SW-969

TEST PROTOCOLS FOR DETERMINING THE "FREE LIQUID" CONTENT OF HAZARDOUS WASTE

This document (SW-969) was prepared for the Office of Solid Waste under contract no. 68-01-3911

U.S. ENVIRONMENTAL PROTECTION AGENCY

December 1983

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 264 and 265

[SWH-FRL 2497-1]

Hazardous Waste Management Facilities; Availability of Information

AGENCY: Environmental Protection Agency.

ACTION: Notice of availability of information and request for comments.

SUMMARY: The Environmental Protection Agency hereby notices the availability of a final contractor report, *Test Protocols for Determining the "Free Liquid" Content of Hazardous Waste*, for public comment. The Agency is preparing a final rule to identify the test protocol to be used to implement the rule restricting "free liquids" in hazardous waste landfills. The report summarizes the results of laboratory tests on a number of test protocols, including the paint filter test that the Agency proposed in the **Federal Register** on February 25, 1982. The Agency requests comments on this report, and serveral related specific issues.

DATES: Comments on the report must be submitted on or before January 27, 1984.

ADDRESS: Comments should be addressed to the Docket Clerk, Office of Solid Waste (WH-562), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, D.C. 20460, telephone (202) 382-4672. Comments should identify the regulatory docket and report title as follows:

"Section 3004. *Test Protocol for Determining the "Free Liquid" Content of Hazardous Waste*".

A copy of the report is available for reading in the EPA Library and the Subtitle C Docket Room (Room S-212A), both located at the above address, during the hours of 9:00 a.m. to 4:00 p.m. Monday through Friday excluding holidays. Copies of the report are also available for reading at the EPA Regional Libraries.

FOR FURTHER INFORMATION CONTACT: For a single copy of the report contact the RCRA Hotline at (800) 424-9346 (toll free) or at (202) 382-3000. For additional information contact Paul Cassidy at (202) 382-4682.

SUPPLEMENTARY INFORMATION: The Agency promulgated interim status standards on May 19, 1980, in 40 CFR 265.314 (45 FR 33249-50) that prohibit the disposal of containerized liquid waste or waste containing free liquids in a hazardous waste landfill. This prohibition went into effect on November 19, 1981. These standards also require that bulk liquids must not be placed in a hazardous waste landfill unless (1) the landfill is equipped with a liner which is chemically and physically resistant to the liquid, and a functioning leachate collection and removal system with a capacity to remove all the leachate produced, or (2) prior to disposal, the bulk liquids are treated so that free liquids are no longer present when the waste is placed in the landfill. The date of compliance for this requirement was also Novmeber 19, 1981. In the May 19, 1980 regulations the Agency also defined free liquid as "liquids which readily separate from the solid portion of a waste under ambient temperature and pressure" (40 CFR 260.10). In the May 19, 1980 preamble (45 FR 33214) the Agency suggested and described the use of an "inclined plane" test as a means to determine (in those cases where it is not obvious) if a waste contains "free liquids."

On February 25, 1982 (47 FR 8311-13), the Agency proposed a paint filter test that could be used to determine the presence of free liquids. Prior to this date, the Agency initiated a study to evaluate all the various test protocols that could be used to determine the existence of free liquids in sludges semi-solids, slurries, and other waste types. The study identified a wide range of possible test protocols (75 in number) that could be used. This number was trimmed down to 19 as potentially useful for determining the presence of free liquids in wastes, and was then further reduced to six for laboratory testing. The six protocols include an inclined plane test, a lab press, a filtration test, a graduated cylinder test, a sieve series, and a paint filter test.

The report being made available today, *Test Protocols for Determining the "Free Liquid" Content of Hazardous Waste*, contains the summary and evaluation of the laboratory test results of these six test protocols. Five non-hazardous waste materials were used to evaluate the test protocols. The five materials were selected because their physical properties are representative of the physical properties of typical hazardous waste sludges. The five waste materials were: drilling mud, air pollution control sludge, paper sludge, separator sludge, and paint sludge. The report also includes an evaluation of the suitability of various absorbent materials to transform a liquid waste or waste with free liquids into a waste that no longer contains free flowing liquids.

The Agency specifically requests comments on the accuracy and completeness of the information presented in the report, especially regarding the paint filter test parts of the report. EPA encourages commenters to suggest remedies or alternatives should any inaccuracy or incompleteness be identified. The Agency is particularly interested in specific comments on the following issues addressed in the report. (1) Whether five minutes is an adequate test period for determining the presence of absence of free liquids in a waste. (2) Should a standard watchglass be used in the test and would the use of a standard watchglass present any problems? (3) Should the funnel used in the paint filter test be fluted to facilitate moisture flow?

Under Executive Order 12291, EPA must judge whether a regulation or rule, including any implementation guidance, is "Major" and therefore subject to the

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THE EFFECT OF FLY ASH ON THE "FREE LIQUID" CONTENT OF AIR POLLUTION CONTROL EQUIPMENT SLUDGE

Test Number	Time	Fly Ash (g)	Replication	"Free Liquid" (ml)
1	5 min.	40	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	39	1	0.0
			2	0.0
			3	trace
	15 min.		1	2.0*
			2	0.0
			3	1.0*
	30 min.		1	2.0*
			2	0.0
			3	1.0*
3	5 min.	37	1	trace
			2	trace
	15 min.		1	1.0*
			2	3.0
	30 min.		1	1.0*
			2	3.0

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF FLY ASH ON THE
"FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	Fly Ash(g)	Replication	"Free Liquid"(ml)
1	5 min.	20	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	18	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	17	1	trace
			2	trace
	15 min.		1	trace
			2	trace

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EXECUTIVE SUMMARY

Six test protocols were laboratory tested and evaluated by SMC Martin to determine the "free liquid" content of five waste materials. The test protocols evaluated included an inclined plane test, a lab press, a filtration test, a graduated cylinder test, a sieve test, and a paint filter test. The paint filter test was proposed on February 25, 1982 by the U.S. Environmental Protection Agency (EPA) to be used as a pass/fail test to determine the presence of "free liquid" in sludges and semisolids.

Five waste materials were used to evaluate the test methods selected for laboratory testing. Waste materials were also used to evaluate the suitability of various absorbent materials. The selected wastes encompassed a variety of textural types and included drilling mud, air pollution control equipment sludge, paint sludge, separator, and paper sludge.

The absorbent materials tested included drilling mud, fly ash, vermiculite, cement kiln dust, Hazorb, Safe-N-Dri, Permasorb #29, and TriPak Solidification Medium. Various amounts of each absorbent material were added to the wastes until no "free liquid" was present when tested with the paint filter test. In general, Permasorb #29 was the most absorbent material tested and fly ash was the least absorbent.

1.0 INTRODUCTION

On December 18, 1978 the U.S. Environmental Protection Agency (EPA) proposed minimum national standards for hazardous waste disposal facilities under Section 3004 of the Resource Conservation and Recovery Act (RCRA). In an attempt to maximize the containment of wastes in a landfill, EPA proposed in the regulations that liquid hazardous wastes not be disposed of in a landfill unless the wastes were treated (i.e., mixed with absorbent material) prior to landfilling, or were treated by in-situ absorbtion in the landfill until a nonflowing consistency was achieved.

EPA promulgated interim status regulations on May 19, 1980 which prohibited the disposal of containerized liquid hazardous wastes or waste containing "free liquids" in a landfill on or after November 19, 1981. At this time, EPA also defined "free liquids" as "liquids which readily separate from the solid portion of a waste under ambient temperature and pressure." The use of an inclined plane test was also suggested to be used to determine if specific wastes contained "free liquids."

Wastes or "free liquids" not absorbed or attenuated in a landfill can migrate through the landfill producing leachate. In an unlined landfill, leachate will percolate downward through the waste-soil matrix to the water table. The leachate then forms a plume of contamination which joins the ground-water flow system and may ultimately discharge to surface waters.

On February 25, 1982, EPA proposed an alternative standard for limiting the landfilling of containerized "free liquid" waste. The proposed standard limited the amount of containerized "free liquids" that could be placed in a landfill. These containerized "free liquids" could be landfilled provided that the volume of such containers did not exceed a formula-determined fraction of the total volume of wastes, and reasonable intermediate cover to be placed in the landfill. EPA also proposed the use of a paint filter test to determine the presence of "free liquid" in individual wastes. In order to encourage compliance with the regulations, EPA also exempted from the requirements of the hazardous waste management regulations, the acts of adding absorbent material to hazardous wastes in containers and adding hazardous waste to absorbent material in a container, at the time waste is first placed in the container, in order to reduce the "free liquids" in a container. On March 22, 1982, EPA once again promulgated interim restrictions prohibiting the landfilling of containers holding "free liquids" unless 1) all free standing liquids have been removed by decanting, or other methods; 2) have been mixed with an absorbent or solidified so that free standing liquid is not longer observed; or 3) have been otherwise eliminated.

SMC Martin was retained to evaluate testing methods which could determine the amount of "free liquid" in waste materials. The study also evaluated the ability of selected materials to absorb "free liquid" in wastes. This report is a summary of the testing program and is submitted as a supplement to the interim reports previously completed. Details of individual tests, previously submitted to EPA, are not included in this report.

2.0 TESTING METHODOLOGY

2.1 Test Materials

2.1.1 Introduction

EPA and SMC Martin selected five nonhazardous waste materials to evaluate test protocols selected for laboratory testing. Wastes were selected with a variety of textural characteristics in order to evaluate the test protocols under varying test conditions. The selected materials included those which could be classified as gelatinous, granular, oily, and fibrous in nature. The materials chosen for testing were drilling mud, air pollution control equipment sludge, paint sludge, separator sludge, and paper sludge.

2.1.2 Drilling Mud

Drilling mud is a finely-ground, sodium-based montmorillonite, western bentonite and is composed of montmorillonite, quartz, feldspar, cristobalite, illite, calcium, and gypsum. Water was added to the drilling mud until the mixture consisted of 89 percent water by weight. It is a gelatinous type of material capable of absorbing large quantities of water over time. When the drilling mud and water were thoroughly mixed, no phase separation was observed.

2.1.3 Air Pollution Control Equipment Sludge

Air pollution control equipment sludge is formed from dust collected from baghouse fabric filters, which are a part of the air pollution control program for steel mills. Dust-bearing gases produced during scrap metal melting pass through filters which trap dust particles. The dust is a granular-type of material containing a high percentage of metals and inorganic particles. Since the dust is dry when collected, water is added to create a waste suitable for testing. It readily absorbs water and does not exhibit a phase separation unless the mixture is mixed vigorously for an extended period of time. The waste material used in the study consisted of 34.5 percent water by weight.

2.1.4 Paint Sludge

Paint sludge is composed of water-based acrylic spray paint used at a metal fabrication plant. During painting, overspray is trapped in recirculated water and accumulates in a sump as sludge. The paint sludge was received as a dry solid mass of material; it was crushed into a granular material to which water was added, producing a suitable waste similar in nature to the original waste. The final testing material was 26 percent water by weight and a phase separation was noted.

2.1.5 API Separator Sludge

API separator sludge is a by-product of the purification process of waste water produced from the production of gasoline and gasoline additives. The waste consists of silts and heavy metals from waste water which are collected from a settling tank. The sludge used for testing contained a large quantity of oil liquid which readily separated from the solids. Each time a sample was collected from the drum, the waste was mixed thoroughly to obtain a representative sample.

2.1.6 Paper Sludge

Paper sludge is dewatered Kraft bleached paper board sludge and contains the following process wastes from Kraft pulping: slaker rejects, burned lime rejects, and green liquor dregs. The solids are composed of fiber, filler, and coating clays. During collection, the sludge is dosed with one percent (by volume) commercial formaldehyde to inhibit biological activity.

The sludge is very dense and fibrous in nature. A phase separation was visible in the drum and the solids remained in the center of the drum surrounded by liquid. Because of the high density of the material, it was difficult to thoroughly mix the sludge to obtain a representative sample.

2.2 Test Protocols

2.2.1 Introduction

An in-depth literature search was conducted to identify and evaluate test methodologies which could be used to determine the "free liquid" content of hazardous wastes. Sources of information included computerized data bases, libraries, and professional contacts. Over 75 test protocols were evaluated and 100 researchers were contacted for the study. Specific protocols were selected and evaluated in extensive laboratory testing with hazardous waste materials.

The tests chosen had to be safe, quick, and easy to implement by the waste generator and/or landfill operator. The test equipment had to be relatively inexpensive, readily available, and applicable to all hazardous wastes. It was also important to select tests which could simulate landfill conditions with reproducible results.

Based on the above criteria, EPA and SMC Martin chose the following six protocols for laboratory evaluation: the inclined plane, lab press, filtration unit, graduated cylinder, sieve series, the paint filter test. The criteria for selection of each protocol is summarized in Table 1.

2.2.2 Inclined Plane

The inclined plane was designed by EPA to determine if sludges and semisolids contain "free liquid." It is a simple phase separation test in which a 1-5 kilogram (Kg)

TABLE 1

Criteria for the Selection of Test Protocols to Determine the "Free Liquid" Content of Hazardous Wastes*

Test Protocol	Ease of Implementation	Test Duration	Simulated Landfill Condition	Applicable to all Wastes	Cost
Inclined Plane	Simple Procedure Minimal operator training needed	5-30 min.	Excavated surface	Phase separation is waste dependent Not suitable for gelatinous types of wastes.	Minimal
Lab Press	Simple procedure Some operator training needed	5 min.	Pressure at various depths	Incomplete phase separation with some wastes.	$ 885.00
Filtration Unit	Some operator training needed	30 min.	Pressure at various depths	Not suitable for granular types of wastes.	$1,400.00
Graduated Cylinder Test	Simple procedure Minimal operator training needed	24 hours	Excavated surface and drum storage	Phase separation is waste dependent Not suitable for gelatinous type of wastes.	Minimal
Sieve Test	Simple procedure	5 min.	Transportation to landfill	Not suitable for fibrous or gelatinous material.	Minimal
Paint Filter	Simple procedure Minimal operator training needed	15 min.	Excavated surface	Not suitable for gelatinous materials.	Minimal

* All of the test protocols were considered to be safe, readily available, reproducible, and easily implemented by the waste generator and/or disposal operator.

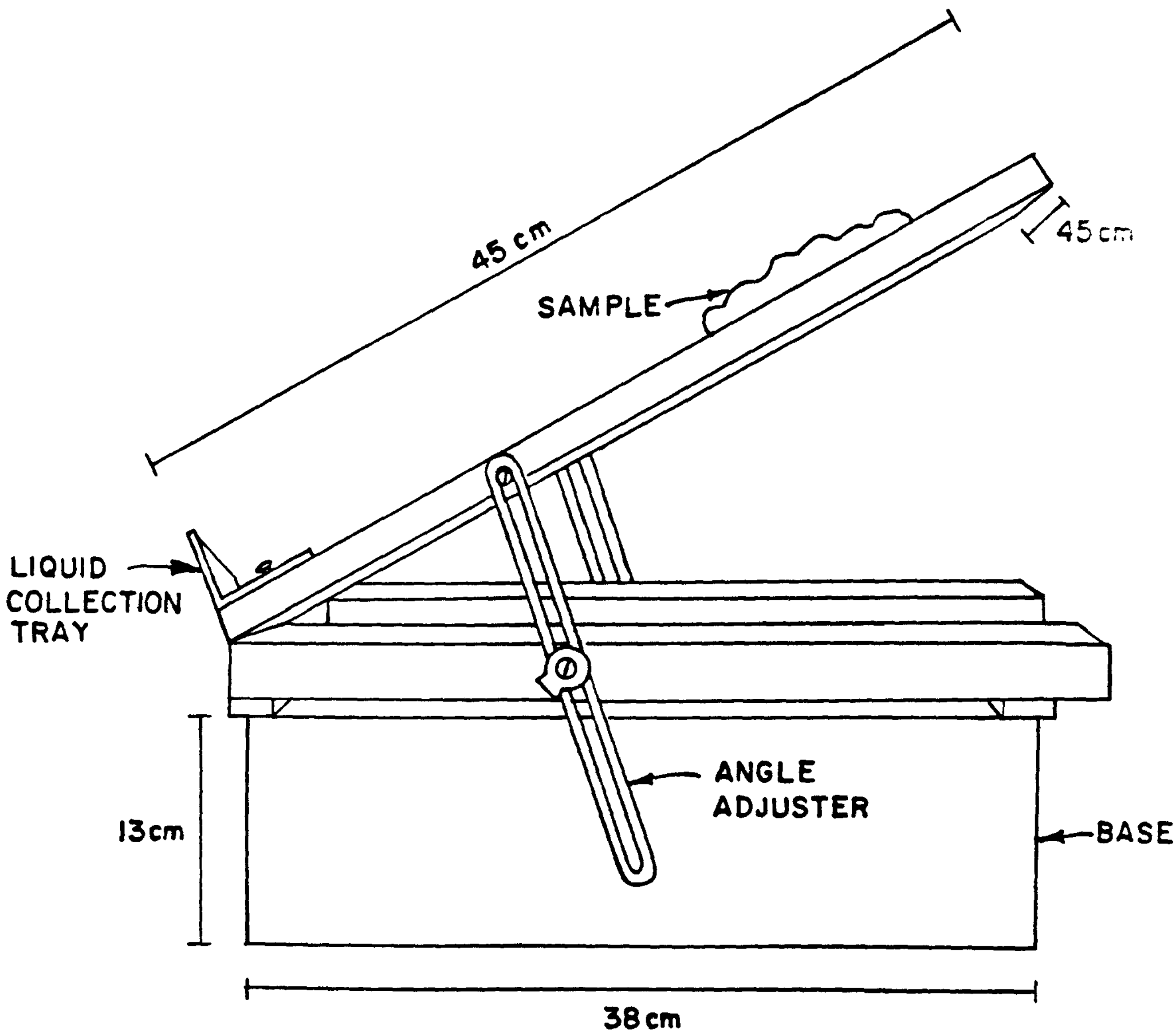
sample is placed on a flat, smooth surface, either level or slightly sloping, for a test duration of at least five minutes (see Appendix A). Testing apparatus is shown in Figure 1. "Free liquid" is defined as any moisture which separates from the sample and is collected and quantified in milliliters (ml).

The test was selected for laboratory evaluation since it is easily implemented by waste generators and/or disposal operators and requires minimal operator training. Test duration is short and equipment is readily available at minimal costs. The surface of the tray used in the test was glass, and collection/quantification apparatus were of stainless steel. Testing materials used with the inclined plane included drilling mud, air pollution control equipment sludge, paint sludge, and separator sludge.

A phase separation of liquids and solids was observed for the air pollution control equipment sludge, paint sludge, and separator sludge. However, only the paint sludge generated sufficient quantities of "free liquid" to be quantified. Though a liquid/solid phase separation was visible in most wastes, the liquid often remained on the test surface and did not flow into the collection tray. Therefore, the "free liquid" for drilling mud, air pollution control equipment sludge, and separator sludge were recorded as the movement of liquids and/or solids.

Figure 1

INCLINED PLANE



Since drilling mud is a gelatinous type of material and phase separation of liquids and solids did not occur at atmospheric pressure, movement of solids on the inclined plane was recorded for each trial. As the angle increased, the movement of drilling mud also increased.

"Free liquid" for the air pollution control equipment sludge was recorded as the movement of liquids on the inclined plane. The solid portion of each sample remained stationary during testing. The movement of "free liquid" for all of the tests, except one, flowed into the collection tray. However, the liquid consisted of only a few drops which were insufficient to quantify. As the angle increased, the amount of time required for the liquid to reach the collection tray decreased. Only one replication required more than 20 minutes for "free liquid" to reach the collection tray.

The paint sludge readily generated "free liquid" which flowed into the collection tray and was quantified. The liquid was cloudy and contained many solids. As the angle increased, the percent "free liquid" generated also increased, since pockets of liquid could separate from the sample. The liquid separated from most of the solids within 20 minutes. The percent "free liquid" generated ranged from 40 percent at the highest angle to less than 1 percent at the lowest angle.

The separator sludge contained "free liquid" which consisted of both liquids and solids. While liquid did not enter the collection tray for all the test samples, the entire sample moved along the plane for every test. The movement of liquid and solids increased proportionally with increasing the angles.

A drawback of the inclined plane deals with the collection and quantification of "free liquid." Frequently, liquids which reached the bottom of the plane adhered to the bottom edge of the glass surface, and ran underneath the glass. This liquid could not be collected for quantification for any of the tests. Also bulk movement of the entire test sample inhibited the separation process of liquids and solids. Refinements of the testing apparatus would minimize these problems.

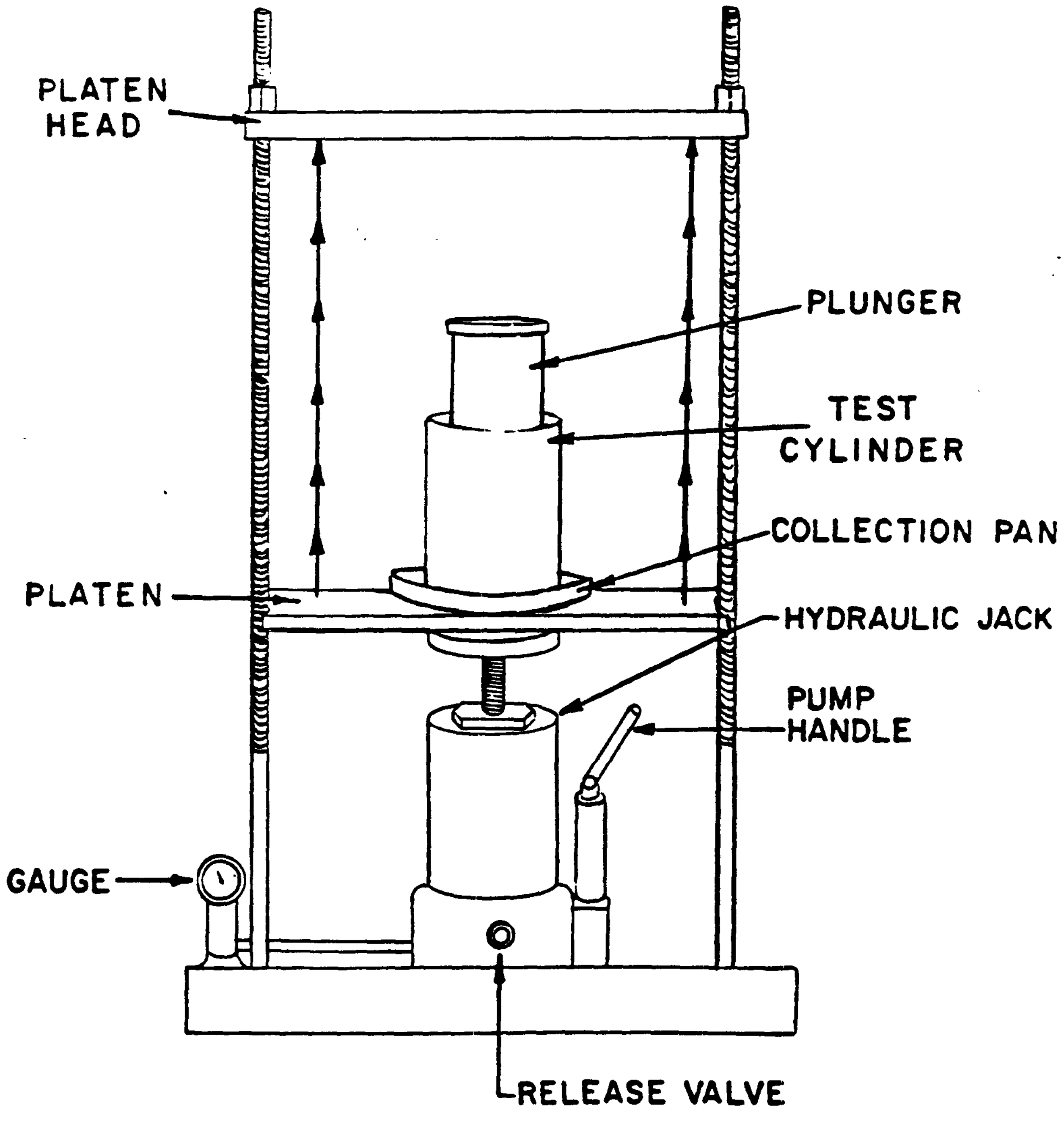
2.2.3 Lab Press

The lab press is a pressure-dependent, phase separation test. The test sample is placed in a test cylinder, equipped with filtration screens, and pressure is applied by a piston between two platen heads (see Figure 2). A pressure gauge is used to regulate pressure throughout the test. Liquid which is extracted within the 5-minute test duration is trapped in a collection pan and quantified.

The test procedure is easily implemented by waste generators and/or disposal operators. Some operator training is required for applying and regulating the pressure from the platen heads. Since pressure can be regulated, the test is ideal for simulating pressures found in a landfill at

Figure 2

LAB PRESS



The air pollution control equipment sludge generated "free liquid" at the three highest pressures but not at the two lowest pressures. A clear liquid was observed at the top of the test cylinder at the conclusion of each test. The "free liquid" generated by the air pollution control equipment sludge ranged from 4 percent of the total weight to less than 1 percent throughout the range of testing pressures.

The paint sludge generated a cloudy, colorless liquid at each of the test pressures which occurred in the collection pan as well as the top of the test cylinder. The solids remaining in the test cylinder were quite dense and retained the shape of test cylinder. The "free liquid" content of the waste ranged from 30 percent of the total weight for the highest test pressure to 7 percent for the lowest test pressure.

The "free liquid" generated by the separator sludge collected at the top of the test cylinder but did not pass through the filter plate into the collection pan at the base of the cylinder. The liquid consisted of a colorless, cloudy liquid and a brown oil-like liquid. The solids remaining in the test cylinder formed a small dense layer of sludge on the surface and bottom of the sample. The portion of the sample between these dense layers appeared to be unchanged. The "free liquid" generated by this test ranged from 12 percent of the total weight at the highest pressure to 3 percent at the lowest pressure.

Several drawbacks were noted during the lab press evaluation. During individual tests, it became difficult to maintain a constant pressure on each test sample. As liquid was extracted from the solids, the volume of the material decreased and, therefore, the pressure also decreased, requiring frequent adjustments. Furthermore, due to the inherent inaccuracy of the gauge, all pressures were approximate.

An additional difficulty observed during testing involved the alignment of the plunger and the cylinder. Many times, the plunger jammed against the side of the test cylinder, preventing an even pressure distribution on the test material, even though pressure registered on the gauge.

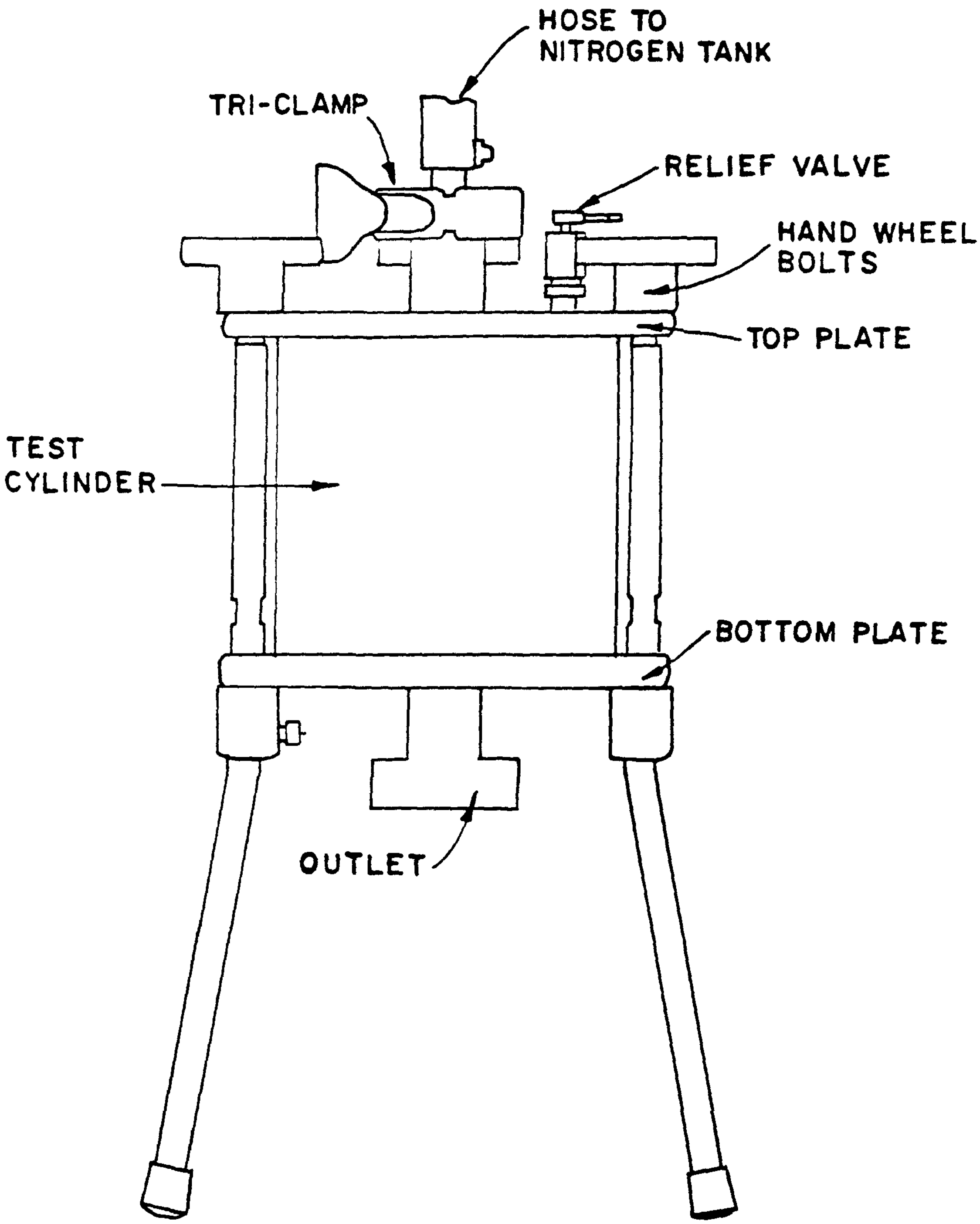
Reaction of wastes with the test cylinder was also observed during the study. During the testing of the air pollution control equipment sludge, the waste reacted with the test cylinder and plunger, resulting in corrosion of the cylinder.

2.2.4 Filtration Unit

The filtration unit is a pressure-dependent phase separation test originally developed for the extraction procedure (EP) toxicity test (see Figure 3). The test sample is placed in a test cylinder with a 0.45 micrometer pore-size filter membrane. Pressure is applied to the test

Figure 3

FILTRATION UNIT



sample by a compressed inert gas (see Appendix C). A gauge is used to maintain a constant pressure throughout the test. Any liquid extracted in the 30-minute test duration is collected and quantified.

Some operator training is required to operate the unit. The test is easily implemented by the waste generator and/or disposal operator and pressures encountered in landfills at various depths can be simulated. Although the cost of the filtration unit was greater than the other test protocol methods evaluated, it is readily available and required only routine maintenance. The internal parts of the filtration unit used in this study were teflon coated to minimize reaction with the wastes.

The filtration unit is a phase separation test which simulates pressures found in a landfill at 100, 80, 60, 40, and 20-foot depths. Compressed nitrogen acts as a piston-like force, extracting "free liquid" from the test sample. The filtration unit was evaluated by testing drilling mud, air pollution control equipment sludge, paint sludge, and separator sludge. Phase separation of liquids and solids was both waste and pressure dependent. The drilling mud was the only waste which could be tested at the five pressures for the specified 30-minute test duration. During the air pollution control equipment sludge and the paint sludge testing, pressures greater than 22 psi (simulated landfill pressure at a 60-foot depth), caused the nitrogen to pass through the sample and out the base of the filtration unit. As a result, no pressure was applied to the test material. A similar situation occurred with the separator sludge, wherein nitrogen would pass through the sample for test durations greater than several minutes.

During testing of the drilling mud, the "free liquid" extracted varied proportionally with pressure through the lowest pressures. However, "free liquid" extracted at the two highest pressures (80-foot and 100-foot depth pressures) was less than the "free liquid" extracted at the simulated landfill depths of 40 and 60 feet. The drilling mud remaining in the filtration unit maintained fluid-like characteristics at the completion of the test. The "free liquid" extracted from the test samples ranged from 5.69 percent at the highest pressure to less than 1 percent at the lowest pressure.

Air pollution control equipment sludge was only tested for the two lowest pressures to prevent nitrogen channeling through and around the samples. The average "free liquid" extracted at these two pressures ranged from 9 percent for the lower pressure to 12 percent for the higher pressure. After testing, the remaining sample formed a crusty layer at the surface and no longer exhibited a phase separation.

The paint sludge was also tested for only the two lowest pressures. The results for both tests were quite variable and in general, more "free liquid" was extracted during the lower pressure test than the higher pressure test. The "free liquid" ranged from 19 percent at the lower pressure to 24 percent for the higher pressure. The paint sludge remaining in the unit no longer exhibited a phase separation and was granular in texture.

The separator sludge was tested at all pressures but only for a test duration of 20 minutes. As the pressure increased, the amount of "free liquid" extracted also in creased. The "free liquid" ranged from 11 percent at the lowest pressure to 23 percent at the highest pressure. The separator sludge remaining in the unit maintained fluid-like characteristics.

Drawbacks encountered when testing with the filtration method included: nitrogen passing through the test sample, quantification of "free liquid", and clogging of the membrane filters. The unit is designed with a slight depression on the base plate of the unit. Liquid collects in this depression and does not readily drain from the unit into the collection beaker. However, this liquid can be poured into the collection beaker at the completion of each test. Visible clogging of the membranes was observed for the separator sludge. The results for drilling mud indicate that clogging occurred for the two highest pressures.

2.2.5 Graduated Cylinder Test

The graduated cylinder test is a gravity-dependent phase separation test developed by EPA. A 100-ml representative sample is placed in a 100-ml graduated cylinder. The cylinder is capped and agitated until it is well mixed. Any liquid which separates from the solids in a 24-hour test duration is considered "free liquid" and is quantified in milliliters (see Appendix D).

The test procedure is very simple and easily implemented by waste generators and/or disposal operators. The test equipment is readily available at minimal cost and minimal operator training is required. Graduated cylinders constructed of glass provide nonreactive surfaces and are recommended for testing to prevent reaction with the samples.

Two trials were performed for each waste. Drilling mud was not tested since drilling mud is gelatinous in nature and typically exhibits a phase separation only under pressure. Air pollution control equipment sludge, paint sludge, separator sludge, and paper sludge were used to evaluate the graduated cylinder test.

A phase separation of liquids and solids was observed for all the wastes except the paper sludge. Solids from the air pollution control equipment sludge settled unevenly during the test. The "free liquid" ranged from 4.5 percent to 5 percent by volume.

"Free liquid" from separator sludge ranged from 3 percent to 4 percent of the test sample.

Only one trial of the paint sludge produced "free liquid"; in the remaining test, the solids did not settle after agitation and adhered to the sides of the cylinder above the 100-ml mark. However, after tapping the base of the cylinder, the solids settled and 5 percent "free liquid" was observed.

The quantity of "free liquid" produced by each waste was also time-dependent. Each waste produced various amounts of "free liquid" at different intervals. "Free liquid" was first observed for the air pollution control equipment sludge after 15 minutes and stabilized after four hours. The paint sludge exhibited "free liquid" after ten minutes of testing and also stabilized after four hours. "Free liquid" was not observed for the separator sludge until 30 minutes of testing had elapsed and did not stabilize until after six hours of testing.

2.2.6 Sieve Series

The sieve test is a gravity-dependent phase separation test recommended by EPA. A 200-ml representative sample of a waste is placed in a series of 10, 18, 35, and 60-mesh screens. The sieves were agitated for a 5-minute test duration. Any liquid which penetrated the bottom screen (60-mesh) was collected and quantified in milliliters (see Appendix E).

The test is simple, requiring minimal operator training and suitable for either the waste generator and/or disposal operator. The test attempts to simulate conditions found in transporting wastes and addresses the problem of "free liquid" settling from solids due to agitation. The equipment is readily available but should be constructed of a nonreactive material.

In this test, liquid is separated from solids by shaking and gravity. Since drilling mud is gelatinous in nature and only exhibits a phase separation under pressure, it was not evaluated with the sieve series. Test materials evaluated included air pollution control equipment sludge, paint sludge, separator sludge, and paper sludge.

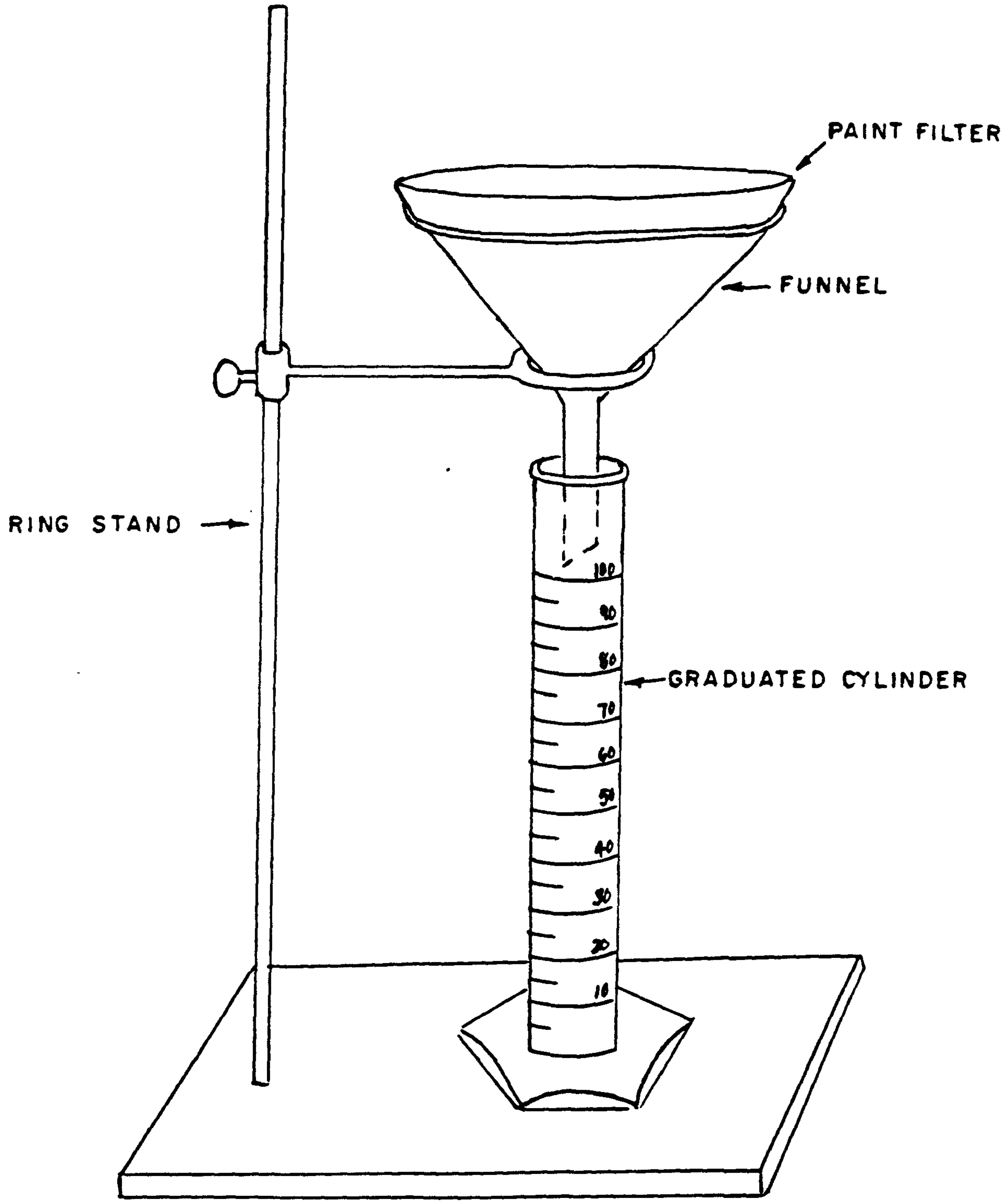
Phase separation of liquids and solids was observed for all the test materials. However, liquid produced by the paint sludge did not pass through the final (60 mesh) sieve while liquid produced by the paper sludge did not pass through the 60 or 35-mesh sieves.

Liquid produced by the air pollution control equipment sludge and the separator sludge did pass through the final sieve and was considered "free liquid." However, the results were variable for both wastes; therefore, four replications were conducted for the air pollution control equipment sludge and five replications were conducted for the separator sludge. The "free liquid" that was quantified for the air pollution control equipment sludge constituted less than 2 percent of the total test material. "Free liquid" for the separator sludge ranged from less than 2 percent to 5 percent of the total amount of material tested.

2.2.7 Paint Filter Test

The paint filter test is a gravity-dependent phase separation test developed by EPA (see Figure 4). A representative, 100 ml sample of a waste is placed in a paint filter which ~~in turn~~ is placed in a funnel. The funnel is supported by a graduated cylinder and covered with a watch glass. Any liquid which drains into the graduated cylinder in a 15-minute test duration is quantified in milliliters (see Appendix F). Liquid which passes through a paint filter is collected in a graduated cylinder and quantified at 15-minute intervals; the test continues until the change in "free liquid" per interval is less than 10 percent.

The paint filter test is easily implemented by waste generators and/or disposal operators. Since the procedure is simple, minimal operator training is required. Equipment is readily available, and the cost is minimal. The funnel and graduated cylinder were constructed of glass. Air pollution control equipment sludge, paint sludge, separator sludge, and paper sludge were employed in this test. A phase separation of liquids and solids was observed for all the wastes.



PAINT FILTER TEST

Figure 4

The air pollution control equipment sludge generated only a trace of "free liquid" during one replication. No "free liquid" was generated in the second replication.

The paint sludge produced "free liquid" for both trials. The liquid constituted 6 percent of the test sample volume. For the paint sludge, both tests were conducted for 45 minutes.

"Free liquid" was also noted in both trials of the separator sludge. The liquid ranged from 5.5 percent and 6.5 percent of the test sample. The test duration for the separator sludge was one hour.

The paper sludge produced the largest quantity of "free liquid", and the test encompassed the longest period of time. After a duration of one hour and 45 minutes, 8.5 percent and 9.5 percent of the sample volume was generated as "free liquid."

3.0 EVALUATION OF SELECTED TEST PROTOCOLS

3.1 Inclined Plane

The inclined plane was capable of determining the presence of "free liquid" in several wastes. A phase separation of liquid and solids was observed for granular and oily types of wastes (paint sludge, air pollution control equipment sludge, and separator sludge). The gelatinous type of waste (drilling mud) did not exhibit any phase separation. However, it did exhibit fluid-like characteristics by moving down the surface of the plane as a cohesive unit of liquids and solids. Only the paint sludge generated sufficient quantities of "free liquid" to be quantified.

The test procedure is simple and easy to implement; materials required for construction of the inclined plane are readily available and inexpensive. The test duration was waste dependent. The granular wastes (air pollution control equipment sludge and paint sludge) required less time for "free liquid" to reach the collection tray than the oily waste. As the angle increased, the time required for "free liquid" to reach the collection tray decreased for all the wastes. However, testing angles of 35° and 45° proved to be excessive, since solids were observed moving down the plane and into the collection tray.

The reproducibility of the test results were waste and angle dependent. As the angle increased for testing drilling mud and paint sludge, the results became more variable. The reverse was true for the air pollution control equipment sludge and separator sludge; as the angle increased, the test results became less variable.

Accurate quantification of "free liquid" proved to be difficult in several test cases. Also, movement along the plane of entire test samples occurred several times, especially at steep test angles. Both problems are due at least in part to design flaws in the construction of the inclined plane. A barrier to prevent bulk movement of the sample would minimize the drawbacks of the test. If the sample was also contained within a porous material (e.g. filter paper or screen), the separation of liquids from the sample could be increased. One-piece construction of the plane and collection tray, possibly constructed of glass, polycarbonate, or similar material, would eliminate any losses of "free liquid."

3.2 Lab Press

The lab press was capable of determining the "free liquid" content of test materials at various simulated landfill depths. "Free liquid" was quantified for all four wastes tested with drilling mud being the only waste which generated solids. The lab press is relatively simple to operate with a short test duration. The required equipment is readily available, though the initial capital investment is relatively high.

Although the procedure is simple and the test duration is short, several drawbacks were encountered during testing. Proper alignment of the piston and test cylinder is critical to proper execution of the test. When the alignment was not perfect, the test plunger would jam against the sides of the test cylinder. Though this situation can be minimized through operator experience, it remains a liability of the test. The test cylinder must be cleaned after every test, which is a cumbersome job given the numerous parts which comprise the cylinder. If the test cylinder is not thoroughly cleaned between trials, accuracy of the test would be severely impaired, an additional liability.

Another problem affecting the efficiency of the lab press is potential reaction of the test cylinder with certain wastes. In this study, the air pollution control equipment sludge reacted with the test cylinder producing slight corrosion. To limit this possibility, test cylinders constructed of less reactive materials should be employed.

3.3 Filtration Unit

Although the test procedure is fairly simple, the initial capital investment is high. Prefilter and membrane filters must be replaced for every test and are relatively expensive. The 30-minute test duration required for the majority of "free liquid" to be extracted from the sample is marginally acceptable.

At the lower range of testing pressures, the unit performed well, yielding satisfactory results for most wastes. However, it cannot be expected to successfully simulate the range of landfill pressures.

Since the prefilters and membrane filters must be replaced after each test, cleaning of the unit itself is relatively simple and should not limit accuracy through long-term use. The cost of the expendable filters will add considerably to annual operating cost for the unit and will pose an additional, although minor, problem concerning disposal of the spent filters.

The filtration unit was not capable of adequately testing any of the wastes for free liquid. The gelatinous material (drilling mud) clogged the membrane filters at the higher testing pressures. The granular materials (air pollution control equipment sludge and paint sludge) could not be tested at the higher testing pressures since the compressed nitrogen passed through the test sample and out the base of the unit. The oily type of waste (separator sludge) was tested for all the simulated landfill depths, however, after 20 minutes of testing, the compressed nitrogen passed through the test sample and out the base of unit.

3.4 Graduated Cylinder Test

The graduated cylinder test is an adequate test for determining the "free liquid" for certain types of wastes. A phase separation of liquids and solids was observed for the granular wastes (air pollution control equipment sludge and paint sludge) and the oily waste (separator sludge). However, the fibrous material (paper sludge) did not generate any "free liquid." The gelatinous type of testing material (drilling mud) was not tested since a phase separation will only occur under pressure.

The test is very simple and easy to implement. Supplies are readily available, inexpensive, and test results were quite reproducible. The test duration employed in this study (24 hours) is impractical for use by either the waste generator or disposal operator. It should be noted that in most of the testing, the majority of the "free liquid" separated from the solid portion of the sample within 4 to 6 hours. It is possible that for the purposes of field testing, the test duration could be shortened without sacrificing accuracy. Given the overall simplicity of the test and reproducibility of the trials, the test should be given serious consideration.

3.5 Sieve Series

The sieve series test was capable of determining the "free liquid" content of specific wastes. A phase separation of liquids and solids was observed for all the test materials, however, only the liquids generated from the air pollution control equipment sludge and separator sludge penetrated the final (60-mesh) screen. "Free liquid" was quantified for both wastes.

The test is very simple, easy to implement, and supplies are readily available at moderate cost. The test duration is short and practical for use by the waste generator or landfill operator. It simulates the effect of agitation on the potential phase separation of the waste. The results of the test were erratic, however, and were not reproducible for the wastes tested. Also, it should be noted that the wastes could clog the screens making thorough cleaning of the screens difficult. The inconsistent results obtained from this test eliminate the sieve series test from further consideration.

3.6 Paint Filter

The paint filter test was capable of determining the presence of "free liquid" for all the wastes tested. A liquid/solid phase separation was observed for each waste and was sufficient to quantify for each waste with the exception of the air pollution control equipment sludge. This waste only produced a trace of "free liquid" during only one of the trials.

The test procedure is simple and easy to implement by the waste generator or landfill operator. Supplies are inexpensive and readily available. Though the paint filters must be replaced after each trial, their cost is low (generally between $0.07 and $0.89) and they are generally available at local paint stores. The least expensive filters are paper and are disposable, and the finest mesh size available is a 60 mesh. These are the type of filters used in the testing program. The higher priced filters are of a plastic material, are a much finer mesh (200 mesh), and can be reused if the waste tested can permit thorough and proper cleaning. Because of these low costs, no serious financial burden will be placed on the waste generators or disposal operators. The test duration is waste dependent with a minimum length of 15 minutes for the initial procedures tested, including Modification No. 1. Modification No. 2 had no specific time limit applied and the results were generally reproducible.

In this study, the test performed well for all wastes with the exception of the air pollution control equipment sludge; when this waste was tested, a small amount of liquid collected on the top surface of the waste and did not percolate through the sample. However, when downward pressure was applied to the watch glass, liquid filtered into the graduated cylinder.

Modification No. 2 of the paint filter test appears to be an adequate, quick, and simple test for determining the presence of "free liquid" in varying waste types. A waiting period of 15 minutes is suggested to determine if any "free liquid" is present in the waste. Since the paint filter test generally satisfies the requirements set by EPA for the selection of a test protocol to determine the presence of "free liquid" in hazardous waste, it was selected by EPA for further testing with absorbent materials.

At this time, it appears that several revisions to the testing procedure could improve the overall reliability of the paint filter test. For example, the test could be evaluated with weights of varying sizes placed on the watch glass. Pressure exerted by a weight on the watch glass could: 1) simulate landfill pressures, and 2) generate a more representative quantity of "free liquid" for each test. Also, the funnel used for testing could be slotted or perforated, promoting drainage of "free liquid" from the test sample.

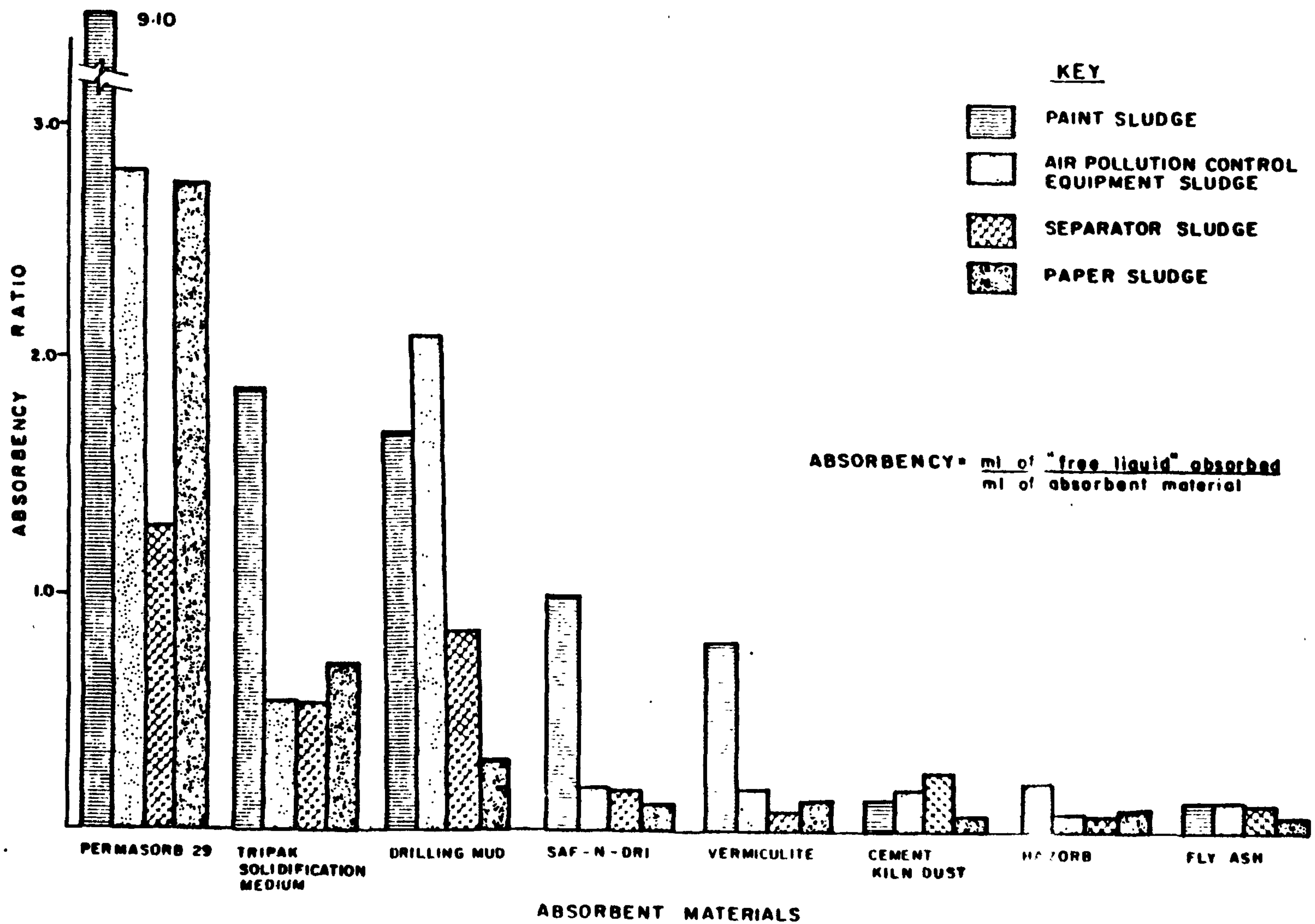

9.10
3.0
2.0
1.0
ABSORBENCY RATIO
KEY
PAINT SLUDGE
AIR POLLUTION CONTROL EQUIPMENT SLUDGE
SEPARATOR SLUDGE
PAPER SLUDGE
ABSORBENCY = ml of "free liquid" absorbed / ml of absorbent material
PERMASORB 29
TRIPAK SOLIDIFICATION MEDIUM
DRILLING MUD
SAF-N-DRI
VERMICULITE
CEMENT KILN DUST
FLY ASH
ABSORBENT MATERIALS

Figure 5

4.0 EVALUATION OF SELECTED ABSORBENT MATERIALS

4.1 Introduction

EPA and SMC Martin selected the following absorbent materials to be tested for determination of absorbtive characteristics for "free liquid" of hazardous wastes: Permasorb #29, TriPak Solidification Medium, Quik-Gel drilling mud, Safe-N-Dri, vermiculite, cement kiln dust, Hazorb, and fly ash. The selection was based on the following criteria:

1. Materials are easily obtained by most waste generators and/or disposal operators.
2. Similarity of relative costs.
3. Ability to attenuate leachate.
4. Degree of absorbency, ratio of milliliters of "free liquid" absorbed per ml of absorbent material.

The waste material selected for testing included paint sludge, air pollution control equipment sludge, separator sludge, and paper sludge. Since the air pollution control equipment sludge did not generate sufficient quantities of "free liquid" when tested with the paint filter test, additional water was added to the waste prior to testing, resulting in a test material consisting of 37 percent water by weight. The four waste materials were tested with varying amounts of each absorbent material to determine the amount of each material required to reach the physical conditions where no "free liquid" was present. This was determined by the paint filter test using a 15-minute test duration. The test was directed at maximizing "free liquid" absorption while minimizing the amount of absorbent material used.

4.2 Permasorb #29

Permasorb #29 is an industrial grade synthetic polymer manufactured by National Starch and Chemical Corporation. It is a granular solid which converts many aqueous-based liquid wastes to solid gels and is capable of absorbing up to 200 times its weight in water. The efficiency of the product is dependent upon the ionic strength and pH of the waste; high ionic concentrations and extreme pHs reduce the absorbent capacity.

As illustrated in Figure 5, Permasborb #29 was an efficient absorbent material for each waste tested. The degree of absorbency varied with each waste and ranged from 9.10 to 1.28 ml absorbed per ml of absorbent (see Appendix G). The effect Permasorb #29 had on the physical characteristics of the wastes also varied with each waste.

The mixing of Permasorb #29 with the waste materials prior to testing had various effects on the wastes. The paint sludge, which required the least amount of Permasorb #29 to absorb the "free liquid," appeared granular and dry after mixing. The air pollution control equipment sludge, separator sludge, and paper sludge all appeared smooth and gelatinous after mixing and did not appear as dry as the paint sludge. However, they appeared to firm up over time.

The paint sludge required the least amount of Permasorb #29 per ml of "free liquid" absorbed and had an absorbency ratio of 9.1 ml absorbed per ml of absorbent. The air pollution control equipment sludge required more Permasorb #29 to absorb the "free liquid" and had an absorbent ratio of 2.8 ml absorbed per ml of absorbent. Both the separator sludge and paper sludge generated less free liquid than the paint sludge, but required more Permasorb #29 to absorb that liquid. The absorbency ratios for the separator sludge and paper sludge were 1.28 and 2.73 ml absorbed per ml of absorbent, respectively.

Since a price was not available from the manufacturer for Permasorb #29, it cannot be completely evaluated. However, it is a valuable absorbent material for numerous reasons, including its ability to increase the viscosity of wastes over time, which in turn increases the ability of the waste to retain "free liquid" under landfill pressure.

4.3 TriPak Solidification Medium

TriPak Solidification Medium is manufactured by Tri Resource Industries as an absorbent for hazardous wastes and is a composite of fullers earth, opal claystone, and other inert absorbent materials. It is available in 50-pound bags or steel and plastic 55-gallon drums. The price per bag is approximately $7.50.

The physical characteristics for each waste changed with the addition of TriPak Solidification Medium. The air pollution control equipment sludge and separator sludge had a smooth paste-like texture after mixing. The granular paint sludge also became paste-like but maintained visible granules. The paper sludge remained fibrous but was drier.

The highest degree of absorbency for TriPak was noted when testing with the granular, water-based, paint sludge (see Appendix H). Although the waste contains the second highest percent "free liquid" for the wastes tested, the absorbency ratio was 1.88 ml absorbed per ml of absorbent. The granular, water-based, air pollution control equipment sludge, and oily separator sludge, which contained the highest and the lowest percent "free liquid" respectively, had the lowest absorbency ratios for TriPak at 0.55 and 0.54 ml absorbed per ml of absorbent, respectively. The fibrous paper sludge had an absorbency ratio of 0.71 ml absorbed per ml of absorbent.

4.4 Drilling Mud

Quik-Gel drilling mud is a finely-ground, premium-grade, sodium-based montmorillonite, western bentonite manufactured by NL Baroid/NL Industries. It is a nontoxic viscosic material used in fresh water or fresh water-based drilling. Its physical composition consists of montmorillonite, quartz, feldspar, cristobalite, ellite, calcium, and gypsum. It is readily available and costs approximately $8.17 per 50-pound bag.

In general, the degree of absorbency for drilling mud varied with each waste, but the effects on the physical characteristics of each waste were similar. Although each waste maintained its invididual characteristics after mixing with the drilling mud (i.e. granular, oily, or fibrous), they all appeared gelatinous-like in nature. The paint sludge maintained its coarse granular but texture was held together in a paste-like gelatinous medium. As the material was being tested using the paint filter method, it appeared to become drier over time. The air pollution control equipment sludge appeared very smooth and gelatinous but after mixing, it appeared wet at the surface. The wetness was absorbed with mixing but reappeared when the material was being tested in the paint filter. The separator sludge appeared gelatinous and oily in nature, while the paper sludge was gelatinous and fibrous. The paper sludge also appeared to be wetter than the other wastes tested.

The highest absorbency ratio for drilling mud was 2.08 ml absorbed per ml of absorbent and was recorded for the air pollution control equipment sludge, which generated the most "free liquid" per 100 ml of waste material tested (see Appendix I). Drilling mud had the lowest absorbency, a ratio of 0.28 ml absorbed per ml of absorbent, for the paper sludge. The paint sludge and separator sludge had absorbency ratios of 1.67 and 0.83 ml absorbed per ml of absorbent, respectively.

Although the ability of drilling mud to attenuate "free liquid" was waste dependent and highly variable, the absorbency ratios for the individual wastes were relatively high in comparison with the majority of the absorbent materials. The product is readily available from the manufacturer and because of its higher absorbency ratio, it is relatively inexpensive. It is also a gelatinous type of material, and like Permasorb #29, it increased the viscosity of the waste over time, which increases the waste's ability to retain "free liquid" under landfill pressure.

4.5 Safe-N-Dri

Safe-N-Dri is an absorbent material manufactured by Oil Dri for the absorption of hazardous liquids. It is composed of calcium bentonite and is available in three grades: Safe-N-Dri Special, Safe-N-Dri Standard, and Safe-N-Dri Powder. The Safe-N-Dri Special has uniform granules. Safe-N-Dri Standard has large and small granules. Safe-N-Dri Powder is a powder and has the highest water and oil absorbency ratio (ml/gm absorbent). The powder was used for all testing. The product is available in 50-pound bags at a cost of $3.25 per bag.

Safe-N-Dri did not absorb "free liquid" as well as any of the previously mentioned absorbent materials. However, in general, it was the least expensive absorbent product per ml of material used, and it was applicable to the various wastes tested.

The physical characteristics of each waste changed with the addition of Safe-N-Dri: the paint sludge maintained its larger granules; the air pollution control equipment sludge was very smooth in texture; the paper sludge and separator sludge exhibited a drier, grainy appearance, with a consistency similar to a paste-like medium. The paper sludge also maintained its fibrous-like nature.

Safe-N-Dri was up to ten times more absorbent for paint sludge than for the other wastes tested (see Appendix J). The air pollution control equipment sludge and separator sludge had absorbency ratios of 0.19 and 0.17 ml absorbed per ml of absorbent, respectively. The lowest degree of absorbency, which was 0.11 ml absorbent per ml of absorbent, was recorded for the paper sludge.

Safe-N-Dri is an inexpensive absorbent material that is applicable to various types of wastes. However, the absorbency ratios are not high, and although no "free liquid" was observed during testing, two of the wastes appeared wet when they were tested. Since the material is relatively inexpensive, more Safe-N-Dri could be added to the wastes to achieve a firmer, drier material, making Safe-N-Dri more productive.

4.6 Vermiculite

Vermiculite is a granular, lightweight, micaceous clay mineral. It is a highly absorbent material which is often used for the absorption of hazardous wastes. It is available in various grades and all tests were conducted with grade-three vermiculite. It is available in four-cubic foot bags and costs approximately $6.25 per bag.

The absorbency ratio varied with each waste; the granular, water-based, paint sludge required the least amount of absorbent material to absorb the "free liquid" present (see Appendix K). The absorbency ratio for vermiculite and paint sludge was 0.8 ml absorbed per ml of absorbent. This was ten times more efficient than the lowest absorbency ratio of 0.08 ml absorbed per ml of absorbent for the oily separator sludge. The granular, water-based, air pollution control equipment sludge and fibrous paper sludge had absorbency ratios of 0.15 and 0.12 ml absorbed per ml of absorbent, respectively.

Vermiculite was the most expensive product per ml of absorbent required to absorb "free liquid" and had low absorbency ratios for three of the four wastes tested. The wastes remained wet after the addition of vermiculite indicating that they would probably not retain potential "free liquid" under landfill conditions or pressures. The addition of more vermiculite to absorb the potential "free liquid" is not considered to be a cost-effective alternative for the waste generators or disposal operators.

4.7 Cement Kiln Dust

Cement kiln dust is a by-product from the process of making cement; as limestone is heated in the kiln, a dust is generated and collected in stacks. It is a common absorbent material used for hazardous wastes. The primary composition is calcium and it is readily available to waste generators or disposal operators located near a cement plant. The cost would consist of loading and transportation costs.

The physical characteristics of each waste varied with the addition of the kiln dust to the waste. The paint sludge maintained a consistency of coarse granules with a light and airy-like matrix. The air pollution control equipment sludge was smooth and appeared wet at the surface. The separator sludge was grainy, wet, and runny; while the paper sludge was fibrous and wet.

Cement kiln dust was the only absorbent tested which was effective for the oily separator sludge. The only separator sludge generated the least amount of "free liquid" per 100 ml of sample tested (see Appendix L). The absorbency ratio for the separator sludge was 0.25 ml absorbed per ml of absorbent. The lowest degree of absorbency was observed for the paper sludge which had an absorbency ratio of 0.06 ml absorbed per ml of absorbent. The air pollution control equipment sludge and paint sludge had absorbency ratios of 0.09 and 0.13 ml absorbed per ml of absorbent, respectively.

Although the cement kiln dust was inexpensive, it was also one of the least absorbent materials tested. This increased volume of absorbent can be of concern when disposing of wastes in a landfill because as the volume of absorbent material required by a waste to attenuate "free liquid" increases, the less space there is available to landfill more wastes.

4.8 Hazorb

Hazorb is a general, all-purpose sorbent material manufactured by Diamond Shamrock Corporation. It is comprised of amorphous, inorganic, foamed silicate glass. It is inert and will not react with hazardous materials, except hydrofluoric acid. Hazorb is formed into lightweight cellular granules that are available in pillow (17" x 26" x 2") or loose form. Tests were conducted using the loose form which is available in cubic-foot bags. The approximate cost per bag is $10.00.

Hazorb had the highest degree of absorbency for the paint sludge, 0.28 ml absorbed per ml of absorbent (see Appendix M). The air pollution control equipment sludge and separator sludge, which generated the most and least amounts of "free liquid" per 100 ml of test sample, respectively, had absorbency ratios of 0.07 and 0.06 ml absorbed per ml or absorbent, respectively. The absorbency ratio using Hazorb for the paper sludge was 0.08 ml absorbed per ml of absorbent. After the addition of the Hazorb, the paint sludge remained granular, but had a light airy matrix of fine paint sludge. The air pollution control equipment sludge was smooth, runny and wet at the surface. The separator sludge was grainy but cohesive and wet, and the paper sludge remained fibrous and wet.

Hazorb was one of the most expensive materials tested because it was one of the least absorbent. More Hazorb absorbent material was required to absorb 1 ml of "free liquid" than compared to the other absorbents. It did not demonstrate any particular affinity to one type of waste, but had similar results for the granular, oily, and fibrous type wastes.

4.9 Fly Ash

Fly ash is a fine-grained, amorphous, glassy material generated by coal-burning power plants and is commonly used as an absorbent material for hazardous wastes. Its elemental composition varies with the parent coal and operational characteristics. Fly ash is considered a waste product and is readily available to many landfill operators and waste generators. Much of the cost associated with using fly ash would consist of loading and transportation charges.

The fly ash had the most consistent absorbency ratio observed in the course of the study (see Appendix N). The abosrbency ratio only ranged from 0.11 to 0.05 ml with air pollution control equipment sludge, paint sludge, and separator sludge being very similar to each other.

While the absorbency ratio was not waste dependent, the physical effect the fly ash had on the wastes varied with each waste material. After mixing with the fly ash, the paint sludge was gritty and dry with less granules than when mixed with other absorbent materials. The air pollution control equipment sludge was smooth with fine grains, while the seprator sludge was grainy and wet but held together as a cohesive unit. The paper sludge was similar to the separator sludge but was fibrous instead of grainy. Although each waste increased in viscosity with the addition of fly ash, only the paint sludge became dry in appearance; the other wastes maintained some flowing or liquid-like characteristics.

The highest degree of absorbency for fly ash was recorded for the air pollution control equipment sludge with a ratio of 0.11 ml absorbed per ml of absorbent. However, the paint sludge and separator sludge were very similar to the air pollution control equipment sludge, with absorbency ratios of 0.10 ml absorbed per ml of absorbent. These wastes had an absorbency ratio twice that of the fibrous paper sludge which was 0.05 ml absorbed per ml of absorbent.

Fly ash is similar to the cement kiln dust since it is readily available and inexpensive to generators located in the vicinity of coal-burning power plants. Therefore, the cost of adding larger quantities of fly ash to the waste maintaining liquid-like characteristics should not pose a problem. However, when there is concern with landfill volumes, a more efficient absorbent material should be utilized.

CONCLUSIONS

The primary purpose of this study was to develop a test method which could accurately determine the "free liquid" content of hazardous wastes. However, the results of this study indicate that no single test method described in this report could accurately determine the "free liquid" content of all wastes with reproducible results for all cases. The four wastes tested with each protocol (excluding drilling mud) represents a very small percentage of the numerous types of hazardous wastes produced by the industrial sector.

Several test methods show promise for use as indicators of the "free liquid" in wastes; however, the tests require improvements in their design and/or test procedures to increase their reliability. Modifications to the inclined plane which would eliminate bulk movement of the sample down the plane, and which would increase the efficiency of the "free liquid" collection procedure, would considerably improve the reliability of the inclined plane test. The test does have potential and should be considered for any future testing by EPA. Its low cost and ease of implementation would minimize operator error and the costs incurred to those required to use this test.

The filtration unit, which had the advantage of being able to simulate landfill pressures, could not be used for testing at the high pressures expected in deep landfills.

However, testing at lower pressures was quick, fairly reliable and the results were generally reproducible. The filtration unit is expensive to purchase and maintain, especially given that the prefilters and membrane filters must be changed after each test at considerable cost.

The laboratory press is commercially available, but at a high cost. Mechanical drawbacks were evident in this test, especially during the alignment of the test sample with the piston of the laboratory press. One of the wastes used in this study reacted with the material of the test cylinder producing corrosion. The complex assembly of the test cylinder required very thorough cleaning which would be time consuming. If the thorough cleaning was not followed after each test, reliability of succeeding tests would be questionable.

The graduated cylinder was inexpensive to purchase and maintain, and the test methodology was simple and required little operator training. Results were generally reproducible, though the 24-hour test duration used in this study was excessive and may not be feasible for operators and generators. However, as shown in the testing, most of the "free liquid" which was generated in each test, separated from the solids within several hours. This test could warrant further consideration by EPA.

The sieve series used for this study is available at moderate cost from many commercial establishments. Though of short duration, the test generally did not yield reproducible results. Also, the test was only marginally successful in separating "free liquid" from the remainder of the sample. Since the sieve series did not yield reproducible results for the waste materials evaluated, it should not be given further consideration by EPA.

The paint filter was generally satisfactory in determining the "free liquid" content of all the wastes tested in this study. Its success in the preliminary phases of the study warranted using the paint filter for the latter stages of the study in testing the absorbent materials. The paint filter as tested in this study could not simulate landfill pressures, which could limit its utility for EPA.

Eight absorbent materials were evaluated in this study using the paint filter test. The absorbent materials were selected to attempt to produce a variety of synthetic and natural materials for testing. All the absorbent materials tested were capable of absorbing various amounts of "free liquid" present in the waste material. In general, Permasorb No. 29 was the most absorbent material tested in this study and fly ash, the least absorbent. The results for each waste, using these materials, were reproducible, however, in all cases. Vermiculite and Hazorb proved to be the most espensive absorbent products per volume used in the study. The least expensive absorbent materials on a volumetric basis were Safe-N-Dri and drilling mud. Though not the most absorbent materials by volume, cement kiln dust and fly ash should also be seriously considered since the cost of obtaining these products is minimal, and usually only dependent on the transportation charges.

RECOMMENDATIONS

Several of the test protocols evaluated in this study warrant consideration by EPA for possible implementation. Several of the test methods evaluated, such as the graduated cylinder, inclined plane, and paint filter, provided accurate reproducible data which could be used as a pass/fail basis for "free liquid" determination. Furthermore, refinement of these test protocols could lead to a more accurate determination of the "free liquid" content of these wastes. In this regard, we recommend that EPA should select one or more of these test methods for refinement and further testing.

While the five test materials used in this study encompassed a variety of textural types, further testing should consider the selection of additional wastes to provide a more rigorous evaluation of the test protocol selected by EPA. For example, wastes which are corrosive or highly reactive would certainly impact the selection of a test protocol to evaluate "free liquid" of that waste.

The absorbent materials evaluated in this project included varieties of synthetic and natural materials. No recommendation for any one particular absorbent material used in this study can be made. Of equal or greater importance to the volumetric absorbtive capacity of absorbent material used is a consideration of the compatibility of the hazardous waste and the absorbent material used for codisposal.

Further, the cost effectiveness of each absorbent material is not only determined by the current retail price, but also by the geographic location of the particular disposal site in question. The location of any particular site will answer questions regarding the transportation costs of particular absorbent materials. A large quantity of the various absorbent materials should be readily available to a disposal operation, either by their proximity to a cement plant or a coal-fired power plant, in the case of cement kiln dust and fly ash, or by their easy accessability in the market place.

APPENDIX A

TEST PROTOCOL RESULTS FOR THE DETERMINATION OF "FREE LIQUID" BY THE INCLINED PLANE

THE DETERMINATION OF "FREE LIQUID"
BY THE INCLINED PLANE

Test Procedure

Summary of Method

A sample of test material is placed on an inclined plane. "Free liquid" drains from the test material by gravity. The liquid is collected and quantified.

Apparatus

1. Inclined plane: An inclined plane from 0° to 45° and capable of supporting a 1 kg test sample.

2. Collection tray: A collection tray capable of collecting any "free liquid" that separates from the test material.

3. Surface: A nonreactive surface which can be removed from the inclined plane for cleaning.

General Procedure

1. Adjust the inclined plan to the desired angle.

2. Weigh 1 Kg of testing material

3. Place the sample along a straight line (parallel to the top and bottom of the plane) on the surface of the plane.

4. Record any linear movement, change in movement, or phase separation of the test material over a predetermined test duration (durations from 5 to 30 minutes were used).

5. Collect all the "free liquid" that has separated from the solids.

6. Calculate the "free liquid" in the original test sample:

$$\frac{\text{weight of "free liquid"}}{\text{weight of original test sample}} \times 100 = \text{\% "free liquid" of test sample}$$

MOVEMENT OF DRILLING MUD ON THE INCLINED PLANE

Angle	Replication	Time	Movement (cm)
5°	1	5 min.	1.5
		10 min.	NC
		15 min.	NC
5°	2	5 min.	2.0
		10 min.	NC
		15 min.	NC
5°	3	5 min.	2.0
		10 min.	NC
		15 min.	NC
5°	4	5 min.	1.0
		10 min.	1.25
		15 min.	NC
5°	5	5 min.	1.5
		10 min.	NC
		15 min.	NC
10°	1	5 min.	5.0
		10 min.	5.75
		15 min.	NC
10°	2	5 min.	4.5
		10 min.	NC
		15 min.	NC
10°	3	5 min.	6.0
		10 min.	NC
		15 min.	NC
10°	4	5 min.	7.0
		10 min.	8.5
		15 min.	NC
10°	5	5 min.	5.75
		10 min.	NC
		15 min.	NC
15°	1	5 min.	13.0
		10 min.	15.0
		15 min.	NC

MOVEMENT OF DRILLING MUD ON THE INCLINED PLANE
(coninued)

Angle	Replication	Time	Movement (cm)
15°	2	5 min.	12.25
		10 min.	14.5
		15 min.	15.0
15°	3	5 min.	10.5
		10 min.	14.5
		15 min.	16.0
15°	4	5 min.	7.5
		10 min.	NC
		15 min.	NC
15°	5	5 min.	8.0
		10 min.	NC
		15 min.	NC
20°	1	5 min.	17.5
		10 min.	20.0
		15 min.	22+
20°	2	5 min.	20.5
		10 min.	22+
		15 min.	NC
20°	3	5 min.	17.0
		10 min.	17.5
		15 min.	NC
20°	4	5 min.	22+
		10 min.	NC
		15 min.	NC
20°	5	5 min.	22+
		10 min.	NC
		15 min.	NC

NC No Change

MOVEMENT AND COLLECTION OF "FREE LIQUID" FOR AIR POLLUTION CONTROL EQUIPMENT SLUDGE ON THE INCLINED PLANE

Angle	Replication	Time	Movement (cm)	Free Liquid(g)
5°	1	5 min.	1.25	
		10 min.	20.5	
		20 min.	22+	
		30 min.	NC	1.1
5°	2	5 min.	5.0	
		10 min.	22+	
		20 min.	NC	
		30 min.	NC	1.95
5°	3	5 min.	0.5	
		10 min.	22+	
		20 min.	NC	
		30 min.	NC	1.85
5°	4	5 min.	10.5	
		10 min.	22+	
		20 min.	NC	
		30 min.	NC	1.7
5°	5	5 min.	0.5	
		10 min.	22+	
		20 min.	NC	
		30 min.	NC	0.9
15°	1	5 min.	7.5	
		10 min.	22+	
		20 min.	NC	
		30 min.	NC	1.5
15°	2	5 min.	1.25	
		10 min.	22+	
		20 min.	NC	
		30 min.	NC	0.0
15°	3	5 min.	0.5	
		10 min.	19.0	
		20 min.	22+	
		30 min.	NC	0.0
15°	4	5 min.	16.0	
		10 min.	22+	
		20 min.	NC	
		30 min.	NC	2.6

MOVEMENT AND COLLECTION OF "FREE LIQUID" FOR AIR POLLUTION CONTROL EQUIPMENT SLUDGE ON THE INCLINED PLANE
(continued)

Angle	Replication	Time	Movement (cm)	Free Liquid(g)
15°	5	5 min.	22+	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	2.0
25°	1	5 min.	22+	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	3.4
25°	2	5 min.	22+	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	1.0
25°	3	5 min.	22+	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	1.8
25°	4	5 min.	22+	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	1.5
25°	5	5 min.	22+	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	0.9
35°	1	5 min.	22+	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	0.0
35°	2	5 min.	22+ (solids)	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	0.0
35°	3	5 min.	22+ (solids)	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	0.0

MOVEMENT AND COLLECTION OF "FREE LIQUID" FOR AIR POLLUTION CONTROL EQUIPMENT SLUDGE ON THE INCLINED PLANE (continued)

Angle	Replication	Time	Movement (cm)	Free Liquid(g)
35°	4	5 min.	12.5	
		10 min.	22+	
		20 min.	NC	
		30 min.	NC	0.0
35°	5	5 min.	22+ (solids)	
		10 min.	NC	
		20 min.	NC	
		30 min.	NC	0.0

NC No Change

"FREE LIQUID" CONTENT OF PAINT SLUDGE AS DETERMINED BY THE INCLINED PLANE

Angle	Replication	Time (min)	Free Liquid (g)
5°	1	5	6.1
		10	7.5
		15	8.76
		20	8.85
		25	8.85
		30	8.85
5°	2	5	5.5
		10	8.0
		15	8.8
		20	9.4
		25	9.5
		30	9.5
5°	3	5	2.6
		10	5.0
		15	5.5
		20	6.4
		25	6.6
		30	6.7
5°	4	5	8.60
		10	8.67
		15	10.02
		20	10.57
		25	10.57
		30	10.57
5°	5	5	8.65
		10	9.05
		15	9.55
		20	9.81
		25	10.35
		30	10.35
15°	1	5	26.50
		10	29.35
		15	30.00
		20	30.32
		25	30.38
		30	30.38

"FREE LIQUID" CONTENT OF PAINT SLUDGE AS DETERMINED BY THE INCLINED PLANE (Continued)

Angle	Replication	Time (min)	Free Liquid (g)
15°	2	5	20.75
		10	26.58
		15	28.35
		20	29.32
		25	29.85
		30	30.15
15°	3	5	34.27
		10	35.12
		15	40.87
		20	41.32
		25	41.67
		30	41.72
15°	4	5	21.02
		10	24.37
		15	24.77
		20	24.77
		25	24.77
		30	24.87
15°	5	5	19.35
		10	25.35
		15	26.75
		20	28.05
		25	28.60
		30	28.95
25°	1	5	19.97
		10	21.87
		15	22.97
		20	23.37
		25	23.57
		30	23.87
25°	2	5	13.22
		10	19.77
		15	21.77
		20	23.77
		25	25.07
		30	26.07

"FREE LIQUID" CONTENT OF PAINT SLUDGE AS DETERMINED BY THE INCLINED PLANE
(Continued)

Angle	Replication	Time (min)	Free Liquid (g)
25°	3	5	17.49
		10	17.82
		15	20.72
		20	21.72
		25	22.67
		30	22.97
25°	4	5	24.1
		10	29.8
		15	32.7
		20	34.2
		25	34.7
		30	35.2
25°	5	5	19.47
		10	23.77
		15	27.87
		20	28.57
		25	29.52
		30	29.97

NC No Change

MOVEMENT OF "FREE LIQUID" AND SOLIDS
FOR SEPARATOR SLUDGE ON THE INCLINED PLANE

Angle	Replication	Time (min)	Movement (cm)
5°	1	5	0.75 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC
5°	2	5	1.5 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC
5°	3	5	0.5 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC
5°	4	5	1.0 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC
5°	5	5	0.5 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC
15°	1	5	2.0 (solids)
		10	2.5 (solids)
		15	NC
		20	2.75
		25	NC
		30	NC

MOVEMENT OF "FREE LIQUID" AND SOLIDS
FOR SEPARATOR SLUDGE ON THE INCLINED PLANE
(Continued)

Angle	Replication	Time (min)	Movement (cm)
15°	2	5	2.0 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC
15°	3	5	1.5 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC
15°	4	5	2.0 (solids)
		10	3.0 (solids)
		15	NC
		20	NC
		25	NC
		30	3.5
15°	5	5	1.0 (solids)
		10	1.5 (solids)
		15	NC
		20	NC
		25	2.0
		30	NC
25°	1	5	5.5 (solids)
		10	NC
		15	9.0
		20	22+
		25	NC
		30	NC
25°	2	5	6.5 (solids)
		10	NC
		15	9.0
		20	15.5
		25	22+
		30	NC

MOVEMENT OF "FREE LIQUID" AND SOLIDS
FOR SEPARATOR SLUDGE ON THE INCLINED PLANE
(Continued)

Angle	Replication	Time (min)	Movement (cm)
25°	3	5	5.0 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	5.5
25°	4	5	4.0 (solids)
		10	NC
		15	NC
		20	NC
		25	4.5
		30	11.5
25°	5	5	5.0 (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	20.0 (1 drop)
35°	1	5	9.5 (solids)
		10	10.0
		15	22+
		20	NC
		25	NC
		30	NC
35°	2	5	12.0 (solids)
		10	18.0
		15	NC
		20	22+
		25	NC
		30	NC
35°	3	5	9.5 (solids)
		10	NC
		15	16.0
		20	22+
		25	NC
		30	NC

MOVEMENT OF "FREE LIQUID" AND SOLIDS
FOR SEPARATOR SLUDGE ON THE INCLINED PLANE
(Continued)

Angle	Replication	Time (min)	Movement (cm)
35°	4	5	8.0 (solids)
		10	NC
		15	9.5
		20	20.0
		25	22+
		30	NC
35°	5	5	7.5 (solids)
		10	NC
		15	NC
		20	8.0
		25	18.0
		30	22+
45°	1	5	14.5 (solids)
		10	15.0
		15	22+
		20	NC
		25	NC
		30	NC
45°	2	5	14.0 (solids)
		10	NC
		15	19.5
		20	22+
		25	NC
		30	22+ (solids)
45°	3	5	22+ (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC
45°	4	5	14.0 (solids)
		10	NC
		15	20.0
		20	22+
		25	NC
		30	18.5 (solids)

MOVEMENT OF "FREE LIQUID" AND SOLIDS
FOR SEPARATOR SLUDGE ON THE INCLINED PLANE
(Continued)

Angle	Replication	Time (min)	Movement (cm)
45°	5	5	22+ (solids)
		10	NC
		15	NC
		20	NC
		25	NC
		30	NC

NC No Change

APPENDIX B

TEST PROTOCOL AND RESULTS FOR THE DETERMINATION OF "FREE LIQUID" BY THE LAB PRESS

THE DETERMINATION OF "FREE LIQUID" BY THE LAB PRESS

Test Procedure

Summary and Method

A sample is placed in the test cylinder of the lab press. Force is applied by a hydraulic piston which simulates landfill pressures. The amount of liquid that is extracted at the specified pressure is quantified.

Apparatus

1. Carver Laboratory Press, Model C 12-ton capacity: Lab press capable of exerting enough pressure to simulate the pressure present in landfills at depths of 20 to 100 feet.

2. Filter Plate Assembly: Includes a filter holding ring and test cylinder capable of separating liquids from solids when pressure is applied.

3. Collection pan: used to collect the liquid extracted during the test. It should be constructed of nonreactive material.

General Procedure

1. Assemble the filter plate assembly with a 16-mesh screen.

2. Assemble the test cylinder. Place the test cylinder over the holding ring, screen side up, until the bottom of holding ring is flush with the bottom of the test cylinder.

3. Weigh out a designated amount of test material (enough to fill the cylinder to the recommended 3/4 in. from the top) and place in the test cylinder. Smooth the surface of the testing material.

4. Place a filter screen on the surface of the test material. Cover this screen with a filter pad and place the plunger on top of the filter pad.

5. Place the test cylinder and plunger in the collection pan on the platen of the press.

6. Apply the desired pressure to the sample for a 5-minute test duration.

7. Remove the test cylinder from the lab press. Remove any "free liquid" that has collected in the collection pan or on the test cylinder and discard.

8. Using the ejector provided with the lab press, eject the solid material from the test cylinder and weigh.

9. Calculate the percent "free liquid" in the original test sample:

a. weight of original test material − weight of sample after pressed = weight of "free liquid" removed from sample

b. $\frac{\text{weight of "free liquid"}}{\text{weight of original test sample}} \times 100$ = % "free liquid" of test sample

"FREE LIQUID" CONTENT (PERCENT) OF
DRILLING MUD AS DETERMINED BY THE LAB PRESS
AT VARIOUS PRESSURES*

43.33 psi	34.67 psi	26.00 psi	17.33 psi	8.67 psi
61.00	49.01	22.48	20.23	8.69
52.15	39.10	33.72	41.21	12.74
68.90	39.94	15.96	14.01	12.36
51.70	51.93	27.65	16.94	7.87
57.85	21.13	25.25	25.81	13.86
Average				
58.32	40.22	25.01	18.06	11.10

* All tests were conducted with a 16 mesh screen for a test duration of 5 minutes.

"FREE LIQUID" CONTENT (PERCENT) OF PAINT SLUDGE
AS DETERMINED BY THE LAB PRESS
AT VARIOUS PRESSURES (psi)*

Replication	43.33	34.67	26.00	17.33	8.67
1	21.18	19.79	15.21	11.07	10.25
2	21.19	22.14	13.39	14.25	9.14
3	19.71	20.43	17.25	11.02	7.91
4	21.17	19.19	15.68	11.91	9.61
5	21.01	18.05	13.57	12.54	7.79
Average	20.85	19.95	15.02	12.16	8.94

* All tests were conducted with a 16 mesh screen for a test duration of 5 minutes.

"FREE LIQUID" CONTENT (PERCENT) OF AIR POLLUTION CONTROL EQUIPMENT SLUDGE AS DETERMINED BY THE LAB PRESS AT VARIOUS PRESSURES (psi)*

Replication	43.33	34.67	26.00	17.33	8.67
1	4.05	2.87	1.82	0.0	0.0
2	2.6	2.67	0.88	0.0	0.0
3	4.27	0.77	1.82	0.0	0.0
4	1.01	3.17	0.97	0.0	0.0
5	3.63	3.17	2.57	0.0	0.0
Average	3.11	2.53	1.61	0.0	0.0

* All tests were conducted with a 16 mesh screen for a test duration of 5 minutes.

"FREE LIQUID" CONTENT (PERCENT) OF SEPARATOR
SLUDGE AS DETERMINED BY THE LAB PRESS
AT VARIOUS PRESSURES (psi)*

Replication	43.33	34.67	26.00	17.33	8.67
1	9.36	8.6	8.1	7.3	3.98
2	7.5	8.6	6.2	5.8	4.94
3	11.9	7.1	7.5	6.5	3.66
4	9.07	7.9	7.7	6.5	4.01
5	8.5	7.8	6.2	8.0	4.86
Average	9.26	8.0	7.14	6.82	4.29

* All tests were conducted with a 16 mesh screen for a test duration of 5 minutes.

APPENDIX C

TEST PROTOCOL AND RESULTS FOR THE DETERMINATION OF "FREE LIQUID" BY THE FILTRATION UNIT

THE DETERMINATION OF "FREE LIQUID"
BY THE FILTRATION UNIT

Test Procedure

Summary and Method

A sample is placed in the test cylinder of the filtration unit. Positive pressure, which simulates landfill pressures, is applied by compressed nitrogen. The amount of "free liquid" that is extracted is collected is quantified.

Apparatus

1. Millipore Hazardous Waste Filtration System: Filtration unit commonly used in EP toxicity testing.

2. Compressed Nitrogen: Capable of exerting enough pressure to simulate the pressure applied at landfills at depths from 20 to 100 feet.

3. Filters: 0.45 micron membrane filter and a prefilter.

4. Distilled water: Used for wetting the filters prior to testing.

General Procedure

1. Wet membrane with distilled water and place on the base screen of the filtration unit.

2. Center the test cylinder onto the membrane.

3. Wet the prefilter and lower it through the top of the test cylinder onto the membrane filter.

4. Weigh out a representative sample of material to be tested (minimum size 100g).

5. Place test sample in test cylinder, making sure to completely cover the bottom of the test cylinder.

6. Place the top plate of the filtration unit on the test cylinder and tighten the hand wheel bolts.

7. Attach pressure tubing to the nitrogen tank and hose adapter on top of the top plate.

8. Apply specified pressure to sample from the compressed nitrogen tank.

9. Collect and weigh all the "free liquid" that is extracted.

10. Subtract 8.67 g from the weight of the "free liquid" extracted, which is the average amount of liquid extracted from the filter and membrane.

11. Calcuate the "free liquid" in the original test sample:

$$\frac{\text{weight of "free liquid"}}{\text{weight of original test sample}} \times 100 = \text{\% "free liquid" of test sample}$$

"FREE LIQUID" CONTENT (PERCENT) OF DRILLING MUD
AS DETERMINED BY THE FILTRATION UNIT
AT VARIOUS PRESSURES (psi)*

Replication	43.33	34.67	26.00	17.33	8.67
1	5.59	2.60	5.85	3.80	0.0
2	2.44	7.15	6.90	2.90	2.45
3	1.99	1.1	4.15	7.15	0.0
4	4.12	2.00	5.65	3.05	0.0
5	5.94	0.35	3.05	5.65	0.9
Average	4.02	2.58	5.12	4.51	0.67

* All tests conducted with an 0.65 um membrane filter for a test duration of 30 minutes.

"FREE LIQUID" CONTENT (PERCENT) OF AIR POLLUTION CONTROL EQUIPMENT SLUDGE AS DETERMINED BY THE FILTRATION UNIT AT VARIOUS PRESSURES (psi)*

Replication	17.33	8.67
1	8.91	9.53
2	9.8	9.34
3	11.54	10.03
4	10.18	10.05
5	9.65	10.25
Average	10.02	9.84

* All tests were conducted with an 0.65 um membrane filter for a test duration of 30 minutes.

"FREE LIQUID" CONTENT (PERCENT) OF PAINT SLUDGE AS DETERMINED BY THE FILTRATION UNIT AT VARIOUS PRESSURES (psi)*

Replication	17.33	8.67
1	23.47	23.12
2	20.17	20.73
3	21.60	19.69
4	20.54	23.30
5	21.16	25.10
Average	21.39	22.38

* All tests were conducted with an 0.65 um membrane filter for a test duration of 30 minutes.

"FREE LIQUID" CONTENT (PERCENT) OF SEPARATOR SLUDGE
AS DETERMINED BY THE FILTRATION UNIT
AT VARIOUS PRESSURES (psi)*

Replication	43.33	34.67	26.00	17.33	8.67
1	22.87	21.6	20.07	17.07	12.1
2	23.31	23.9	20.55	20.7	12.6
3	21.28	20.3	19.39	18.1	12.23
4	21.41	22.7	19.46	19.91	11.1
5	22.53	20.71	20.36	17.91	12.07
Average	22.28	21.8	19.96	18.73	12.02

* All tests conducted with an 0.65 um membrane filter for a test duration of 20 minutes.

APPENDIX D

TEST PTOTOCOL AND RESULTS FOR THE DETERMINATION OF "FREE LIQUID" BY THE GRADUATED CYLINDER TEST

THE DETERMINATION OF "FREE LIQUID" BY THE GRADUATED CYLINDER TEST

Test Procedure

Summary of Method

100 ml of a representative sample of a waste is placed in a 100-ml graduated cylinder. The cylinder is corked and agitated until the waste is thoroughly mixed. Any liquid which settles to the top of the cylinder is considered "free liquid."

Apparatus

1. 100 ml graduated cylinder
2. Cork

General Procedure

1. Place 100 ml of a representative sample of a waste in a 100-ml graduated cylinder.
2. Cork the graduated cylinder.
3. Agitate the waste until the sample is well mixed.
4. Allow the sample to set for 24 hours.
5. Record the amount of "free liquid" (ml) which has settled to the top of the graduated cylinder.

"FREE LIQUID" AS DETERMINED BY THE GRADUATED CYLINDER

Time	Replication	Paint Sludge	Air Pollution Control Equipment Sludge	Separator Sludge	Paper Sludge
5 min.	1	0 ml	0 ml	0 ml	0 ml
	2	0	0	0	0
10 min.	1	0	0	0	0
	2	2.5	0	0	0
15 min.	1	0	0	0	0
	2	2.5	1	0	0
20 min.	1	0	0	0	0
	2	2.5	2	0	0
25 min.	1	0	1	0	0
	2	2.5	2	0	0
30 min.	1	0	2	1	0
	2	2.5	2	0	0
35 min.	1	0	2	2	0
	2	3	2	1	0
40 min.	1	0	2	3	0
	2	3	2	2	0
45 min.	1	0	2	3	0
	2	3	2	2	0
50 min.	1	0	2	3	0
	2	3	2.5	2	0
1 Hour	1	0	2.5	3	0
	2	3	3	2	0
1 Hr/15 min.	1	0	3	3	0
	2	3	3	2	0
1 Hr/30 min.	1	0	3	3	0
	2	3	3	2	0
1 Hr/45 min.	1	0	3	3	0
	2	3	3.5	2	0
2 Hours	1	0	4	3	0
	2	4	4	2	0

"FREE LIQUID" AS DETERMINED BY THE GRADUATED CYLINDER
(Page2)

Time	Replication	Paint Sludge	Air Pollution Control Equipment Sludge	Separator Sludge	Paper Sludge
2 Hr/30 min.	1	0 ml	4 ml	3 ml	0 ml
	2	4	4	2	0
3 Hours	1	0	4	3	---
	2	4	4	2	---
4 Hours	1	0	4.5	3	---
	2	4	4	2	---
5 Hours	1	0	4.5	3	---
	2	4	5	2	---
24 Hours	1	0*	4.5	4	---
	2	4	5	3	---

* The paint sludge did not settle during the test, but when stamped down after the test was completed, 5 ml of liquid settled out.

TABLE 2

"FREE LIQUID" AS DETERMINED BY THE PAINT FILTER
Modification No. One

Time	Replication	Air Pollution Control Equipment Sludge	Paint Sludge	Separator Sludge	Paper Sludge
15 min.	1	trace	4.0	1.0*	3.0
	2	0.0	4.0	2.0*	3.0
30 min.	1	trace	5.5	4.0	4.0
	2	0.0	5.5	3.5*	5.0
Change in "free liquid"	1	0	1.5	3.0	1.0
	2	0	1.5	1.5	2.0
45 min.	1	---	6.0	5.5	5.0
	2	---	6.0	5.0	6.0
Change in "free liquid"	1	---	0.5	1.5	1.0
	2	---	0.5	1.5	1.0
1 Hour	1	---	---	6.5	6.0
	2	---	---	5.5	7.0
Change in "free liquid"	1	---	---	1.0	1.0
	2	---	---	0.5	1.0
1 hr/ 30 min.	1	---	---	---	8.0
	2	---	---	---	9.0
Change in "free liquid"	1	---	---	---	1.0
	2	---	---	---	1.0
1 hr/ 45 min.	1	---	---	---	8.5
	2	---	---	---	9.5

TABLE 2
"FREE LIQUID" AS DETERMINED BY THE PAINT FILTER
Modification No. One
(Page 2)

Time	Replication	Air Pollution Control Equipment Sludge	Paint Sludge	Separator Sludge	Paper Sludge
Change in "free	1	---	---	---	0.5
liquid"	2	---	---	---	0.5
Total "free	1	trace	6.0	6.5	8.5
liquid"	2	0.0	6.0	5.5	9.5

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

TABLE 3

"FREE LIQUID" AS DETERMINED BY THE PAINT FILTER
Modification No. Two

Replication	Air Pollution Control Equipment Sludge	Paint Sludge	Separator Sludge	Paper Sludge
1	0.0	3.0	2.0*	1.0*
2	0.0	3.0	1.0*	2.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF "PERMASORB" ON THE "FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	"Permasorb" (g)	Replication	"Free Liquid" (ml)
1	5 min.	1.0	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	0.7	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	0.6	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	1.0*
			2	1.0*
	45 min.		1	3.0
			2	3.0
	1 hour		1	3.0
			2	3.0

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

APPENDIX E

TEST PTOTOCOL AND RESULTS FOR THE DETERMINATION OF "FREE LIQUID" BY THE SIEVE TEST

THE DETERMINATION OF "FREE LIQUID" BY THE SIEVE SERIES

Test Procedure

Summary of Method

A representative sample of a waste is placed in a 10, 18, 35, and 60-mesh sieve series. The sieves are agitated and any liquid which penetrates the bottom 60-mesh sieve is considered "free liquid."

Apparatus

1. 10, 18, 35, and 60-mesh screen sieves.

General Procedure

1. Place 200 ml of a representative sample of a waste in a 10, 18, 35, and 60-mesh sieve series.
2. Agitate the sieves for a 5-minute test duration.
3. Measure the amount of liquid (ml) which penetrated the bottom 60-mesh screen.

TABLE 1

"FREE LIQUID" AS DETERMINED BY SIEVE TEST

Waste	Replication	"Free Liquid" (ml)
Paint Sludge**	1	2.0*
	2	1.0*
Air Pollution Control Equipment Sludge	1	2.0*
	2	0.0
	3	0.0
	4	0.5*
Separator Sludge	1	3.5*
	2	0.0
	3	7.0
	4	2.0*
	5	3.0*
Paper Sludge	1	0
	2	0

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

** Liquid did not pass through the 60-mesh screen and Readings were made using only the 10, 18, and 35 mesh screens.

APPENDIX F

TEST PROCEDURE AND RESULTS FOR THE DETERMINATION OF "FREE LIQUID" BY THE PAINT FILTER TESTS

THE DETERMINATION OF "FREE LIQUID" BY THE PAINT FILTER TEST

Test Procedure

Summary of Method

100 ml of a waste is placed in a paint filter in a funnel. A watch glass is placed on top of the waste. Any liquid which is generated by the waste is considered "free liquid" and is measured in a 100 ml graduated cylinder.

Apparatus

1. Paint filter
2. Funnel
3. Watch glass
4. 100 ml graduated cylinder

General Procedure

1. Collect 100 ml of a representative sample of waste.
2. Place the waste in the paint filter, in a funnel, and cover with a watch glass.
3. Collect all "free liquid" generated in a 100 ml graduated cylinder.
4. Record the amount of "free liquid" (ml) generated after a test duration of 5 and 15 minutes.
5. If the change in "free liquid" is greater than 10 percent, record the amount of "free liquid" at 15-minute intervals until the change is less than 10 percent.

TABLE 1

"FREE LIQUID" AS DETERMINED BY THE PAINT FILTER

Time	Replication	Paint Sludge	Air Pollution Control Equipment Sludge	Separator Sludge	Paper Sludge
5 min.	1	4 ml	1.5 ml*	1 ml*	0
	2	3.5*	0	1 *	0
	3	---	1 *	---	---
	4	---	1 *	---	---
10 min.	1	5	2 *	1 *	0
	2	3.5*	0	1 *	0
	3	---	2 *	---	---
	4	---	2 *	---	---
15 min.	1	5	3 *	2 *	0
	2	3.5*	0	2 *	0
	3	---	3 *	---	---
	4	---	3 *	---	---
20 min.	1	5	4 *	2 *	0
	2	3.5*	0	2 *	0
	3	---	3 *	---	---
	4	---	4 *	---	---
25 min.	1	5	4 *	3 *	0
	2	3.5*	0	3 *	trace
	3	---	3 *	---	---
	4	---	4 *	---	---
30 min.	1	5	4 *	4	trace
	2	3.5*	0	3 *	trace
	3	---	3 *	---	---
	4	---	4 *	---	---
35 min.	1	5	4 *	4.5	trace
	2	3.5*	0	3.5*	trace
	3	---	3 *	---	---
	4	---	4 *	---	---
40 min.	1	5	4 *	4.5	trace
	2	3.5*	0	3.5*	trace
	3	---	3 *	---	---
	4	---	4 *	---	---
45 min.	1	5	4 *	4	2 *
	2	3.5*	0	5	3 *
	3	---	3 *	---	---
	4	---	4	---	---

TABLE 1
"FREE LIQUID" AS DETERMINED BY THE PAINT FILTER
(Page 2)

Time	Replication	Paint Sludge	Air Pollution Control Equipment Sludge	Separator Sludge	Paper Sludge
50 min.	1	5	4 *	5	2 *
	2	3.5*	0	5	3 *
	3	---	3 *	---	---
	4	---	4 *	---	---
55 min.	1	5	4 *	5.5	2 *
	2	3.5*	0	5	3 *
	3	---	3 *	---	---
	4	---	4 *	---	---
1 Hour	1	5	4 *	5.5	2 *
	2	3.5*	0	5	3 *
	3	---	3 *	---	---
	4	---	4 *	---	---
1 Hr/15 min.	1	5	4 *	6	3 *
	2	3.5*	0	5.5	3 *
	3	---	3 *	---	---
	4	---	4 *	---	---
1 Hr/30 min.	1	5	4 *	6.5	3 *
	2	3.5*	0	6	3 *
	3	---	3 *	---	---
	4	---	4 *	---	---
1 Hr/45 min.	1	5	4 *	7	3 *
	2	3.5*	0	6.5	3 *
	3	---	3 *	---	---
	4	---	4 *	---	---
2 Hours	1	5	4 *	7.5	3 *
	2	3.5*	0	7	3 *
	3	---	3 *	---	---
	4	---	4 *	---	---
2 Hr/30 min.	1	5	4 *	8	3 *
	2	3.5*	0	7.5	3 *
	3	---	3 *	---	---
	4	---	4 *	---	---
3 Hours	1	5	4 *	8.5	3 *
	2	3.5*	0	8	4
	3	---	3 *	---	---
	4	---	4 *	---	---

TABLE 1
"FREE LIQUID" AS DETERMINED BY THE PAINT FILTER
(Page ~~2~~ 3)

Time	Replication	Paint Sludge	Air Pollution Control Equipment Sludge	Separator Sludge	Paper Sludge
4 Hours	1	5	4 *	9	3.5*
	2	3.5*	trace	9	4
	3	---	3 *	---	---
	4	---	4 *	---	---
5 Hours	1	5	4 *	10	4
	2	3.5*	trace	9	5.5
	3	---	3 *	---	---
	4	---	4 *	---	---
6 Hours	1	5	4 *	10.5	---
	2	3.5*	trace	9.5	---
	3	---	3 *	---	---
	4	---	4 *	---	---

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE DETERMINATION OF "FREE LIQUID" BY THE PAINT FILTER TEST

Test Procedure

Summary of Method

100 ml of a waste is placed in a paint filter in a funnel. A watch glass is placed on top of the waste. Any liquid which is generated by the waste is considered "free liquid" and is measured in a 100 ml graduated cylinder.

Apparatus

1. Paint filter
2. Funnel
3. Watch glass
4. 100 ml graduated cylinder

General Procedure

1. Collect 100 ml of a representative sample of waste.
2. Place the waste in the paint filter in a funnel and cover with a watch glass.
3. Collect the "free liquid" generated in a 100 ml graduated cylinder.
4. Record the amount of "free liquid" generated in ml every 5 minutes for the first hour, every 15 minutes for the second hour, every half hour for the third hour, and every hour for the next three hours.

Modification No. 1:

General Procedure

1. Collect 100 ml of a representative sample of waste.

2. Place the waste in the paint filter, in a funnel, and cover with a watch glass.

3. Collect the "free liquid" generated in a 100 ml graduated cylinder.

4. Record the amount of "free liquid" (ml) generated after a test duration of 15 minutes.

5. Stir the test sample and allow it to drain for 15 minutes.

6. Record the amount of "free liquid" generated.

7. Calculate the change in "free liquid" that has drained from the test sample after 15 minutes and after one-half hour.

8. If the change in "free liquid" is greater than 10 percent, record the amount of "free liquid" at 15-minute intervals until the change is less than 10 percent.

Modification No. 2:

General Procedure

1. Collect 100 ml of a representative sample of waste.

2. Place the waste in the paint filter in the funnel and cover with a watch glass.

3. Note any "free liquid" which is generated.

APPENDIX G
ABSORBENT MATERIALS
TEST RESULTS: "PERMASORB"

THE EFFECT OF "PERMASORB" ON THE "FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	"Permasorb" (g)	Replication	"Free Liquid" (ml)
1	5 min.	1.0	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	0.7	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	0.6	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	1.0*
			2	1.0*
	45 min.		1	3.0
			2	3.0
	1 hour		1	3.0
			2	3.0

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF "PERMASORB" ON THE
"FREE LIQUID" CONTENT OF PAPER SLUDGE

Test Number	Time	"Permasorb"(g)	Replication	"Free Liquid"(ml)
1	5 min.	1.0	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	0.6	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	0.5	1	0.0
			2	1.0*
	15 min.		1	trace
			2	2.0*
	30 min.		1	1.0*
			2	3.0*
	45 min.		1	2.0*
			2	4.0*
	1 hour		1	2.0*
			2	4.0

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF "PERMASORB" ON THE
"FREE LIQUID" CONTENT OF PAINT SLUDGE

Test Number	Time	"Permasorb" (g)	Replication	"Free Liquid" (ml)
1	5 min.	0.5	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	0.3	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	0.2	1	0.0
			2	0.0
	15 min.		1	1.0
			2	0.0
4	5 min.	0.1	1	1.0*
			2	1.0*
	15 min.		1	2.0*
			2	1.0*
			1	2.0*
			2	1.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF "PERMASORB" ON THE
"FREE LIQUID" CONTENT OF AIR POLLUTION
CONTROL EQUIPMENT SLUDGE

Test Number	Time	"Permasorb" (g)	Replication	"Free Liquid" (ml)
1	5 min.	1.0	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	0.9	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	0.8	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
4	5 min.	0.7	1	trace
			2	trace
	15 min.		1	trace
			2	trace

APPENDIX H

ABSORBENT MATERIALS

TEST RESULTS: TRIPAK SOLIDIFCATION MEDIUM

THE EFFECT OF TRIPAK SOLIDIFICATION MEDIUM
ON THE "FREE LIQUID" CONTENT OF PAPER SLUDGE

Test Number	Time	TriPak Solidification Medium (g)	Replication	"Free Liquid" (ml)
1	5 min.	8	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	7	1	trace
			2	0.0
	15 min.		1	trace
			2	0.0

THE EFFECT OF TRIPAK SOLIDIFICATION MEDIUM
ON THE "FREE LIQUID" CONTENT OF PAINT SLUDGE

Test Number	Time	TriPak Solidification Medium (g)	Replication	"Free Liquid" (ml)
1	5 min.	4	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	3	1	0.0
			2	trace
	15 min.		1	trace
			2	1.0*
	30 min.		1	trace
			2	1.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF TRIPAK SOLIDIFICATION MEDIUM ON THE "FREE LIQUID" CONTENT OF AIR POLLUTION CONTROL EQUIPMENT SLUDGE

Test Number	Time	TriPak Solidification Medium (g)	Replication	"Free Liquid" (ml)
1	5 min.	17	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	16	1	0.0
			2	0.0
	15 min.		1	trace
			2	1.0*
	30 min.		1	trace
			2	1.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF TRIPAK SOLIDIFICATION MEDIUM
ON THE "FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	TriPak Solidification Medium (g)	Replication	"Free Liquid" (ml)
1	5 min.	7	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	6	1	0.0
			2	0.0
	15 min.		1	1 drop
			2	trace
	30 min.		1	1.0*
			2	

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

APPENDIX I

ABSORBENT MATERIALS

TEST RESULTS: DRILLING MUD

THE EFFECT OF DRILLING MUD ON THE
"FREE LIQUID" CONTENT OF PAINT SLUDGE

Test Number	Time	Drilling Mud (g)	Replication	"Free Liquid" (ml)
1	5 min.	10	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	5	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	3	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
4	5 min.	2	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
5	5 min.	1	1	trace
			2	trace
	15 min.		1	2.0*
			2	2.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF DRILLING MUD ON THE
"FREE LIQUID" CONTENT OF PAPER SLUDGE

Test Number	Time	Drilling Mud (g)	Replication	"Free Liquid" (ml)
1	5 min.	10	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	9	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	8	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	1.0*
			2	2.0*
	45 min.		1	1.0*
			2	2.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF DRILLING MUD ON THE
"FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	Drilling Mud (g)	Replication	"Free Liquid" (ml)
1	5 min.	10	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	5	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	3	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
4	5 min.	2	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
5	5 min.	1	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF DRILLING MUD ON THE "FREE LIQUID" CONTENT OF AIR POLLUTION CONTROL EQUIPMENT SLUDGE

Test Number	Time	Drilling Mud (g)	Replication	"Free Liquid" (ml)
1	5 min.	2	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	1	1	trace
			2	0.0
			3	0.0
	15 min.		1	trace
			2	trace
			3	0.0

APPENDIX J

ABSORBENT MATERIALS

TEST RESULTS: "SAFE-N-DRI"

THE EFFECT OF "SAFE-N-DRI" ON THE
"FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	"Safe-N-Dri" (g)	Replication	"Free Liquid" (ml)
1	5 min.	7	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	6	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	5	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	1.0*
			2	1.0*
	45 min.		1	2.0*
			2	1.0*
	1 hour		1	2.0*
			2	1.0

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF "SAFE-N-DRI" ON THE "FREE LIQUID" CONTENT OF PAINT SLUDGE

Test Number	Time	"Safe-N-Dri" (g)	Replication	"Free Liquid" (ml)
1	5 min.	5	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	3	1	0.0
			2	0.0
			3	0.0
	15 min.		1	trace
			2	0.0
			3	0.0
	30 min.		1	trace
3	5 min.	2	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
4	5 min.	1	1	trace
			2	0.0
			3	0.0
	15 min.		1	trace
			2	0.0
			3	0.0

THE EFFECT OF "SAFE-N-DRI" ON THE
"FREE LIQUID" CONTENT OF AIR POLLUTION
CONTROL EQUIPMENT SLUDGE

Test Number	Time	"Safe-N-Dri"(g)	Replication	"Free Liquid"(ml)
1	5 min.	15	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	13	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	12	1	trace
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	2.0*
			2	2.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF "SAFE-N-DRI" ON THE
"FREE LIQUID" CONTENT OF PAPER SLUDGE

Test Number	Time	"Safe-N-Dri" (g)	Replication	"Free Liquid" (ml)
1	5 min.	15	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	14	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	13	1	0.0
			2	0.0
			3	0.0
	15 min.		1	0.0
			2	trace
			3	trace
	30 min.		1	trace
			2	1.0
			3	trace
	45 min.		1	1.0*
			2	2.0*
	1 hour		1	1.0*
			2	2.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

APPENDIX K

ABSORBENT MATERIALS

TEST RESULTS: VERMICULITE

THE EFFECT OF VERMICULITE ON THE
"FREE LIQUID" CONTENT OF PAINT SLUDGE

Test Number	Time	Vermiculite(g)	Replication	"Free Liquid"(ml)
1	5 min.	1	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	0.6	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	0.5	1	trace
			2	trace
	15 min.		1	trace
			2	1.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF VERMICULITE ON THE
"FREE LIQUID" CONTENT OF PAPER SLUDGE

Test Number	Time	Vermiculite(g)	Replication	"Free Liquid"(ml)
1	5 min.	3	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	2	1	0.0
			2	0.0
	15 min.		1	trace
			2	0.0
	30 min.		1	1.0*
			2	trace
	45 min.		1	1.0*
			2	trace

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF VERMICULITE ON THE
"FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	Vermiculite (g)	Replication	"Free Liquid" (ml)
1	5 min.	5	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	3	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	2	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	2.0*
			2	2.0*
	45 min.		1	3.0
			2	3.0
	1 hour		1	3.0
			2	3.0

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF VERMICULITE ON THE
"FREE LIQUID" CONTENT OF AIR POLLUTION
CONTROL EQUIPMENT SLUDGE

Test Number	Time	Vermiculite(g)	Replication	"Free Liquid"(ml)
1	5 min.	5	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	4	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	3	1	trace
			2	trace
	15 min.		1	trace
			2	trace

APPENDIX L

ABSORBENT MATERIALS

TEST RESULTS: CEMENT KILN DUST

THE EFFECT OF CEMENT KILN DUST ON THE "FREE LIQUID" CONTENT OF PAINT SLUDGE

Test Number	Time	Cement Kiln Dust(g)	Replication	"Free Liquid" (ml)
1	5 min.	20	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	15	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	14	1	0.0
			2	0.0
	15 min.		1	1.0*
			2	1.0*
	30 min.		1	1.0*
			2	1.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF CEMENT KILN DUST ON THE
"FREE LIQUID" CONTENT OF PAPER SLUDGE

Test Number	Time	Cement Kiln Dust(g)	Replication	"Free Liquid"(ml)
1	5 min.	25	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	24	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	trace
			2	trace

THE EFFECT OF CEMENT KILN DUST ON THE "FREE LIQUID" CONTENT OF AIR POLLUTION CONTROL EQUIPMENT SLUDGE

Test Number	Time	Cement Kiln Dust (g)	Replication	"Free Liquid" (ml)
1	5 min.	30	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	27	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	26	1	0.0
			2	0.0
			3	0.0
	15 min.		1	trace
			2	0.0
			3	0.0
4	5 min.	25	1	trace
			2	trace
	15 min.		1	trace
			2	trace

THE EFFECT OF CEMENT KILN DUST ON THE
"FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	Cement Kiln Dust(g)	Replication	"Free Liquid"(ml)
1	5 min.	5	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	4	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	3	1	0.0
			2	0.0
			3	0.0
	15 min.		1	0.0
			2	trace
			3	0.0
	30 min.		2	1.0*
	45 min.		2	2.0*
	1 hour		2	2.0*
4	5 min.	2	1	0.0
			2	0.0
	15 min.		1	1.0*
			2	1.0*
	30 min.		1	1.0*
			2	1.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

APPENDIX M

ABSORBENT MATERIALS

TEST RESULTS: "HAZORB"

THE EFFECT OF "HAZORB" ON THE
"FREE LIQUID" CONTENT OF PAINT SLUDGE

Test Number	Time	"Hazorb" (g)	Replication	"Free Liquid" (ml)
1	5 min.	1	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	0.8	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	0.7	1	trace
			2	trace
	15 min.		1	trace
			2	trace

THE EFFECT OF "HAZORB" ON THE
"FREE LIQUID" CONTENT OF PAPER SLUDGE

Test Number	Time	"Hazorb" (g)	Replication	"Free Liquid" (ml)
1	5 min.	2	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	1	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min		1	2.0*
			2	2.0*
	45 min.		1	3.0
			2	3.0
	1 hour		1	3.0
			2	

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

THE EFFECT OF "HAZORB" ON THE
"FREE LIQUID" CONTENT OF AIR POLLUTION
CONTROL EQUIPMENT SLUDGE

Test Number	Time	"Hazorb" (g)	Replication	"Free Liquid" (ml)
1	5 min.	4	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	3	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min		1	trace
			2	3.0
	45 min.		1	trace
			2	3.0
3	5 min.	2	1	1.0*
			2	2.0*
	15 min.		1	1.0*
			2	2.0*

* Reading is less than the minimum marking on the graduated cylinder and is an approximation.

APPENDIX N

ABSORBENT MATERIALS

TEST RESULTS: FLY ASH

THE EFFECT OF "HAZORB" ON THE
"FREE LIQUID" CONTENT OF SEPARATOR SLUDGE

Test Number	Time	"Hazorb" (g)	Replication	"Free Liquid" (ml)
1	5 min.	2	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	1	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	trace
			2	trace

THE EFFECT OF FLY ASH ON THE
"FREE LIQUID" CONTENT OF PAINT SLUDGE

Test Number	Time	Fly Ash(g)	Replication	"Free Liquid"(ml)
1	5 min.	40	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	36	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
3	5 min.	35	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	trace
			2	trace

THE EFFECT OF FLY ASH ON THE "FREE LIQUID" CONTENT OF PAPER SLUDGE

Test Number	Time	Fly Ash(g)	Replication	"Free Liquid"(ml)
1	5 min.	51	1	0.0
			2	0.0
	15 min.		1	0.0
			2	0.0
2	5 min.	50	1	0.0
			2	0.0
			3	0.0
	15 min.		1	trace
			2	0.0
			3	0.0
	30 min.		1	trace
			2	0.0
			3	0.0
3	5 min.	49	1	0.0
			2	0.0
	15 min.		1	trace
			2	trace
	30 min.		1	trace
			2	trace

APPENDIX G

ABSORBENT MATERIALS

TEST RESULTS: "PERMASORB"