high solids content feed sludge with a lot of grit and sand will cause erosion of the centrifuge. Centrifuges, in general, have maintenance problems because of the constant spinning motion.

Centrifuges are easy to operate and, because they are enclosed, are not large emitters of VOCs. What VOCs they do emit are emitted from the feed inlet and the cake outlet areas, as shown in Figure 2-3.

2.3 PLATE AND FRAME FILTRATION

The plate and frame filtration device is comprised of a series of recessed plates which operate on fluid pressure (Ponder and Bishop, 1990). The pressure is created by pumping sludge into the plate and frame filter and forcing a separation of solids from liquids. As more sludge is pumped, the pressure increases causing the filtrate to pass through the filter cloth leaving the cake. When the filter cloth becomes saturated, the feed is stopped, the plates disassembled, and the filter cake removed. Normally, the batch filtration process operates for approximately eight hours before the filters become saturated. Figure 2-4 shows a plate and frame filter press.

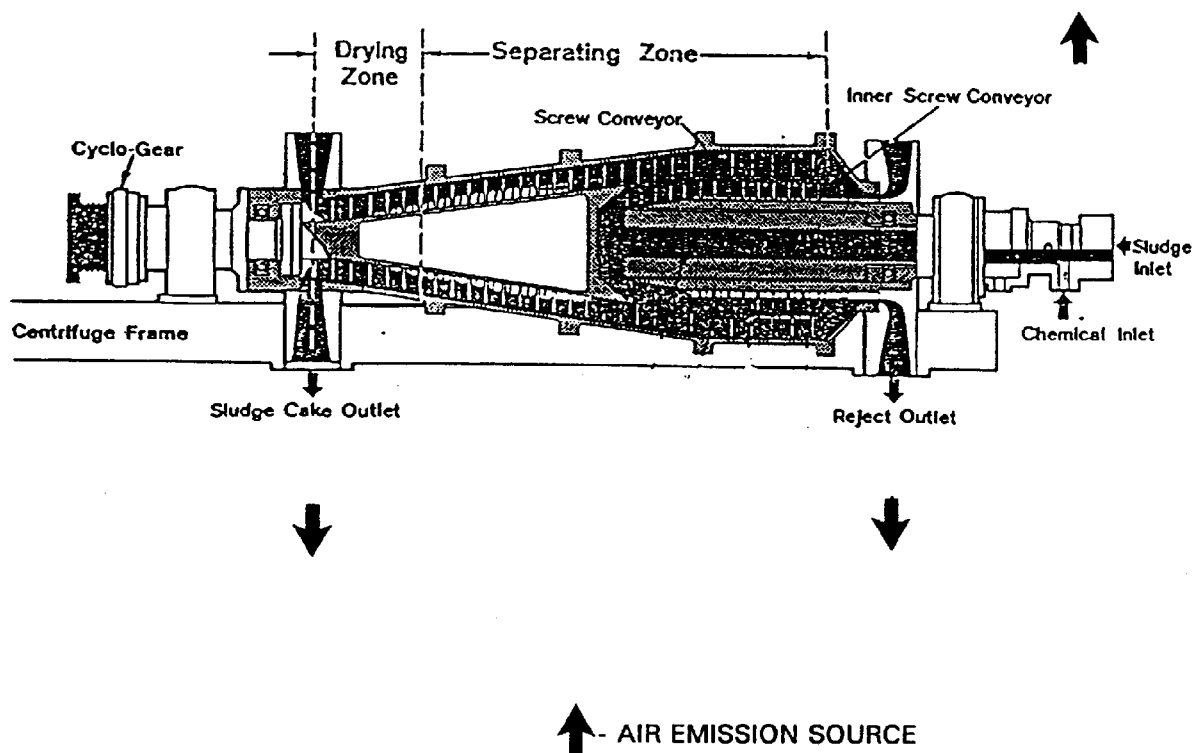


Figure 2-3. Horizontal scroll centrifuge.

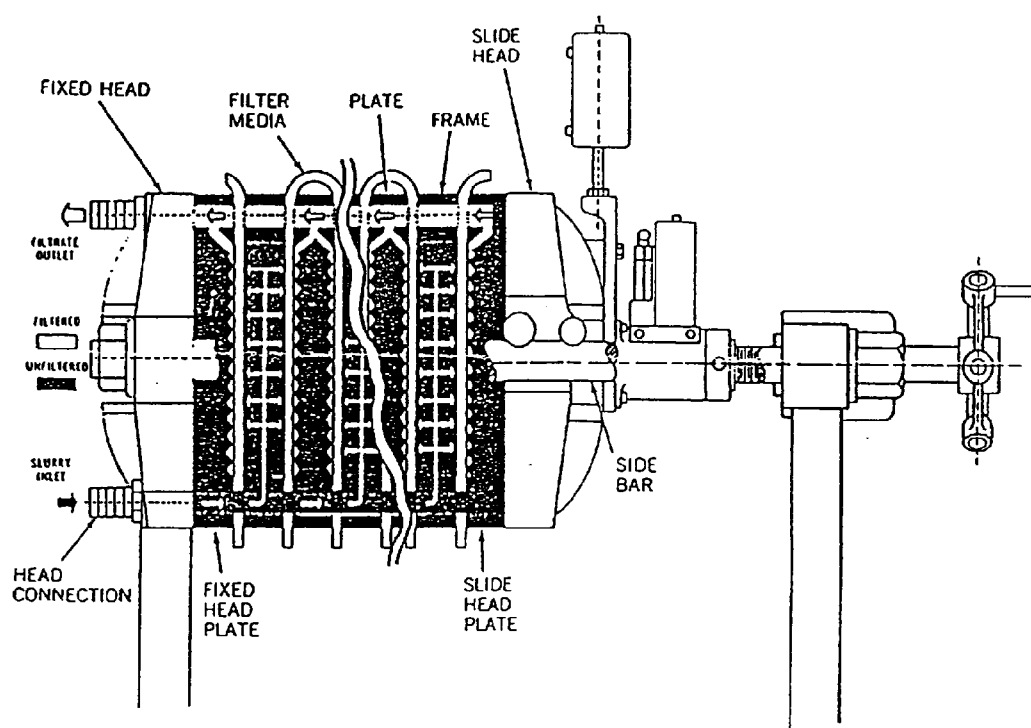


Figure 2-4. Plate and frame filter press.

The plate and frame filtration method is used for sludge that is difficult to dewater for cases where a high solids content cake is necessary and for small dewatering operations which can operate in a batch mode. Plate and frame filter presses are an inexpensive method of dewatering sludge. However, they require the use of a filter precoat (normally diatomaceous earth) which increases the volume of solid waste to dispose.

Because the plate and frame press is enclosed, there are virtually no VOC emissions during dewatering. However, VOC emissions occur when the frame is opened and the cake is removed.

2.5 VACUUM FILTERS

The vacuum filter process is comprised of a large cylindrical drum that rotates through a vat containing sludge (Ponder and Bishop, 1990). Vacuum filters use atmospheric pressure as the driving force. This force causes the liquid phase to move through a porous media and separate from the solids. The drum rotates through three zones. In the cake forming zone, a vacuum is applied to the submerged section of the drum which causes the filtrate to pass through the porous surface media and cake to form on the surface of the drum. As the drum rotates, the filter cake is carried to the drying zone. This zone is also under vacuum and further dries the cake. As the drum rotates further, the cake is carried into the discharge zone where the vacuum is removed and the cake is scraped off the drum. Figure 2-5 shows a typical vacuum filtration system.

The use of the vacuum filter method has declined as other methods have proven to be more economical and technically feasible. Vacuum filters require a large amount of filter precoat to prevent filter blinding. With the passage of the Land Ban regulations, it became more costly and difficult to dispose of solid hazardous waste which includes the large quantities of contaminated precoat generated by vacuum filters. Besides disposal considerations, vacuum filters have high fuel costs associated with the operation of the vacuum pump. On the positive side, VOC emissions from vacuum filters are limited to the vacuum pump. The vacuum pump can be enclosed to reduce the emissions.

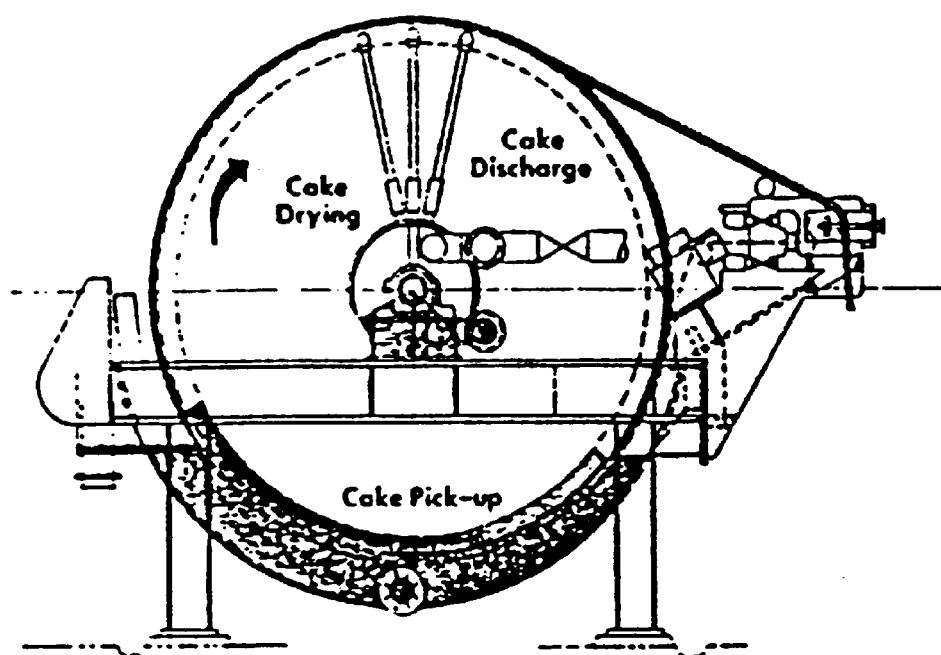


Figure 2-5. Rotary vacuum filter.