Paper No. 94-4064
An ASAE Meeting Presentation

The Sidewinder - An Improved Lagoon Sampler

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Written for Presentation at

1994 International Summer Meeting
ASAE/ASCE

Kansas City, Missouri

June 19-22, 1994

Summary:
The Sidewinder is a device to remove grab samples of liquid and sludge from wastewater treatment lagoons. Improvements over existing samplers include an automatic shut-off device to limit sample size, and a detachable sampling head to increase ease of cleaning and transport.

Keywords: Animal Manure, Wastewater, Lagoons, Sampling Device

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Abstract

The Sidewinder is an improved device to remove grab samples from wastewater treatment lagoons. The sample taking mechanism is based on a design developed at Clemson University (Kroes et al, 1987). The named Sidewinder was inspired by the air-to-air missile, because both designs are equipped with detachable "warheads". The Sidewinder lagoon sampler's detachable sampling head increases ease of cleaning and transport. The Sidewinder's high pressure seal reduces sample leakage and contamination. The Sidewinder is equipped with an automatic sample cut off mechanism to limit sample volume to 1140 ml.

Introduction

The Kroes-Barth-Dodd (KBD) sampler is a device for collecting sludge from livestock waste lagoons (Kroes et al., 1987). The KBD sampler, in its simplest form is a sealed pipe lowered into a lagoon from a boat. Once the sampler is lowered to a specified depth, a spring loaded sampling port is opened and liquid is drawn into the pipe. The port is then closed and the sampler is lifted back into the boat.

A copy of KBD sampler was built on the West Tennessee Experiment Station in the winter of 1993 for use in a lagoon characterization study. The sampler was found inadequate for our needs for three reasons: 1) sample size is determined entirely by how long the sample port is left open; therefore, reducing the likelihood of removing a discrete grab sample. 2) The large diameter pipe used to construct the KBD is too bulky for use in a small boat. 3) The O-ring seal and low tension springs of the KBD sampler did not adequately seal off the sampler port.

Objectives

Our objective was to improve the basic design of the KBD sampler with these criteria in mind.

1. The sampler should automatically shut itself off once a 1 liter volume is removed.

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2. The sampler should be as easy to operate as possible.

3. The sampler should be constructed for easy disassembly into component parts for ease of transport and cleaning.

4. The sampler should provide an effective seal to reduce the possibility of sample contamination and leakage.

In addition to these objectives, the sampler was to be constructed of standard materials obtainable in Jackson, Tennessee.

Sampler Design

Construction drawings of the Sidewinder lagoon sampler are given in Figures 1 through 3. The sampler has three main components: a sampler head, a sampling stem (threaded aluminum conduit) and a compound pulley system. All three components are interchangeable. For example, the sampler can reach deeper depths by adding sections of conduit and increasing the length of the center pull cable.

The Sidewinder was designed to meet design criteria as follows:

<u>Automatic sample cutoff</u>: Sample size is limited to a maximum of 1140 ml by the airlock device shown in figures 1 and 2. The airlock operates fairly simply. Once liquid volume reaches approximately 1000 ml, a 28.7 ml plastic ball (standard table tennis ball) seats against a rubber seal, preventing more liquid from entering the sampler. At deep depths, liquid is forced into the sample chamber under pressure. As a result, evacuated air moves through sealing orifice at high velocity, and the light plastic ball is lifted against the seal before a full sample is collected. We compensated for this phenomenon by placing a small air flow restricting orifice downstream of the sealing orifice. The restricting orifice was created by drilling a 3 mm hole in a rubber stopper and placing the stopper 75 mm into the aluminum conduit. Air pressure builds behind the smaller orifice, reducing the pressure differential and airflow velocity across the sealing orifice.

<u>Ease of operation</u>: Sample size is limited to 1 liter; therefore, the mass of a full sampler is only 1 kg greater than the mass of an empty sampler. The sampling stem is a hand-sized 32 mm in diameter and is manageable in lengths up to 6 m. To sample shallow depths, extensions are removed until the stem is a minimum of 3 m long. The pulley ropes are not rethreaded when stem length is altered. The pulley system is detached from the top of the stem and the varying lengths of center pull cable are snapped into place. The compound pulley system has the extra benefit of creating a downward force on the sampler when the port is opened. This

downward force helps prevent pulling the sampler out of sludge when collecting a sample.

<u>Ease of transport and cleaning</u>: The Sampler head is detachable. Lengths of sampler stem are carried to the sampling site on a standard truck pipe rack. The interior of the sample chamber is cleaned with the sampler head detached by running a hose down through the airlock device. The sample port slider slips over the top of airlock device when the the sampler head is removed. The wooden nose cone is also removable. If contamination of lagoon liquids is not a problem, the sample chamber is easily cleaned by plunging the open chamber up and down into liquid.

<u>Sample sealing</u>: The slider is held against a standard 2 1/2" toilet tank gasket by two steel springs. Force against the gasket is 13kg when the sample port is closed. The compound pulley system is needed for mechanical advantage to pull against the high tension springs. The upper slider seal is a custom made o-ring fitted into a groove at the upper portion of the slider cover.

Results and Discussion

<u>Sample Sealing</u>

Two tests were conducted in the shop to adjust spring tension for an effective seal.

1. Immersion test: The sampler was immersed in water to a depth of 3.4 m. The slider cover was kept closed for 30 seconds. The port was opened immediately after lifting the sampler out of the water. An effective seal was established when no liquid was observed escaping the port.

2. Internal pressure test: The sampler was positioned vertically on dry ground. The sampler head and stem were filled with water to a maximum head 3.4 m. If water level remained constant in the stem for 8 hours, an effective seal was established.

<u>Sample Size</u>

An annoying side affect of the airlock device is that sample size decreases as sampling depth increases (Figure 4). Collecting a sample is a four step process. With the slider cover closed, the sample chamber is at atmospheric pressure -- regardless of depth. Once the slider cover is lifted, liquids enter the sample chamber at fluid pressure. The rate of liquid rising in the chamber is proportional to the difference between fluid pressure and atmospheric pressure. Air is also rising ahead of the column of liquid. The plastic ball will rise at a rate proportional to the difference between air velocity and the ball's terminal velocity. If the ball rises too quickly, it will seat against the seal and shut off sample flow prematurely. Once seated, the ball is held against the seal under pressure. Pressure differential across the ball is difference between fluid pressure at sample depth and atmospheric pressure. This pressure differential is maintained after the slider cover is closed.

Ideally, the ball will do two things: 1) Rise at rate constant over a wide range of air velocities. 2) Form a tight seal even at low pressure differentials.

Effect of ball terminal velocity on sample size: Our first attempt at improving sampler performance was to increase the terminal velocity of the ball. Table 1 lists size, mass, specific gravity, and estimate terminal velocity of three balls used in trials. Liquid samples were taken at various depth by lowering the Sidewinder over the side of a swimming pool. Table 2 gives volumes of air trapped at the top of the sampling chamber with the slider cover held open three seconds. Three seconds was chosen as a sampling time because all three balls could be heard shutting off the airlock within three seconds of opening the slider cover. A negative air volume in Table 2 indicates that the chamber was completely filled and liquid leaked through the seal. Table 2 clearly indicates the effect of the ball's terminal velocity on sample size. At a depth of 2.67 m, the airlock with a hard rubber ball collected a sample 160 ml larger than the airlock with the table tennis ball. The hard rubber ball did not form a very tight seal, however. Table 3 lists the difference in volume of air trapped when the slider cover was left open 30 seconds and 3 seconds. Negative volumes in Table 3 indicate that air escaped past the seal after the ball had closed the airlock. The table tennis ball formed a tight seal regardless of depth. The paddle ball formed a better seal as depth increased. This is probably because the soft spongy ball was deformed and flattened against the orifice at higher pressures. The hard rubber ball leaked air (and liquid) even at higher pressures.

Effect of air flow restriction on sample volume: The Table Tennis ball was chosen for further testing because of its superior seal forming characteristics. A second attempt was made to reduce the speed at which the ball rises. This time, we kept the ball's terminal velocity constant, but reduced the speed of air flowing through the sealing orifice. This was accomplished by placing a airflow restricting orifice 75 mm downstream of sealing orifice. Table 4 lists volumes of entrapped air using restricting orifices between 1.5 and 4 mm in diameter. Data is missing at 0.9 and 1.67 m for the 1.5 and 2 mm orifices because 3 seconds was not sufficient time to draw a sample. Restricting airflow had little effect on sealing as shown in Table 5.

Performance of Final Design

The final airlock design included a table tennis ball and a 3 mm airflow restricting orifice. Performance of the Sidewinder taking liquid samples with and without airflow restriction is shown in Figure 4. As seen in this figure, using an airflow restricting airlock increased sample size at all depths and reduced the effect of fluid pressure on sample size.

Performance with sludge samples is given in Figure 6. Sludge sample size at 4.26 m depth was 500 ml without use of an airflow restrictor. The sidewinder collects slightly smaller samples of sludge than liquids at all depths. A possible explanation is that sludge samples require a greater pressure differential to flow into the sample chamber. Also, there is greater error in measuring volume due to the tendency of sludge to stick to the interior of the sampler.

Conclusions

The Sidewinder is an improvement over existing lagoon grab samplers due to its ease of cleaning, reduction in bulkiness, ease in transport, and employment of an airlock device to automatically shut off sample collection. Automatic sample cut off was achieved using a rising ball airlock. A 3 mm airflow restricting orifice in the airlock device increased overall sample size and substantially reduced the influence of sample depth on sample size.

References

Jelle Kroes, C.L. Barth, and R.B. Dodd. 1987. Sludge sampler for waste lagoons. Applied Engineering in Agriculture. 3(2):258.

Table 1. Characteristics of airlock balls used in trials.

	Dia (mm)	mass (g)	volume (ml)	Specific Gravity	Calculated Terminal Velocity (m/s)
Table Tennis	38	2.3	28.7	0.0794	0.67
Paddle Ball	55	39.3	87.1	0.451	7.6
Hard Rubber	48	53.0	57.9	.920	12.

Table 2. Volume of entrapped air (ml): slider cover open 3 seconds: no flow restriction, average of three samples.

sample depth (m)	Table Tennis	Paddle Ball	Hard Rubber
0.90	161	158	-18
1.67	211	167	102
2.67	328	252	164

Table 3. Volume of entrapped air (ml) with slider cover held open 30 seconds minus volume of entrapped air (ml) with slider cover held open 3 seconds: no flow restriction, average of three samples at each sample time.

Sample Depth (m)	Table Tennis	Paddle Ball	Hard Rubber
0.90	0	-58	-133
1.67	25	-18	-153
2.67	-7	-17	-329

Table 4. Volume of entrapped air (ml): Slider cover open 3 seconds, Table Tennis ball, average of 3 samples.

Sample depth (m)	1.5 mm	2 mm	3 mm	4 mm	no restriction
0.90			-19	-22	161
1.67			-14	3	211
2.67	-19	13	18	98	329

Table 5. Volume of entrapped air (ml) with slider cover held open 30 seconds minus volume of entrapped air (ml) with slider cover held open 3 seconds: Table Tennis Ball, Average of three samples at each sample time.

sample depth (m)	1.5 mm	2 mm	3 mm	4 mm	no restriction
0.9			2	-5	0
1.67			-3	-7	25
2.67	0	8	8	-2	-7

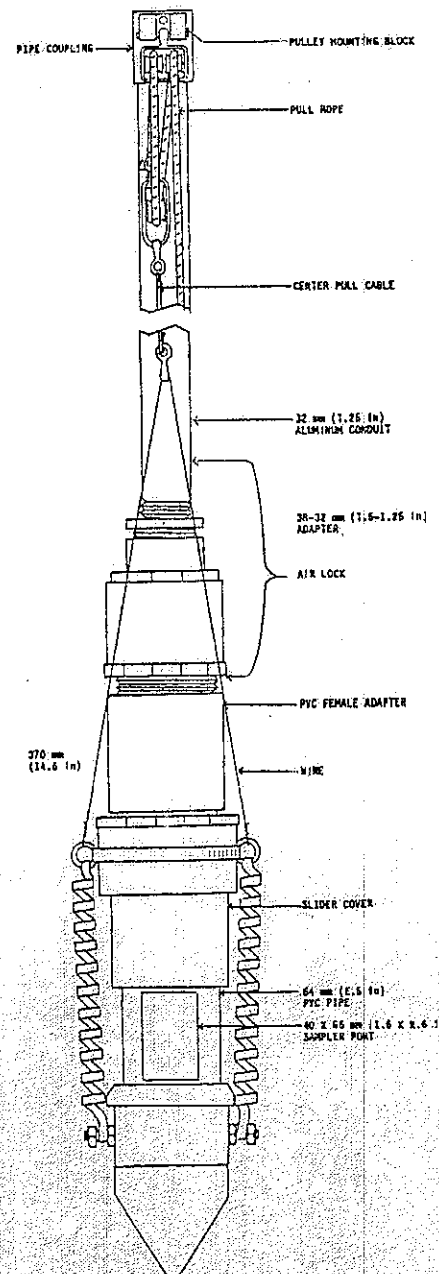


Fig. 1 The Sidewinder Lagoon Sampler

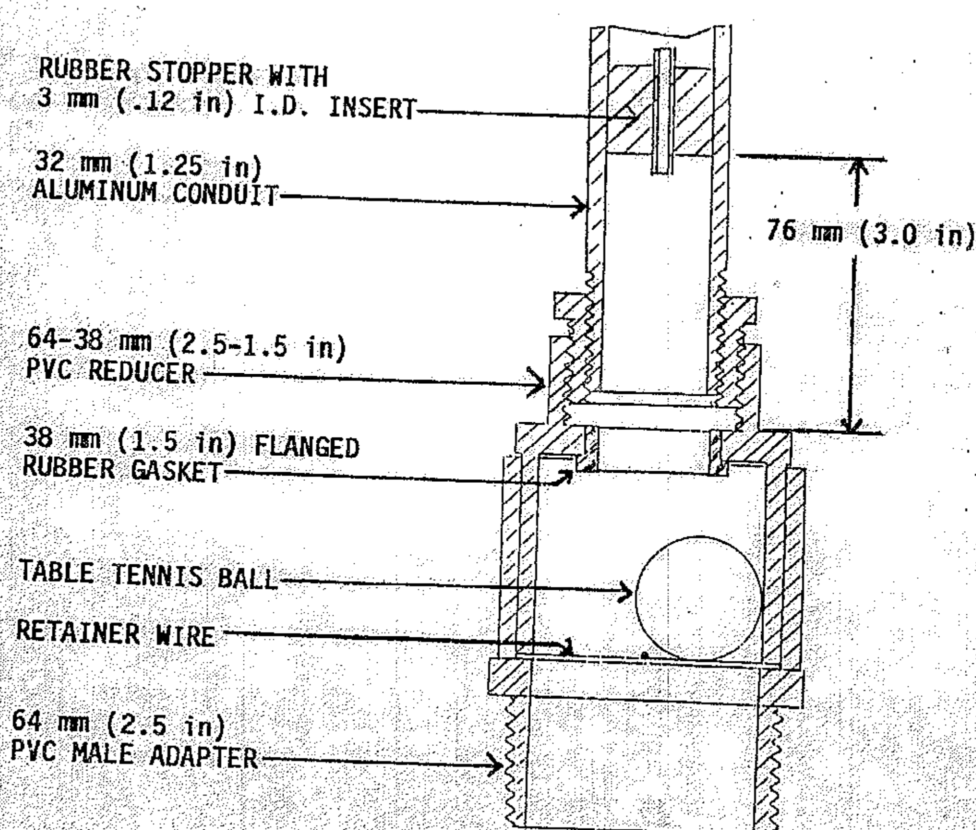
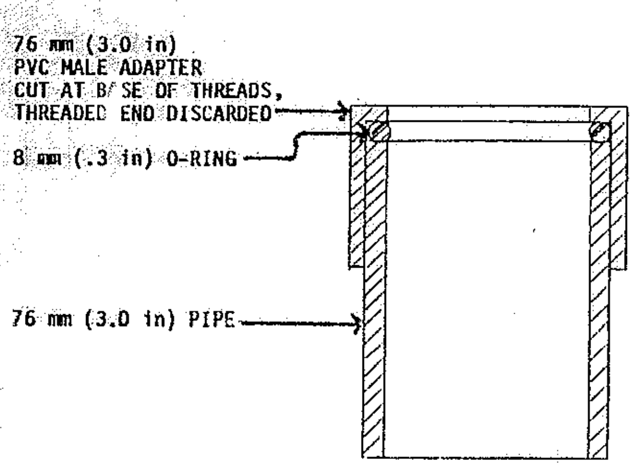


Fig. 2 Detail of Airlock Device

a)



b)

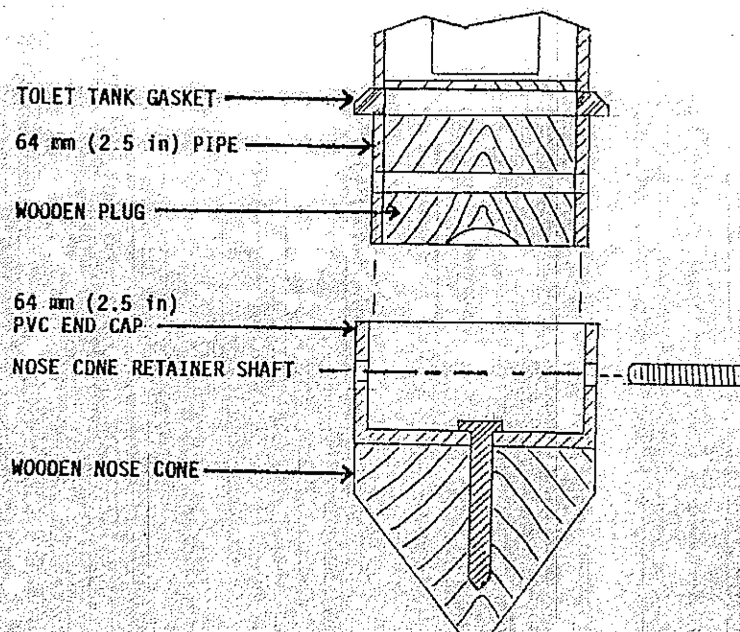


Fig. 3 Details of Sampling Chamber
a) Slider Cover b) End Piece

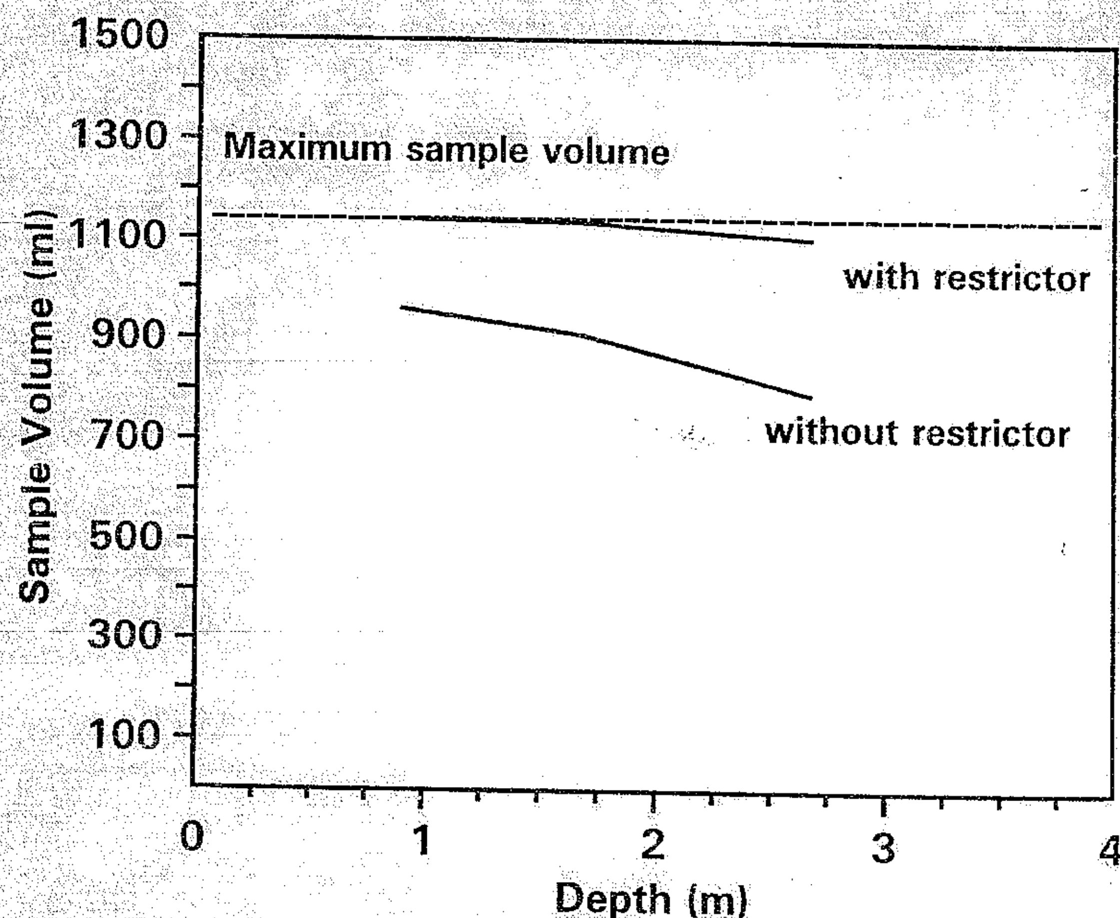


Fig. 4 Performance of Sidewinder Lagoon Sampler Taking Liquid Samples With and Without 3 mm Airflow Restricting Orifice

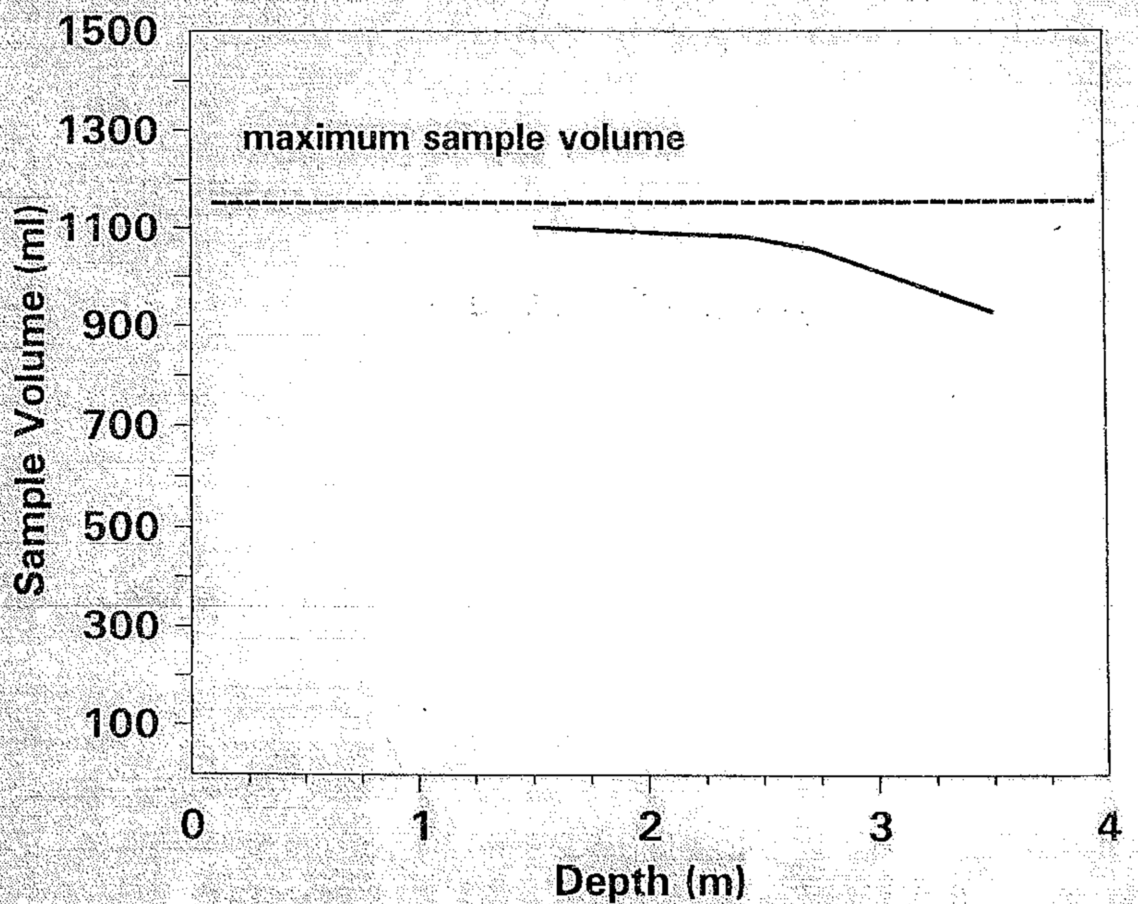


Fig. 5 Performance of Sidewinder Lagoon Sampler Taking Sludge Samples, Airlock with 3mm Airflow Restricting Orifice Installed