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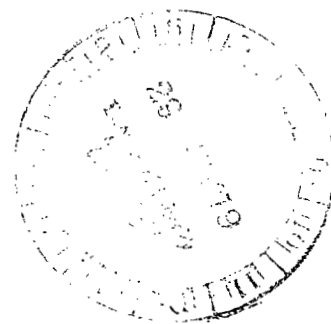
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Description and Field Test Results of an In Situ Coliform Monitoring System

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SUMMARY

A prototype in situ system for monitoring the levels of fecal coliforms in shallow water bodies was developed and evaluated. This system was based on the known relationship between the concentration of the coliform bacteria and the amount of hydrogen they produce during growth in a complex organic media. The prototype system consists of a sampler platform which sits at the bottom of the water; a surface buoy which transmits sampler-generated data; and a shore station which receives, displays the data, and controls the sampler. This semi-automatic prototype operates in a batch mode and takes and processes up to 10 samples, on command, at any time over a period of 1 to 2 weeks. After this period it must be refurbished before the next set of samples can be taken.

The prototype system was evaluated at one fresh water and three estuarine sites. These four sites were characterized by a range of fecal coliforms from less than 1 to 2000 per 100 ml of water. The concept of remote monitoring of fecal coliform concentrations by utilizing a system based on the electrochemical method was verified during the evaluation of the prototype. Although the present prototype has limitations such as batch operation, high power requirements, deployment difficulties, and hydrogen electrode instability, these problems could be overcome in later models. Future use of this concept is envisioned as a monitoring tool rather than as a regulatory tool; it may be used to define concentration variation in heavily contaminated areas, or as an early warning system in clean waters.

INTRODUCTION

The principal biological indicator of water pollution is the presence of coliforms. In the Standard Methods for the Examination of Water and Wastewater (ref. 1), the approved methods for coliform analysis are the most probable number (MPN) and membrane filtration (MF) tests. Both laboratory tests are laborious and time consuming; the MPN test requires 24 to 96 hr to complete and the MF test, 24 hr. In view of the increased interest in the water resources of the United States and the ever present threat of fecal contamination, increased emphasis has been placed on the development of automated in situ systems, rather than laboratory methods, to meet the extensive surveillance required to maintain coliform standards.

Recently, Wilkins et al. (ref. 2) developed an electrochemical technique for detecting bacteria based on the time of hydrogen (H_2) evolution. Studies indicated that the electrochemical method could also be used to detect fecal coliforms (ref. 3) and that the electrodes were readily adaptable to an in situ system. In an extension of these studies, an automated system for the in situ monitoring of coliforms in water was developed to circumvent many of the current problems of enumerating coliforms, namely, sample acquisition, transport, trained laboratory technicians, and the times required to process a sample. (24 to 96 hr). In order to test the in situ concept for monitoring coliforms

adequately, a two-phase field evaluation program was conducted. Phase one was conducted in fresh and estuarine waters in the vicinity of the Langley Research Center, Hampton, Virginia. Phase two was conducted at Caven Point, New Jersey, in cooperation with the Environmental Protection Agency (EPA). This report describes a pilot model of the in situ monitoring system and presents the results of the field evaluations.

CONCEPT

It has been well established that certain groups of bacteria, including fecal coliforms, produce carbon dioxide and hydrogen from the metabolism of carbohydrates. When a selective growth medium, lauryl tryptose broth (LTB), is inoculated with a water sample containing fecal coliforms and incubated at 44.5° C, the growth of the nonfecal forms is inhibited or suppressed. Thus, the buildup of hydrogen by the fecal coliforms in LTB at 44.5° C can then be detected by the electrochemical method described in references 2 and 3.

The electrochemical detection method (EDM) can best be explained with reference to the laboratory apparatus illustrated in figure 1. The apparatus consists of a flask, the culture, the culture growth media (LTB), and the electrodes. The culture is maintained at incubation temperature (44.5° C) in the water bath.

A strip chart recording of a typical hydrogen response curve is shown in figure 2. The sample contained 1.9 cells of fecal coliforms per 100 ml. Characteristically, a hydrogen response curve is determined by an increase in cell voltage and consists of a lag period followed by a period of potential buildup due to the hydrogen evolution, and then a decline in the measured potential. The relationship between inoculum size and length of lag period is shown in figure 3. It is this relationship that serves as the basis for the in situ coliform monitoring system. For example, LTB at 44.5° C is inoculated with a water sample in which the number of fecal coliforms is unknown. The time from inoculation to a buildup in hydrogen is then used to obtain the number and range of fecal coliforms by referring to a standard curve similar to that shown in figure 3. Thus, the in situ system takes advantage of the selective medium and incubation temperature to suppress the nonfecal forms and the linear relationship between the number of fecal coliforms and buildup in hydrogen to determine the number of fecal coliforms.

SYSTEM DESCRIPTION

The pilot model, shown in figure 4, is made up of a base station and the in situ monitoring platform which consists of a float and the subsurface sampler. The base station contains the communication equipment and the display and controls for monitoring the sampling operations. A closeup of the base station control panel is shown in figure 5.

Figure 6 shows the in situ monitoring platform consisting of the buoy and the sampler module connected together by a flexible hose. The buoy (fig. 7)

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provides a base for the antenna, and marks the location of the subsurface sampler. The buoy is a cylindrical tank approximately 33.02 cm long and 24.13 cm in diameter and has domed ends. A stabilizing bar, about 38.10 cm long and 6.35 cm in diameter, is attached to the lower end of the cylinder. A pipe through the center of the buoy provides a passageway between the antenna base and the flexible hose attached to the sampler lid. The pipe and flexible hose provide a vent and a passageway for the antenna lead from the antenna to the control module in the subsurface sampler. A photograph of the sampler housing and the major subassemblies is shown in figure 8. The sampler housing is made of 6061 aluminum alloy. The gross weight of the sampler, including the hoisting rig, is about 453.6 kg. Because of the size and weight of the system, deployment and retrieval required experienced "riggers" and the use of a heavy-duty, mobile crane.

The base of the sampler, shown in figure 9, contains the power supply and the control module components. The power supply consists of eight 12-V automotive storage batteries of the sealed, no-maintenance type. Six of the batteries are connected in a series/parallel arrangement that provides the power, 270 W-hr at 24 V, to operate the incubation heater and the sample intake valves. This power is sufficient to maintain the system operable from 8 to 15 days. The operating time depends upon the outside water temperature. The two remaining batteries are connected in parallel and supply the power, 140 W-hr at 12 V, to operate the control module.

The control module provides a communication link with the remote base station and controls all the sampling and data processing functions. Figure 10 shows the control module components. The telemetry unit is a conventional very high frequency (VHF) transceiver, operating at a frequency of 162.125 MHz. It receives signals transmitted from the base station through the antenna and transmission lines. These signals are transferred to the command unit of the control module, which in turn activates the sample intake system, processes the signal from the electrodes, and stores the data for transmission to the base station.

The midsection (fig. 11) houses the incubator and a circular trough containing water in which the 10 sample bottles are suspended. An electrical strap heater surrounds the outer wall of the trough and heats the water to maintain the sample at a temperature of 44° to 45° C. The trough is embedded in foam insulation. The midsection is attached to the bottom by 12 bolts. An O-ring seals the mating surfaces.

The top section (fig. 12) contains the apparatus that performs the sample intake and sampling functions. Located radially around the outer wall are 10 intake valves that extend inwardly through the wall toward a cylindrical inner wall. Attached to the inner wall are solenoids which activate the intake valves. The arrangement of a typical intake valve is shown in figures 13 and 14. The sample bottle is suspended from the underside of the top section and contains a liquid level switch, an intake tube, and the electrodes.

The electrode assembly (fig. 15) consists of a combination platinum redox electrode element and a saturated calomel electrode element. The platinum

electrode is sealed in glass and is situated within the glass tube containing the calomel reference electrode.

The lid contains fittings that provide the connections for the vent and antenna line leading to the float. The lid, the top, and the midsections are connected by marman clamps. All mating surfaces contain O-ring seals.

SYSTEM OPERATION

When a remote water monitoring platform is deployed in a water body of interest, the connecting tube is adjusted to sufficient length to connect the antenna buoy to the sampler platform. The sampler sits on the bottom while the buoy floats on the water surface. The sampler is located on the bottom to minimize disturbances caused by surface wave action which can affect the electrode/liquid interface and result in a false signal input to the control module. The platform can tilt up to 15° from the horizon without affecting the response of the electrode to the hydrogen production.

The function of the control module is illustrated on the block diagram in figure 16. The first sampling process is initiated by depressing the "take sample" button on the base station control panel. The command recognition unit differentiates between the two signals received from the telemetry unit: a "take sample" signal and an "interrogate" signal. The take sample signal activates a solenoid and initiates the hydrogen-sensing electrode. When the interrogate signal is activated, the control module transmits data only on command. When the take sample signal is activated, the spring-loaded solenoid valve extends into the surrounding body of water. Water enters the passageway around the valve and travels through the supply tube into the sampling bottle. Water entering the bottle from the intake valve causes the float to rise along the float stem. Permanent magnets in the float activate a reed switch in the float stem when a predetermined liquid level (100 ml) is reached. The solenoid is then deactivated and the intake valve closes.

The electrodes are connected to an analog-to-digital converter which includes an up/down binary counter. A clock provides pulses to the analog-to-digital converter, to a threshold counter, and to a 60-min timer that inhibits the threshold counter for the first 60 min of operation. This time period allows the analog-to-digital converter to capture and track the electrode potential and also permits the electrode potential to stabilize after the sample has been inserted into the nutrient medium. After the first 60 min, the threshold counter counts the equivalent number of digital pulses from the clock that correspond to 30 mV of input potential change. When this time is reached, a signal from the threshold counter reverses the timer that was started when the nutrient medium was inoculated with the sample. The timer then times backwards until a count equivalent to an additional 60 mV potential change is detected by the threshold counter. At this time the timer stops and displays a time interval at the base station equal to the length of time after the inoculum begins the production of measurable amounts of H_2.

The relationship between the status lights on the base station control panel and the clock operating mode can be illustrated with reference to the

response curve in figure 17. From point ① where the sample enters the sample bottle to point ② on the response curve, the clock is timing "up" (increasing). Between these two points, the up/down light on the control panel is on. Between the points ② and ③, the clock is timing "down" (decreasing). This mode is indicated when the up/down light is off. At point ③ on the response curve, the "complete" light becomes activated and the clock will stop. The clock should be reading a time on the response curve equivalent to point ② which is the approximate point of departure from the baseline, or the actual "lag time." Points ③ and ④ were chosen on the assumption that the electrode response curve follows the logarithmic growth rate curve of bacteria. The insert shown in figure 17 is a typical growth rate curve of bacteria (taken from ref. 4). During the logarithmic phase, it can be shown that for a growth rate, or potential change in the ratio of 1 to 3, that is, from 30 to 90 mV above the baseline, the time interval between 0 and 30 mV is equal to the time interval between 30 and 90 mV.

This technique for arriving at the endpoint requires about 1 hr to time up to point ③ and back; however, it does minimize a false endpoint, which can be triggered by spurious signals. These signals can cause fluctuations in the baseline response curve.

The control module will continue to index from solenoid to solenoid in a clockwise fashion as each "take sample" command is received until all sample chambers are filled. Sample locations 1 to 10 are indicated on the sample number display at the base station. In order to reduce the power drain on the batteries, the control module transmits data only when the command "interrogate" is activated at the base station. This command gives the current status of the contents of each sample chamber. The "interrogate" signal is activated at the base station control panel (fig. 5). The control module can also activate the system warning lights located at the upper right-hand side of the control panel. The first light on the left is the battery power warning light and is activated when the power level drops to approximately 40 percent of capacity. The middle light is activated when a leak is detected in the platform. The third lamp is activated when the incubation temperature drops below 44° C.

FIELD TESTS

Description of Test Sites

The locations of the four test sites are shown in figure 18. The first deployment was made in the Big Bethel Reservoir. This reservoir supplies potable water for various federal and military installations. The second deployment was at a marina located on the northwest branch of Back River which is an estuary of the Chesapeake Bay complex. This site is maintained by the United States Air Force. The third local deployment was in the York River, at Cheatham Annex, in Yorktown, Virginia. Cheatham Annex is a United States Naval installation. In the fourth deployment, the in situ sampler was tested in the Hudson River at Caven Point, New Jersey.

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Test Preparation and Procedures

Each deployment was preceded by two series of laboratory tests, the first series being performed on the bench, and the second, in a small water tank. Both series of tests were performed with known concentrations of coliforms. The coliforms were directly injected into the sample bottle through the vent tube. The sampling process was then actuated with the intake valve locked in the closed position. The bench tests were performed by use of an external recorder to verify the response of the electrodes and electronic system to the production of hydrogen by the coliforms. The immersion tests were performed in a manner similar to the bench tests except that the platform was temporarily raised above the water level. The lid was removed each time that the sample was injected into the sample bottle. The immersion tests were performed mainly to verify the remote operations of the system components.

The sampler midsection is prepared for each test in the microbiology laboratory. The microbiology procedures consist of, first, sterilization of the midsection to kill the organisms in the sample bottles and on the surfaces that come in contact with the sample during the intake operation. Next, the sample bottles were removed, emptied, filled with 100 ml of LTB, and reattached to the midsection. The midsection is again sterilized in an autoclave at 121° C for 15 min.

The redox combination electrodes were sterilized separately by immersion in a 90° C water bath for approximately 35 min. Under sterile conditions, the electrodes were positioned in the sampler midsection and the unit was incubated at 35° C for 24 hr. If no growth of organisms was observed in the LTB after the 24-hr incubation period, the intake and processing systems were considered to be sterile. The midsection and other platform components were assembled. Then final system operational performance checks were made prior to delivery.

Prior to deployment at the test site, sample position 1 was challenged with a known concentration of Escherichia coli, as a final check of the system operation. During the test, "grab" samples were taken at the same depth and location of the platform each time the take sample command was initiated at the base station. These samples were analyzed for fecal coliforms in the laboratory for comparison with in situ measurements. The laboratory analyses include the membrane filtration technique. (See ref. 1.) Fecal coliform measurements were made in situ for platform positions 2 to 9. After the platform was returned to the laboratory, an analysis was made of the media in position 10 to determine whether "in-contamination" might have occurred during the test. Measurements were also made of the liquid levels in all 10 positions.

Data Analysis

At the completion of each port sample test, the time displayed on the base station control panel was used to predict the number and the range of fecal coliforms/100 ml from a dose response curve. (See fig. 3.) This figure was developed from dose-response curves obtained on samples from local water sites (ref. 3). Fecal coliform counts using standard methods were correlated with electrochemical detection time endpoints for graded concentrations of the water

sample. A line was fitted through the data by the method of least squares.
The standard error of estimate was calculated for each set of data. The fitted
line and standard error of estimate constituted the number and range of fecal
coliforms shown in figure 19. Predicted fecal coliform counts for each deploy-
ment are noted in table I. The following grading system was used to correlate
in situ predicted fecal coliform counts obtained from table I with the membrane
filtration laboratory counts: "good" indicated that the laboratory counts were
within the range of the predicted values, "fair" results had differences by a
factor of 10 to 100, and "poor" the differences by a factor of 100 to 1000.

RESULTS

The results of the four deployments are presented in table I. Each deploy-
ment will be described separately.

Big Bethel Reservoir

The laboratory fecal coliform counts at this site were low with a mean of
0.63/100 ml for 8 samples with a standard deviation of 0.74 (based on table I).
When the platform endpoints were used to predict the level of fecal coliforms,
the results for sample ports 2 to 6 were only fair in that the predicted val-
ues were 10 to 100 times greater than the laboratory values. In three cases,
ports 7 to 9, the agreement between predicted and actual values was poor in
that the high counts predicted on the basis of short endpoints exceeded the
laboratory values by many orders of magnitude.

Posttest studies showed that the mean volume of liquid (media + sample)
for ports 2 to 9 was 203 ml with a standard deviation of 5.4; for ports 1
and 10, the volumes of media were 96 and 92 ml, respectively. The slight
increase noted in ports 2 to 9 was probably due to water retained in the
delivery tube which was released into the sample container at the time the
volume was measured. The loss in ports 1 and 10 could be accounted for by
evaporation.

Back River

The fecal coliform counts were slightly higher than the previous site
with a mean of 8.86/100 ml and a standard deviation of 13 (based on table I).
The results for sample port 1 were not presented in table I; the fecal coli-
form count was 36/100 ml, and the platform endpoint was 4 hr for a predicted
fecal count of 630/100 ml with a range of 158 to 1985.

In five samples, ports 2 to 6, the agreement between the predicted counts
and the laboratory values was good. In three samples, ports 2, 3, and 6, the
laboratory counts were within the predicted range; in one case the predicted
range was 3 to 40 and the actual count was 2. For sample 5, the predicted
count was less than 1 per 100 ml and the laboraory value was 1.0/100 ml.
As in the previous deployment, there were three sample ports, 1, 7, and 8,
in which the predicted counts differed from the laboratory values by many

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orders of magnitude. These predicted high values were based on the short endpoints of 2 to 4 hr as compared with the longer endpoints of 9 to 14 hr for the other samples.

Posttest studies indicated that for sample ports 1 to 8, the mean volume of liquid in the sample containers was 195 ml with a standard deviation of 5 ml. Water samples were not processed for sample port 9 because of the higher predicted counts experienced with samples 7 and 8. Liquid levels were not determined in samples 9 and 10.

York River

As compared with the two previous deployments, there was a slight increase in the mean number of fecal coliforms for the six samples tested in the York River, namely, 27/100 ml with a standard deviation of 33 (based on table I).

In sample ports 1 to 3, the predicted counts were considerably less than the laboratory values by a factor of 10 to 100. The lack of coliform counts for samples 5 and 6 precluded relating the predicted in situ values with the laboratory data. There was a good agreement, however, between the predicted values and the laboratory counts for samples 7 to 9. In situ endpoints in excess of 15 hr were considered to be indicative of low counts, that is, $\leq 1.0/100$ ml. Although sample 9 had a laboratory count of 5/100 ml and the predicted count was $\leq 1.0/100$ ml, this could be a reflection of sampling error.

Posttest studies indicated that for sample containers 2 to 9 the mean volume of liquid was 193 ml with a standard deviation of 5 ml. The volumes in containers 1 and 10 were 85 and 96 ml, respectively.

Caven Point

The fecal coliform counts were considerably higher than those experienced during previous deployments (based on table I). The mean value for eight samples was 633/100 ml with a large dispersion in the data as shown by the standard deviation of 591. The counts ranged from a low of 150/100 ml to a high of 2000/100 ml.

In two samples, ports 3 and 7, base station endpoints were not obtained. For the six endpoints (ports 2, 4 to 6 and 8, and 9), there was good agreement between the predicted fecal coliform values and the laboratory MF counts. In all cases the laboratory counts were within the range of predicted values. In four samples, ports 2, 4, 5, and 6, the predicted counts were higher than the laboratory values with a mean difference of 209 between the two sets of data. For sample ports 8 and 9, the predicted counts were lower than the laboratory values with a mean difference of 201.

Posttest studies indicated that the mean volume for sample containers 2 to 9 was 198 ml with a standard deviation of 5.6 ml; samples 1 and 10 both had volumes of 95 ml.

DISCUSSION AND INTERPRETATION

One important aspect of this program is the relationship between in situ predicted coliform counts and the values obtained with conventional laboratory techniques. Reference 3 describes a fundamental difference between the two methods; namely, the electrochemical technique is based on a graded or "time to response" relationship whereas conventional procedures are quantal or all-or-none observations. In addition to these differences, the eventual use of the data from the two methods also differs. For example, MPN or MF results are used to regulate the sanitary quality of the water for consumption, for swimming at bathing beaches, etc., and coliform values beyond those prescribed by law result in condemnation procedures. In its current state of development, the electrochemical method cannot be viewed in the same light as the MPN or MF procedures. Rather, its explicit application in the in situ system was for monitoring the degree of contamination at the test site. On that basis, the base station response times were arbitrarily divided into the the following groups depending on the degree of contamination; endpoints between 3 and 6.5 hr would be indicative of heavy contamination (400 to 6000 counts/100 ml), response times in the range of 6.5 to 10 hr would be moderate contamination (25 to 400 counts/100 ml), 10 to 14 hr would indicate light contamination (1 to 25 counts/100 ml), and over 14 hr would indicate fairly clean water. The results obtained during the field evaluation would tend to support these designations. For example, base station response times at Caven Point, New Jersey, were approximately 6.5 hr and indicated heavy pollution; this result was in agreement with the mean fecal coliform counts of 633/100 ml. On the other hand, base station response times at the York River deployment were extended (12 to 17 hr) and indicated light contamination. This result was also in agreement with laboratory mean fecal coliform values of 27 counts/100 ml.

Limited studies confirmed the ability of fecal forms to adapt and multiply at 44.5° C while the growth of nonfecal forms was suppressed at this incubation temperature. In those cases where fecal forms were absent, or present in low numbers as compared with the nonfecal forms, the nonfecal forms would eventually grow and produce a response with the electrochemical methods. Another factor is the role of fecal coliform-positive Klebsiella in conventional tests (ref. 5) and the electrochemical method. Although no concerted effort was made to identify pink isolates on Endo agar, a number were identified as Klebsiella pneumoniae and more research is needed in this area. During the field evaluations it was noted that in two deployments, Big Bethel Reservoir and Back River, no macroscopic growth was evident in sample port 10 containers but subculture revealed low numbers of a Bacillus sp. No growth was observed on the subculture of the York River and Caven Point deployments, and the reasons for the low levels of contamination in the two cases are not apparent at this time.

CONCLUDING REMARKS

The concept of remotely monitoring the levels of fecal coliforms with the electrochemical method was verified although utility of the in situ system would be limited to specific ecological situations. At present, it appeared that the in situ concept would be most useful in defining areas that are heavily contaminated with fecal coliforms. Placed in clean areas suspected of receiving large

amounts of pollution, the system could be utilized as an "early warning" of contamination. Based on the limited data and experience obtained during four deployments, the in situ sampler has to be viewed as a monitoring tool rather than as a regulatory tool that would require precise measurement for legal action. There were a number of features associated with the current design of the in situ system that restricted its general utility. For example, in view of the size and weight of the system, deployment and retrieval required experienced "riggers" and the use of a heavy duty, mobile crane. The "batch" design limited the number of samples that could be processed to 10; the unit must then be retrieved and refurbished before other samples may be taken. If the unit was located in water temperatures of $\leq 8.0^\circ$ C, the power requirements on the batteries to maintain a water bath temperature of 44.5° C restricted deployment time to less than 10 days.

Langley Research Center
National Aeronautics and Space Administration
Hampton, VA 23665
October 25, 1978

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TABLE I.- RESULTS OF IN SITU COLIFORM MONITORING SYSTEM

Parameters	Results from sample port –							
	2	3	4	5	6	7	8	9
Big Bethel Reservoir								
Fecal coliform counts, number/100 ml	[a]1.0	0	2.0	0	0	0	1.0	1.0
Platform endpoint times, hr:min	8:56	8:08	7:48	8:36	7:56	2:04	3:08	5:32
Predicted fecal coliform counts, number/100 ml . . .	10	32	32	20	32	39 810	10 000	630
Range of predicted counts, number/100 ml . . .	2 to 32	6 to 100	6 to 100	5 to 63	6 to 100	10 000 to 158 000	2500 to 39 800	126 to 2500
Back River								
Fecal coliform counts, number/100 ml	17	2.0	8.0	1.0	30	1.0	Not determined	Not determined
Platform endpoint times, hr:min	9:16	9:24	9:09	14:56	10:36	1:52	2:24	Not determined
Predicted fecal coliform counts, number/100 ml . . .	8	8	10	≤1.0	3	3162	1995	Not determined
Range of predicted counts, number/100 ml . . .	2 to 25	2 to 25	3 to 40	--------------	0.8 to 12	794 to 10 000	630 to 6310	Not determined
York River								
Fecal coliform counts, number/100 ml	17	64	74	Not determined	Not determined	0	2	5
Platform endpoint times, hr:min	15:42	14:14	12:42	12:06	[b]17:00	17:00	17:00	17:00
Predicted fecal coliform counts, number/100 ml . . .	≤1.0	1.0	3.0	5	≤1.0	≤1.0	≤1.0	≤1.0
Range of predicted counts, number/100 ml . . .	-----------	0.2 to 3.0	0.8 to 12.0	1 to 16	--------------	-----------------	--------------	--------------
Caven Point								
Fecal coliform counts, number/100 ml	460	250	580	150	250	2000	600	780
Platform endpoint times, hr:min	5:34	No end point	6:14	7:06	6:38	No end point	6:38	6:30
Predicted fecal coliform counts, number/100 ml . . .	1000	------------	630	250	398	-----------------	398	398
Range of predicted counts, number/100 ml . . .	250 to 3162	------------	158 to 1995	79 to 10 000	126 to 1259	-----------------	126 to 1259	126 to 1259

[a]Laboratory test data using MF technique.
[b]No endpoint at conclusion of 17-hour run.
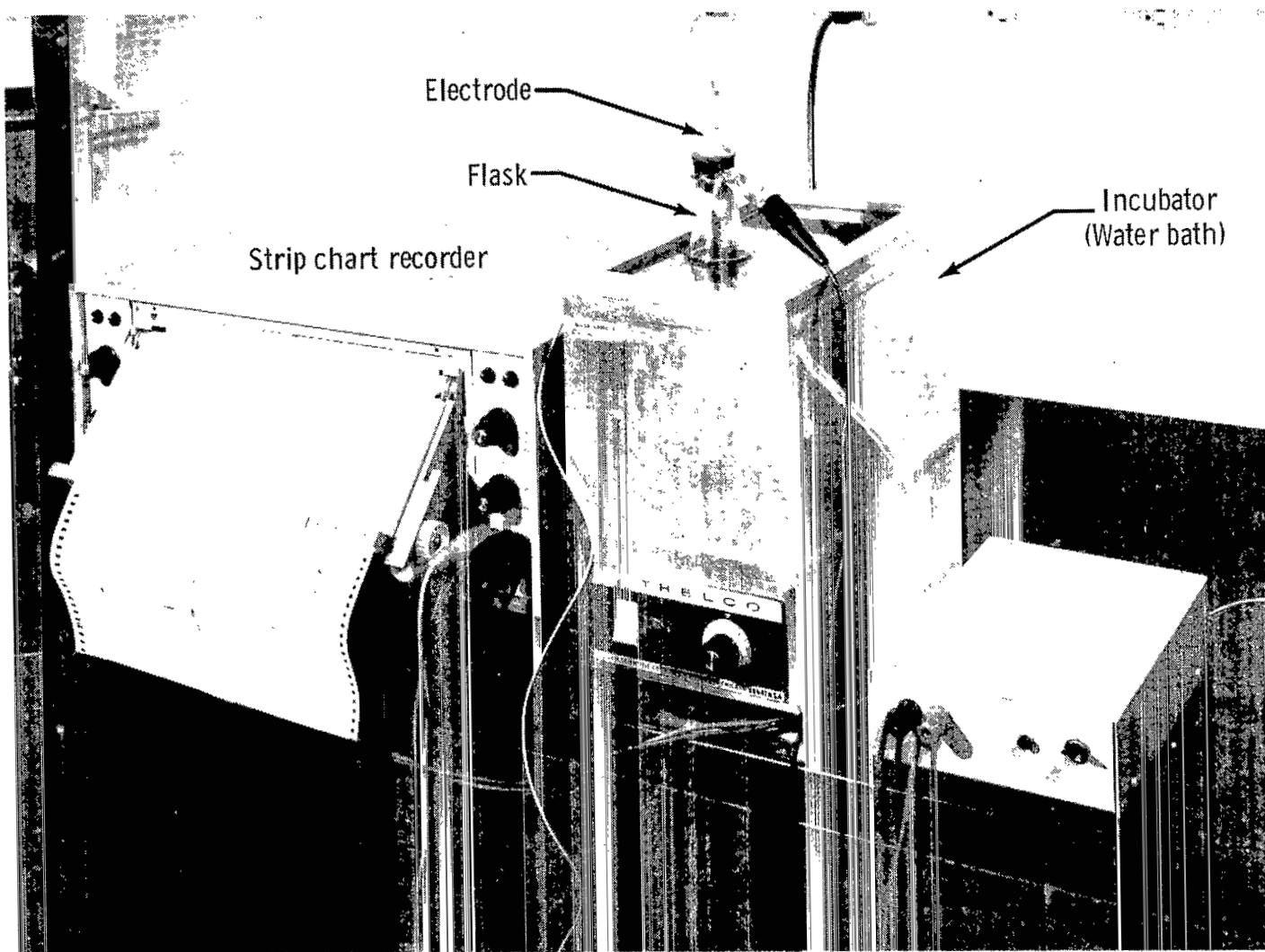
L-74-6125.1

Figure 1.- Experimental setup for performing hydrogen response measurements.
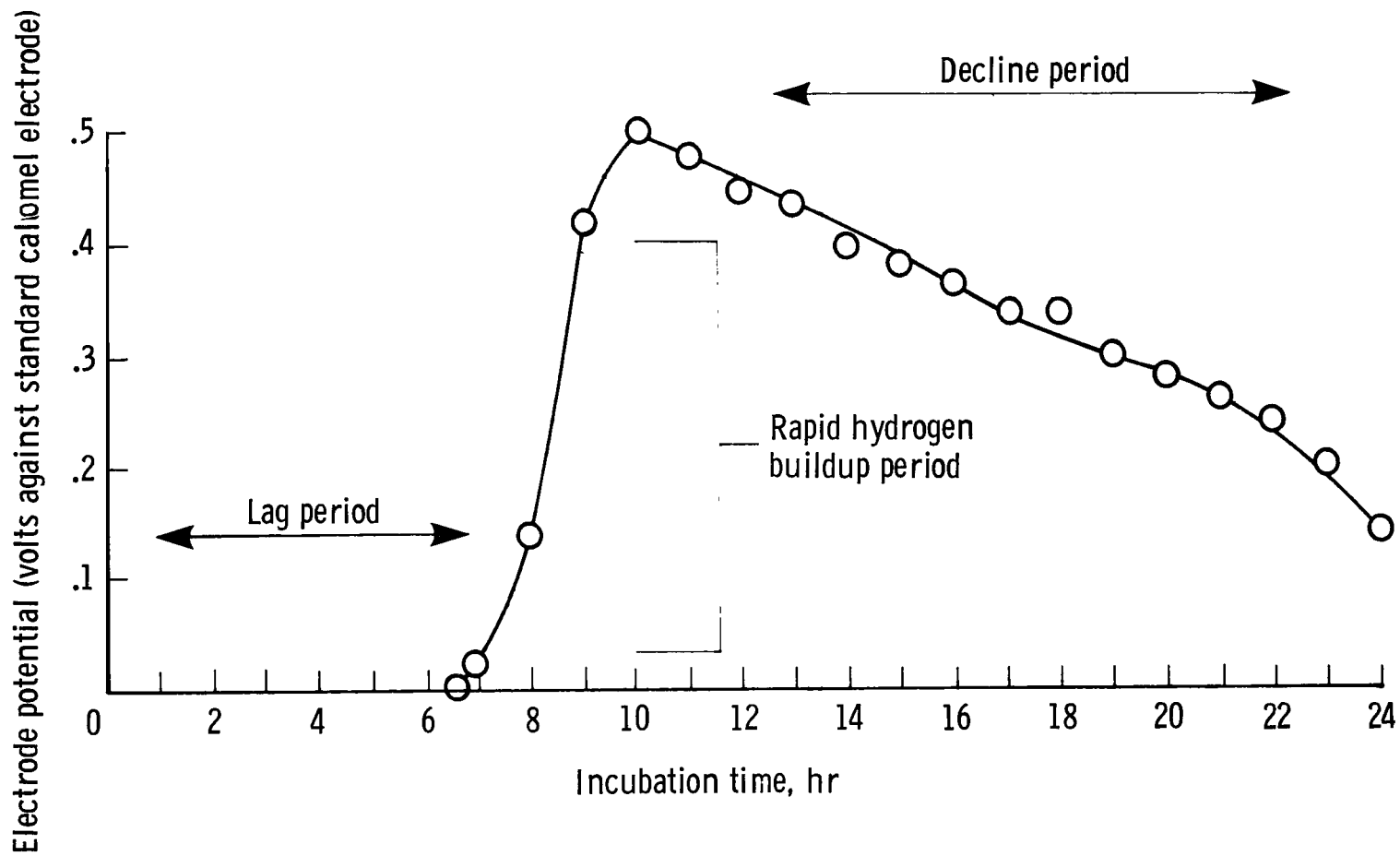
Figure 2.- Strip-chart tracing of hydrogen response curve for 1.9 cells/100 ml.
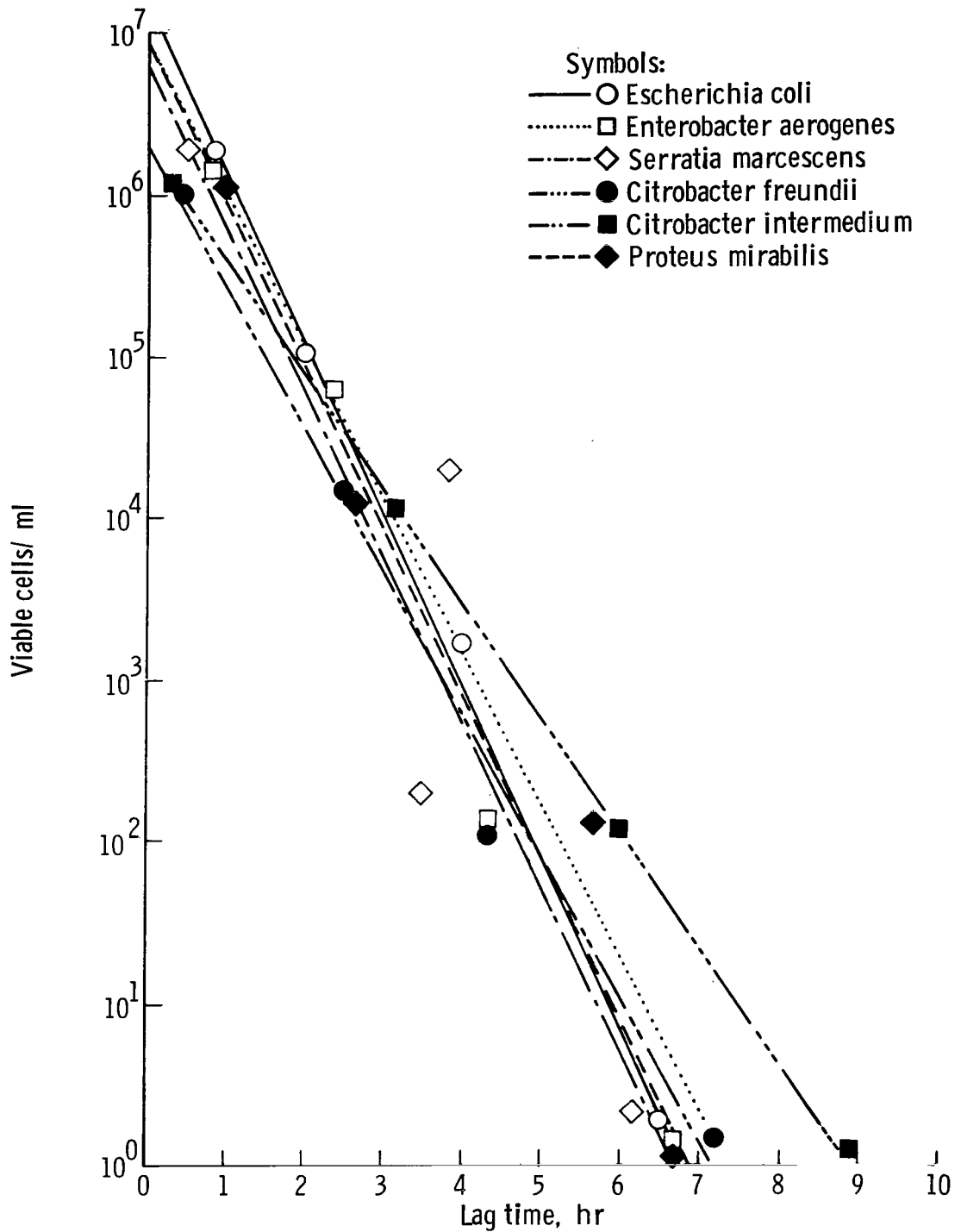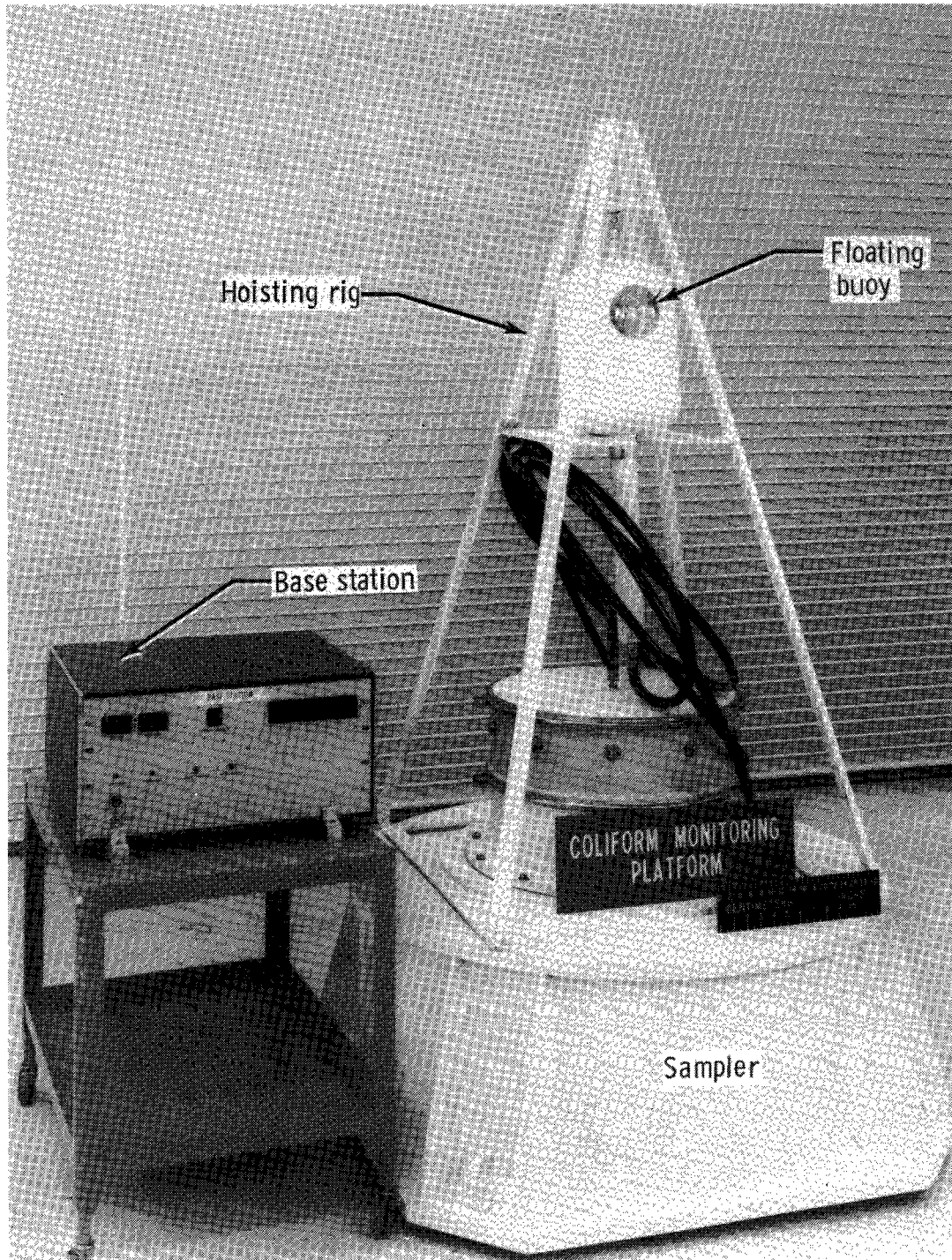
Figure 3.- Relationship between inoculum size and length of lag period. (Lines fitted by method of least squares.)

Floating
buoy

Hoisting rig

Base station

COLIFORM MONITORING
PLATFORM

Sampler

L-78-338.1

Figure 4.- In situ coliform monitoring system.
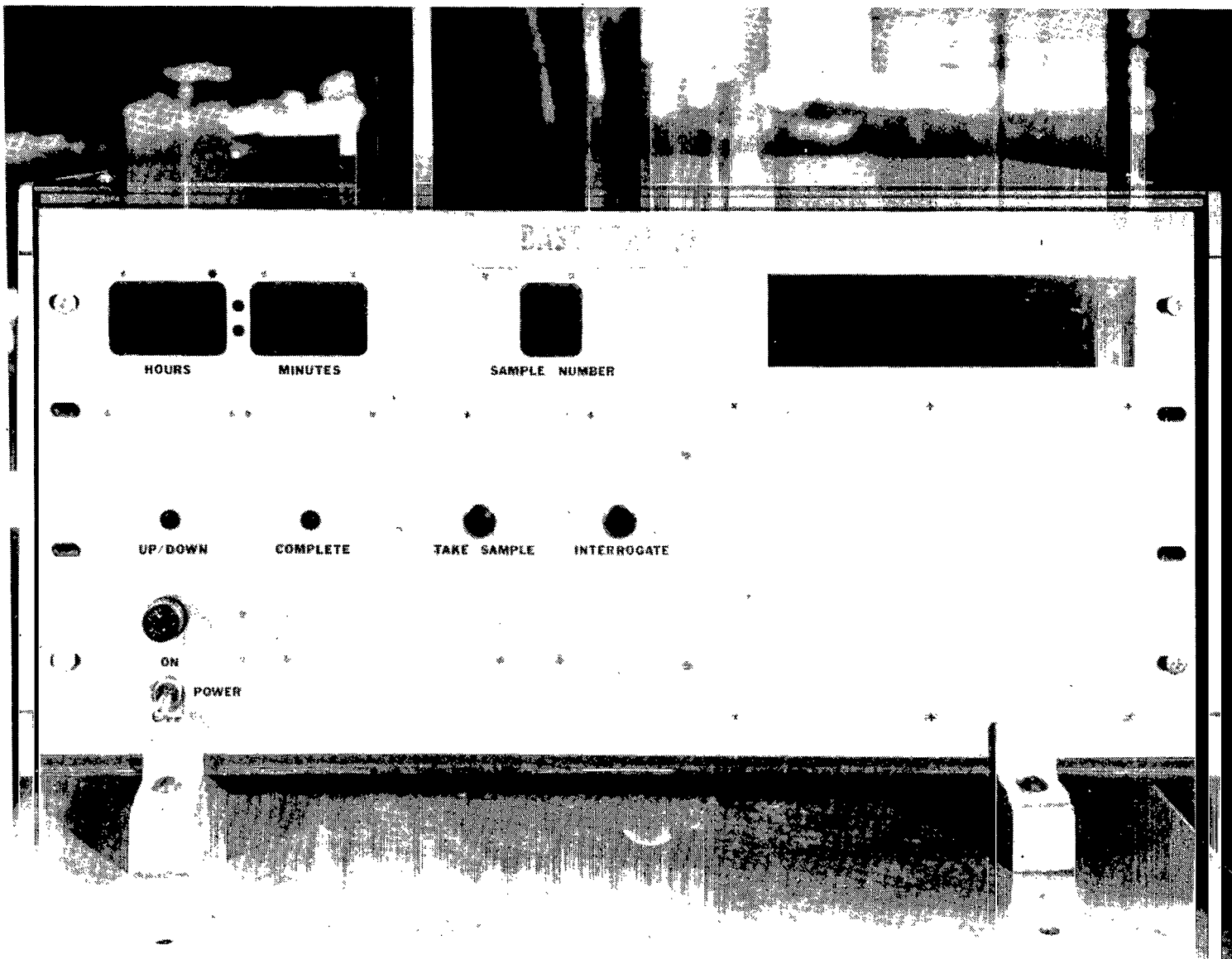
L-78-339

Figure 5.- Base station control panel.
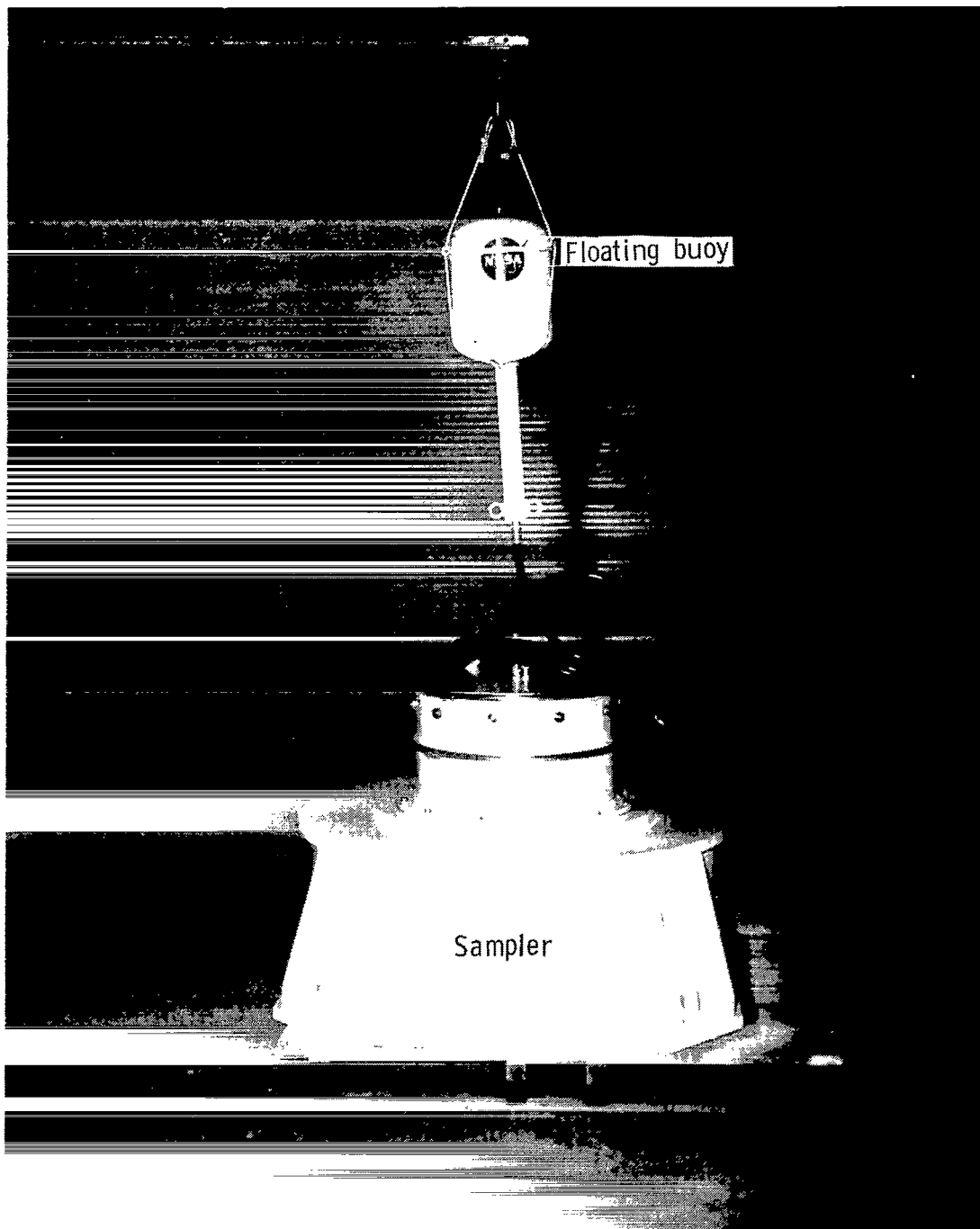
L-77-4292.1

Figure 6.- In situ monitoring platform.
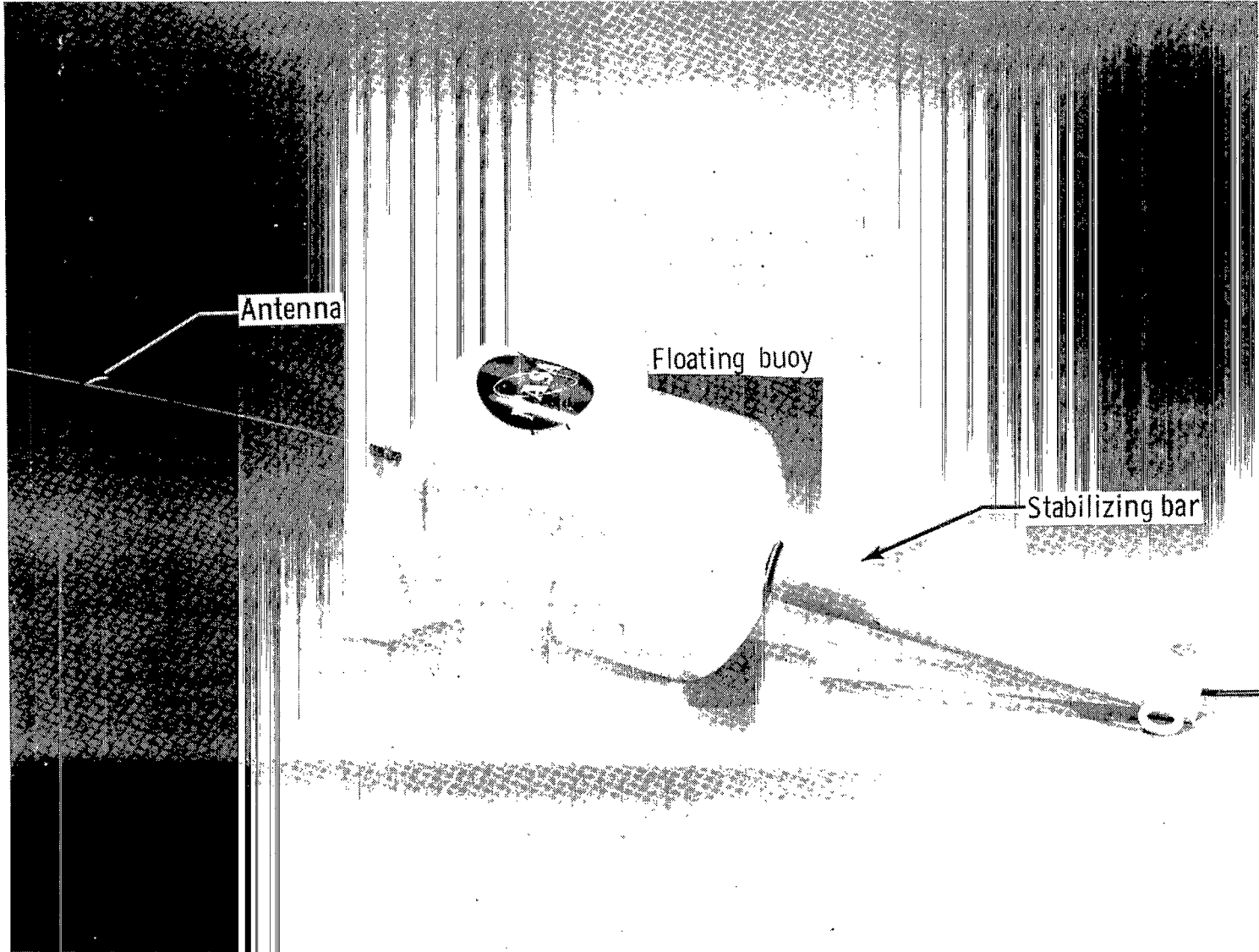
Figure 7.- Marker buoy.

L-75-6925.1

ELECTRONICS COMPARTMENT

BATTERY COMPARTMENT
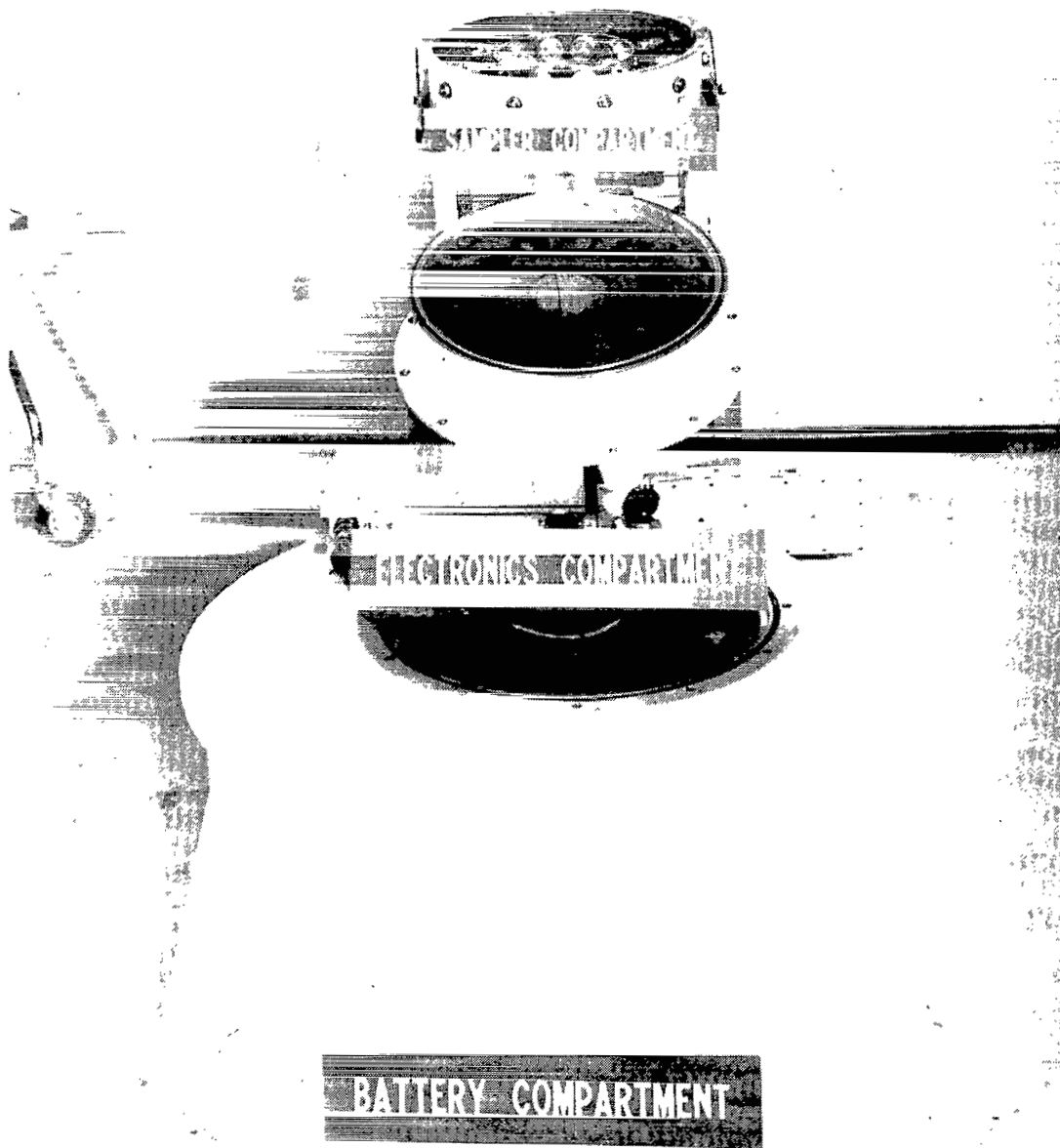
L-78-336

Figure 8.- Sampler showing major components.

Control module compartment
(Transceiver)

Power supplies

Control module compartment
(Control and data processing unit)

L-78-335.1

Figure 9.- Base section.

Control and
data processing
components

Transceiver
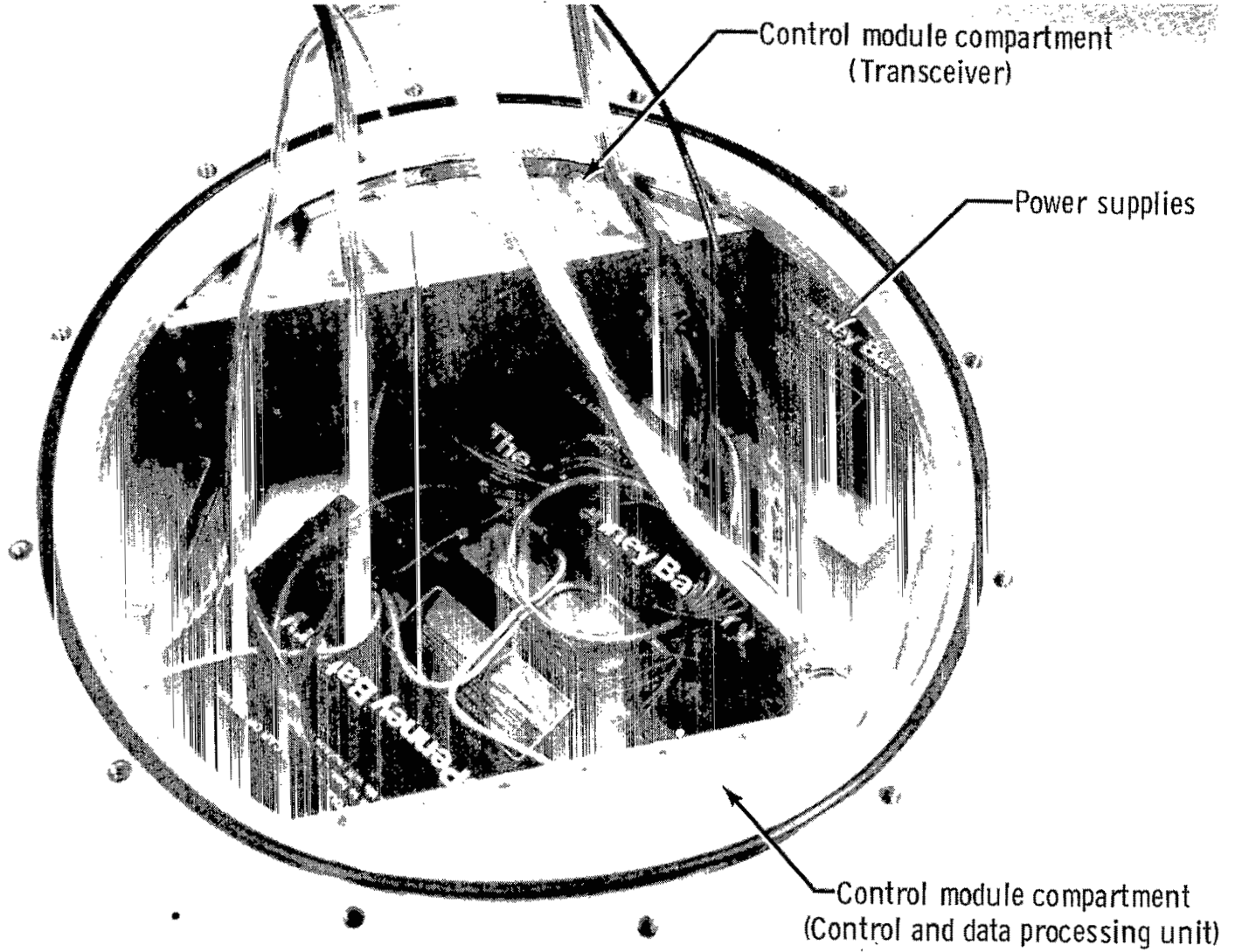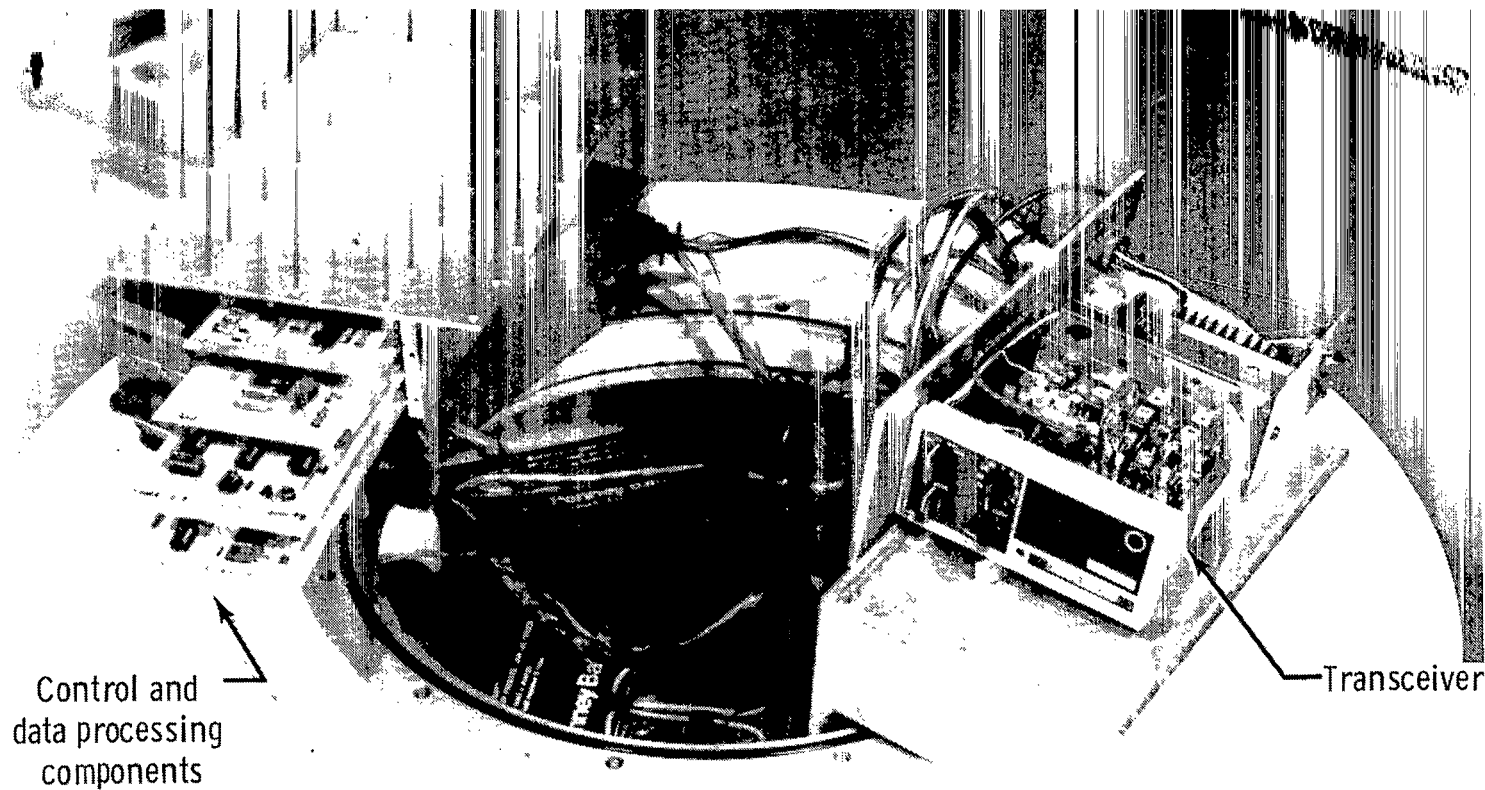
L-78-333.1

Figure 10.- Base section showing control module components.

—Insulation

—Trough

—Strap heater
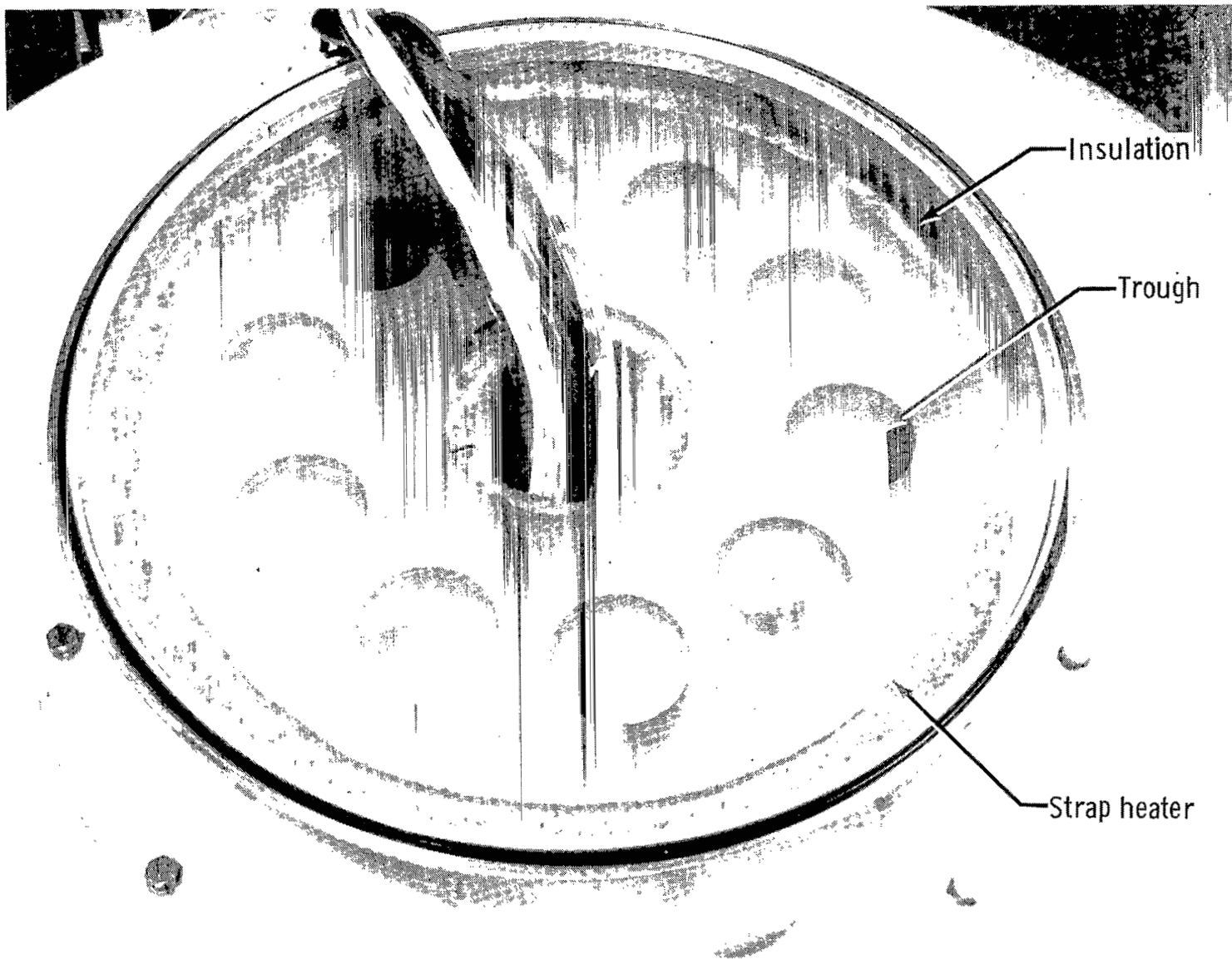
L-78-337.1

Figure 11.- Midsection showing incubator.

—Valve solenoid

—Intake
valve
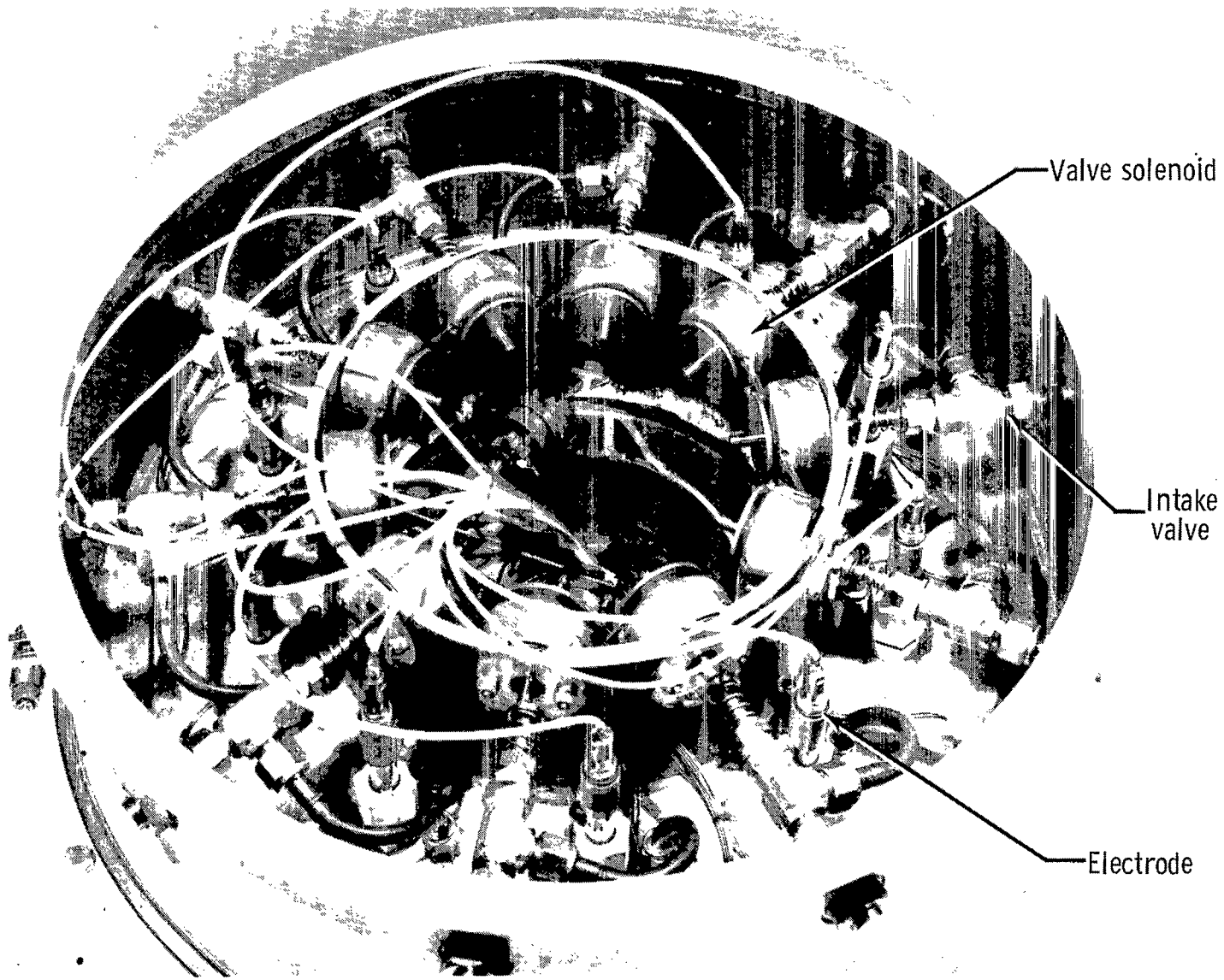
—Electrode

L-78-340.1

Figure 12.- Top section showing valve arrangement.
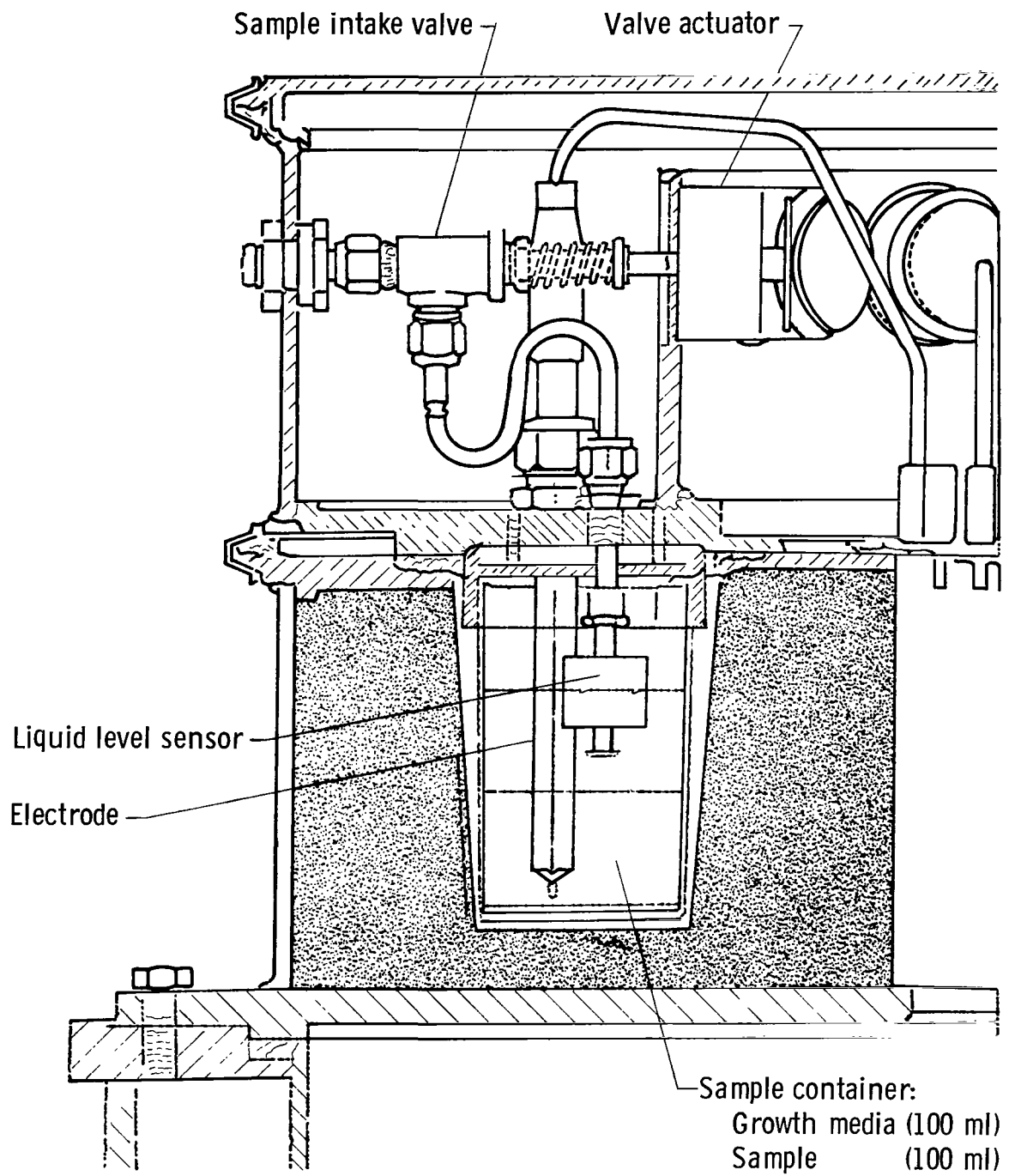
Figure 13.- Typical intake system components.

L-75-7778

Figure 14.- Plastic model of midsection showing arrangement of intake
system components.
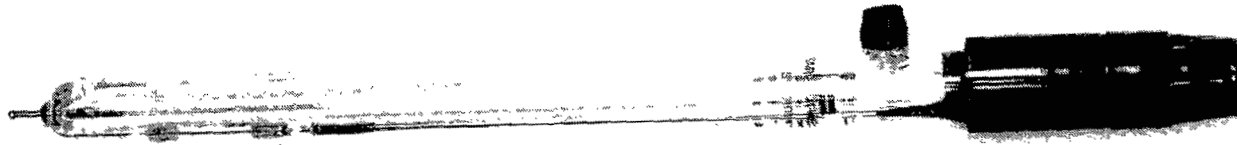
Figure 15.- Electrode assembly.

L-77-5463

Remote sending
and receiving
station

Telemetry

Interrogate

Command
recognition

Solenoids

Take
sample

Memory

Timer

Multiplexer

Detector

Water samples
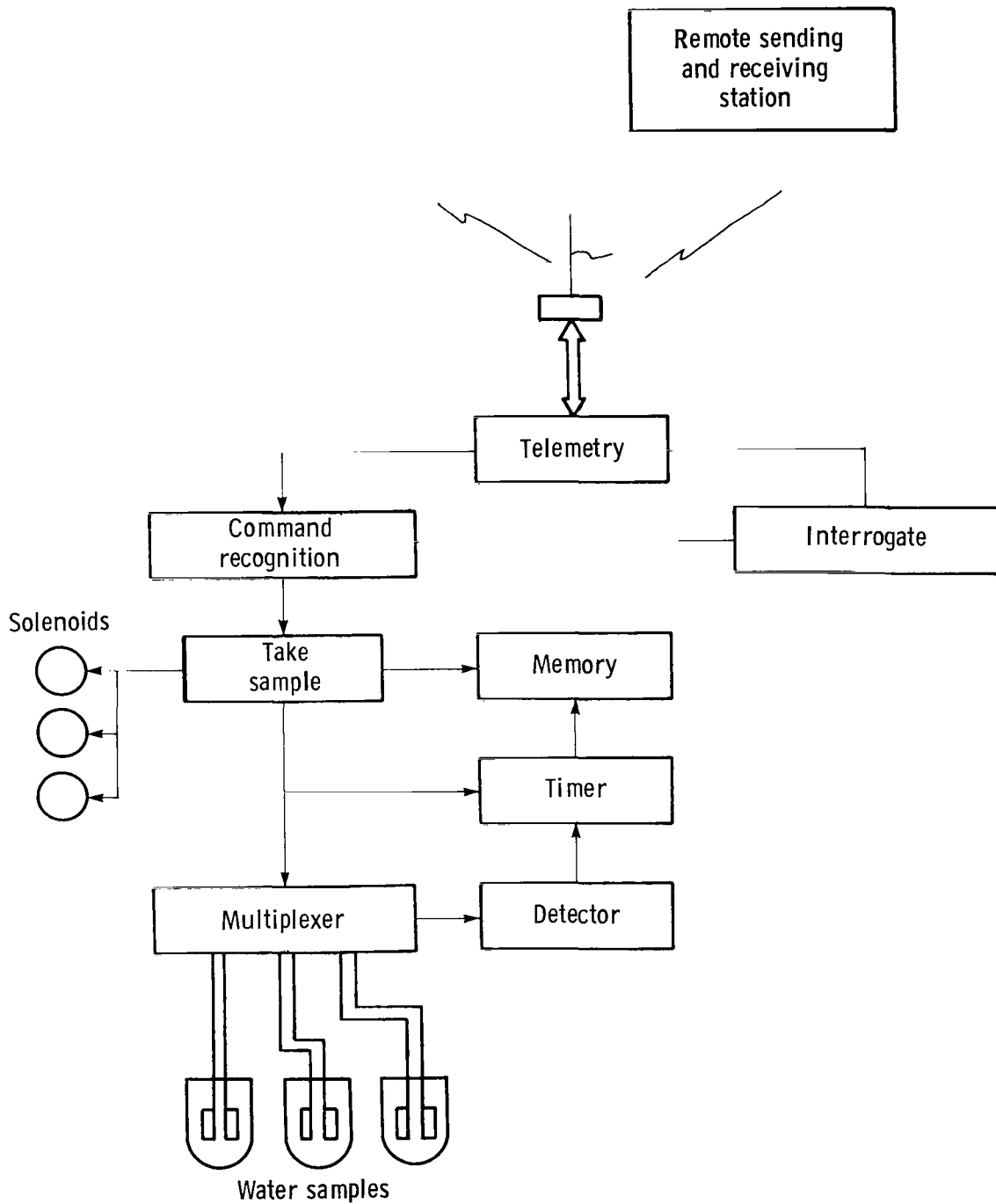
Figure 16.- Block diagram showing components of control module.
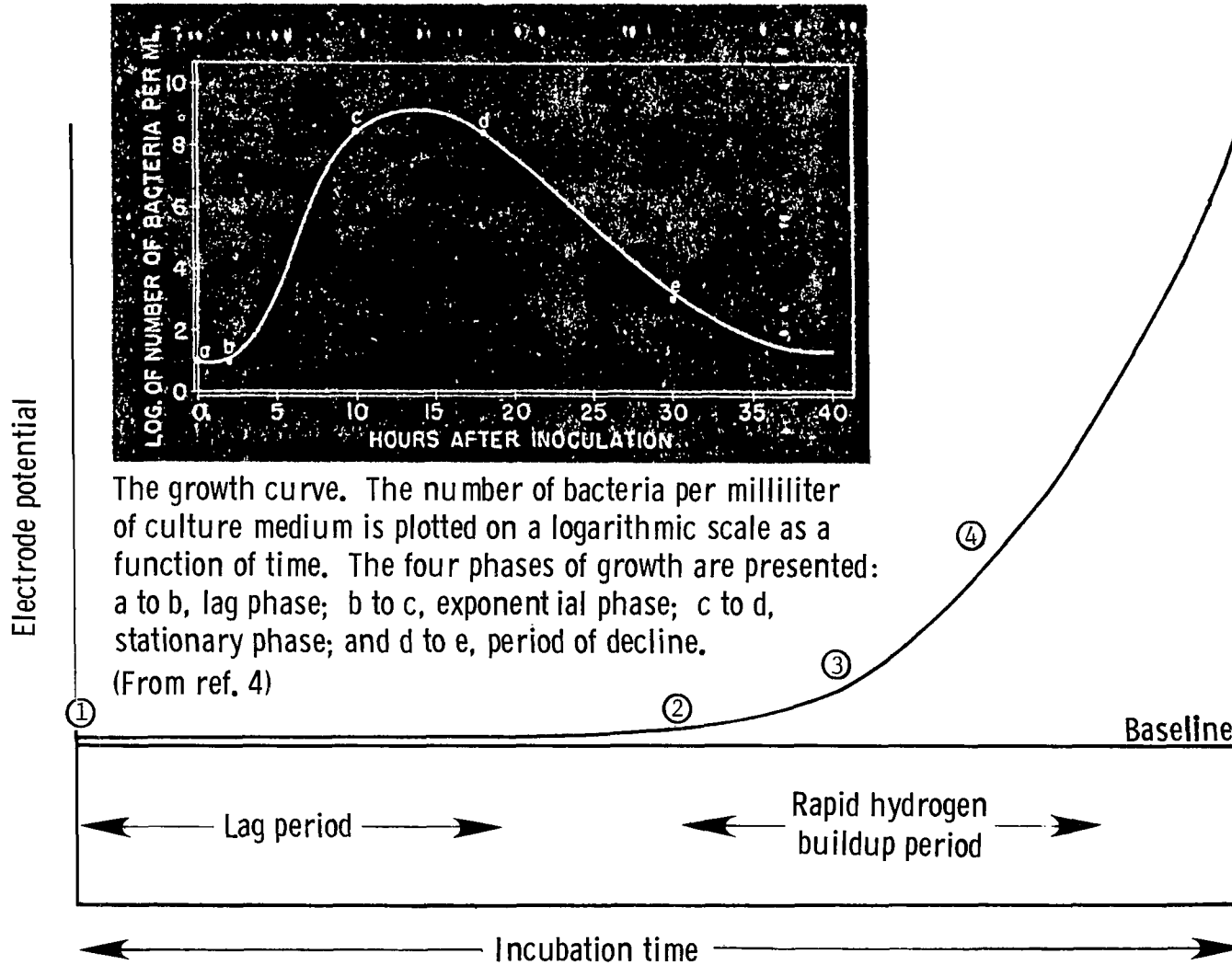
The growth curve. The number of bacteria per milliliter
of culture medium is plotted on a logarithmic scale as a
function of time. The four phases of growth are presented:
a to b, lag phase; b to c, exponential phase; c to d,
stationary phase; and d to e, period of decline.
(From ref. 4)

Electrode potential

Baseline

Lag period

Rapid hydrogen
buildup period

Incubation time

Figure 17.- Typical pilot model response curve illustrating clock operating
modes. Insert shows growth rate curve of typical bacteria. Note simi-
larity between buildup in electrode potential and growth rate of bacteria.
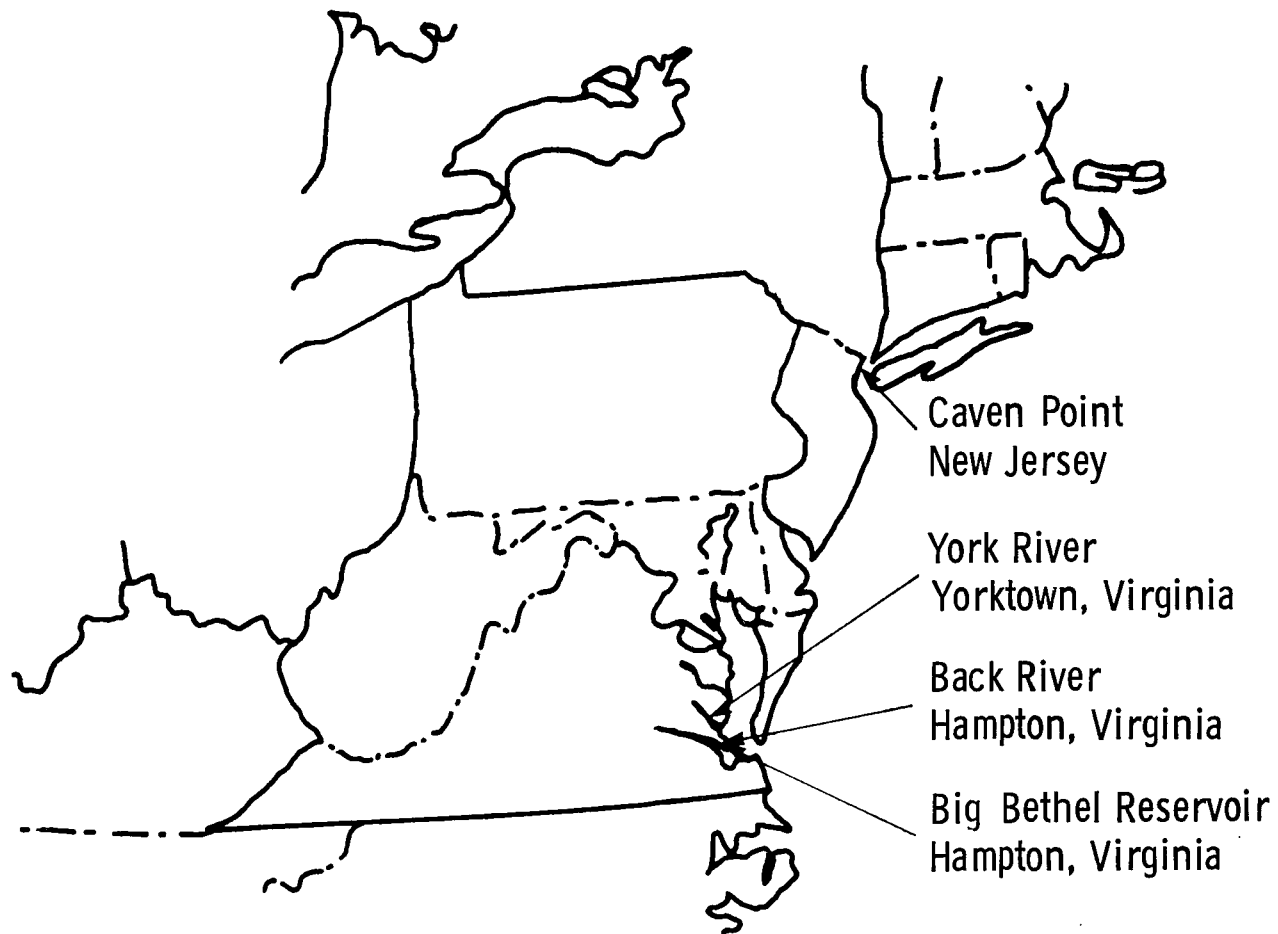
(a) Map showing general locations of test sites.
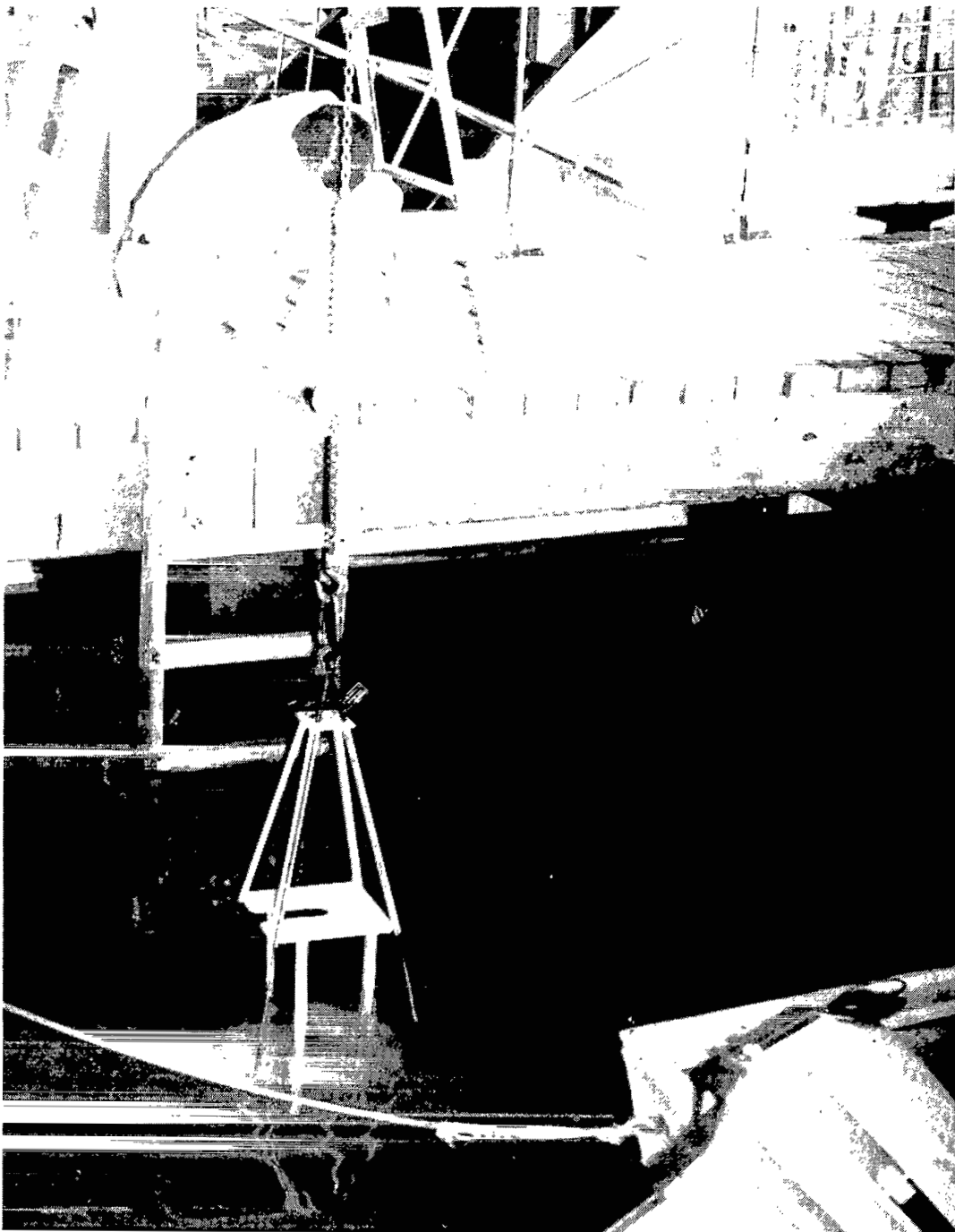
Figure 18.- Platform deployment.
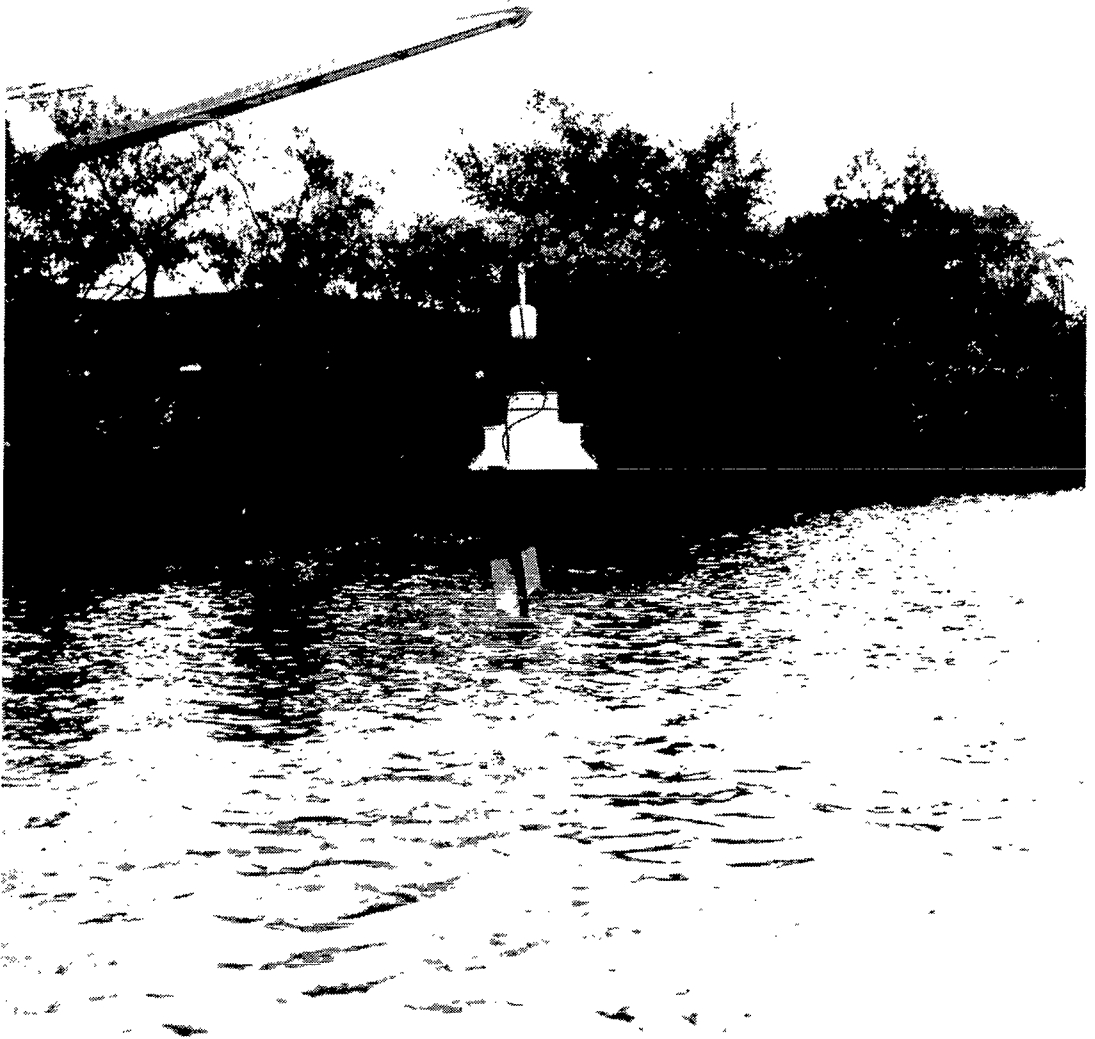
L-76-4481

(b) Big Bethel Reservoir site (operated by U.S. Army.)
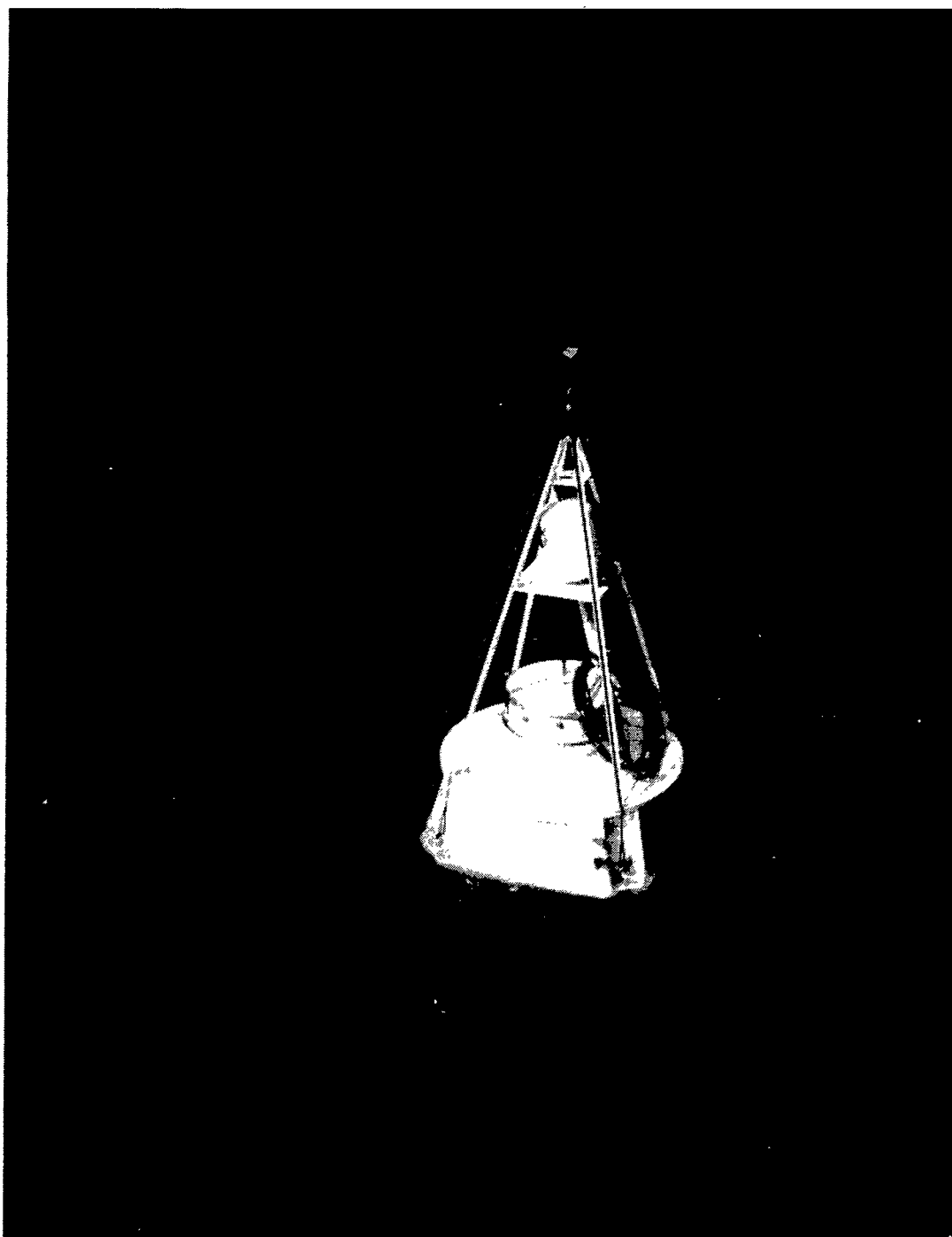
Figure 18.- Continued.

L-76-6708

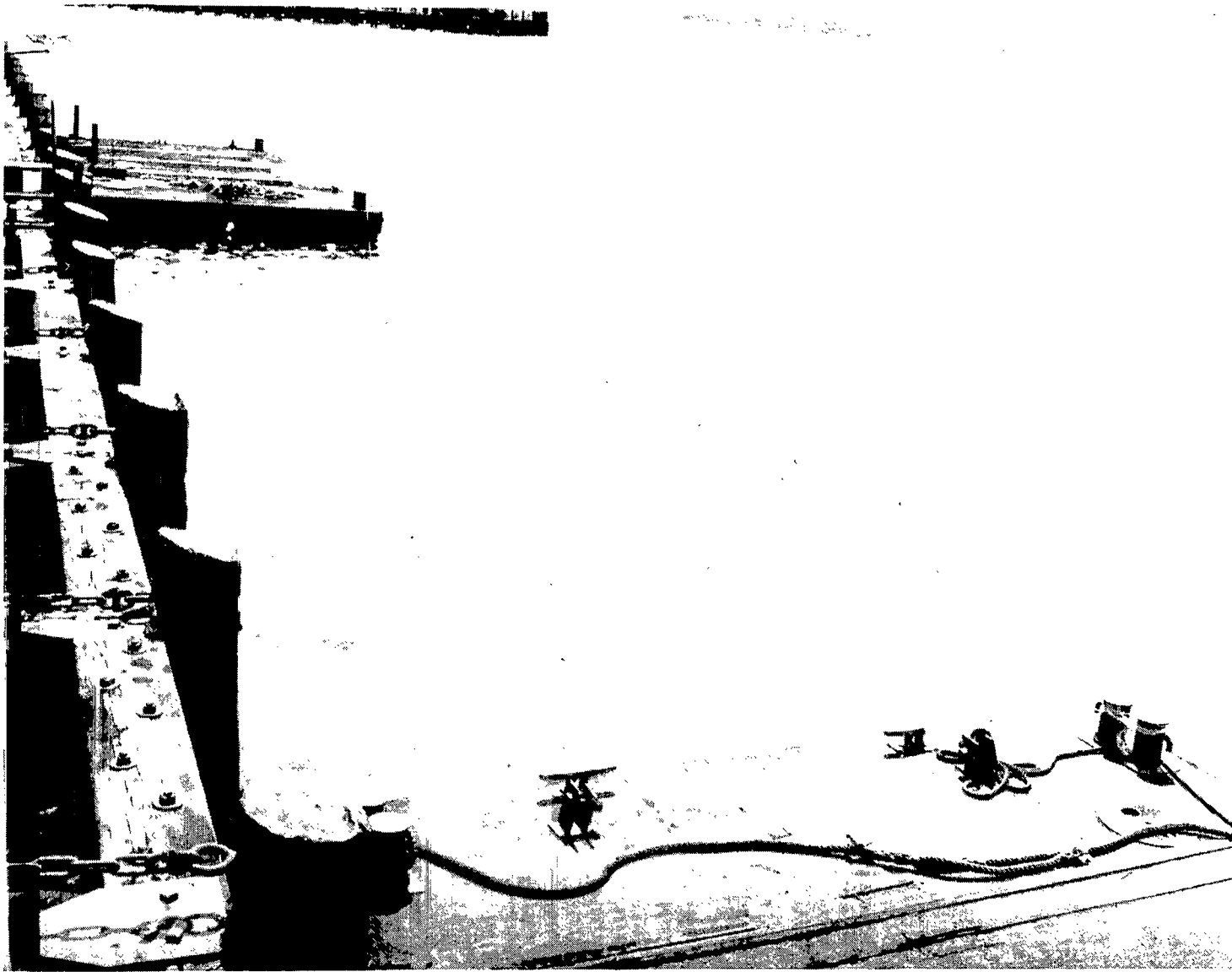(c) Back River site at U.S. Air Force Boat Facility.

Figure 18.- Continued.

L-77-6869

(d) York River site at U.S. Navy Dock Facility.

Figure 18.- Continued.

L-77-2782

(e) Caven Point site adjacent to U.S. Army Corps of Engineers Dock Facility.
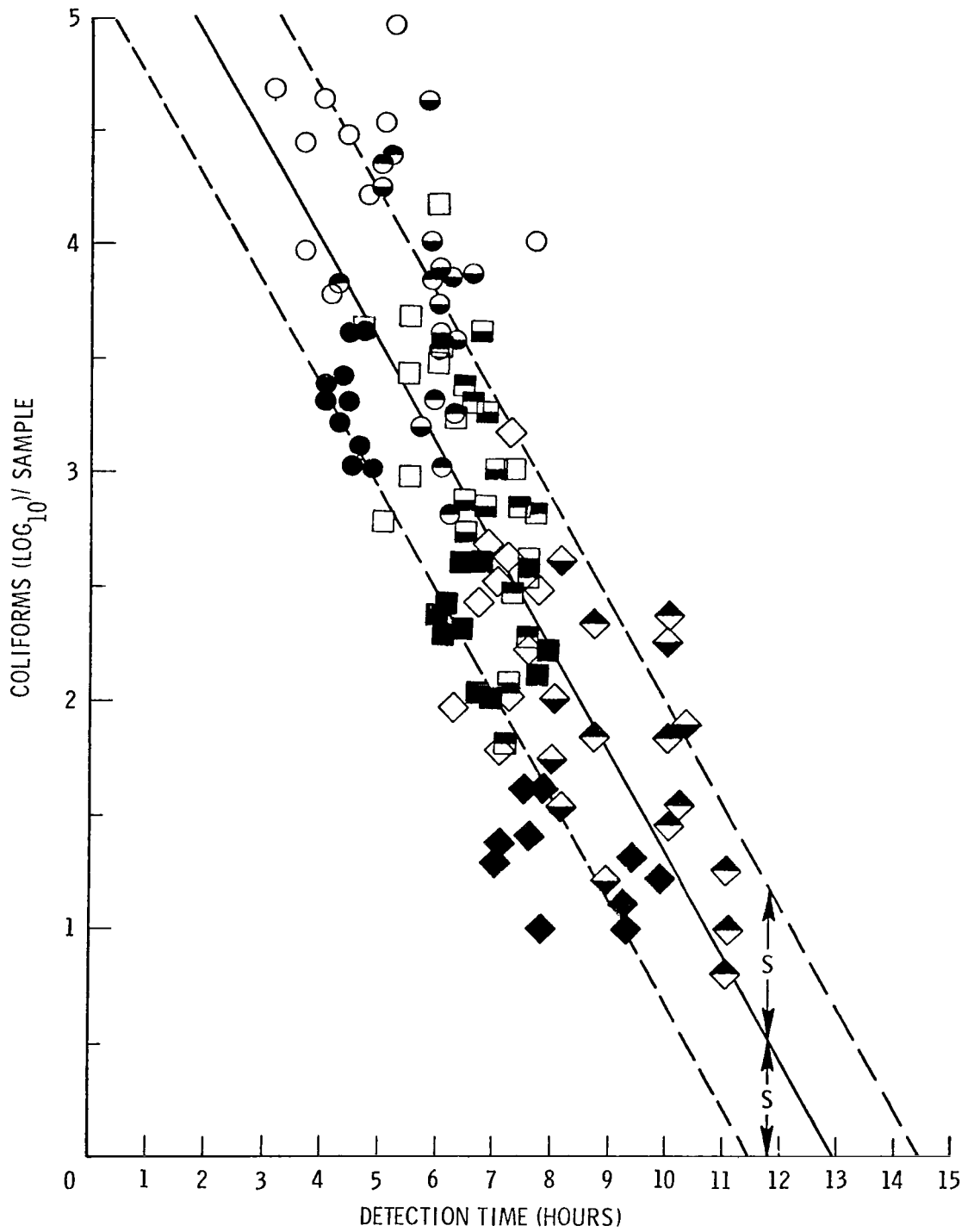
Figure 18.- Concluded.

Figure 19.- Linear relationship between fecal coliforms and detection
time for estuarine water samples.

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15. Supplementary Notes

16. Abstract

A prototype in situ system for monitoring the levels of fecal coliforms in shallow water bodies was developed and evaluated. This system was based on the known relationship between the concentration of the coliform bacteria and the amount of hydrogen they produce during growth in a complex organic media. The prototype system consists of a sampler platform, which sits on the bottom; a surface buoy, which transmits sampler-generated data; and a shore station, which receives, displays the data, and controls the sampler. The prototype system was evaluated at one fresh water and three estuarine sites. These four sites were characterized by a range of fecal coliforms from less than 1 to 2000 per 100 ml of water. The concept of remote monitoring of fecal coliform concentrations by utilizing a system based on the electrochemical method was verified during the evaluation of the prototype. Future use of this concept is envisioned as a monitoring tool rather than as a regulatory tool.

17. Key Words (Suggested by Author(s)) Sampler platform In situ monitoring Coliform detection	18. Distribution Statement Unclassified – Unlimited Subject Category 45
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