SPECIAL STUDIES OF A SANITARY LANDFILL

Robert C. Merz, et al

University of Southern California
Los Angeles, California

1970

PB196148

Final Summary Report

January 1, 1964 to December 31, 196[illegible]

and

Third Progress Report

January 1, [illegible] to December 31, [illegible]

STANDARD TITLE PAGE FOR TECHNICAL REPORTS

1. Report No.	EPA-SW-8RG-70
2. Govt. Accession No.	
3. Recipient's Catalog No.	
4. Title and Subtitle	SPECIAL STUDIES OF A SANITARY LANDFILL
5. Report Date	1970 (Issue)
6. Performing Organization Code	
7. Author(s)	Robert C. Merz and Ralph Stone
8. Performing Organization Rept. No.	
9. Performing Organization Name and Address	University of Southern California Los Angeles, California
10. Project/Task/Work Unit No.	
11. Contract/Grant No.	UI 00518-08; 8 RO1 UI00518-07;*
12. Sponsoring Agency Name and Address	Bureau of Solid Waste Management, Public Health Service, U.S. Department of Health, Education, and Welfare Rockville, Maryland 20852
13. Type of Report & Period Covered	Final and Interim Reports--1964-1968
14. Sponsoring Agency Code	
15. Supplementary Notes	*9 RO1 SW 00028-06; EF-00160-05; EF-00160-04.

16. Abstracts

Model sanitary landfill cells were constructed and, over a 4+ year period, subjected to simulated environmental conditions such as added water, aeration, and aerobic and anaerobic operation. The effect of these conditions on percolation, gas quality and production, settlement, and temperature was measured. Examination of core samples taken at the end of the study period showed that refuse in the aerated cell was well decomposed except for plastics and other inerts and that refuse in the anaerobic cells was easily identifiable. Based on an original cell depth of 20 feet, volume reduction in the aerated cell was 21.5% and in the anaerobic cells, 11.5%. The four parts of this report detail the activity during the last year of the project and summarize the data collected for the span of the project (1/1/64 to 12/31/68).

17. Key Words
Refuse di
Environn

17b. Identifie
Aerobic
Landfill

17c. COSATI

18. Distributi
Rel

FORM CFSTI

SPECIAL STUDIES OF A SANITARY LANDFILL

This final summary report (SW-8rg), which is combined with the first, second, and third progress reports, and final report on factors controlling utilization of sanitary landfill sites, work performed under Research Grant No. UI-00518-08 to the University of Southern California was written by ROBERT C. MERZ and RALPH STONE

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Solid Waste Management
1970

A WEALTH OF LANDFILL DATA

The objective of the Federal solid waste program is to aid efforts across the Nation to develop economic and efficient practices for managing our increasing volumes of solid waste. As authorized under the Solid Waste Disposal Act (Public Law 89-272), the Bureau of Solid Waste Management has made almost 100 research grants to nonprofit institutions for the purpose of stimulating and accelerating new or improved technology for handling the Nation's discarded solids.

The present document reports on work completed under one of those research grants. This grant has funded a long-term study of a sanitary landfill, the technical term for engineered deposit of solid waste within the earth under controlled conditions. The main effort over the years of this grant has been to document in engineering terms the changes that take place within sanitary landfills. We trust that other researchers will be able to use this wealth of landfill data gathered over the four-year period.

--RICHARD D. VAUGHAN, *Director*
Bureau of Solid Waste Management

PREFACE

On March 25, 1966, the Department of Civil Engineering of the University of Southern California submitted a final report, "Factors Controlling Utilization of a Sanitary Landfill Site," which is reproduced herein as Appendix 8.3. Funds had been provided by two grants from the U.S. Public Health Service, EF-00160-04 and EF-00160-05, covering the period January 1, 1964 to December 31, 1965. Special studies of the sanitary landfill were continued and expanded under new grants, SW-00028-06 covering the 1966 calendar year, UI-00518-07 covering the 1967 calendar year, and UI-00518-08 covering the 1968 calendar year. Progress reports entitled "Special Studies of a Sanitary Landfill" were submitted for the years 1966 and 1967 and are included in this volume as Appendices 8.2 and 8.1. The appendices give detailed information concerning the construction, instrumentation, and initial performance of the four landfill test cells described as A, B, C, and D.

The present report is offered both as a third statement of progress, since only the data collected during 1968 are included, and as a final summary report, with discussion of results of the four-year study and statement of conclusions drawn.

ACKNOWLEDGMENTS

The project was under the joint direction of Robert C. Merz, Chairman, Department of Civil Engineering, and Ralph Stone, Research Associate. Field assistance was provided by Ramon Beluche and George de la Guardia. The County Sanitation Districts of Los Angeles County constructed the *test cells and provided field assistance when requested. The help of the* staff of the Sanitation Districts, John D. Parkhurst, Chief Engineer and General Manager, and Lester Haug, Deputy Assistant Chief Engineer, is most gratefully acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ILLUSTRATIONS

4. SUMMARY STATEMENTS

The purposes of the field investigation, utilizing landfill cells having a depth of approximately 20 ft and an earth cover of 2 ft, were to (1) study the percolation through the landfill as a result of application of sufficient water to maintain a golf course type turf, (2) study the percolation through the landfill as a result of application of sufficient water to simulate the rainfall pattern of a temperate climate (Seattle), (3) study the effects of aerating a landfill, (4) measure settlement of both aerobic and anaerobic landfills, (5) study the quality of gas produced in the landfills receiving the various treatments, and (6) determine the volume of gas produced by a known quantity of refuse decomposing under anaerobic conditions.

Data were developed as a result of the construction of model landfills and their treatment under selected environmental conditions. Practical application of the reported data requires detailed knowledge of individual landfill conditions - existing or proposed - best known to the responsible authorities.

1. Initial landfill compaction ratios from 2.1 to 2.2, and an in-place density of 1000 lb per cu yd were achieved for the 3 test cells A, B and C. The in-place density for Cell D was 634 lb per cu yd.
2. Cell A, receiving the Seattle rainfall equivalent of 184 in. plus an extra 30 in. (for a total of 214 in. of water), exhibited some percolation into the subgrade as evidenced by a 7% increase in the percent moisture of the subgrade over that of undisturbed soil at similar depth. At the close of the project, the differential was 12.5%.
3. Cell B, receiving 392 in. of applied irrigation water, exhibited greater percolation into the subgrade as evidenced by a 15% increase in the moisture content of the subgrade over that of undisturbed soil at similar depth. At the close of the project, the differential was 41%.

4. The growth of Bermuda grass was successfully maintained on an anaerobic landfill with a top earth cover of 2 ft especially prepared to favor turf growth.
5. The greatest settlement of 4.25 ft occurred in aerobic Cell C. The 2 anaerobic cells each settled 2.20 ft.
6. In anaerobic Cells A and B, after ageing 2 yr, the major gas constituents by volume were carbon dioxide and methane in almost equal amounts (nearly 50%). Oxygen and nitrogen were present in small, varying amounts.
7. Cell C was aerobically operated and the gas composition was dependent upon the duration of the blower operation. The gas samples obtained during aeration were characteristically high in nitrogen and oxygen, and low in carbon dioxide and methane.
8. The maximum temperature reached in anaerobic Cell A was 108 deg F after 79 days. Over the final 2 yr of the 4+ yr study the temperature ranged between 53 and 88 deg F.
9. The maximum temperature reached in Cell B was 120 deg F after 31 days. Over the final 2 yr of the 4+ yr study the temperature ranged between 60 and 90 deg F. Although intended to be an anaerobic cell, its performance was influenced by the passage of air from aerobic Cell C notwithstanding a 5-ft wide, continuous adobe-shale barrier.
10. The maximum temperature reached in Cell C was 193 deg F after 174 days. Over the final 2 yr of the 4+ yr study the temperature ranged between 90 and 164 deg F. Bottom temperatures reached peaks high enough to destroy thermistors. Smoke emanations with fire were noted on a few occasions. The cell temperature was affected by the aeration cycle.
11. A cell similar in construction to Cell A or B, but smaller, intended for quantitative studies of gas production, was unsuccessful although

constructed with extreme care by professional plastic fabricators. The polyethylene envelope was not able to store gas.

12. The maximum temperature reached in Cell D was 117 deg F after 368 days. Over the final 2 yr, the temperature ranged between 67 and 120 deg F.
13. Seventy-three cubic yards of refuse packed into an underground sealed and instrumented steel tank produced 2027 cu ft of gas, or 27.7 cu ft per cu yd of refuse, over 907 days. Virtually all the gas was produced between the 230th and 600th day.
14. Final examination of the cell materials during the coring operation showed the aerated Cell C refuse to be well decomposed except for plastics and other inerts. In contrast, the anaerobic cells A and B refuse was easily identifiable.
15. Based on the original cell depth of 20 ft, the volume reduction achieved through aeration amounted to 21.5%. The volume reduction achieved in the anaerobic cells was 11.5%.
16. Epoxy-coated steels supplied by factory specialists provided protection against severe corrosion. Stainless steel thermistors, copper conduits, teflon-coated leads, galvanized pipe, and asphalt-coated steel were found to be inadequate for this type of investigation. All seriously deteriorated or failed because of high temperatures, corrosion, or strain exerted by differential settlement.

5. SUMMARY REPORT

5.1 Percolation. Cells A and B were constructed for the purpose of studying percolation resulting from (1) the application of water in accordance with the Seattle rainfall pattern of 1961 and (2) the application of water necessary to support a golf-course like turf. In both cases, efforts to measure moisture content of the landfill material by moisture probes and percolation by entrapment of water in collection lysimeters or cans were unsuccessful. A program of cell coring, with cores subjected to laboratory analysis for their moisture content, was initiated in August, 1966.

Water was applied manually to Cell A, the intent being to duplicate the established Seattle monthly increments. The schedule was immediately upset in 1964 when unintentional flooding took place, and again in September 1967 when an adjacent reservoir overflowed. Nevertheless, reference to Table 5.1.1 will show that the Seattle rainfall total was closely approximated in 1966, 1967 and 1968. The amount applied in 1965 was reduced to compensate for the 1965 flooding.

The water applied to the turf on top of Cell B was automatically controlled by tensiometers, beginning in October 1964. Irrigation proceeded in normal manner except for brief periods when the tensiometers needed repair. In September 1967 the reservoir overflow placed an unwanted volume of water on the cell, and from July through October 1968 faulty operation of the tensiometers placed considerable unnecessary water on the cell.

Table 5.1.1 indicates that the amount of water applied to Cell B during 1968 was from 1.75 to 2.75 times the amount applied in previous years. This is not considered particularly damaging to the investigation since any landfill or golf course turf could be subjected to unexpected flooding.

TABLE 5.1.1

SUMMARY OF WATER APPLICATION TO CELLS A, B AND C								
Year	Site Rainfall In.	Seattle Rainfall Pattern In.	Water Applied to Cells, In.			Total Water Applied to Cells, In.		
			A	B	C	A	B	C
1964*	4.13	13.72	52.98	23.75	4.13	57.11	27.88	4.13
1965	24.63	42.52	5.24	60.42	24.63	29.87	85.05	24.63
1966	14.59	42.52	28.70	41.57	14.59	43.29	56.16	14.59
1967	18.77	42.52	21.37	49.63	18.77	40.14	68.40	18.77
1968	9.39	42.52	33.94	145.28	9.39	43.33	154.67	9.39
Totals		183.78				213.74	392.09	71.51

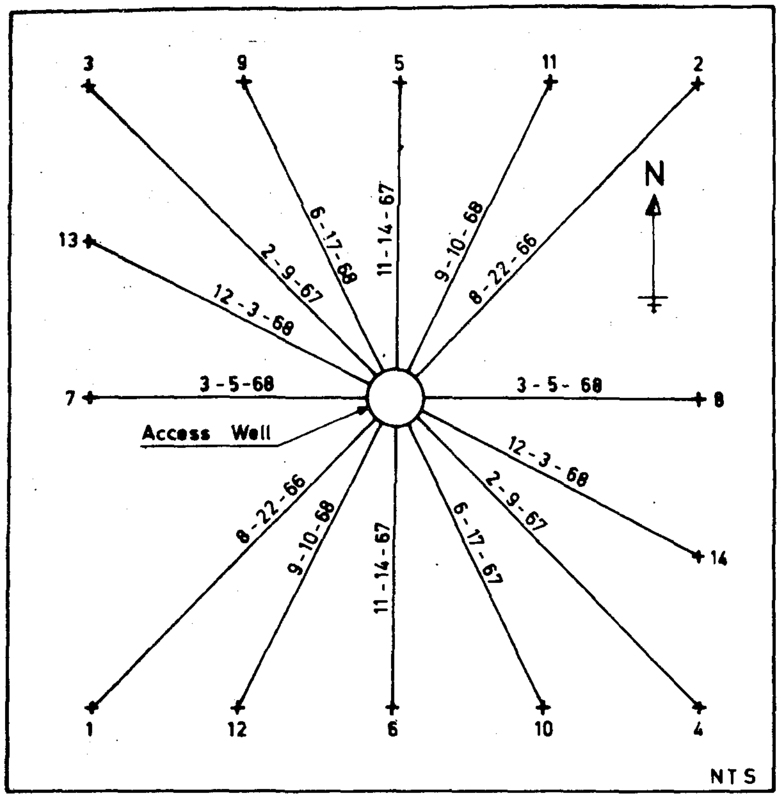
* Last 4 months only.

The total amounts of water applied to Cells A and B were approximately 214 and 392 in., respectively. As stated above, the effect of this water on the moisture content of the cells and the possible movement of water down through the cells and into the subgrade was checked by coring in the cells in August, 1966, February and November 1967, and every 3 months thereafter in 1968. Figure 5.1.1 locates the cores for all three cells and carries the coring dates. Core samples taken at 2-ft depth increments were placed in sealed containers immediately and transported to the laboratory where their moisture contents were determined. All data are summarized in the graphic presentation of Table 5.1.2. Moisture contents on a dry weight basis have been averaged for bands consisting of the top 6 ft, the middle 8 ft, and the bottom 6 ft.

The top band of Cell A always had the lowest moisture content of the 3 bands With 2 exceptions, the earth cover exhibited still lower moisture content. A combination of the upward rise of the water through the cover by capillarity with subsequent evaporation, and of downward movement of the water through the cell, would account for this. At least during the final year of the project, the moisture content of the middle band was considerably greater than the bottom band, indicating great capacity of the fill material to retain water. Of greatest interest and importance is the fact that the moisture content of the subgrade varied only -4% +7% from an average of 31% over the entire time, and was only 7% more than the native soil samples taken from equivalent depth. The indication is that little water has percolated into the tight, adobe-shale subgrade.

The picture presented by the data of Cell B is not quite as clear. In this case, there were 2 cores in which the moisture content of the top band was not less than any other band. The top earth cover had the least moisture content in all cases. There was no consistency in the relationship of the

FIGURE 5.1.1



TIME AND LOCATION OF LANDFILL CORES, CELLS A, B & C

Note :- All cores were located approximately
5 ft. from the cell boundary
The cores were 8 in. dia
The coring dates appear on the cell location lines

moisture content of the middle band to the bottom band. It is significant that the moisture content of the subgrade averaged 39% - or about the same as Cell A - until the September-December period of 1968 when it averaged 77%. This increase correlates with the excessive amounts of water applied to the surface in July, August, September and indicates that under such an unusual condition there was appreciable percolation into the subgrade.

Cell C of course was kept in a drier condition by reason of aeration. Attention is called to the fact that to prevent movement of air through the cover and into the atmosphere, an impervious membrane was stretched over the cell one foot below the surface. Because of the varied off-on cycle of the blower, as well as extended on and off periods, the data do not fall into any pattern permitting rational explanation. As expected, the bottom band which received the full benefit of the air admitted was always much drier than the middle band and, over the final year, was the driest band. Over the last 6 mo, the average moisture content of the bottom band was only 34%. The average moisture content of the subgrade was 30%. Sampling of the subgrade was discontinued after June, 1968 to avoid further damage to the air gridwork. Since Cell C received only rainfall totalling 72 in., most of which should have been stopped by the membrane, plus about 8 in. applied through the subsurface spray piping between September and October 1966 to purposely increase the moisture content, it may be concluded that no percolation into the subgrade took place.

5.2 <u>Gas Quality</u>. Samples of the gaseous environment within Cells A, B and C were taken on a regular basis over the entire period of the investigation until August 1968. By then, the original field installation had deteriorated to the point where gas samples were suspect. For instance, many of the gas samples from the anaerobic Cell A were analyzing as air. Replacement of some

AVERAGE PERCENT MOISTURE CONTENT OF TOP, MIDDLE AND LOWER BANDS OF CELLS A, B AND C ON A DRY WEIGHT BASIS FROM CORE SAMPLES

Cell / Band (depth, in.)	1	2	3	4	5	6	7	8	Control core from adjacent undisturbed soil	9	10	Control core from adjacent undisturbed soil	11	12	Control core from adjacent undisturbed soil	13	14	Control core from adjacent undisturbed soil
CELL A — Cover (2 to 0)	-	-	28.5	31.0	26.9	26.4	27.0	137.9	27.7	21.7	27.1	19.4	22.8	29.1	22.9	39.6	45.8	27.
CELL A — Top Band (0 to -6)	99.1	59.1	57.6	57.7	41.4	87.2	65.2	97.9	29.0	70.5	53.8	26.4	39.1	55.2	26.0	66.5	38.7	[illegible]
CELL A — Middle Band (-6 to -14)	130.1	118.1	108.0	113.7	98.2	109.0	137.9	172.5	24.3	135.3	91.4	23.5	360.2	124.9	23.3	205.2	184.1	[illegible]
CELL A — Bottom Band (-14 to -20)	118.5	143.1	98.7	98.9	123.3	134.2	98.8	109.0	26.2	110.3	83.0	26.0	130.0	109.9	25.8	241.9	147.8	31.
CELL A — Subgrade (-20 to -24)	34.8	35.2			44.1	34.0	40.1	35.9	32.1	36.1	33.1	29.9	35.2	37.6	-	42.5	-	-
CELL B — Cover (2 to 0)	-	-	-	-	28.7	31.1	52.8	19.9		24.6	17.6		34.8	33.5		42.8	44.2	
CELL B — Top Band (0 to -6)	53.8	105.0	103.2	92.0	62.6	61.6	50.5	69.0		228.0	52.8		55.5	74.6		101.2	84.8	
CELL B — Middle Band (-6 to -14)	52.4	112.5	151.7	84.8	80.7	116.1	163.4	106.4		166.5	109.7		143.1	189.7		172.8	157.4	
CELL B — Bottom Band (-14 to -20)	54.2	71.3	99.2	68.0	137.6	161.3	106.5	102.7		179.1	181.8		101.9	111.8		149.8	160.1	
CELL B — Subgrade (-20 to -24)	31.2	30.7	-	-	34.2	50.3	30.1	47.5		40.4	33.4		38.1	84.4		-	71.3	
CELL C — Cover (2 to 0)	-	-	-	-	13.4	18.9	-	19.0		20.4	24.9		21.4	29.3		31.1	16.6	
CELL C — Top Band (0 to -6)	79.7	27.2	64.3	70.2	72.4	52.0	66.4	75.5		51.9	96.5		60.8	101.4		63.4	110.6	
CELL C — Middle Band (-6 to -14)	103.5	105.2	88.5	130.4	80.9	96.2	105.6	101.1		79.7	114.0		81.0	94.2		90.3	149.6	
CELL C — Bottom Band (-14 to -20)	96.7	90.8	73.3	87.9	29.4	71.4	30.8	27.1		62.4	53.0		30.3	26.4		37.2	42.6	
CELL C — Subgrade (-20 to -24)	39.1	49.5	14.3	-	20.0	28.0	30.1	26.7		27.8	-		-	-		-	-	
Date	8-22-66		2-9-67		11-14-67		3-5-68			6-17-68			9-10-68			12-2-68		
TOTAL INS.	110		136		166		187			198			200			213		

of the copper leads in the access well, and overhauling of the chromatograph equipment including column replacement, did not correct the situation. Earlier, brief gaps in the data were generally caused by operating difficulties with the analytical equipment.

The gas components determined were carbon dioxide, methane, nitrogen, oxygen, and hydrogen. The maximum concentration found for the various gases at the two sample depths in each cell is reported in Table 5.2.1. The time (in days following cell completion) at which the maximum value was obtained is also shown as the parenthetical figure. It will be noted that the peak concentrations of nitrogen and carbon dioxide occurred early in the study, followed by a buildup in the concentration of methane.

This change in the concentration of gas constituents with time is clearly evident in the data of Table 5.2.2. The preparation of the data of this table was based on the chronological grouping of some 150 analyses into the time intervals indicated and averaging them. In Cell A, carbon dioxide concentrations gradually decreased over the first 2 yr from approximately 85% to 55% and then held at approximately 50% over the final 2 yr. Conversely, methane built up from approximately 5% at the start to approximately 45% after 2 yr, with little change occurring after that time. Nitrogen was never a major component in the gas samples taken from Cell A.

Cell B was similar to Cell A as far as construction was concerned. It did receive nearly twice as much water as Cell A. More important, there was abundant evidence that some of the air applied to Cell C was able to move through the undisturbed, 5-ft thick adobe-shale barrier separating the 2 cells and into Cell B. This was true especially during the first 2 yr or so when the aeration equipment was able to function normally on a planned program. The carbon dioxide decreased over the first 6 mo from approximately 85% to 50% at the upper level, and from approximately 70% to 40% at the lower level. Over the last 2

TABLE 5.2.1

MAXIMUM GAS COMPONENTS IN PERCENT BY VOLUME AND TIME OF OCCURRENCE IN CELLS A AND B

Gas Component	7-Foot Depth		13-Foot Depth	
	Cell A	Cell B	Cell A	Cell B
N_2	16.0 (290)	75.9 (234)	24.3 (34)	81.2 (181)
CO_2	95.4 (48)	94.4 (35)	96.3 (48)	92.7 (42)
CH_4	63.6 (1113)	61.6 (1063)	58.5 (1106)	57.1 (1091)
H_2	0.4 (123)	0.2 (65)	0.2 (34)	0.3 (58)
O_2	5.7 (34)	6.7 (893)	4.4 (72)	8.3 (35)

Note: The figures in parentheses indicate number of days elapsed since completion of cell.

TABLE 5.2.2

AVERAGE MAJOR GAS COMPONENTS IN PERCENT BY VOLUME FOR INDICATED TIME INTERVALS IN CELLS A AND B

Time Interval Since Cell Completion	Gas Component	7-Foot Depth		13-Foot Depth	
		Cell A	Cell B	Cell A	Cell B
Start to 3 Months	N_2	5.2	16	7.2	25
	CO_2	88	83	84	72
	CH_4	5	1.4	6.3	1.4
3 Months to 6 Months	N_2	3.8	46	1.3	58
	CO_2	76	51	73	40
	CH_4	21	1.7	25	1.1
6 Months to 1.0 Year	N_2	0.4	42	4.2	54
	CO_2	65	42	61	37
	CH_4	29	13	31	6.7
1.0 Year to 1.5 Years	N_2	1.1	17	2.2	43
	CO_2	52	48	58	35
	CH_4	40	33	40	20
1.5 Years to 2.0 Years	N_2	0.4	1.9	0.9	20
	CO_2	53	54	55	48
	CH_4	47	43	44	29
2.0 Years to 2.5 Years	N_2	0.2	0.5	0.6	3.9
	CO_2	52	52	54	53
	CH_4	48	47	44	42
2.5 Years to 3.0 Years	N_2	1.3	6.6	2.0	11
	CO_2	46	48	49	38
	CH_4	51	44	49	42
3.0 Years to 3.5 Years	N_2	0.9	3.7	3.6	6
	CO_2	50	50	48	47
	CH_4	47	45	47	46
3.5 Years to 4.0 Years	N_2	0.4	2.6	0.4	1
	CO_2	51	51	49	50
	CH_4	48	46	51	49

yr, the concentrations at both levels were comparable at 50%. Methane built up at each level over the first 2 yr from approximately 1% to 40%, and then held fairly constant over the balance of the time at approximately 45%. Nitrogen was a major component only during the first 1.5 yr, reaching concentrations of 55%.

The data of Cell C cannot be grouped in the above described fashion, for the on-off blower periods and the blower cycle used governed the gas composition more than the elapsed time. In general, when the blower was operating, the analysis would come up to expectations: oxygen as high as 20%, nitrogen as high as 80%, carbon dioxide as low as 1%, and methane as low as 0.5%. Table 5.2.3 carries a complete tabulation of blower on-time, during which Cell C received aeration. Many combinations of on-time and off-time were used, and it was ultimately found that an on-time of 1.0 hr and an off-time of 0.25 hr resulted in the maintenance of a satisfactory cell environment. Early in the investigation, when the fill material was fresh, a combination of even shorter on-time and longer off-time would result in too rapid oxidation accompanied by high temperatures, smoke, occasional fire (2), and odor problems.

5.3 Settlement. The bench marks used to measure settlement were concrete monuments originally set flush with the cell surface. There were 4 at each cell, located about 12 ft from the access well on N-S and E-W diameters. The reported settlement refers to the average movement of these benchmarks. There were portions of the cells that settled to a greater extent. In Cell C, for instance, the surface settlement around the access well was over 6 ft. The surveys were conducted weekly at the start for about the first 3 mo, biweekly for the next 3 mo, and then at approximately monthly intervals. Total settlement of Cells A, B and C is summarized in Table 5.3.1 and graphed in Figure 5.3.1. Cells A and B each settled a total of 2.20 ft and Cell C settled a total of 4.25 ft. The fact that the aerobic Cell C settled more than anaerobic Cells A and B is due to the greater reduction in volume of refuse through

TABLE 5.2.3

SUMMARY OF BLOWER "ON" TIME, CELL C

Time Interval Days	Blower Cycle		Remarks
	Hr On	Hr Off	
28-69	0.5	5.5	
69-104	0.5	2.5	
104-168	1.0	2.0	Odor complaints
182-193	0.5	2.5	
193-209	0.5	1.0	Fire in cell
259-286	0.5	2.5	Blower connections replaced
286-303	0.5	7.5	
305-402	0.5	7.5	Motor repaired
416-426	0.5	3.5	
428-465	0.5	3.5	Motor damaged, air lines flooded
601-844	0.5	3.5	Blower connections replaced
844-1145	0.5	1.0	Recirculation cell gas discontinued at 862 day
1145-1229	1.0	0.5	
1229-1266	1.0	0.25	Odor complaints
1277-1286	1.0	0.25	Ordor complaints
1294-1312	1.0	0.25	Heavy rain; cave-in around access well; blower flooded
1314-1316	1.0	0.25	Air line clogged
1361-1368	1.0	0.25	Air line clogged
1469-1606	1.0	0.25	Air line connected to access well

Note: Days reckoned from time of cell completion.

TABLE 5.3.1

SUMMARY OF CELL SETTLEMENT

Elapsed Time Since Cell Completion*		Total Settlement of Cell Surface in Feet Cell		
Years	Months	A	B	C
0	1	-	-	0.09
0	2	0.07	0.07	0.22
0	3	0.14	0.05	0.36
0	4	0.20	0.10	0.67
0	5	0.24	0.14	1.08
0	6	0.28	0.17	1.27
1	0	0.41	0.28	1.66
1	6	0.52	0.43	1.90
2	0	0.63	0.61	2.24
2	6	0.76	0.75	2.61
3	0	1.06	0.95	3.28
3	6	1.36	1.29	3.83
4	0	1.76	1.67	4.13
4	6	2.24	2.22	4.29

* Times approximate
Original cell depth was 20 ft

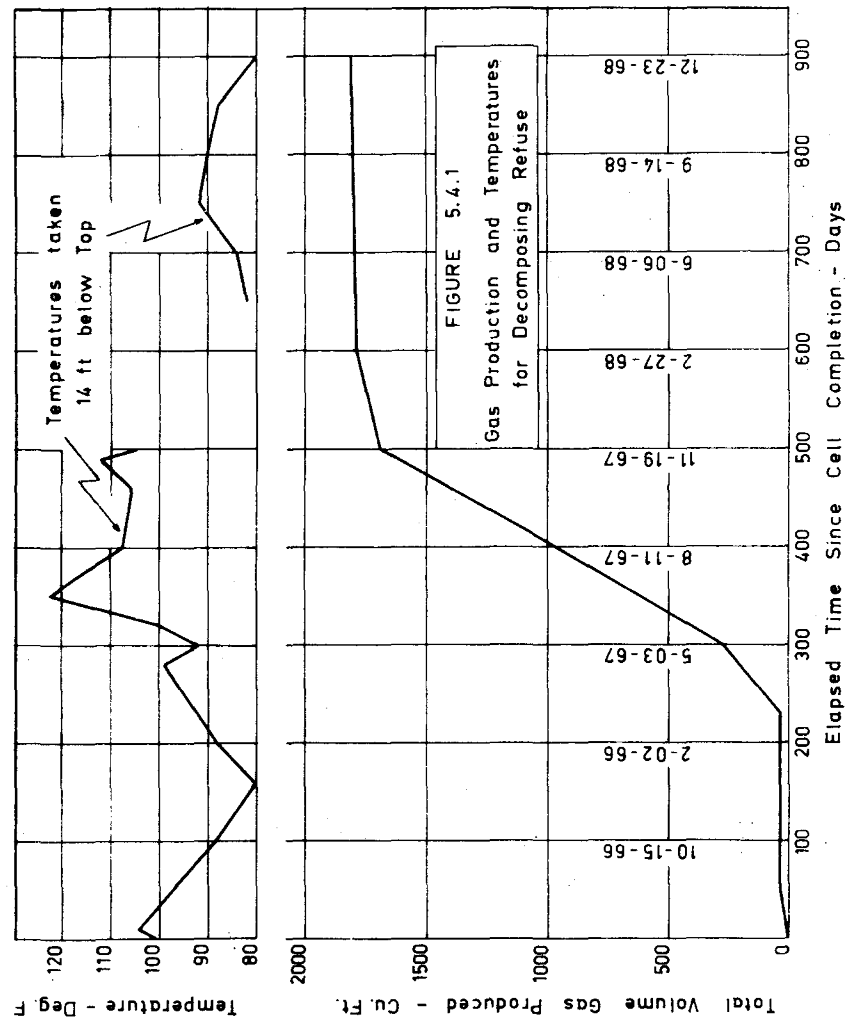


FIGURE 5.4.1
Gas Production and Temperatures for Decomposing Refuse

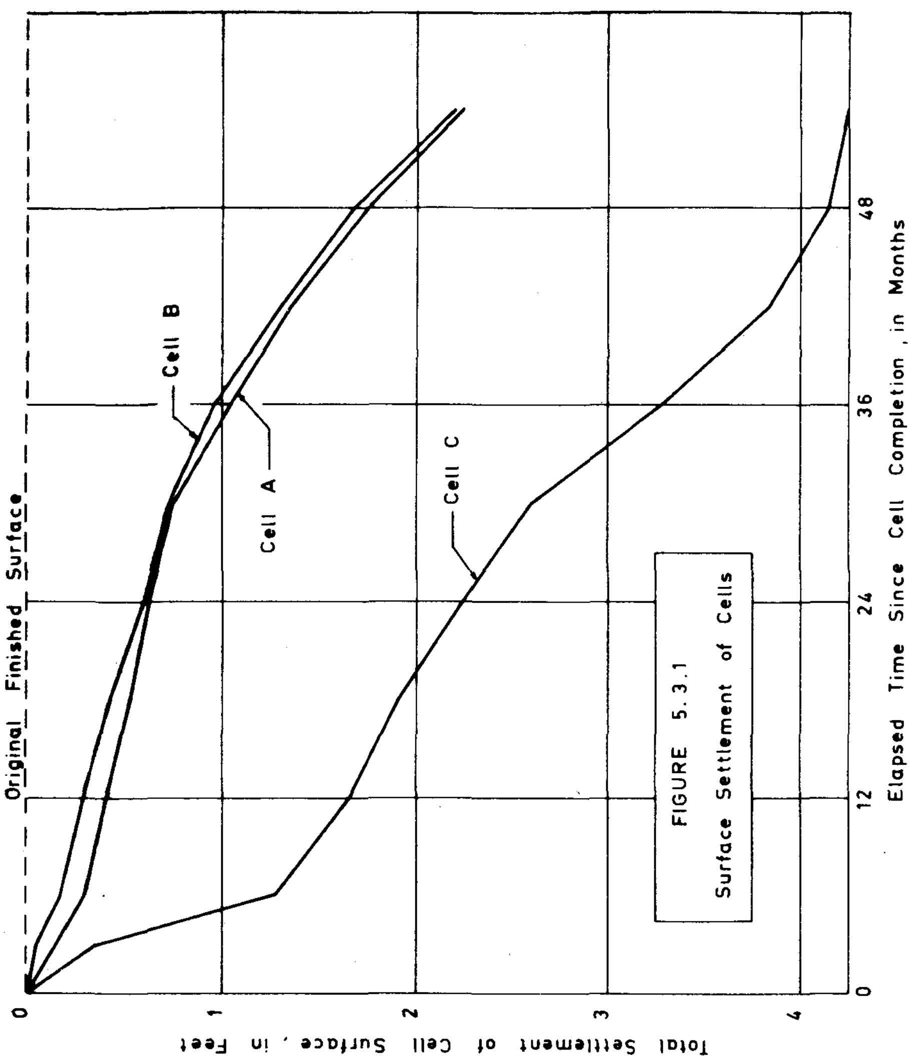


FIGURE 5.3.1
Surface Settlement of Cells

oxidation of the organic matter present. There was little identifiable matter in the December corings of Cell C other than plastic, rubber, some metal, scorched paper, and highly decomposed rags.

5.4 Gas Production. The gas production of Cell D - the only purpose for which it was constructed - is graphically illustrated in Figure 5.4.1. This cell consisted of a 10,000 gal underground steel storage tank, 95 in. I. D. x 28 ft high x ¼ in. th, which was packed with refuse, instrumented, and carefully sealed. The amount of gas produced was 2027 cu ft over a 907-day period. This is equivalent to 27.7 cu ft per cu yd of refuse.

The initial release of gas occurred within the first 3 days following packing and sealing of the tank. Only one cubic foot was produced in the following 50 days, and then none until the 230th day. This long period of non-production could have been due to acidification or low temperatures unfavorable to bacterial action. By the time gas production ceased, the temperatures within the tank were less than 90 deg F and ultimately dropped to the low seventies. The pickup in gas production accompanied a rise in temperature as shown in the Figure 5.4.1.

Gas production might also have been delayed until the tank was fully stabilized as an anaerobic unit. After packing, the tank was tested for leakage by admitting compressed air, and the unit was initially aerobic.

A manometer was fitted into a gas line and was used as a constant check to make certain there were no leaks in the tank or piping.

5.5 Temperatures. All cells reached maximum temperatures very early in the study. Cell A reached 108 deg F after 79 days, Cell B 120 deg F after 31 days, Cell C 193 deg F after 174 days, and Cell D 117 deg F after 368 days. Over the final 2 yr, temperatures in Cell A ranged between 53 and 88 deg F, in Cell B between 60 and 90 deg F, in Cell C between 90 and 164 deg F, and in Cell D between 67 and 120 deg F. Cell D, during the final year, never rose above 92 deg F.

6. PROGRESS REPORT - 1968

6.1 External Climatic Factors. Monthly average air temperatures and daily rainfalls were obtained from the Pomona Weather Station records and are recorded in Table 6.1.1. Daily temperatures are recorded in Table 6.5.1. The total rainfall at the test site was 9.4 in.

6.2 Application of Water. In Table 6.2.1 are shown the amounts of water applied to Cell A. The required annual amount of water to simulate the selected Seattle rainfall of 1961 is 42.52 in. The actual amount of water applied during the year was 33.94 in. irrigation water plus 9.39 in. rainfall for a total of 43.33 in.

In Table 6.2.2 are shown the amounts of water applied to Cell B. The actual amount of water applied during the year was 145.28 in. of irrigation water plus 9 39 in. rainfall for a total of 154.67 in. Faulty operation of the tensiometer equipment resulted in the application of far more water than necessary during July, August, and September for support of the Bermuda grass.

The coring program initiated on August 22, 1966 for the purpose of determining the moisture content of the cells was continued. The cells were cored every 3 mo beginning in March, 1968 and samples were taken at 2-ft depth increments. The top cover and subgrade were also sampled when feasible. The moisture analyses for the 2 cores of Cell A appear in Table 6.2.3.

The moisture content of the core profile averaged 50% on a wet weight basis during the year, an increase of 5% over the previous year. The moisture content of the subgrade was again less than that of the bottom layer of the refuse in all but a single case, indicating very slow movement of water into the ground or greater water capillarity of the refuse than the ground. At the bottom of the table are shown the average moisture contents for the top portion of the cell (2-6 ft), the middle portion (8-14 ft), and the bottom portion

TABLE 6.1.1

External Climatic Factors

Month 1968	Day	Rainfall, In Daily	Rainfall, In Cumulative	Temperatures, Deg F Ave Max	Temperatures, Deg F Ave Min	Temperatures, Deg F Mean
January	3	0.05		64.2	42.9	53.6
	11	0.14				
	16	0.05				
	27	0.37				
	28	0.40				
	31	0.13	63.20			
February	09	0.25		69.3	50.1	59.7
	10	0.11				
	13	0.34				
	14	0.26				
	17	0.01				
	27	0.03	64.20			
March	02	T		70.4	47.7	59.0
	06	0.02				
	07	0.15				
	08	3.83				
	13	0.18				
	14	0.06				
	17	0.03				
	18	T	68.47			
April	01	0.12				
	02	0.50				
May	06	T				
	12	0.03				
	13	T				
	21	T	68.50	76.2	53.5	64.9
June	07	0.03	68.53	81.9	56.9	69.4
July	28	0.05	68.58	90.1	61.9	76.0
August	01	0.00	68.58	87.7	60.8	74.3
September	01	0.00T	68.58	86.4	60.3	73.4
October	03	0.13				
	14	0.02				
	30	0.32	69.05	78.4	55.4	67.0

(Continued on Page 21)

TABLE 6.1.1 (Continued)

External Climatic Factors

Month 1968	Day	Rainfall, In		Temperatures, Deg F		
		Daily	Cumulative	Ave Max	Ave Min	Mean
November	04	0.04				
	15	0.42				
	16	0.03	69.54	71.2	49.4	60.3
December	11	0.06				
	15	0.02				
	16	0.20				
	20	0.10				
	25	0.54				
	26	0.37	70.83	62.0	48.5	51.8

TABLE 6.2.1

Actual Amounts of Water Applied to Cell A

Month 1968	Water Gal	Applied In.	Rainfall In.	Total Water Applied, In.		Seattle, Wash. Rainfall Water Required, In.	
				Monthly	Cumulative	Monthly	Cumulative
January	12,688	6.64	1.14	7.78	178.19	7.71	148.99
February	12,913	8.08	1.00	9.08	187.27	9.11	158.10
March	1,750	0.70	4.27	4.97	192.24	4.45	162.55
April	3,373	1.80	0.62	2.42	194.66	2.35	164.90
May	3,500	2.00	0.03	2.03	196.69	3.07	167.97
June	2,184	1.00	0.03	1.03	197.72	0.54	168.51
July	1,619	0.31	0.05	0.36	198.08	0.75	169.26
August	4,971	2.17	0.00	2.17	200.25	0.82	170.08
September	0	0	0.00	0.00	200.25	0.46	170.54
October	5,476	2.55	0.47	3.02	203.27	3.27	173.81
November	4,568	4.69	0.49	5.18	208.45	4.67	178.48
December	4,366	4.00	1.29	5.29	213.74	5.32	183.80

TABLE 6.2.2

Actual Amounts of Water Applied to Cell B

Month 1968	Water Applied Gal	Water Applied In.	Rainfall In.	Total Water Applied, In. Monthly	Total Water Applied, In. Cumulative
January	0	0	1.14	1.14	238.51
February	0	0	1.00	1.00	239.51
March	0	0	4.27	4.27	243.78
April	5,120	3.28	0.62	3.90	247.68
May	9,373	6.00	0.03	6.03	253.71
June	3,422	2.20	0.03	2.23	255.94
July	53,709	34.43	0.05	34.48	290.42
August	85,107	54.50	0.00	54.50	344.92
September	43,564	27.80	0.00	27.80	372.72
October	42,399	14.36	0.47	14.83	387.55
November	1,901	1.22	0.49	1.71	389.26
December	2,328	1.49	1.29	2.78	392.04

TABLE 6.2.3

CELL A MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	March 1968				June 1968			
	Core No. 7		Core No. 8		Core No. 9		Core No. 10	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover	21.2	27.0	58.0	137.9	17.8	21.7	21.3	27.1
2	14.5	17.0	95.3	131.6	22.4	28.8	10.9	12.2
4	48.2	93.1	14.3	16.7	48.7	95.1	38.1	61.5
6	46.1	85.5	59.2	145.4	46.7	87.6	46.7	87.7
8	59.9	149.1	64.4	180.8	43.1	75.7	52.5	109.6
10	47.0	88.7	55.7	125.9	57.2	133.4	33.5	142.4
12	63.3	172.5	62.2	164.2	67.1	203.6	46.0	85.2
14	58.6	141.3	69.3	219.0	56.3	128.6	73.9	28.3
16			58.7	142.2	64.8	184.4	43.5	77.0
18	50.5	102.0	57.7	136.6	53.2	113.8	56.8	131.5
20	48.9	95.5	32.5	48.2	27.4	32.8	28.9	40.6
Subgrade	28.6	40.1	26.4	35.9	26.4	36.1	24.9	33.1
Averages 2-6	36.3	65.2	56.3	97.9	39.3	70.5	31.9	53.8
8-14	57.2	137.9	62.9	172.5	55.9	135.3	51.5	91.4
16-20	49.7	98.8	49.6	109.0	48.5	110.3	43.1	83.0
Entire Core	48.6	105.0	56.9	131.1	48.7	108.8	43.1	77.6

(Continued on Page 25)

TABLE 6.2.3 (Continued)

CELL A MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	September 1968				December 1968			
	Core No. 11		Core No. 12		Core No. 13		Core No. 14	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover	18.5	22.8	22.6	29-1	28.3	39.6	31.4	45.8
2	23.8	31.1	23.4	30.5	18.6	22.9	22.6	29.3
4	30.0	42.1	32.5	48.1	44.7	81.0	13.2	15.3
6	30.6	44.0	46.5	86.9	48.9	95.6	41.7	71.7
8	79.1	365.7	52.2	109.1	25.7	34.6	61.1	73.0
10	58.8	142.9	54.9	121.6	22.2	28.5	59.2	145.4
12	78.5	412.1	59.5	147.1	59.4	146.5	76.1	317.9
14	83.9	520.1	54.9	121.6	86.3	611.0	66.7	200.0
16	56.9	132.3	61.4	158.9	60.8	155.0	72.7	266.5
18	67.0	202.7	55.0	122.2	84.4	539.7	56.4	129.3
20	35.5	55.0	32.7	48.7	23.7	31.1	32.3	47.6
Subgrade	26.0	35.2	27.3	37.6	29.8	42.5	-	-
Averages 2-6	28.1	39.1	34.1	55.2	37.4	66.5	25.8	38.7
8-14	75.1	360.2	55.4	124.9	48.4	205.2	65.8	184.1
16-20	53.1	130.0	49.7	109.9	56.3	241.9	53.8	147.8
Entire Core	54.4	194.8	47.3	99.5	47.5	174.6	50.2	129.6

(16-20ft). The band with the highest moisture content was between 8 and 14 ft below the surface.

The moisture analyses for the 2 cores of Cell B appear in Table 6.2.4. The moisture content of the core profile averaged 50% on a wet weight basis, the same as Cell A despite the application of nearly 3.5 times as much water. The moisture content of the subgrade was generally from 10% to 25% less than that of the bottom layer of refuse, again indicating slow movement of water into the ground. However, the moisture content of the earth cover was little different from that of the top layer of refuse, especially after application of the excessive amounts of water during the summer months. Considering the greater application of water to Cell B, and that the top cover of the cell was prepared for the growing of turf, the relationship is reasonable. The average moisture contents of the designated cell bands again indicate a downward transfer of water as in Cell A, and, with the exception of the June cores, again show that the highest moisture content was in the 8-14 ft band. Direct observation of core samples taken at the bottom at the Fall coring showed a condition of saturation.

Cell C received no water during the year other than the normal rainfall of 9.39 in. The moisture analyses for the 2 cores of Cell C appear in Table 6.2.5. The moisture content of the core profile averaged 40% on a wet weight basis. In contrast to Cells A and B, the driest material was always found in the bottom band, a condition to be expected since the forced air was introduced into the landfill from air ducts located beneath the fill. Sampling of the subgrade was discontinued because of the danger of striking the air ducts.

The core descriptions and core temperatures for all of the cells for the final coring in December are presented in Table 6.2.6. As expected, the cores of Cell C demonstrated an advanced stage of decomposition over Cells A and B. Paper and paper products were frequently scorched, grass with the original

TABLE 6.2.4

CELL B MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	March 1968				June 1968			
	Core No. 7		Core No. 8		Core No. 9		Core No. 10	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover	34.6	52.8	16.6	19.9	19.7	24.6	14.9	17.6
2	29.6	42.1	28.2	39.2	27.4	37.7	16.9	20.4
4	27.3	37.6	44.8	81.3	67.4	206.8	26.5	36.1
6	41.8	71.8	46.4	86.4	81.5	439.6	50.4	101.8
8	59.3	145.7	60.8	154.9	56.6	130.2	33.1	49.4
10	-	-	43.3	76.5	37.7	60.6	61.7	161.0
12	65.4	188.7	45.6	83.9	78.1	356.7	57.2	133.4
14	60.9	155.7	52.5	110.4	54.5	118.6	48.7	94.8
16	61.2	157.6	45.9	84.8	72.8	267.7	73.8	282.2
18	54.1	117.9	58.8	142.7	64.2	179.7	61.9	162.8
20	30.6	44.0	44.6	80.6	47.4	90.0	50.1	100.5
Subgrade	23.1	30.1	32.2	47.5	28.7	40.4	25.0	33.4
Averages 2-6	32.9	50.5	39.8	69.0	58.8	228.0	31.3	52.8
8-14	61.9	163.4	50.6	106.4	56.6	166.5	50.2	109.7
16-20	48.6	106.5	49.8	102.7	61.5	179.1	61.9	181.8
Entire Core	47.8	106.8	47.1	94.1	58.7	188.8	48.0	114.2

(Continued on Page 28)

TABLE 6.2.4 (Continued)

CELL B MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	September 1968				December 1968			
	Core No. 11		Core No. 12		Core No. 13		Core No. 14	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover	25.8	34.8	25.1	33.5	30.0	42.8	30.6	44.2
2	24.7	32.9	30.4	43.7	30.9	44.6	33.2	47.9
4	39.1	64.2	92.0	72.4	56.2	128.3	50.6	102.4
6	41.0	69.5	51.8	107.7	56.6	130.6	49.9	104.1
8	63.1	168.9	62.8	168.5	67.4	206.3	64.7	182.9
10	52.7	111.5	61.0	156.6	51.6	106.4	66.8	201.6
12	60.5	153.4	75.2	299.1	73.1	189.6	29.8	42.5
14	58.1	138.6	57.4	134.5	65.4	189.0	66.9	202.6
16	57.0	132.6	61.0	156.6	64.5	181.4	68.0	192.3
18	53.7	116.0	49.9	99.5	68.5	218.5	67.9	211.5
20	36.4	57.1	44.2	79.2	33.1	49.5	43.4	76.6
Subgrade	27.6	38.1	45.4	84.4	-	-	41.4	71.3
Averages 2-6	34.9	55.5	41.4	74.6	47.9	101.2	44.6	84.8
8-14	58.6	143.1	64.1	189.7	64.4	172.8	57.1	157.4
16-20	49.0	101.9	51.7	111.8	55.4	149.8	59.8	160.1
Entire Core	48.6	104.5	53.6	131.8	56.7	144.4	54.1	136.4

TABLE 6.2.5

CELL C MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	March 1968				June 1968			
	Core No. 7		Core No. 8		Core No. 9		Core No. 10	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover	-	-	16.0	19.0	16.9	20.4	19.9	24.9
2	24.2	32.0	29.0	40.8	26.1	39.2	23.5	30.7
4	45.0	81.7	44.4	79.9	29.3	41.4	57.3	134.4
6	46.7	85.6	51.4	105.7	42.9	75.0	55.4	124.4
8	48.7	95.1	53.2	113.8	41.0	69.6	49.3	97.3
10	37.6	60.3	46.7	87.5	48.0	92.4	53.2	113.9
12	51.1	104.3	48.9	95.8	47.7	91.2	51.5	106.2
14	61.9	162.7	51.8	107.4	39.6	65.6	58.1	138.7
16	24.4	32.3	21.8	27.9	59.8	148.9	49.1	96.4
18	24.5	32.5	22.1	28.4	19.0	24.5	24.8	33.0
20	21.8	27.6	20.0	25.0	12.1	13.8	22.9	29.7
Subgrade	23.2	30.1	21.0	26.7	21.8	27.8	-	-
Averages 2-6	46.8	66.4	41.6	75.5	32.8	51.9	45.4	96.5
8-14	49.8	105.6	50.1	101.1	44.1	79.7	53.0	114.0
16-18	23.6	30.8	21.3	27.1	30.3	62.4	32.3	53.0
Entire Core	41.0	71.4	43.4	71.2	36.6	66.2	44.5	93.0

(Continued on Page 30)

TABLE 6.2.5 (Continued)

CELL C MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	September 1968				December 1968			
	Core No. 11		Core No. 12		Core No. 13		Core No. 14	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover	17.6	21.4	18.4	29.5	23.7	31.1	14.2	16.6
2	26.4	35.9	21.5	27.3	27.7	38.4	27.8	39.6
4	33.9	51.4	44.7	80.8	41.4	70.7	56.2	128.3
6	48.8	95.2	66.2	196.2	44.7	81.2	62.1	163.9
8	38.4	62.3	48.4	93.7	50.7	102.7	57.5	135.1
10	54.0	117.6	47.7	91.3	47.7	-	53.8	116.5
12	46.0	85.3	49.4	97.7	40.8	68.9	67.2	204.6
14	20.0	58.7	-	-	49.8	99.2	58.7	142.3
16	27.2	37.4	20.1	26.4	26.6	36.3	34.3	51.0
18	19.9	24.9	23.3	30.4	26.5	36.1	27.9	37.8
20	22.2	28.5	18.4	22.5	28.1	39.2	24.7	38.9
Subgrade	-	-	-	-	-	-	-	-
Averages 2-6	36.4	60.8	44.1	101.4	37.9	63.4	48.7	110.6
8-14	39.6	81.0	48.5	94.2	47.3	90.3	59.3	149.6
16-18	23.1	30.3	20.6	26.4	27.1	37.2	29.0	42.6
Entire Core	33.7	59.7	34.0	66.6	38.4	63.6	47.0	105.8

TABLE 6.2.6

LOG OF CORES FOR CELLS A, B AND C - DECEMBER, 1968

Cell and Core No.	Elapsed Time Since Cell Completion Days	Distance Below Top of Cell Ft	Temp Deg F	Observation
A-13	1625	0	62	Dirt
		2	59	
		4	60	Pulpy, moist material
		6	74	Chunky, very decomposed, rotten rags
		8	68	Wood and plastic unaffected
		10	74	Damp, chunky, pulpy paper, green grass
		12	72	Some plastic decomposed, metal shiny
		14	72	Rubber and wood unaffected
		16	72	Rotten rags, wax paper unaffected
		18	68	Muddy grey clay
		22	70	Loose grey clay
A-14	1625	0	66	Dirt
		2	66	Dirt moist
		4	70	Rotten rags, chunky material no identity
		6	76	Pulpy moist paper, wood unaffected
		8	70	Plastic and tennis hoes unaffected
		10	69	Plastic and cellophane unaffected
		12	68	Glass and hose unaffected
		14	70	Much paper and grass decomposed
		16	74	Moist damp chunks no identity, metal shiny
		18	74	Grass clippings green, hose unaffected
		20	74	Loose moist grey clay
B-13	1625	0	66	Dirt moist
		2	66	
		4	68	Loose and pulpy material
		6	68	Loose and pulpy material
		8	74	Grass unaffected, paper pulpy, metal shiny
		10	74	Plaster and wood unaffected
		12	73	Brown chunk material no identity
		14	76	Rubber unaffected, grass light green
		16	76	Wet dark decomposed material
		18	76	Metal shiny
		20		Wet dirt

(Continued on Page 32)

TABLE 6.2.6 (Continued)

LOG OF CORES FOR CELLS A, B AND C - DECEMBER, 1968

Cell and Core No.	Elapsed Time Since Cell Completion Days	Distance Below Top of Cell Ft	Temp Deg F	Observation
B-14	1625	0	62	Dirt
		2	64	Dirt
		4	66	Moist slushy material, green grass
		6	70	Wood, plaster and rubber unaffected
		8	72	Very wet pulpy paper, shiny metal
		10	72	Much glass unaffected, even labels
		12	74	Rotten wet muddy rags
		14	74	Plastic unaffected, shiny metal
		16	74	Rubber unaffected
		18	80	Wire unaffected
		20	80	Dark mud
		22		Dirt
C-13	1602	0	66	Dirt
		2	68	Dirt
		4	74	Rotten rags, loose dry chunks
		6	80	Brown burnt paper, no grass
		8	86	Plastic, hose and metal unaffected
		10	98	Paper burnt and illegible
		12	98	Hot dry very decomposed material
		14	102	Aluminum unaffected
		16	106	Dark brown decomposed materials
		18	106	Loose moist sand
		20	100	
C-14	1602	0	70	Dirt
		2	70	Dirt
		4	74	Decomposition evident, wood unaffected
		6	78	Rotten rags, metal oxidized
		8	90	Glass and plastic unaffected
		10	90	Dark warm chunky material
		12	90	Rubber hose unaffected, no grass
		14	90	Decomposed material, no identity
		16	98	Dirt
		18	102	Some oxidized metal, mostly dirt
		20	100	Dirt

green color was rarely seen, and there was much unidentifiable material.

6.3 <u>Settlement</u>. The settlement of all cells was periodically measured by survey, and the data are given in Table 6.3.1. During the year, Cell A settled an additional 0.89 ft, Cell B 0.93 ft, and Cell C 0.51 ft. This was the first year in which settlement of the aerated Cell C lagged behind Cells A and B. Cells A and B settled nearly twice as much as Cell C, thereby reducing the settlement of Cell C from what had been 3 times as much as Cells A and B to twice as much. Cells A and B each settled a total of approximately 2.20 ft, and Cell C settled a total of approximately 4.25 ft.

The differential settlement between the top half and the bottom half of all cells increased during the year. In Cell A the differential was 0.70 ft, in Cell B 0.86 ft, and in Cell C 0.64 ft. This is simply indicative of an increase in the "equivalent" density of the bottom fill material.

6.4 <u>Gas Quality</u>. As shown in Table 6.4.1, Cell A continued to produce a gas high in carbon dioxide and methane at top and bottom levels. Oxygen and nitrogen were present in varying minor amounts. There was no hydrogen.

As shown in Table 6.4.2, Cell B also continued to produce a gas high in carbon dioxide and methane at top and bottom levels. Oxygen and nitrogen were present in varying minor amounts. There was no hydrogen.

The gas analyses for Cell C are shown in Table 6.4.3, and this table should be correlated with Table 6.4.4 which summarizes blower operation. Heavy rains in March caused a cave-in around the access well and permitted surface water to move down along the casing and into the aeration channels thereby effectively blocking air passage. This difficulty was later compounded by the collapse of the main air line because of corrosion. In August, the main air line was relocated to discharge directly into the center access well, and any aeration was achieved by passage of air through existing openings or ports in the access well casing and into the cell. Because of the mistaken belief that air passage was

Cell Settlement Data

Elapsed Time Since Cell Completion (Days)	Total Settlement of Cell Surface, Ft			Total Settlement of Mid-Depth Surface, Ft		
	Cell Number			Cell Number		
	A	B	C	A	B	C
1266			3.8225			3.28
1290	1.4025	1.3300		1.03	0.84	
1294			3.9050			3.36
1318	1.4250	1.4000		1.05	0.89	
1329			4.0325			3.48
1353	1.5250	1.4800		1.10	0.94	
1357			4.0200			3.46
1381	1.5700	1.5050		1.13	0.95	
1378			4.0375			3.47
1402	1.6225	1.5425		1.17	0.98	
1429			4.0925			3.52
1453	1.7500	1.6675		1.25	1.06	
1452			4.1175			3.52
1476	1.8000	1.7150		1.28	1.08	
1483			4.1525			3.55
1507	1.9150	1.7925		1.34	1.11	
1509			4.1775			3.57
1533	1.9980	1.8675		1.38	1.13	
1546			4.2100			3.60
1570	2.0755	1.9475		1.39	1.18	
1584			4.2325			3.62
1608	2.1705	2.0925		1.48	1.29	
1606			4.2575			3.62
1630	2.2155	2.1825		1.51	1.36	

TABLE 6.4.1

Gas Composition in Cell A

Date 1968	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-04	1269	52.38	0.02	47.52	0.00	0.08	48.43	0.01	51.40	0.00	0.16
1-08	1273	52.42	0.03	47.47	0.00	0.08	48.86	0.02	50.90	0.00	0.22
1-15	1280	52.16	0.01	47.78	0.00	0.05					
1-22	1287	51.39	0.04	48.43	0.00	0.14	48.85	0.11	50.64	0.00	0.40
1-29	1294	51.83	0.03	47.97	0.00	0.17	46.84	0.08	52.77	0.00	0.31
2-05	1301	52.10	T	47.80	0.00	0.10	48.55	0.04	51.29	0.00	0.12
2-12	1308	53.16	0.02	46.74	0.00	0.08	50.70	0.06	49.04	0.00	0.20
2-26	1322	52.08	0.02	47.78	0.00	0.12	50.20	0.07	49.57	0.00	0.16
3-11	1336	44.20	0.15	54.14	0.00	1.51	36.41	0.09	62.06	0.00	1.44
3-23	1348	50.93	0.03	48.76	0.00	0.28	44.31	0.07	55.19	0.00	0.43
4-08	1364	52.29	0.06	47.37	0.00	0.28	47.82	0.07	51.91	0.00	0.20
4-16	1372	51.36	0.60	45.75	0.00	2.29	49.68	0.07	50.08	0.00	0.17
4-22	1378	52.44	0.03	47.42	0.00	0.11					
4-29	1385	51.40	0.05	48.25	0.00	0.30	48.90	0.07	50.84	0.00	0.19
5-06	1392	52.00	0.32	46.49	0.00	1.19	45.83	0.01	54.08	0.00	0.08
5-13	1399	51.64	0.04	48.18	0.00	0.14	47.64	0.07	52.11	0.00	0.18
5-20	1406	52.10	0.06	47.52	0.00	0.32	48.00	0.07	51.73	0.00	0.20
6-03	1420	52.38	0.03	47.32	0.00	0.27	50.16	0.06	49.57	0.00	0.21
6-10	1427	52.63	0.01	47.27	0.00	0.05	49.64	0.13	49.64	0.00	0.59
6-21	1438	52.39		47.50	0.00		55.14	0.56	42.14	0.00	2.16
7-02	1450	51.52	0.02	48.41	0.00	0.05					
7-08	1456	50.99	0.06	48.90	0.00	0.05	55.16	0.15	43.77	0.00	0.92
7-15	1463										
7-22	1470	63.03	0.04	36.82	0.00	0.11	46.78	1.08	46.78	0.00	4.76
7-29	1477	50.49	0.08	49.23	0.00	0.20					
8-05	1484	52.39	0.03	47.48	0.00	0.10					
8-14	1493	52.76	0.04	47.07	0.00	0.13	47.62	0.67	48.93	0.00	2.78

TABLE 6.4.2

Gas Composition in Cell B

Date 1968	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-04	1269	51.83	0.03	48.08	0.00	0.06	52.20	0.10	47.38	0.00	0.32
1-08	1273	52.04	0.02	47.90	0.00	0.04	51.78	0.03	48.06	0.00	0.13
1-15	1280	53.55	0.01	46.41	0.00	0.03		0.16			
1-22	1287	52.74	0.04	47.06	0.00	0.16					
1-29	1294	52.98	0.15	46.29	0.00	0.58	47.10	2.52	48.83	0.00	3.97
2-05	1301	53.01	0.16	46.30	0.00	0.53	51.94	0.05	47.71	0.00	0.30
2-12	1308	54.04	0.03	45.72	0.00	0.21					
2-26	1322	53.73	0.05	46.06	0.00	0.16					
3-11	1336						39.69	0.28	53.66	0.00	6.37
4-16	1372	51.20	0.82	43.73	0.00	3.95	52.81	0.05	46.87	0.00	0.27
4-22	1378	45.94	0.76	49.16	0.00	4.14	53.01	0.01	46.90	0.00	0.08
4-29	1385	50.78	0.80	44.43	0.00	3.99	45.09	0.03	54.73	0.00	0.15
5-06	1392	49.60	0.91	45.54	0.00	3.95	53.27	0.05	46.41	0.00	0.27
5-13	1399	49.84	0.90	45.19	0.00	4.07	52.84	0.04	46.89	0.00	0.23
5-20	1406	50.14	0.84	45.00	0.00	4.02	53.16	0.05	46.54	0.00	0.25
6-03	1420						51.39	0.05	48.30	0.00	0.26
6-10	1427	48.33	1.92	42.91	0.00	6.84	52.65	0.04	47.28	0.00	0.03
6-21	1438	48.29	1.01	46.68	0.00	4.02	46.69	1.61	48.16	0.00	3.54
7-02	1450						49.25	0.03	50.60	0.00	0.12
7-08	1456						46.27	0.05	53.51	0.00	0.17
7-15	1463						36.99	0.10	62.39	0.00	0.52
7-22	1470										
7-29	1477						50.22	0.04	49.55	0.00	0.19
8-05	1484						52.99	0.07	46.62	0.00	0.32
8-14	1493						44.99	0.30	53.88	0.00	0.83

TABLE 6.4.3

Gas Composition in Cell C

Date 1968	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn From Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-04	1245	40.46	0.51	24.13	T	34.90	17.69	11.50	11.59	0.00	59.22
1-08	1249	10.89	9.09	1.42	0.00	78.60	4.66	16.84	1.04	0.00	77.46
1-15	1256	8.89	9.25	3.26	0.00	78.60	1.62	21.00	0.66	0.00	76.72
1-22	1263	15.00	4.39	T	T	80.61	0.43	20.67	0.12	0.00	78.78
1-29	1270	28.70	1.38	22.36	0.10	47.46	3.37	18.80	1.22	0.00	76.61
2-05	1277	28.74	3.05	22.37	0.08	45.76	3.26	19.21	1.31	0.00	76.22
2-12	1284	15.53	3.22	0.32	0.03	80.90	0.99	20.68	0.18	0.00	78.15
2-20	1292	34.70	0.84	37.47	0.07	26.92	33.63	0.69	27.59	0.00	38.09
2-26	1298	8.66	8.37	0.54	0.01	82.42	0.49	20.88	0.12	0.00	78.51
3-11	1312	49.80	1.01	6.38	0.09	42.78	4.08	17.07	2.51	0.00	76.34
3-23	1324	45.02	0.45	51.25	0.03	3.25	44.67	0.26	49.49	0.00	5.58
4-08	1340	47.71	0.66	49.13	0.02	2.48	44.49	0.57	44.49	0.00	11.43
4-16	1348	47.53	0.48	49.83	0.04	2.12	40.10	0.73	32.52	0.00	26.65
4-22	1354	49.85	0.26	48.73	0.03	1.13	31.07	2.00	20.99	0.00	45.94
4-29	1361	47.01	0.30	51.26	0.03	1.40	42.10	0.89	26.86	0.00	30.15
5-06	1368	50.86	0.32	47.54	T	1.28	23.74	3.96	9.64	0.00	62.66
5-13	1375	48.19	0.27	50.18	0.03	1.33	43.12	0.80	26.34	0.00	29.74
5-20	1382	48.99	0.26	49.58	0.03	1.14	44.13	0.72	25.62	0.00	29.53
6-03	1396	50.72	0.24	47.35	0.02	1.67	44.51	0.80	25.02	0.00	29.67
6-10	1403	51.50	0.19	47.39	0.05	0.87	25.72	1.40	12.36	0.00	60.52
6-21	1414	25.49	2.40	60.91	0.07	11.13	19.56	4.94	6.78	0.00	68.72
7-02	1426	49.77	0.52	47.66	0.03	2.02					
7-15	1439	43.03	1.26	39.61	0.03	16.07					
7-22	1446						49.27	0.08	50.10	0.00	0.55
7-29	1453	48.77	0.43	46.64	0.00	4.16					
8-05	1460	51.12	0.62	44.73	0.00	4.15					
8-14	1469	46.25	1.92	43.36	0.00	8.47					
10-28	1543		21.9			78.1		21.4			78.6
11-01	1547		21.4			78.6		21.7			78.3
11-14	1560		21.22			78.78		20.55			79.45

TABLE 6.4.4

Summary of Blower Operation, Cell C

Elapsed Time In Days Following Completion of Cell		Blower		Blower Cycle		Remarks
B	C	On	Off	Hr on	Hr off	
	1229	x		1.0	0.25	
	1249	x				Steam emitted
	1256	x				Odor complaint
	1259	x				Odor complaint
1290	1266		x			Smoke appeared to be emitted 5.0 ft water bottom Cell B
	1277	x				729 gal applied to surface
	1286		x			Odor problem - steam emitted
	1292		x			Earth cover applied over periphery
1318	1294	x				
	1298	x				Slight odor - steam emitted
	1309	x				Heavy rains - cave-in around access well
1336	1312		x			Blower full of water
	1314	x				
	1316		x			Stoppage in air distribution system
1381			x			
	1361	x				
	1368		x			Unable to clear air distribution lines
1402			x			
1446			x			6.0' off water in Cell B
1478			x			
	1469	x				Connected line from blower to access well and started blower
1507		x				
1573		x				
1630	1606		x			Blower turned off

being blocked by flooded ducts, the collapse of the air line was not discovered for about 3 mo and consequently the blower was not operated for this period.

Values of carbon dioxide and methane were predictably high during the long off period of the blower. Conversely, oxygen and nitrogen values were high during the blower on periods.

6.5 Cell Temperatures. The temperature data for Cells A and B are presented in Table 6.5.1, and for Cell C in Table 6.5.2. To obtain the internal temperatures of Cells A and B (following failure of thermistors), thermometers were suspended in 3/4-in. dia, water-filled pipes which, in turn, were set into the shafts established by the coring operation. The system was the same as that installed for Cell C in 1967. All of the temperature readings are correlated with the date on which they were taken and the total elapsed time in days following completion of each cell.

In Cell A, the temperature range was 40 deg F, from 60 deg F in the winter to 100 deg F in the summer.

In Cell B, the temperature range was 28 deg F, from 62 deg F in the winter to 90 deg F in the summer. The excessive amounts of water applied apparently had a cooling effect.

In Cell C, the temperature range at a depth of 4 ft was 43 deg F, from 76 deg F to 119 deg F. At the 10-ft depth, the range was 63 deg F, from 84 deg F to 143 deg F. With the blower operating in the normal manner, temperatures at the 10-ft depth were much higher than at the 4-ft depth. With the blower off, the temperature differential was slight.

6.6 Gas Production. In Table 6.6.1 are presented the performance data for Cell D for 1968. Gas production within the cell totalled less than 100 cu ft, with less than one-fourth of it being collected over the final 8 mo. There was virtually no gas produced over the last 6 mo. Frequent checking insured that there were no leaks in the system.

TABLE 6.5.1

Temperatures in Cells A and B

Date 1968	Air Temperature* Deg F Max	Min	Mean	Elapsed Time Since Cell Completion (Days)	Cell A Deg F	Cell B Deg F
4-16	65.1	53.0	59.0	1372	62	62
4-22	72.0	44.0	62.0	1378	69	72
4-29	86.1	51.8	69.0	1385	68	76
5-06	72.2	52.6	62.4	1392	64	66
5-13	62.0	49.4	55.7	1399	65	65
5-20	81.2	49.1	65.0	1406	77	77
5-31	79.0	59.0	69.0	1417	69	69
6-03	82.8	57.1	70.0	1420	72	75
6-10	86.6	51.4	69.0	1427	72	76
6-17	96.6	61.4	79.0	1434	78	80
6-29	73.7	56.0	64.8	1446	88	80
7-02	87.8	53.8	70.8	1449	78	82
7-08	90.7	68.8	79.7	1455	77	78
7-15	83.4	59.7	72.5	1462	74	75
7-22	92.3	62.8	77.3	1469	81	84
7-29	91.3	66.8	81.0	1476	84	86
8-05	89.2	59.7	74.4	1483	82	84
8-14	79.2	56.9	68.0	1492	80	82
8-20	77.6	61.0	69.3	1498	75	76
8-29	96.9	67.0	82.0	1507	-	90
9-09	103.2	70.0	87.0	1518	76	78
9-17	89.8	53.9	71.8	1526	77	76
9-24	99.1	59.0	79.0	1533	76	76
10-01	68.5	60.1	64.3	1540	75	75
10-07	70.4	59.2	64.8	1546	75	75
10-18	85.0	57.0	71.0	1557	74	74
10-28	80.2	55.4	67.8	1567	74	73
11-03	70.0	49.2	59.6	1573	73	73
11-11	81.1	53.0	67.0	1581	73	73
11-18	73.1	49.4	62.2	1588	73	73
11-25	62.5	44.1	53.3	1595	72	73
12-02	62.7	41.4	52.0	1602	72	70
12-08	69.6	42.9	56.3	1608	68	70
12-15	59.6	48.7	54.2	1615	65	68
12-30	66.3	39.2	52.7	1630	60	66

* Data from Pomona Weather Bureau

Cell temperatures from thermometers suspended in 3/4-in., water-filled pipes installed March 5 in cored holes. Thermometers located 8 ft above bottom.

TABLE 6.5.2

Temperatures in Cell C

Date 1968	Elapsed Time Since Cell Completion (Days)	Temperatures, °F Air* Max	Min	Mean	In Cell at Distances Indicated above Bottom 10 Ft	2 Ft
1-04	1245	60.5	38.3	49.4	119	143
1-08	1249	60.0	34.2	47.4	102	123
1-15	1256	67.8	45.8	56.8	88	94
1-22	1263	75.2	46.7	61.1		84
1-29	1270	54.7	35.2	45.0	102	110
2-05	1277	73.4	49.8	61.6	112	126
2-14	1286	61.2	46.5	53.9		
2-20	1292	59.0	53.0	56.0	112	122
2-26	1298	75.0	56.4	65.7	92	96
4-16	1348	65.1	53.0	59.0	118	120
4-22	1354	72.0	44.0	62.0	118	121
4-20	1361	86.1	51.8	69.0	118	120
5-06	1368	72.2	52.6	62.4	118	118
5-13	1375	62.0	49.4	55.7	118	122
5-20	1382	81.2	49.1	65.0	118	112
5-31	1393	79.0	59.0	69.0	118	110
6-03	1396	82.8	57.1	70.0	118	112
6-10	1403	86.6	51.4	69.0	118	
6-21	1414	96.6	61.4	79.0	118	117
6-29	1422	73.7	56.0	64.8	118	117
7-02	1426	87.8	53.8	70.8	118	111
7-08	1432	90.7	68.8	79.7	117	114
7-15	1439	83.4	59.7	72.5	118	118
7-22	1446	92.3	62.8	71.3	116	114
7-29	1453	91.3	66.8	81.0	116	114
8-05	1460	89.2	59.7	74.4	115	113
8-14	1469	79.2	56.9	68.0	115	109
8-20	1475	77.6	61.0	69.3	115	110
8-29	1484	96.9	67.0	82.0	116	116
9-09	1494	103.2	70.0	87.0	116	115
9-17	1502	89.8	55.1	71.8	116	118
9-24	1508	99.1	59.0	79.0	115	117
10-01	1516	68.5	60.1	64.3	112	115
10-07	1522	70.4	59.2	64.8	110	115
10-18	1533	85.0	57.0	71.0	109	116
10-28	1543	80.2	55.4	67.8	116	109
11-03	1549	70.0	49.2	59.6	116	106
11-11	1557	81.1	53.0	67.0	114	107
11-18	1564	73.1	49.4	62.2	112	107
11-25	1571	62.5	44.1	53.3	116	104
12-02	1578	62.7	41.4	52.0	116	104
12-08	1584	69.6	42.9	56.3	115	102
12-15	1591	59.6	48.7	54.2	114	102
12-30	1606	66.3	39.2	52.7	114	102

* Data from Pomona Weather Bureau

Cell temperatures from thermometers installed in water baths and placed in cored holes.

TABLE 6.6.1

Gas Production and Temperatures in Cell D

Date 1968	Elapsed Time Since Cell Completion (Days)	Cumulative Volume of Gas Produced (cu ft)	Cell Pressure In. Water	Temperatures at Locations Below Top of Cell, Deg F 4 ft	14 ft
1-04	546	1928.51	0.50	62	
1-08	550	1933.50	0.25		
1-15	557	1939.14	0.00	68	
1-15	557	1939.14			
1-18	560	1941.66	0.12	68	
1-22	564	1945.25	0.25	68	
1-25	567	1951.87			
1-29	571	1956.90	0.25	69	
2-05	578	1963.78	3.50	70	
2-12	585	1971.99	0.25	78	
2-20	593	1978.13	0.25	77	
2-22	595	1979.22			
2-26	599	1982.55	0.25	81	
3-05	607	1982.55			
3-11	613	1983.23		80	
3-15	617	1983.38			
3-23	625	1983.78		76	
3-28	630	1983.94		76	
4-08	641	1984.27	0.25	74	
4-16	649	1989.17	0.25	75	76
4-22	655	1989.86	2.50	75	82
4-29	662	1994.28	0.25	74	82
5-06	669	1997.56	0.50	74	82
5-13	676	2001.22	0.00	74	81
5-20	683	2004.17	0.25	80	88
5-31	694	2018.01	0.50	79	81
6-03	697	2018.54	0.50	79	84
6-10	704	2019.11	0.25	75	84
6-21	715	2023.35		88	84
6-29	723	2023.45	0.25	88	84
7-02	726	2023.45		82	89
7-08	732	2023.53	0.375	82	86
7-15	739	2025.84		83	87
7-22	746	2026.48	1.4	86	83
7-29	753	2026.50	0.4	88	92
8-05	760	2026.51		86	91
8-14	769	2026.51	8.4*	85	90
8-20	775		1.0	82	87
8-29	784	2027.01		86	90
9-09	795	2027.12		88	90
9-17	803		0.1	86	90
9-24	810	2026.70		85	90
10-01	817	2026.70		85	90
10-07	823	2026.70		80	90

(Continued on Page 43)

TABLE 6.6.1 (Continued)

Gas Production and Temperatures in Cell D

Date 1968	Elapsed Time Since Cell Completion (Days)	Cumulative Volume of Gas Produced (cu ft)	Cell Pressure In. Water	Temperatures at Locations Below Top of Cell, Deg F 4 ft	14 ft
10-18	834	2026.71	0.5	80	89
10-28	844	2026.71		79	89
11-03	850	2026.71	0.5	73	88
11-11	858	2026.72		78	89
11-18	865	2026.72	0.25	75	89
11-25	872	2026.72		72	88
12-02	879	2026.72		68	86
12-08	885	2026.72	0.2	67	85
12-15	892	2026.72		59	80
12-30	907	2026.73		59	80

* Feed line to wet test cell closed for 4 days
Temperatures measured by thermometers installed in water baths

The last thermistor in the tank failed. A hole was drilled as close as possible to the tank wall. A 3/4-in. dia water-filled pipe was placed in this hole, and a thermometer was lowered into the pipe to a depth of 14 ft. Still available was a thermometer installed in an internal pipe at a depth of 4 ft.

The temperature at the 14-ft depth ranged from 76 deg F to 92 deg F. The temperature at the 4-ft depth (inside of the tank) ranged from 59 deg F to 88 deg F.

Photograph 1
Clamshell Used for Excavating
for Cell D

Photograph 2
Delivery of Cell D to Site

Photograph 3
Installation of Cell D

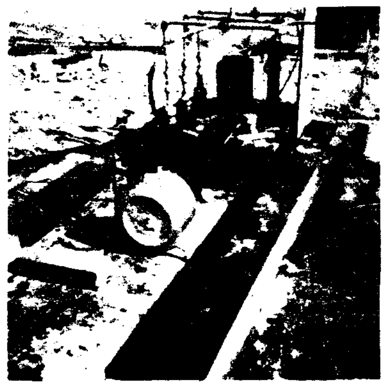
Photograph 4
Installation of Cell D

Photograph 5
Installation of Cell D

Photograph 6
Assembly of Internal Gas
Collection Piping for Cell D

Photograph 7
Gas Collection Piping Installed at
Top Level During Packing of Cell D

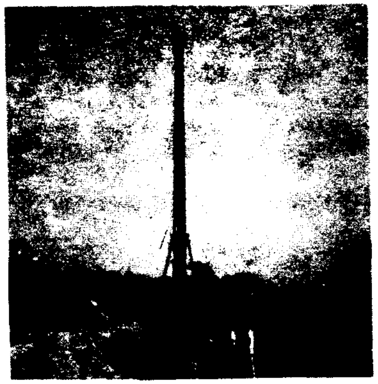
Photograph 8
External Gas Collection
Manifold, Cell D



Photograph 9
External Gas Collection
Manifold, Cell D

Photograph 10
External Gas Collection
Manifold, Cell D

Photograph 11
Cover Plate for Cell D Manhole
Showing Gas Line Connectors
and Pipe Used as Water Bath
for Thermometer at 4-ft Depth



Photograph 12
Coring Rig

Photograph 13
Core Examination

Photograph 14
Core Examination

Photograph 15
View of Cell C (March 1968)
Showing Surface Settlement

Photograph 16
View of Cell C Showing Access Well
Exposed by Surface Settlement

Photograph 17
View of Cell C Showing Settlement and
Development of Surface Cracks

7. PROJECT CO-INVESTIGATORS

The following are brief sketches of the professional personnel who served as co-investigators.

A. Robert C. Merz

Born September 13, 1911, at Milwaukee, Wisconsin

BS in Civil Engineering, 1933, University of Wisconsin
MS in Civil Engineering, 1950, University of Wisconsin

1935-1948, Sanitary Engineer, Chain Belt Co., Milwaukee, Wisconsin
1948-1950, Instructor, University of Wisconsin
1950-date, Professor and Chairman, Department of Civil Engineering, Assistant Dean, School of Engineering, University of Southern California

Member ASCE (F), AWWA, APHA, WPCF, ASEE, AIDIS, RSH, Chi Epsilon, Tau Beta Pi, Sigma Xi, Phi Kappa Phi, Blue Key
Senior Sanitary Engineer, USPHS (Inac. Res.)
Certified by EEIB

B. Ralph Stone

Born April 2, 1921, at New York, New York

BS in Engineering, 1943, University of California (Berkeley)
MS in Civil Engineering, 1944, University of California (Berkeley)

1944-1946, U. S. Public Health Service
1946-1948, U. N. World Health Organization (in China)
1948-1949, Inst. of Inter-American Affairs (in Colombia, S.A.)
1949-1951, Research Assoc., University of California (Berkeley)
1951-1953, Project Engineer, Fluor Corp., Los Angeles, California
1953-date, Research Assoc., University of Southern California, and Consulting Sanitary Engineer in private practice, President, Ralph Stone and Company, Inc. - Engineers

Registered Professional Engineer
Member ASCE (F), AWWA, ACS, WPCF, APHA, APWA, RSH, ASPO, AIP
Senior Sanitary Engineer, USPHS (Inac. Res.)
Certified by EEIB

SPECIAL STUDIES OF A SANIT[illegible]

Grant Number 8 R01 [illegible]

Second Progress Report to

Office of S[illegible]

United States Public Health [illegible]
Department of Health, Education [illegible]

January 1, 196[illegible] to [illegible] 31, 196[illegible]

Prepared by [illegible] Investigators

[illegible]
[illegible]

[illegible]
Research Associate

University of Southern California
Los Angeles, California

SPECIAL STUDIES OF A SANITARY LANDFILL

Grant Number 8 R01 UI00518-07

Second Progress Report to

Office of Solid Wastes

United States Public Health Service
Department of Health, Education, and Welfare

January 1, 1967 to December 31, 1967

Prepared by Principal Investigators

Robert C. Merz, Chairman
Department of Civil Engineering

Ralph Stone
Research Associate

University of Southern California
Los Angeles, California

UNIVERSITY OF SOUTHERN CALIFORNIA
SCHOOL OF ENGINEERING
UNIVERSITY PARK
LOS ANGELES, CALIFORNIA 90007

DEPARTMENT OF CIVIL ENGINEERING

March 15, 1968

Mr. Henry C. Steed, Jr.
Chief, Office of Grants Administration
Dept. of Health, Education and Welfare
National Center for Urban and Industrial
Health
222 East Central Parkway
Cincinnati, Ohio 45202

Subject: 8 R01 UI00518-07

Dear Mr. Steed:

Forty copies of our Second Progress Report covering the investigation made under the subject grant on the "Special Studies of a Sanitary Landfill" are submitted to you with this letter. This report summarizes the project activity and services performed during the 1967 calendar year.

Respectfully submitted,

Robert C. Merz, Chairman
& Principal Investigator

RCM:bb

2. FOREWORD

On March 25, 1966, the Department of Civil Engineering of the University of Southern California submitted a final report on the factors controlling the use of a sanitary landfill site. Funds were provided by two grants from the United States Public Health Service, EF-00160-04 and 5R01-EF-00160-05. Copies of the report are available from the University.

These special studies of a sanitary landfill were continued and expanded under new grants, 9R01-SW-00028-06 covering the 1966 calendar year, and 8 R01-UI-00518-07 covering the 1967 calendar year. This report is offered as a second statement of progress, and only the data collected during 1967 are included. Readers are referred to the above referenced reports for full and complete information concerning the construction, instrumentation and initial performance of the four landfill test cells described as A, B, C, and D.

The project is under the joint direction of Robert C. Merz, Chairman, Department of Civil Engineering, and Ralph Stone, Research Associate. Field assistance was provided by Damian Curran and George De La Guardia, undergraduates, Capt. Gerald Barbour, Master of Science candidate, and Ramon Beluche, Doctoral candidate.

3. ACKNOWLEDGMENTS

This investigation was supported in whole by Public Health Service Research Grant No. UI-00518-07 from the National Center for Urban and Industrial Health.

The County Sanitation Districts of Los Angeles County constructed the test cells and provided field assistance when requested. The help of the staff of the Sanitation Districts and of John D. Parkhurst, Chief Engineer and General Manager, are most gratefully acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

4. CELLS A, B, AND C

4.1 External Climatic Factors. Monthly average air temperatures and daily rainfalls were obtained from Pomona Weather Station records and are recorded in Table 4.1.1. Daily temperatures are recorded in Tables 4.5.1 through 4.5.3. The total rainfall at the test site for the full 3.5 yr. period of study (to December 31, 1967) has been 62.1 in. The total rainfall for 1966 was 18.8 in.

4.2 Application of Water. In Table 4.2.1 are shown the amounts of water applied to Cell A. The figures shown are cumulative since the start of this investigation in September 1964. The required annual amount of water to be applied to simulate the Seattle rainfall is 42.52 in. The actual amount of water applied during the year was 21.37 in. irrigation water plus 18.77 in. rainfall for a total of 40.14 in.

There is a water supply reservoir located on top of a high hill adjacent to the research site. On September 3, this reservoir accidentally overflowed, and the water cascaded down the hill and onto the surfaces of Cells A and B. Based on flood markings, the minimum amount of water estimated to have entered Cell A was 3750 gal and was included in the September entry in Table 4.2.1. The minimum amount of water estimated to have entered Cell B was 2450 gal and was included in the September entry in Table 4.2.3.

The coring program initiated on August 22, 1966, for the purpose of determining the moisture content of the cells, was continued. The cells were cored in February and again in November, and samples were taken at 2-ft depth increments. The top cover and the subgrade were also sampled. The samples were sealed immediately and transported to the laboratory where their moisture contents were determined. The core descriptions and the core temperatures appear in Tables 4.5.4 and 4.5.5. The moisture results for Cell A are presented in Table 4.2.2.

TABLE 4.1.1

External Climatic Factors

Month	Day	Rainfall, In		Temperatures, Deg F		
		Daily	Cumulative	Ave Max	Ave Min	Mean
Jan.	6	T		65.8	41.8	53.8
	22	1.44				
	23	0.93				
	24	2.10				
	25	0.45				
	31	0.16	48.37			
Feb.	14	T	48.37	71.2	43.7	57.5
March	4	0.15		67.8	47.3	57.6
	10	T				
	11	0.37				
	12	0.18				
	13	0.57				
	14	0.37				
	31	0.60	50.61			
April	1	0.08				
	2	0.44		63.4	42.8	53.1
	4	0.20				
	7	0.47				
	11	0.68				
	12	0.01				
	15	0.01				
	18	0.43				
	19	0.58				
	20	0.04				
	21	0.47				
	22	0.46				
	24	0.23				
	29	0.08	54.79			
May	10	0.16		77.2	52.3	64.7
	28	T				
	29	0.04				
	30	T				
	31	0.05	55.04			
June	10	T		77.2	53.8	65.5
	12	0.05	55.09			
July			55.09	91.3	61.8	76.6

(Continued on Page 3)

TABLE 4.1.1 (Continued)

External Climatic Factors

Month	Day	Rainfall, In.		Temperatures, Deg F		
		Daily	Cumulative	Ave Max	Ave Min	Mean
Aug.	30	T	55.09	94.6	68.1	81.4
Sept.	2	T		84.7	63.3	74.0
	10	0.01				
	22	T				
	23	T				
	27	0.18				
	28	0.10				
	29	T				
	30	T	55.38			
Oct.			55.38	84.8	55.4	70.1
Nov.	19	1.90		72.7	52.9	62.8
	20	0.91				
	21	0.90				
	28	0.08				
	30	0.86	60.03			
Dec.	8	0.07		60.5	41.7	51.1
	16	0.05				
	17	0.03				
	18	1.22				
	19	0.66	62.06			

TABLE 4.2.1

Actual Amounts of Water Applied to Cell A

Month	Water Applied		Rainfall	Total Water Applied, In.		Seattle, Wash. Rainfal Water Required, In.	
	Gal	In.	In.	Monthly	Cumulative	Monthly	Cumulativ
1964-65					86.98		56.24
1966					43.29		42.52
1967							
January	709	0.45	5.08	5.53	135.80	7.71	106.47
February	0	0	T	0	135.80	9.11	115.58
March	0	0	2.24	2.24	138.04	4.45	120.03
April	0	0	4.18	4.18	142.22	2.35	122.38
May	0	0	0.25	0.25	142.47	3.07	125.45
June	2,041	1.17	0.05	1.22	143.69	0.54	125.99
July	2,459	1.62	-	1.62	145.31	0.75	126.74
August	9,461	5.06	T	5.06	150.37	0.82	127.56
September	9,836	5.60	0.29	5.89	156.26	0.46	128.02
October	8,340	4.28	-	4.28	160.54	3.27	131.29
November	603	0.41	4.65	5.06	165.60	4.67	135.96
December	6,303	2.78	2.03	4.81	170.41	5.32	141.28

TABLE 4.2.2

CELL A MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	February 1967				November 1967			
	Core No. 1 NW Corner		Core No. 2 SE Corner		Core No. 1 N Side		Core No. 2 S Side	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover	22.2	28.5	23.7	31.0	21.2	26.9	20.9	26.4
2	21.3	27.1	29.8	42.4	12.3	14.1	11.3	12.7
4	30.8	44.6	34.8	53.3	28.1	39.1	60.7	154.3
6	50.3	101.1	43.6	77.3	41.5	70.9	48.7	94.7
8	44.1	78.7	47.5	91.3	39.6	65.7	44.0	78.6
10	52.8	112.0	51.1	104.4	56.6	130.3	60.1	150.5
12	51.8	107.7	52.7	111.3	53.5	115.0	49.6	98.5
14	52.3	109.6	59.5	147.9	45.0	81.9	48.0	108.4
16	61.5	159.6	58.9	143.0	48.7	95.1	64.0	177.5
18	46.8	87.9	52.4	110.8	53.4	114.6	60.7	154.5
20	32.6	48.5	30.1	43.1	61.6	160.1	41.4	70.7
Subgrade					30.6	44.1	25.4	34.0
Averages 2-06	34.1	57.6	36.1	57.7	27.3	41.4	40.2	87.2
8-14	50.3	102.0	52.7	113.7	48.7	98.2	50.4	109.0
16-20	47.0	98.7	47.1	98.9	54.6	123.3	55.4	134.2
Entire Cell	44.4	87.6	46.0	92.4	44.0	88.7	48.9	110.0

TABLE 4.2.3

Actual Amounts of Water Applied to Cell B

Month	Water Applied		Rainfall	Total Water Applied, In	
	Gal	In.	In	Monthly	Cumulative
1964-66					169.02
1967					
January	0	0	5.08	5.08	174.10
February	3,571	2.30	0	2.30	176.40
March	0	0	2.24	2.24	178.64
April	0	0	4.18	4.18	182.82
May	7,236	4.64	0.25	4.89	187.71
June	10,822	6.96	0.05	7.01	194.72
July	14,060	9.05	-	9.05	203.77
August	14,617	9.37	T	9.37	213.14
September	19,186	12.30	0.29	12.59	225.73
October	7,685	4.92	-	4.92	230.65
November	57	0.04	4.65	4.69	235.34
December	0	0.00	2.03	2.03	237.37

TABLE 4.2.4

CELL B MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	February 1967				November 1967			
	Core No. 1 SW Corner		Core No. 2 NE Corner		Core No. 1 N Side		Core No. 2 S Side	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover					22.3	28.7	23.7	31.1
2	44.2	79.2	39.2	64.6	26.1	35.3	25.6	34.4
4	54.7	120.7	53.9	116.9	46.1	85.5	37.9	61.0
6	51.6	106.6	48.6	94.6	40.1	67.0	47.2	89.3
8	63.3	172.4	48.6	94.5	44.4	79.9	49.0	96.0
10	63.0	170.3	53.7	116.1	46.7	87.6	51.6	106.4
12	37.5	60.1	35.7	55.5	41.5	70.1	51.1	104.3
14	67.1	204.1	42.2	72.9	45.8	84.4	61.2	157.8
16	47.2	89.2	45.9	84.9	-	-	65.1	186.2
18	63.1	170.8	47.7	90.7	57.8	136.9	63.0	170.0
20	27.3	37.6	22.0	28.3	58.0	138.3	56.1	127.8
Subgrade					25.5	34.2	33.5	50.3
Averages 2-06	50.2	103.2	47.2	92.0	37.5	62.6	36.9	61.6
8-14	57.7	151.7	45.1	84.8	44.6	80.7	53.2	116.1
16-20	45.9	99.2	38.5	68.0	57.9	137.6	61.3	161.3
Entire Cell	51.9	121.1	43.8	81.9	45.2	87.3	50.8	113.3

TABLE 4.2.5

CELL C MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	February 1967				November 1967			
	Core No. 1 NW Corner		Core No. 2 SE Corner		Core No. 1 N Side		Core No. 2 S Side	
	Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
Earth Cover					11.7	13.4	15.9	18.9
2	26.7	36.3	27.8	38.4	26.7	36.4	18.2	22.3
4	28.7	40.2	43.5	77.0	57.2	133.5	24.4	32.3
6	53.8	116.3	48.8	95.2	32.0	47.1	50.4	101.6
8	51.0	103.9	60.8	155.4	50.0	100.1	49.9	99.6
10	52.0	108.4	55.7	125.6	41.0	69.5	46.9	88.3
12	43.4	76.6	54.0	117.6	43.8	77.8	47.7	91.3
14	39.4	65.0	55.2	123.0	43.2	75.9	51.4	105.7
16	46.1	85.3	57.0	132.3	28.3	39.4	52.8	111.9
18	38.0	61.3	30.3	43.5	16.2	19.3	23.6	31.0
20	-	-	-	-	-	-	-	-
Subgrade	12.5	14.3			16.7	20.0	21.9	28.0
Averages 2-06	36.4	64.3	40.0	70.2	38.6	72.4	31.0	52.0
8-14	46.5	88.5	56.4	130.4	44.5	80.9	49.0	96.2
16-18	42.1	73.3	43.7	87.9	22.2	29.4	38.2	71.4
Entire Cell	44.9	85.1	48.1	100.9	37.6	66.6	40.6	76.0

The moisture content of the cell as a whole, on a wet weight basis, remained virtually unchanged during the interval between corings despite the application of 29.8 in. water. On a dry weight basis, the moisture content increased 10%. By the end of the year, the moisture content of the earth cover was considerably higher than that of the top layer of refuse, indicating the ready capillary rise of water from the top layer of refuse for subsequent evaporation from the bare cell surface. The moisture content of the subgrade, 2 ft below the landfill, was considerably less than that of the bottom layer of refuse, when sampled in November, indicating slow movement of water into the ground. At the bottom of Table 4.2.2 are shown the average moisture contents for the top portion of the cell (2-6 ft), the middle portion (8-14 ft), and the bottom portion (16-20 ft). The November figures indicate that a downward transfer of water has taken place, since in February the band with the highest moisture content was between 8 and 14 ft below the surface.

In Table 4.2.3 are shown the amounts of water applied to Cell B. The figures shown are cumulative, as in the case of Cell A described above. The actual amount of water applied during the year was 49.58 in. of irrigation water applied on demand by the tensiometer equipment (and including the aforementioned reservoir drainage) plus 18.77 in. rainfall for a total of 68.35 in. This was adequate to maintain an excellent turf cover on top of the cell.

Cell B received 61.2 in. water between corings. The picture presented by analysis of the core samples in Table 4.2.4 is as follows. The moisture content of the cell as a whole on a wet or dry weight basis remained virtually unchanged, and the moisture content of the subgrade when sampled in November was considerably less than that of the bottom layer of refuse, again indicating slow movement of water into the ground. However, the moisture content of the earth cover was little different from that of the top layer of refuse.

Considering that Cell B received more than twice the amount of water applied to Cell A (on call from the tensiometer control equipment), and considering that the top cover of Cell B was especially prepared to resist passage of applied water, the relationship is reasonable. The average moisture contents in November for the designated cell portions (as noted above in Cell A) again indicate a downward transfer of water as in Cell A, and again show that the depth with the highest moisture content was between 8 and 14 ft below the surface in February.

Cell C received no water during the year other than normal rainfall of 18.8 in. The cell has continued to exhibit a loss of moisture. The moisture content of the cell as a whole decreased from 46.5% to 39.1% on a dry weight basis. In contrast to Cells A and B, the driest material is found in the bottom portion (16-18 ft) in both February and November, a condition to be expected since the forced air is introduced into the fill from the air ducts located beneath the fill. For the same reason, there is little difference in the moisture contents of the bottom portion of the cell and the subgrade.

4.3 Settlement. The settlement of all cells was periodically measured by survey, and the data are given in Table 4.3.1. During the year, Cell A settled an additional 0.57 ft, Cell B 0.51 ft and Cell C 1.14 ft. As shown, Cells A and B have each settled a total of approximately 1.30 ft and Cell C has settled a total of 3.75 ft or nearly three times as much. The rate of settlement of all cells has been fairly uniform with the few exceptions probably caused by expansion of the adobe cover soil.

The bench marks used to measure settlement are concrete monuments originally set flush with the cell surface. There are four at each cell, located about 12 ft from the access well on N-S and E-W diameters. The reported settlement refers to the average movement of these benchmarks. There are portions of the cells that have settled to a greater and lesser extent. In Cell C, for

TABLE 4.3.1

Elapsed Time Since Cell Completion (days)	Total Settlement of Cell Surface, Ft			Total Settlement of Mid-Depth Surface, Ft		
	Cell Number			Cell Number		
	A	B	C	A	B	C
896			2.6075			2.18
920	0.8300	0.7850		0.65	0.53	
935			2.7100			2.32
959	0.8575	0.8150		0.68	0.54	
963			2.8075			2.42
987	0.9075	0.8500		0.71	0.57	
991			2.8775			2.48
1015	0.8900	0.8500		0.71	0.57	
1044			3.0550			2.60
1068	0.9750	0.9150		0.77	0.60	
1079			3.2350			2.78
1103	1.0550	0.9825		0.83	0.65	
1110			3.3550			2.86
1134	1.0925	1.0175		0.84	0.65	
1148			3.4600			2.94
1171	1.1550	1.0725		0.88	0.68	
1180			3.5875			3.05
1204	1.2400	1.1475		0.93	0.72	
1208			3.6950			3.17
1232	1.3100	1.2375		0.97	0.77	
1222			3.7525			3.24
1246	1.3275	1.2550		0.98	0.80	

Cell Settlement Data

instance, the surface settlement around the access well is more than 5 ft.

The differential settlement between the top half and bottom half of Cells A and B increased during the year. In Cell A the differential is now 0.35 ft, and in Cell B it is 0.46 ft. The differential in Cell C remained 0.51 ft. This is simply indicative of an increase in the "equivalent" density of the bottom fill material.

While there were no serious caveins during the year, surface fissures continued to develop and these were filled in as soon as possible.

4.4 Gas Production. As shown in Table 4.4.1, Cell A continued over the entire year to produce a gas high in carbon dioxide and methane at top and bottom levels. Oxygen and nitrogen were present in varying minor amounts. There was no hydrogen. There has been no marked change in the gas composition from what it was during 1966.

As shown in Table 4.4.2, Cell B also continued to produce a gas high in carbon dioxide and methane at top and bottom levels. And again, because of air from Cell C moving over 25 ft through an adobe soil wall into Cell B, oxygen was generally present in quantities up to 4 percent, whereas the Cell A value was generally less than one percent. The continuing presence of oxygen is not normally compatible with the presence of methane, and yet the technique as well as the equipment used were thoroughly checked and appeared to be satisfactory.

The gas analyses for Cell C are shown in Table 4.4.3, and this table should be correlated with Table 4.4.4 which summarizes blower operation.

The blower steadily supplied air at desired on-off schedules throughout the full year. The cycle of on 0.5 hr and off 1.0 hr started on Dec. 1, 1966, was continued to Sept. 26, 1967. On that date the cycle was changed to on 1.0 hr and off 0.5 hr. The change was made simply to determine what the effect of more air would be in the gas composition and temperatures.

The data indicate there was little immediate or long-time change in the

TABLE 4.4.1

Gas Composition in Cell A

Date 1967	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface: 7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-03	903	48.75	0.07	50.86	0	0.32	50.94	0.16	48.30	0	0.60
1-18	918	50.77	0.48	46.88	0	1.87	53.32	0.55	43.89	0	2.24
2-01	932	44.44	0.24	54.33	0	0.99					
3-08	967						49.24	1.68	42.76	0	6.32
3-15	974	53.05	0.05	46.70	0	0.20	51.80	0.65	45.03	0	2.52
3-22	981	52.24	0.03	47.63	0	0.10	51.04	1.27	42.86	0	4.83
3-29	988	51.46	0.02	48.47	0	0.05	53.80	0.19	45.29	0	0.72
4-06	996	48.23	0.02	51.65	0	0.10	48.75	0.42	49.15	0	1.68
5-03	1023	49.49	0.07	50.20	0	0.24	48.02	0.06	51.67	0	0.25
5-11	1031	47.18	0.02	52.74	0	0.06	46.85	0.10	52.67	0	0.38
6-12	1063	40.75	0.02	59.14	0	0.09					
6-19	1070	37.05	3.66	46.82	0	12.47	43.02	0.03	56.73	0	0.22
6-26	1077	43.18	0.94	51.18	0	4.70					
7-03	1084	43.73	0.64	53.07	0	2.56	32.36	3.71	42.51	0	21.42
7-10	1091	41.20	2.03	52.70	0	4.07	40.44	0.91	55.25	0	3.40
7-25	1106	38.01	2.27	48.37	0	11.35	38.40	0.87	58.48	0	2.25
8-01	1113	34.09	0.38	63.64	0	1.89	35.67	3.30	52.46	0	8.57
8-08	1120	51.90	0.67	45.44	0	1.99	46.22	0.01	53.74	0	0.03
8-16	1128	50.00	0.85	47.23	0	1.92	48.28	3.28	35.34	0	13.10
8-22	1134	44.12	2.37	45.59	0	7.92	51.27	1.98	36.83	0	9.92
8-29	1141	51.23	1.24	41.33	0	6.20	43.64	4.27	37.88	0	14.21
9-26	1169	53.48	0.67	43.15	0	2.70					
10-03	1176	53.97	1.02	40.95	0	4.06	52.57	1.83	38.29	0.00	7.31
10-09	1182	53.35	T	44.35	0	2.30	53.61	1.00	40.40	0.00	4.99

(Continued on Page 14)

TABLE 4.4.1 (Continued)

Gas Composition in Cell A

Date 1967	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface: 7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
10-23	1196	52.75	0	46.18	0	0.00	54.33	0.00	45.67	0.00	0.00
10-30	1203	53.89	0	46.11	0	0.00	54.57	0.00	45.43	0.00	0.00
11-06	1210	53.25	0.07	46.51	0	0.17					
11-27	1231	51.55	0.01	48.38	0	0.06	49.19	0.04	50.60	0.00	0.17
12-04	1238	51.60	0.32	46.88	0	1.20	46.60	0.06	53.03	0.00	0.37
12-11	1245	52.91	0.01	47.03	0	0.05	50.80	0.07	48.98	0.00	0.15
12-21	1255	51.67	0.01	48.19	0	0.13	43.88	0.05	55.20	0.00	0.87
12-28	1262	49.71	0.03	50.16	0	0.10	47.82	0.03	51.89	0.00	0.26

TABLE 4.4.2

Gas Composition in Cell B

Date 1967	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-03	903	53.30	0.05	46.23	0	0.42	51.51	0.15	47.67	0	0.67
1-18	918	64.37	0.79	29.34	0	5.50	50.50	1.54	33.27	0	14.69
2-01	932	52.39	0.13	46.41	0	1.07	43.73	1.56	44.80	0	9.91
2-22	953	47.17	2.61	38.35	0	11.87					
3-08	967	42.27	3.39	33.73	0	20.61					
3-15	974	45.62	4.26	33.68	0	16.44	37.74	2.66	37.85	0	21.75
3-22	981	57.48	0.70	38.71	0	3.11					
3-29	988	48.00	0.78	45.47	0	5.75					
4-06	996	53.63	0.14	45.45	0	0.78					
5-03	1023	57.38	0.04	42.39	0	0.19	52.35	0.25	46.44	0	0.25
5-11	1031	53.48	0.05	46.33	0	0.14					
6-12	1063	38.34	0.01	61.56	0	0.19	21.47	2.29	38.39	0	2.29
6-19	1070	41.82	0.01	58.11	0	0.06	30.13	0.60	33.27	0	0.60
6-26	1077	31.72	2.80	51.48	0	14.00	32.35	1.82	43.21	0	22.62
7-03	1084	41.41	1.98	46.70	0	9.91	39.43	1.66	43.27	0	15.64
7-10	1091	41.65	1.18	48.28	0	8.89	34.46	0.46	57.06	0	8.02
7-25	1106	48.12	0.65	47.31	0	3.92	37.98	0.20	52.33	0	9.49
8-01	1113	37.91	1.29	58.21	0	2.59	38.30	0.13	50.35	0	11.22
8-08	1120	41.27	3.13	46.23	0	9.37	48.64	0.19	44.12	0	7.05
8-16	1128	47.10	3.18	39.13	0	10.59	47.01	0.12	47.01	0	5.86
8-22	1134	51.22	3.96	35.57	0	9.25	45.22	0.93	45.11	0	8.74
8-29	1141	44.49	3.21	39.46	0	12.84	49.14	0.40	39.45	0	11.01
9-12	1155	53.25	2.46	38.39	0	5.90	51.91	1.19	43.33	0	3.57
9-21	1164	48.07	2.41	43.50	0	6.02	50.55	0.62	42.62	0	6.21
9-26	1169	53.85	2.00	38.15	0	6.00	44.79	1.45	42.17	0	11.59

(Continued on Page 16)

TABLE 4.4.2 (Continued)

Gas Composition in Cell B

Date 1967	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
10-03	1176	57.20	1.40	35.80	0	5.60	39.13	2.37	38.51	0	19.99
10-09	1182	56.64	T	40.51	0	2.85	53.13	0.34	38.78	0	7.75
10-23	1196	52.74	0.00	43.96	0	0.00	41.53	0.35	54.96	0	3.16
10-30	1203	54.19	0.00	45.81	0	0.00	43.12	0.11	55.18	0	1.59
11-06	1210	52.24	0.00	47.76	0	0.00	50.36	0.15	38.55	0.02	10.92
11-27	1231	49.94	0.02	49.86	0	0.18	50.42	0.03	49.32	0.00	0.23
12-04	1238	48.28	0.16	50.98	0	0.58					
12-11	1245	51.85	0.31	46.66	0	1.18	53.31	0.03	46.54	0	0.12
12-21	1255	46.06	0.07	53.55	0	0.32	49.81	0.04	49.89	0	0.26
12-28	1262	51.83	0.06	47.80	0	0.31	51.07	0.03	48.75	0	0.15

TABLE 4.4.3

Gas Composition in Cell C

Date 1967	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-03	879	16.37	12.28	14.96	0	54.81	20.56	11.30	15.85	0	52.29
1-18	894	8.35	15.95	2.67	0	73.03	8.00	15.79	3.12	0	73.09
2-01	908	12.58	13.43	8.71	0	65.28	20.43	8.96	11.03	0	59.58
2-22	929	6.14	16.02	2.22	0	75.65	10.53	14.84	4.78	0	69.85
3-08	943	21.48	11.23	18.27	0	49.02	23.74	9.66	18.93	0	47.67
3-15	950	26.87	8.95	21.65	0	42.53	22.93	10.97	16.71	0	49.39
3-22	957	4.26	17.43	2.19	0	76.12	14.08	12.40	6.26	0	67.26
3-29	964	8.87	14.06	2.93	0	74.14	9.99	13.35	3.89	0	72.77
4-06	972	27.62	7.43	22.49	0	42.46	27.30	7.11	22.42	0	43.17
4-13	979	28.42	7.39	23.53	0	40.66	30.98	7.06	25.00	0	36.96
5-03	999	19.71	10.87	19.20	0	50.22	32.19	5.05	29.10	0	33.66
5-11	1007	15.45	13.32	16.17	0	55.06					
6-19	1046						8.76	15.52	7.59	0	68.13
6-26	1053						11.02	13.83	7.61	0	67.54
7-03	1060						10.30	10.30	14.65	0	64.75
7-10	1067						8.92	19.80	8.84	0	62.44
7-25	1082	20.72	3.18	10.51	0	65.59					
8-01	1089	22.94	0.74	11.73	0	64.59					
8-08	1096	25.79	1.40	12.11	0	60.70	5.24	11.56	2.87	0	80.33
8-16	1104	29.63	1.21	14.81	0	54.35	2.12	17.62	1.53	0	78.73
8-22	1110	11.43	8.29	6.28	0	74.00	1.87	15.56	2.17	0	80.40
9-12	1131	9.40	9.58	5.13	0	75.89	1.79	18.06	2.42	0	77.73
9-21	1140	4.98	10.49	3.09	0	81.44	2.90	17.78	2.90	0	76.42
9-26	1145	9.01	7.78	4.61	0	78.60					

(Continued on Page 18)

TABLE 4.4.3 (Continued)

Gas Composition in Cell C

Date 1967	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
10-03	1152						3.94	18.64	2.87	0	74.55
10-09	1158						2.66	19.26	1.03	0	77.05
10-23	1172						2.01	20.09	0.40	0	77.50
10-30	1179						4.57	18.15	1.52	0	75.76
11-06	1186						1.37	20.65	0.55	0	77.43
12-04	1214	51.34	0.16	46.96			2.82	19.33	1.42	0	76.43
12-11	1221						6.33	17.57	3.45	0	72.65
12-28	1238						6.24	16.87	3.87	0	73.02

TABLE 4.4.4

Summary of Blower Operation, Cell C

Elapsed Time in Days Following Completion of Cell		Blower		Blower Cycle		Remarks
B	C	On	Off	Hr on	Hr off	
	877	x		0.5	1.0	
	954	x				Steam emitted from Cell C
980		x				3.5 ft water bottom Cell B
1015	991	x				8.5 ft water bottom Cell B 4.0 in. water bottom Cell C
1148		x				Cell B cave-in due to flooding
1150		x				6.5 ft water bottom Cell B
1157		x				5.5 ft water bottom Cell B
1162		x				5.0 ft water bottom Cell B
	1145	x		1.0	0.5	
1171	1147	x				6.2 ft water bottom Cell B Installed new tarpaulin Cell C
1183		x				5.0 ft water bottom Cell B
	1179	x				Odor problem Cell C
1204		x				4.5 ft water bottom Cell B
	1182	x				Filled and compacted surface fissures Cell C
1218		x				4.5 ft water bottom Cell B
	1196	x				Cave-in around access well, caused by rain
1232		x		1.0	0.5	6.8 ft water bottom Cell B

analysis of the gas taken from the lower portion of the cell. Oxygen values remained in the range of 17-20 percent, carbon dioxide in the range of 1-6 percent, and nitrogen in the range of 73-77 percent. While it was expected that methane would disappear, small amounts persisted.

Difficulties were encountered in obtaining valid gas samples from the upper portion of the cell during this interval of 3 mo. Methane, for instance, was found in quantities that appeared unreasonably high.

4.5 Cell Temperatures. In Tables 4.5.1 through 4.5.3 are presented the temperature data for all of the cells. For each cell are shown the maximum, minimum and average temperatures for the air, the access well temperature, and the internal temperatures. All of these readings are correlated with the date on which they were taken and the total elapsed time in days following the completion of each cell.

During the year, Cell A at mid-depth experienced a range of 24 F deg from 58 in the winter to 82 in the summer.

In Cell B, the temperature range was 22 F deg from 60 in the winter to 82 in the summer.

Thermistors in Cell C at mid-depth and bottom levels failed in 1966. To obtain internal temperatures, thermometers immersed in water baths were suspended in 2-in. dia pipes which, in turn, were set into the shafts established by the coring operation. The mid-depth temperatures are seen to be consistently higher than bottom temperatures due to the fact that the air introduced into the bottom of the cell has a cooling effect. By the end of November, after 2 mo of increased blower operation, the temperature had risen as high as 162 deg F. When Cell C was cored in November, the core temperatures at depths of 8-12 ft on the North side confirmed this value. However, core temperatures on the South side of the cell were much lower through the middle portion, ranging from 106-130 deg F. The temperatures of all core samples are included in the

TABLE 4.5.1

Temperatures in Cell A

Date 1967	Elapsed Time Since Cell Completion (days)	Temperatures, °F Air* Max	Air* Min	Air* Avg	Access Well	In Cell at Depths Indicated Below Finished Elevation 4 Ft	10 Ft	16 Ft
1-05	905	57	39	48	64	61	67	68
1-12	912	70	45	58	65	61	67	67
1-27	927	71	41	56	53	53	60	68
2-01	932	63	42	53	55	55	61	66
2-07	938	71	42	57	52	54	58	58
4-13	1003	60	45	53	58	57	63	67
4-27	1017	71	47	59	59	62	64	74
5-04	1024	71	45	58	60	60	64	68
5-11	1031	67	49	58	61	62	63	68
5-18	1038	81	55	68	62	64	64	66
5-25	1045	71	58	65	62	65	63	70
6-12	1063	62	53	58	66	68	61	72
6-19	1070	81	54	68	65	67	64	68
6-26	1077	90	53	72	66	69	65	72
7-03	1084	86	59	73	67	72	73	80
7-10	1091	94	58	76	68	76		73
8-01	1113	90	63	77	73		80	
8-08	1120	88	63	76		79	82	71
8-16	1128	93	68	81	76	82	69	74
8-22	1134	90	64	77	83	88	70	79
8-29	1141	105	69	87	93	97	70	80
9-12	1155	89	68	79	76	80	69	75
9-21	1164	82	58	70	76	78	69	72
9-26	1169	82	62	72	76	78	69	75
10-03	1176	80	58	69	87	82	79	
10-09	1182	86	53	70	87	81	79	
10-16	1189	93	54	74	77	79	75	
10-23	1196	84	51	68	80	78	79	
10-30	1203	81	56	69	76	70		
11-06	1210	52	73	63	82			
11-27	1231	52	66	59	65	63	71	
12-04	1238	61	39	50	60	60	66	
12-11	1245	68	37	53	63	76	72	
12-21	1255	54	33	44	56		74	
12-28	1262	63	45	54	61			

* Data From Pomona Weather Bureau

TABLE 4.5.2

Temperatures in Cell B

Date 1967	Elapsed Time Since Cell Completion (days)	Temperatures, °F Air* Max	Air* Min	Air* Avg	Access Well	In Cell at Depths Indicated Below Finished Elevation 4 Ft	10 Ft	16 Ft
1-05	905	57	39	48	65	67	75	
1-12	912	70	45	58	65	67	74	
1-27	927	71	41	56	53	64	73	
2-01	932	63	42	53	55	64	72	
2-07	938	71	42	57	54	60	68	
4-13	1003	60	45	53	59	71	70	
4-27	1017	71	47	59	59	67	72	
5-04	1024	71	45	58	64	64	72	
5-11	1031	67	49	58	64	64	70	
5-18	1038	81	55	68	68	64	70	
5-25	1045	71	58	65	70	64	70	
6-12	1063	62	53	58	69	70	70	
6-19	1070	81	54	68	70	66	70	
6-26	1077	90	53	72	77	68	71	
7-03	1084	86	59	73	79	72	74	
7-10	1091	94	58	76	76	71	73	
8-01	1113	90	63	77	84			
8-08	1120	88	63	76	80	74	74	
8-16	1128	93	68	81	90	74	77	
8-22	1134	90	64	77	87	82		
8-29	1141	105	69	87		78	75	
9-12	1155	89	68	79	80	76	74	
9-21	1164	82	58	70	79	76	74	
9-26	1169	82	62	72	76	76	76	
10-03	1176	80	58	69	81	78	78	
10-09	1182	86	53	70	76		76	
10-16	1189	93	54	74	79	80	80	
10-23	1196	84	51	68	75	77	74	
10-30	1203	81	56	69	65			
11-06	1210	52	73	63				
11-27	1231	52	66	59	52	73	67	
12-04	1238	61	39	50		73	60	
12-11	1245	68	37	53	50	75		
12-21	1255	54	33	44		70	60	
12-28	1262	63	45	54				

* Data From Pomona Weather Bureau

TABLE 4.5.3

Temperatures in Cell C

Date 1967	Elapsed Time Since Cell Completion (days)	Temperatures, °F						
		Air*			Access Well	In Cell at Depths Indicated Below Finished Surface		
		Max	Min	Avg		4 Ft	*10 Ft	*20 Ft
1-05	881	57	39	48	105	97		
1-12	888	70	45	58	106	96		
1-27	903	71	41	56		95		
2-01	908	63	42	53	91	95		
2-07	914	71	42	57	87	94		
3-21	956	74	47	62			141	103
3-28	963	65	45	55			130	94
3-29	964	63	48	56			137	93
4-06	972	68	42	55			164	117
4-13	979	60	45	53	98	102	161	120
4-27	993	71	47	59	93	97	154	125
5-04	1000	71	45	58	97		152	124
5-11	1007	67	49	58		95	133	110
5-18	1014	81	55	68	94	94	122	97
5-25	1021	71	58	65	108	96	115	90
6-12	1039	62	53	58	97		115	102
6-19	1046	81	54	68	93			
6-26	1053	90	53	72	112		110	100
7-03	1060	86	59	73			114	100
7-10	1067	94	58	76			112	104
8-01	1089	90	63	77			104	100
8-08	1096	88	63	76			110	104
8-16	1104	93	68	81			112	106
8-22	1110	90	64	77			114	106
8-29	1117	105	69	87			116	106
9-12	1131	89	68	79			115	108
9-21	1140	82	58	70			112	108
9-26	1145	82	62	72			112	108
10-03	1152	80	58	69			104	104
10-09	1158	86	53	70			105	102
10-16	1165	93	54	74			107	103
10-23	1172	84	51	68			111	102
10-30	1179	81	56	69			112	101
11-06	1186	52	73	63			118	103
11-27	1207	52	66	59			164	116
11-28	1208	52	61	57			162	116
12-04	1214	61	39	50			158	118
12-11	1221	68	37	53			154	122
12-21	1231	54	33	44			145	119
12-28	1238	63	45	54			142	120

* Data from thermometers installed in water baths and placed in core holes.

log shown in Table 4.5.5.

5. CELL D

5.1 <u>Performance</u>. In Table 5.1.1 are presented the performance data covering the entire 18-mo period following completion of the installation of Cell D. Cell, in this case, refers to the 10,000 gal underground steel storage tank, 95 in. I.D. x 28 ft high x 1/4 in. th., which was packed with refuse, instrumented, and carefully sealed.

Gas production within the cell totalled less than one cubic foot between mid-July and the end of August, 1966. There was no gas produced from that date until February 22, 1967. During this interval, the tank was observed to be under a partial vacuum, indicating there was no gas leakage taking place. Beginning on that date and to year's end, 1919 cu ft were measured, equivalent to 26.3 cu ft per cu yd of refuse.

During this period of gas production, temperatures within the cell rose slowly and reached optimum values for bacterial activity throughout the tank by June 12. During the last 6 mo, the temperatures (by thermistors) ranged from 92 to 120 deg F. At the end of August, a thermometer was placed in a water bath and lowered into a 2-in. dia sealed pipe originally affixed within the top cover plate of the cell. This thermometer thus reads the temperature existing at the top level of the refuse in the tank, about 3 ft below ground level. The data are included in Table 5.1.1 and are observed to be well below the internal recorded temperatures.

TABLE 4.5.4

Cell and Core No.	Elapsed Time Since Cell Completion Days	Distance Below Top of Cell Ft	Observation
LOG OF CORES FOR CELLS A, B AND C - FEBRUARY, 1967			
A-NW	940	2	Moist refuse
		4	Mushy - black chunks - light odor
		6	Strong odor - metal shiny - grass light green
		8	Paper in chunks - cloth unaffected - mild odor
		10	Grass light green - paper legible - mild odor
		12	Grass light green - metal shiny - plastic new
		14	Grass, wood unaffected - cloth rotten
		16	Grass green - plastic unaffected - mild odor
		18	Materials massed together - rags rotted
		20	Bottom muddy
A-SE	940	2	Dry cool dirt - shiny metal
		4	Material dry and decomposed - cellophane unaf.
		6	Mushy, chunky material - rubber unaffected
		8	Mushy, decomposed material - mild odor
		10	Grass brown - cloth unaffected
		12	Material dry and loose
		14	Material very moist - ident. difficult - plastic unaffected
		16	Plastic - glass - rubber unaffected
B-SW	940	2	Dirt only
		4	Moist - no odor
		8	Black, mushy decomposed material
		10	Mushy paper - shiny metal - mild odor
		12	Rags rotten - paper legible - leaves unaf.
		14	Grass green - metal shiny - strong odor
		16	Rags rotten
		18	Grass decomposed - paper legible - metal shiny - plastic unaf. - no odor
		20	Bottom wet clay
B-NE	940	4	Mushy material - yellow chunky paper
		6	Paper legible - mild odor
		8	Material dry, loose, decomposed - paper legible
		10	Plastic and glass unaffected - mild odor
		12	Metal shiny
		16	Paper yellow but legible - strong odor
		18	Same
		20	Moist clay bottom

(Continued on Page 26)

TABLE 4.5.4 (Continued)

Cell and Core No.	Elapsed Time Since Cell Completion Days	Distance Below Top of Cell Ft	Observation
LOG OF CORES FOR CELLS A, B AND C - FEBRUARY, 1967			
C-NW	917	2	Dirt only
		4	Paper chunk, legible - cloth rotten
		6	Material chunky, brown, decomposed - metal oxidized - 114 deg F
		8	Black, charred material - strong burnt odor - 128 deg F
		10	Material very decomposed - glass unaf. 144 deg F
		12	Material very decomposed - cans black - plastic unaffected - 158 deg F
		14	Charred and burnt - little identifiable material - 164 deg F
		16	Very strong odor - wood burnt - 158 deg F
		18	Same - plastic unaffected - 154 deg F
		20	Bottom gravel - injured clay pipe
C-SE	917	2	Dirt dry
		4	Grass dark green, mushy, moist
		6	Materials black, moist - metal oxidized - plastic unaffected
		8	Paper mushy, moist but legible - 105 deg F
		10	Most material black, unidentifiable - cellophane brittle - 105 deg F
		12	Same - rubber hose and plastic unaf.
		14	Cloth rotted - wood unaffected - strong odor - 120 deg F
		18	Clay bottom - moist

TABLE 4.5.5

LOG OF CORES FOR CELLS A, B AND C - NOVEMBER, 1967

Cell and Core No.	Elapsed Time Since Cell Completion Days	Distance Below Top of Cell Ft	Core Temp. Deg F	Observation
A-N	1218	2	72	Dirt only
		4	70	Recognizable wood, rags - spicy
		6	68	Same - septic odor
		8	70	Refuse partially decomposed - musty
		10	74	Grass green - musty
		12	74	Undecomposed straw - spicy
		14	75	Refuse well decomposed - spicy
		16	75	Same - wood and grass recognizable
		18	75	Same - musty
		20	75	Mostly soil - balsamic
		22	74	Soil - balsamic
A-S	1218	2	68	Soil - earthy
		4	69	Refuse moldy - septic
		6	72	Refuse partially decomposed - spicy
		8	72	Grass and rags evident - musty
		10	73	Grass green - paper legible - musty
		12	73	Material slimy - septic
		14	74	Refuse partially decomposed - septic
		18	75	Advanced decomposition - slimy - spicy
		20	74	Same
		22	72	Subgrade - spicy
B-N	1218	2	69	Soil - earthy
		4	70	Grass, wood, paper recog. - musty
		8	72	Same
		10	74	Refuse partially decomposed - musty
		12	76	Same - newsprint legible - musty
		14	79	Same - leaves unchanged - spicy
		18	78	Same - septic
		20	78	Well decomposed - slimy - septic
		22	76	Subgrade soil - musty
B-S	1218	2	70	Soil - earthy
		4	73	Grass, paper unchanged - musty
		6	78	Same - branches unchanged - musty
		8	90	Same - spicy
		10	88	Refuse partially decomposed - spicy
		12	85	Rags, plastic, leaves unchanged - spicy
		14	87	Same
		16	85	Refuse slimy - septic
		18	86	Same
		20	84	Wood, paper, sticks, leaves recognizable
		22	84	Subgrade soil - musty

(Continued on Page 28)

TABLE 4.5.5 (Continued)

LOG OF CORES FOR CELLS A, B AND C - NOVEMBER, 1967

Cell and Core No.	Elapsed Time Since Cell Completion Days	Distance Below Top of Cell Ft	Core Temp. Deg F	Observation
C-N	1193	2	108	Soil only - musty
		4	111	Granular appearance - musty
		6	114	Refuse partially decomposed - musty
		8	168	Paper charred - wood recognizable - balsamic
		10	154	Granular appearance - paper charred - balsamic
		12	158	Same - advanced decomposition - musty
		14	145	Same
		16	118	Same
		18	109	Soil mostly - musty
		20	106	Subgrade soil - musty
C-S	1193	2	87	Soil only - earthy
		4	90	Mostly soil - earthy
		6	114	Paper, wood, plastic unchanged - musty
		8	106	Grass appeared burnt - balsamic
		10	137	Paper burnt - musty
		12	130	Paper and wood burnt - musty
		14	127	Refuse well decomposed - musty
		16	115	Same
		18	106	Mostly soil - musty
		20	98	Subgrade soil - musty

TABLE 5.1.1

CELL D PERFORMANCE DATA

Date 1967	Days Following Completion of Cell	Cumulative Volume of Gas Produced Cu Ft	Cell Pressure In. Water	Temperatures at Locations Below Top of Cell Deg F				
				Bottom	21 Ft	14 Ft	7 Ft	Top
1-05	182			80	84	86	76	
1-12	189			80	82	83	70	
1-27	204			80	84	88	76	
2-01	209			81	85	89	75	
2-07	215			73	74	77	67	
2-22	230	40.63						
2-28	236	40.84						
3-03	239	41.07						
3-07	243	41.29						
3-08	244	41.50						
3-15	251	41.73						
3-19	255	42.01						
3-21	257	42.47						
3-22	258	42.92						
3-24	260	43.33						
3-28	264	43.66						
3-29	265	48.15						
4-04	271	72.47						
4-06	273	80.39						
4-13	280	113.30		86	91	99	86	
4-25	292	180.15						
4-27	294	192.10		89	93	94	83	
5-04	301	238.43		87	92	92	82	
5-11	308	288.26		87	89	91	82	
5-18	315	329.07		87	91	97	86	
5-25	322	403.06		87	92	100	91	
6-12	340	465.58		92	101	107	98	
6-17	345	520.48						
6-19	347	541.64		91	98	108	97	
6-26	354	629.10		94	99	122	101	
7-01	359	682.85						
7-03	361	701.89		105	110	112	103	
7-10	368	758.13		98	110	117	100	
7-17	375	813.49						
7-22	380	853.27	5.3					
7-25	383	878.72	13.0					
8-01	390	929.38	19.0					
8-03	392	942.91	17.0					
8-07	396	971.06	13.0					
8-08	397	975.31	12.3	118	100	108	103	
8-16	405	1044.70	18.0	120	110	115	111	
8-18	407	1062.31	17.0					
8-22	411	1095.45	19.5	107	110	112	106	
8-29	418	1155.61	29.3	95	120	113		91
8-31	420	1180.79	2.5					90

TABLE 5.1.1 (Continued)

CELL D PERFORMANCE DATA

Date 1967	Days Following Completion of Cell	Cumulative Volume of Gas Produced Cu Ft	Cell Pressure In. Water	Temperatures at Locations Below Top of Cell Deg F				
				Bottom	21 Ft	14 Ft	7 Ft	Top
9-05	425	1231.43	0.3					90
9-06	426	1241.32	2.0					90
9-07	427	1249.91						89
9-12	432	1292.23	10.0	93	98	106		90
9-14	434	1306.59						89
9-19	439	1338.84	13.0					87
9-21	441	1348.67	17.0	93	98	106		86
9-26	446	1369.36	22.0		97	106		86
9-28	448	1375.15	30.0					86
10-03	453	1402.12	11.0	94	100	108		87
10-09	459	1431.20	24.5	93	87	110		85
10-10	460	1438.00	5.5					85
10-16	466	1493.42	20.5	98	108	116		86
10-23	473	1535.26	12.0		110			84
10-30	480	1577.83	15.0	98	102	107		83
10-31	481	1584.35	11.0					84
11-02	483	1602.95	11.0					84
11-06	487	1624.23	23.0		116	112		84
11-14	495	1672.36	22.5					84
11-16	497	1691.70	1.0					86
11-27	508	1772.55	0.5		106	105		74
11-28	509	1778.54						74
12-04	515	1811.08	0.5		104	110		68
12-11	522	1860.58	36.0		105			68
12-19	530	1893.52	0.0					62
12-21	532	1899.47	0.5		110	104		62
12-28	539	1917.83	4.0		92	99		62

Note: Wet Test Cell used to measure gas produced through 8-08-66
Gasometer used to measure gas produced beginning 8-09-66
No gas produced after 8-29-66
450 gal water added to cell 9-07 and 9-08-66

6. PRELIMINARY CONCLUSIONS

With this investigation now two-thirds through its scheduled time, some preliminary conclusions can be drawn from the data presented.

1. The Seattle rainfall pattern (about 40 in. per yr) has brought about a slow percolation of water through the test cell and into the subgrade.
2. The golf course irrigation pattern (about 62 in. per yr) has brought about a slow percolation of water through the test cell and into the subgrade.
3. The principal gases present in the anaerobic cells have been carbon dioxide and methane; and in the aerobic cell carbon dioxide, oxygen, and nitrogen.
4. Gas production within the 10,000 gal sealed tank during the last, most active 10 mo totalled 1880 cu ft, equivalent to 25.8 cu ft per cubic yard of refuse.
5. The surface settlement of the aerated cell, over the 3.5 yr test period, has been nearly 3 times that of the anaerobic cells.
6. The growth of Bermuda grass has been successfully maintained for 3.5 yr on an anaerobic landfill with an earth cover of 2 ft.

Grant Number [illegible]

First Progress Report to

Office of Solid Wastes

United States Public Health Service

Department of Health, Education, and Welfare

[illegible] 1966 to December [illegible] 1966

SPECIAL STUDIES OF A SANITARY LANDFILL

Grant Number 9 R01 SW 00028-06

First Progress Report to

Office of Solid Wastes

United States Public Health Service
Department of Health, Education, and Welfare

January 1, 1966 to December 31, 1966

Prepared by Principal Investigators

Robert C. Merz, Chairman
Department of Civil Engineering

Ralph Stone
Research Associate

University of Southern California
Los Angeles, California

UNIVERSITY OF SOUTHERN CALIFORNIA
SCHOOL OF ENGINEERING
UNIVERSITY PARK
LOS ANGELES, CALIFORNIA 90007

DEPARTMENT OF CIVIL ENGINEERING

March 15, 1967

Mr. Henry C. Steed, Jr.
Chief, Research and Training Grants
Office of Solid Wastes
Department of Health, Education and Welfare
United States Public Health Service
Washington, D.C. 20201

Subject: OSW-RTG
9 R01 SW 00028-06

Dear Mr. Steed:

Forty copies of our First Progress Report covering the investigation made under the subject grant on the "Special Studies of a Sanitary Landfill" are submitted to you with this letter.

We are grateful for the opportunity to make this contribution to the science of solid waste disposal, and look forward to continuance of the project.

Respectfully submitted,

Robert C. Merz, Chairman
& Principal Investigator

RCM:jb

2. FOREWORD

On March 25, 1966, the Department of Civil Engineering of the University of Southern California submitted a final report on the factors controlling the use of a sanitary landfill site. Funds were provided by two grants from the United States Public Health Service, ZF-00160-04 and 5R01-EF-00160-05. Copies of the report are available from the University.

These special studies of a sanitary landfill were continued and expanded under a new grant, 9R01-SW-00028-06, covering the 1966 calendar year. It is this work which is reported upon in the following pages. Since this report is offered as a statement of progress, only those data collected during 1966 are included; and readers are referred to the above referenced report for full and complete information concerning the construction, instrumentation and initial performance of the three landfill cells described as A, B and C. A fourth cell D was created especially for the current study, and is thus covered fully in this report.

The project is under the joint directorship of Prof. Robert C. Merz, Chairman, Department of Civil Engineering, and Research Associate Ralph Stone. Field assistance is being provided by student research assistants, Damian Curran and George De la Guardia.

3. ACKNOWLEDGMENTS

This research has been supported by the Public Health Service Research Grant 9 R01 SW 00028-06.

The County Sanitation Districts of Los Angeles County constructed the test cells and provided field assistance when requested. The help of the staff of the Sanitation Districts and of John D. Parkhurst, Chief Engineer and General Manager, are most gratefully acknowledged.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

4. EXISTING CELLS A, B, AND C

4.1 External Climatic Factors. Monthly average air temperatures and daily rainfalls were taken from Pomona Weather Station records and recorded in Table 4.1.1. Monthly average humidities were discontinued by the Weather Bureau after March, 1966. Daily temperatures and humidities are recorded in Tables 4.5.1 through 4.5.3. The total rainfall on the test site for the full period of study (to December 31, 1966) has been 43.3 in. The total rainfall for 1966 was 14.6 in.

4.2 Application of Water. In Table 4.2.1 are shown the amounts of water applied to Cell A. The figures shown are cumulative since the start of this investigation in September 1964. The required annual amount of water to be applied to simulate Seattle rainfall is 42.52. The actual amount of water applied during the year was 28.70 in. irrigation water plus 14.59 in. rainfall for a total of 43.29 in.

Since no leach has been withdrawn from even the top collection can after application of more than 10 ft of water over 28 months, it appears to be a reasonable assumption that percolating water is bypassing the collection cans. A coring program was initiated on August 22, at which time all cells were cored at opposite corners and samples were taken at 2 ft depth increments. The samples were sealed immediately and transported to the laboratory where their moisture contents were determined. The results appear in Table 4.2.3. It is seen that the moisture content at one cell location varied from 45 to 60 per cent on a wet weight basis or 82 to 147 per cent on a dry weight basis; and at a second location varied from 32 to 64 per cent on a wet weight basis or 47 to 180 per cent on a dry weight basis. Averaging all figures, the respective moisture contents were 53 and 117 per cent. The computed moisture content of the cell at the time of construction was 97 per cent on a dry

TABLE 4.1.1

External Climatic Factors

Month 1966	Day	Inches of Rainfall		Temperatures			Humidity
		Daily	Cumulative	Ave. Max.	Ave. Min.	Mean	Ave. (%)
Jan.	1	0.01		63.5	39.3	51.4	37.4
	16	0.01					
	30	1.00					
	31	0.15	29.87				
Feb.	1	T		63.5	41.7	52.6	44.7
	2	0.17					
	6	1.33					
	7	0.11					
	8	0.04					
	10	T					
	24	T					
	25	T	31.52				
March	1	T		70.4	46.7	58.6	45.2*
	14	T					
	16	T					
	24	T					
	25	0.34	31.86				
April	3	T		73.9	50.6	62.3	
	9	T	31.86				
May	8	T		73.7	53.8	63.7	
	9	0.04					
	25	T					
	26	T					
	30	T	31.90				
June	16	T	31.90	82.0	57.3	70.1	
July	29	T		88.2	60.3	74.3	
	30	T	31.90				
Aug.		0	31.90	89.8	62.8	76.3	
Sept.	19	T					
	27	T		85.3	58.9	72.1	
	28	T					
	29	0.04	31.94				
Oct.	4	T		81.1	54.1	67.6	
	10	0.14					
	11	T	32.08				

(Continued on Page 3)

TABLE 4.1.1 (Continued)

External Climatic Factors

Month	Day	Inches of Rainfall		Temperatures			Humidity
		Daily	Cumulative	Ave. Max.	Ave. Min.	Mean	Ave. (%)
Nov.	7	2.08					
	8	0.25		68.8	48.6	58.7	
	17	T					
	23	0.19					
	28	0.02					
	29	0.03	34.65				
Dec.	3	2.61		64.7	43.5	54.1	
	4	0.01					
	5	2.79					
	6	2.37					
	7	0.44					
	26	0.42	43.29				

* Final reporting of this figure by U. S. Weather Bureau. All data from Weather Station, Pomona, California.

TABLE 4.2.1

Actual Amounts of Water Applied to Cell A

Month	Water Applied		Rainfall	Total Water Applied, In.		Seattle, Wash. Rainfall Water Required, In.	
	Gal	In.	In.	Monthly	Cumulative	Monthly	Cumulative
1964-65					86.98		56.24
1966							
January	0	0	1.17	1.17	88.15	7.71	63.95
February	0	0	1.65	1.65	89.80	9.11	73.06
March	0	0	0.34	0.34	90.14	4.45	77.51
April	1,740	1.00	T	1.00	91.14	2.35	79.86
May	2,017	0.88	0.04	0.92	92.06	3.07	82.93
June	16,709	8.99	T	8.99	101.05	0.54	83.47
July	11,268	4.65	T	4.65	105.70	0.75	84.22
August	7,627	4.08	-	4.08	109.78	0.82	85.04
September	10,974	6.12	0.04	6.16	115.94	0.46	85.50
October	4,151	2.49	0.14	2.63	118.57	3.27	88.77
November	436	0.25	2.57	2.82	121.39	4.67	93.44
December	392	0.24	8.64	8.88	130.27	5.32	98.76

TABLE 4.2.2

Actual Amounts of Water Applied to Cell B

Month	Water Applied Gal	Water Applied In.	Rainfall In.	Total Water Applied, In. Monthly	Total Water Applied, In. Cumulative
1964-65					112.86
1966					
January	0	0	1.17	1.17	114.03
February	0	0	1.65	1.65	115.68
March	0	0	0.34	0.34	116.02
April	916	0.54	T	0.54	116.56
May	6,640	4.25	0.04	4.29	120.85
June	18,457	11.82	T	11.82	132.67
July	8,130	5.22	T	5.22	137.89
August	14,778	9.45	-	9.45	147.34
September	8,545	5.47	0.04	5.51	152.85
October	7,543	4.82	0.14	4.96	157.81
November	0	0	2.57	2.57	160.58
December	0	0	8.64	8.64	169.02

TABLE 4.2.3

CELL MOISTURE DETERMINED FROM CORE SAMPLES

Distance Below Top of Cell (ft)	Cell A				Cell B				Cell C			
	Core No. 1 SW Corner		Core No. 2 NE Corner		Core No. 1 NW Corner		Core No. 2 SE Corner		Core No. 1 SW Corner		Core No. 2 NE Corner	
	Per Cent Moisture				Per Cent Moisture				Per Cent Moisture			
	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt	Wet Wt	Dry Wt
2	45.1	82.1			22.1	28.3			47.2	89.2		
4	55.2	123.4	32.0	47.0	44.2	79.3	54.9	121.5	41.2	70.1	21.4	27.2
6	47.9	91.8	41.5	71.1			47.0	88.5			51.7	106.8
8	53.8	116.4	57.1	132.8			58.7	141.9	54.5	119.7	50.3	101.4
10	55.5	124.5	52.6	111.2	38.1	61.6	50.1	100.4			55.1	122.8
12	59.5	147.1	55.4	124.0	30.2	43.2	51.2	104.8	46.6	87.4	47.8	91.5
14	57.0	132.6	51.4	105.5	33.6	50.7	46.9	88.2	54.5	119.7	47.6	90.8
16	53.0	112.7	57.5	135.2	39.1	64.3	47.7	91.3	47.2	89.0		
18	53.9	116.9	64.4	180.8	32.3	47.6	25.6	34.4	44.9	81.5		
20	55.7	125.9										
Bottom	25.8	34.8	26.0	35.2	23.8	31.2	23.5	30.7	28.1	39.1	33.1	49.5

weight basis indicating that the applied water has effectively increased the moisture content. If only the bottom half of the cell is considered, from which moisture is not readily drawn through capillarity and subsequent evaporation, the average figure increases to 131 per cent on a dry weight basis, indicating effective downward percolation of the applied water.

In Table 4.2.2 are shown the amounts of water applied to Cell B. The figures shown are cumulative, as in the case of Cell A described above. The actual amount of water applied during the year was 41.57 in. of irrigation water applied on demand by the tensiometer equipment plus 14.59 in. rainfall for a total of 56.16 in. This was very adequate to maintain an excellent turf cover on top of the cell.

At the time of construction, this Cell B had had 9 half drums with open end up installed within it in a descending spiral pattern between top and bottom for tracking vertical penetration of the percolating irrigation water. Leach was withdrawn from the top collection can only, despite application of some 14 ft. of water. Suspecting that the collection cans were being by-passed by the percolating water, this cell was also cored at opposite corners on August 22. The results of moisture determinations made on sealed samples are shown in Table 4.2.3. It is seen that the moisture content at one cell location varied from 22 to 44 per cent on a wet weight basis or 28 to 79 per cent on a dry weight basis; and at the second location varied from 26 to 59 per cent on a wet weight basis or 34 to 142 per cent on a dry weight basis. Averaging all figures, the respective moisture contents were 43 and 80 per cent. The computed moisture content of the cell at the time of construction was 73 per cent on a dry weight basis, indicating that the applied water has had a slight effect on the cell. If only the bottom half of the cell is considered, the average figure decreases to 66 per cent on a dry weight basis -- and a behavior just the reverse of Cell A is observed. There are several reasons for this. First, the addition of water to Cell B is controlled by two

pairs of tensiometers, each pair consisting of a unit installed 3 in. below the surface and another unit installed 6 in. below the surface. When an unsatisfactory soil-moisture relationship was reached at any of the four tensiometers, the spray system was activated and irrigation took place until the proper soil-moisture condition was obtained at all tensiometers. Ideally, only enough water was to be applied at one time to take care of the turf demand, with no excess left to percolate down through the cell. Second, the top cover for Cell B was carefully made up by combining "Loamite" with native soil to produce a material which would hold moisture rather than permit its passage. On the contrary, Cell A was covered with an imported sandy silt which would readily permit passage of surface water through it. Third, air introduced into Cell C is known to penetrate into Cell B and would have a drying out effect at least in the lower portion of the cell. Fourth, the collection pans do not appear to entrap moisture effectively. These reasons partially explain and justify the non-entrapment of leach.

Cell C had been subject to flooding on several occasions for various reasons during its first 18 months of existence, principally channeling of surface waters into crevices and cave-ins, and moisture determinations made on core samples could not be considered meaningful. Nevertheless, the cell was cored along with Cells A and B and the moisture data are presented in Table 4.2.3. The data did suffice to indicate that at the lower depths the cell was drying out and that the moisture content should be increased before a condition could be reached which would slow down or stop bacterial activity. Water was therefore admitted to Cell C through the spray piping built into the cell at the time of construction. Between early September and mid-October, 12,800 gal. were added at regular intervals in small increments.

4.3 Settlement. The settlement of all cells was periodically measured by survey, and the data are presented in Table 4.3.1. During the year Cell A

TABLE 4.3.1

Cell Settlement Data						
Elapsed Time Since Cell Completion (days)	Total Settlement of Cell Surface in Feet			Total Settlement of Mid-Depth Surface in Feet		
	Cell Number			Cell Number		
	A	B	C	A	B	C
517			1.88			1.63
541	0.52	υ.43		0.41	0.35	
552			1.93			1.67
576	0.55	0.47	1.96	0.44	0.39	1.69
597	0.56	0.48		0.44	0.39	
601			2.05			1.76
625	0.62	0.57		0.50	0.45	
641			2.07			1.77
665	0.59	0.57		0.47	0.42	
670			2.13			1.81
694	0.61	0.58		0.50	0.44	
698			2.18			1.84
722	0.63	0.61		0.51	0.44	
723			2.24			1.88
747	0.66	0.65		0.52	0.47	
758			2.31			1.92
782	0.68	0.66		0.55	0.47	
788			2.37			1.95
812	0.70	0.68		0.56	0.47	
816			2.44			2.00
843	0.73	0.71		0.57	0.48	
858			2.52			2.11
885	0.76	0.75		0.61	0.50	

settled an additional 0.24 ft, Cell B 0.32 ft and Cell C 0.64 ft. As shown, Cell A and B have each settled a total of 0.75 ft and Cell C has settled a total of 2.50 ft or 3.33 times as much. As shown in Table 4.3.2, the rate of settlement of the surfaces of all cells has been fairly uniform with few exceptions.

The differential settlement between the top half and bottom half of each cell increased during the year. In Cell A the differential is 0.15 ft, in Cell B 0.25 ft, and in Cell C 0.51 ft. This is simply indicative of an increase in the "equivalent" density of the bottom fill material.

Additional cave-ins occurred during the year in Cell C, and numerous fissures developed on the surface of all 3 cells, but especially C. The cave-ins were backfilled as soon as possible and the fissures were packed with sand.

4.4 <u>Gas Production</u>. As shown in Table 4.4.1, Cell A continued over the entire year to produce a gas high in carbon dioxide and methane at top and bottom levels. Oxygen and nitrogen were present in varying minor amounts. A trace of hydrogen appeared in only 9 samples. There has been no marked change in the gas composition from what it was over the last half of 1965.

As shown in Table 4.4.2, Cell B also continued to produce a gas high in carbon dioxide and methane at top and bottom levels. And again, because of air from Cell C moving into Cell B, oxygen was always present in quantities much higher than found in Cell A. The presence of oxygen is not normally compatible with the presence of methane, and yet the technique as well as the equipment used was thoroughly checked often enough for them not to be suspect. It is to be noted that the gas composition changed greatly when the blower serving Cell C was put into operation for the first time in the year early in April, and that 3 months elapsed before a steady state analysis was reached. At the close of the year, the analysis was much the same as at the close of 1965.

The gas analyses for Cell C are shown in Table 4.4.3; the summary of the blower operation is shown in Table 4.4.4, and the two tables should be

TABLE 4.3.2

Rates of Cell Settlement			
Time Increment (Month)	Rate of Settlement of Surface in Feet per month		
	Cell A	Cell B	Cell C
Seventeenth	0.04	0.04	0.03
Eighteenth	0.03	0.03	0.04
Nineteenth	0.04	0.03	0.10
Twentieth	0.02	0.08	0.02
Twenty-first	0	0	0.05
Twenty-second	0.02	0.01	0.05
Twenty-third	0.03	0.04	0.08
Twenty-fourth	0.03	0.03	0.06
Twenty-fifth	0.02	0.01	0.06
Twenty-sixth	0.02	0.03	0.07
Twenty-seventh	0.03	0.01	0.07
Twenty-eighth	0.02	0.05	

TABLE 4.4.1

Gas Composition in Cell A

Date	Elapsed Time In Days Following Completion of Cell	Per Cent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-06-66	539	54.07	0.15	45.37	0	0.41	50.60	0.16	48.74	0	0.50
1-13	546	51.60	0.11	48.01	0	0.28	52.82	0.09	46.82	0	0.27
2-10	574	51.55	0.20	47.75	0	0.50	52.88	0.12	46.63	0	0.37
2-17	581	55.25	0.19	43.97	0	0.59	54.91	0.09	44.69	0	0.31
2-24	588	51.58	0.17	47.72	0	0.53	55.85	0.09	43.74	0	0.32
3-03	595	48.75	0.03	51.11	0	0.11	50.32	0.02	49.58	0	0.08
3-10	602	53.39	0.16	45.98	0	0.47	56.87	0.08	42.79	0	0.26
3-17	609						54.58	0.05	45.19	0	0.18
3-24	616	52.86	0.08	46.87	0	0.19	56.00	0.08	43.66	0	0.26
3-31	623	50.94	0.03	48.96	0	0.07	54.45	0.18	44.87	0	0.50
4-21	643	52.08	0.05	47.67	0	0.20	52.91	0.04	46.93	0	0.12
4-28	650	53.78	0.21	45.48	0	0.53	55.06	0.06	44.69	0	0.19
5-05	657	54.58	0.13	44.90	0	0.39	57.70	0.07	41.99	0	0.24
5-19	671	55.38	0.16	43.94	0	0.52	57.47	0.03	42.40	0	0.10
5-26	678	57.29	0.13	42.10	0	0.48	57.00	0.03	42.86	0	0.11
6-02	685	53.31	0.04	46.49	0	0.16	56.03	0.05	43.74	0	0.18
6-15	698	52.28	0.03	47.58	0	0.11	53.23	0.03	46.66	0	0.08
6-20	706	52.65	0.27	46.11	0	0.97	50.93	1.52	42.14	0	5.41
7-16	729	52.73	0.23	46.31	0.02	0.71	50.10	2.02	40.15	0	7.73
8-11	755	53.92	0.10	45.71	0.04	0.23					
8-18	762	46.62	0.02	53.26	0	0.10	54.24	0.02	45.69	0.07	0.05
8-29	773	52.07	0.02	47.86	0.02	0.03	53.81	0.04	46.06	0	0.14

(Continued on Page 13)

TABLE 4.4.1 (Continued)

Gas Composition in Cell A

Date	Elapsed Time In Days Following Completion of Cell	Per Cent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
9-01-66	776	52.65	0.02	47.22	0.02	0.09	54.10	0.02	45.82	0	0.06
9-08	783	54.08	0.13	45.45	0.01	0.33	60.36	0.03	39.48	0	0.13
9-15	790	55.41		44.46	0.03	0.08	49.42	0.03	50.41	0	0.14
9-20	795						55.97	0.03	43.91	0	0.09
9-27	802						55.64	0.31	43.41	0	0.64
10-04	809	51.28	0.23	47.76	0.01	0.72	61.20	0.57	36.19	0	2.04
10-11	815	51.25	0.03	48.61	0.01	0.10	51.22	0.44	46.71	0	1.63
11-01	836	53.45	0.12	45.98	0	0.45	52.34	0.14	47.01	0	0.51
11-15	850	49.96	0.05	49.80	0	0.19	60.55	0.06	39.15	0	0.24
11-29	864	54.59	0.05	45.21	0	0.15	51.18	0.08	48.24	0	0.50
12-28	893						49.35	1.19	44.86	0	4.59

Note: Chromatograph down for repairs 4-7 to 4-20 and 7-16 to 8-4.

TABLE 4.4.2

Gas Composition in Cell B

Date	Elapsed Time In Days Following Completion of Cell	Per Cent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-06-66	539	54.46	0.19	44.77	0	0.58	52.16	0.69	45.07	0	2.08
1-13	546	52.62	0.14	47.07	0	0.20	52.56	0.32	46.36	0	0.76
2-10	574	54.78	0.21	44.53	0	0.48	57.82	0.22	41.43	0	0.53
2-17	581	54.49	0.17	44.93	0	0.41	51.67	0.12	47.88	0	0.33
2-24	588	55.77	0.26	43.28	0	0.69	61.16	0.31	37.58	0	0.95
3-03	595	52.97	0.03	46.90	0	0.10	61.56	0.04	38.27	0	0.13
3-10	602						63.35	0.05	36.48	0	0.12
3-17	609						59.94	0.06	39.85	0	0.15
3-24	616	54.69	0.13	44.89	0	0.29	59.85	0.14	39.77	0	0.24
3-31	623	56.29	0.02	43.69	0	0.05	59.08	0.07	40.63	0	0.22
4-21	643	46.46	1.43	33.17	0	18.94	26.19	4.68	6.92	0	62.21
4-28	650	53.68	1.64	36.07	0	8.61	31.32	5.50	7.57	0	55.61
5-05	657	54.13	1.00	40.29	0	4.58	32.40	5.44	7.21	0	54.95
5-19	671	54.99	0.78	40.85	0	3.58	36.60	3.30	16.28	0	43.82
5-26	678	56.20	0.64	40.44	0	2.72	37.15	4.98	17.51	0	40.36
6-02	685	54.91	0.33	43.50	0	1.26	41.23	3.94	22.95	0	31.88
6-15	698	52.88	0.09	46.70	0	0.33	45.52	3.06	33.46	0	17.96
7-16	729	52.75	0.46	45.04	0	1.74	48.11	1.42	34.66	0	15.81
8-04	748	54.84		44.39	0.04		53.86		37.11	0.01	
8-11	755	53.89	0.07	45.77	0.01	0.26	53.28	1.18	39.44	0.01	6.09
8-18	762	51.99	0.08	47.62	0	0.31	52.85	0.93	39.51	0	6.71
8-29	773	53.68	0.03	46.15	0.02	0.12	52.38	0.88	43.14	0	3.60
9-01	776	51.64	0.20	47.37	0.01	0.78	51.75	0.84	43.07	0.01	4.33

(Continued on Page 15)

TABLE 4.4.2 (Continued)

Date	Elapsed Time In Days Following Completion of Cell	Gas Composition in Cell B — Per Cent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface								
		7 Feet					13 Feet			
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
9-08-66	783	53.85	0.13	45.69	0.01	0.32	54.37	0.76	41.33	0	3.54
9-15	790	50.90	0.06	48.82	0.01	0.21	54.13	1.17	38.92	0.01	5.77
9-20	795	52.14	0.07	47.28	0.01	0.50	52.41	0.87	43.18	0	3.54
9-27	802	54.20	0.14	45.25	0.01	0.40	53.99	0.32	44.35	0.01	1.33
10-04	809	49.96	0.07	49.61	0.04	0.32	54.67	0.41	42.93	0	1.99
10-11	815	51.56	0.14	47.82	0.04	0.44	53.63	0.21	45.03	0.04	1.09
11-01	836	52.70		46.54	0.01		53.79	1.45	38.17	0	6.59
11-15	850	51.07	0.03	48.73	0	0.17	53.34	1.14	40.68	0	4.84
11-29	864	50.24	0.42	47.54	0	1.80	50.46	1.78	37.70	0	10.06
12-28	893	34.28	6.67	33.70	0	25.35	51.34	0.43	46.51	0	1.72

Note: Chromatograph down for repairs 4-7 to 4-20 and 7-16 to 8-4.

TABLE 4.4.3

Date	Elapsed Time In Days Following Completion of Cell	Gas Composition in Cell C — Per Cent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface								
		7 Feet					13 Feet			
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
1-06-66	518	57.34	0.36	40.82	0.33	1.15	44.72	3.86	37.73	0	13.69
1-13	525	61.78	0.43	36.76	0.27	0.76	18.43	15.41	17.37	0	48.79
2-10	553	59.73	0.48	38.65	0.32	0.82	48.20	2.82	41.37	0	7.61
2-17	560	57.14	0.18	41.91	0.18	0.59					
2-24	567	61.10	0.15	38.10	0.17	0.48					
3-03	574	58.88	0.07	40.62	0.20	0.23	32.45	7.49	31.88	0	28.18
3-10	581	59.35	0.18	39.81	0.19	0.47	43.59	5.26	34.50	0	16.65
3-17	588	58.67	0.32	40.25	0.10	0.66	38.98	6.41	35.37	0	19.24
3-24	595	59.16	0.12	40.24	0.16	0.32	32.88	9.68	26.77	0	30.67
3-31	602	60.11	0.79	36.43	0.17	2.50	41.51	4.12	35.62	0	18.75
4-21	622	19.63	4.55	4.50	0.01	71.21	15.36	9.27	7.37	0	68.00
4-28	629	23.90	12.23	4.03	0.15	59.69	14.53	13.79	4.35	0	67.33
5-05	636	24.67	7.04	4.88	0.09	63.32	15.53	12.53	6.17	0	65.77
5-19	650	24.28	6.36	4.87	0.16	64.33	15.89	11.73	5.88	0	66.50
5-26	657	18.46	9.34	3.68	0.04	68.48	17.59	12.60	8.31	0	61.50
6-02	664	19.89	9.06	4.59	0.06	66.40	19.96	9.47	7.23	0	63.34
6-15	677	19.87	6.44	5.04	0	68.65	6.66	14.69	3.49	0	75.16
7-16	708	10.79	5.66	7.73	0.04	75.78	5.27	11.39	2.84	0	80.50
8-04	727	16.82		4.15	0.10		7.44		4.21	0	
8-11	734	19.98	7.89	8.29	0.06	63.78	7.36	16.55	4.61	0	71.48
8-18	741	11.44	7.62	11.12	0.04	69.78	9.50	15.49	5.30	0	69.71
8-29	752	22.64	7.98	18.13	0.05	51.20	10.13	17.03	7.42	0	65.42
9-01	755	21.91	8.33	17.84	0.03	51.89	7.59	17.61	5.69	0	69.11

(Continued on Page 17)

TABLE 4.4.3 (Continued)

Gas Composition in Cell C

Date	Elapsed Time In Days Following Completion of Cell	Per Cent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
9-08-66	762	32.43	6.75	14.86	0.08	45.88	5.24	17.56	6.74	0	70.46
9-15	769						10.24	16.07	3.66	0	70.03
9-20	774	21.25	10.03	21.45	0.03	47.24	9.45	17.56	5.62	0	67.37
9-27	781	10.97	16.08	8.60	0.02	64.33	8.84	16.74	5.77	0	68.65
10-04	788	11.38	15.93	4.92	0	67.77	12.89	8.56	39.12	0	39.43
10-11	795	6.81	18.20	0.59	0.01	74.39	19.37	11.40	7.63	0	61.60
10-23	807	10.37	18.09	4.84	0.01	66.69	7.64	16.91	4.18	0	71.27
11-01	816	14.24	14.74	5.93	0.02	65.07	8.38	17.80	4.38	0	69.44
11-15	830						10.22	16.69	8.22	0	64.87
11-29	844	14.69	12.20	8.27	0.02	64.82	5.19	17.96	3.20	0	73.65
12-28	873	17.17	13.85	13.06	0	55.92	16.33	14.29	11.80	0	57.58

Note: Chromatograph down for repairs 4-7 to 4-20 and 7-16 to 8-4.

TABLE 4.4.4

Summary of Blower Operation, Cell C

Elapsed Time in Days Following Completion of Cell		Blower		Blower Cycle		Remarks
A and B	C	On	Off	Hr on	Hr off	
541	517		x			Leach withdrawn upper level Cell B
576	552		x			Leach withdrawn upper level Cell B; 31 in. water bottom Cell B
625	601	x		0.5	3.5	Blower started after being off for 112 days because of delay in motor repair and flooding of air distribution system. Leach withdrawn upper level Cell B; 20 in. water bottom Cell B
667	643	x				12 in. water bottom Cell B 2 in. water bottom Cell C
791	767	x				Started adding water to Cell C through top spray system
817	793	x				Finished adding water to Cell C through top spray system 12800 gal added
819	795	x				Replaced blower connections
847	823	x				Cave-in in Cell C, 3-1/2 ft dia by 4 ft deep, near edge; hot spot temperature was 180 deg F December 1, 1966
869	844	x		0.5	1.0	
	862	x				Recirculation of Cell gas discontinued

correlated. As stated in the preceding paragraph, the blower was put back into service early in April, and the immediate effect on the gas composition is evident. The nitrogen content increased greatly, accompanied by a decrease in carbon dioxide and methane, all as expected. While oxygen also increased as anticipated, there remained considerably more methane than expected.

It is emphasized that for the last 9 months of the year the blower was in continuous operation: on 0.5 hr and off 3.5 hr to December 1 and then on 0.5 hr and off 1.0 hr. The data obtained during that time have been very consistent -- more so than during any other operating period when blower operation was either changed or shut down. The effect of increasing the blower "on" time on December 1 is reflected in the last sample taken on December 28 when, at the upper level, the carbon dioxide and methane decreased and the oxygen and nitrogen increased. The new cycle had little effect on the cell bottom environment.

4.5 Cell Temperatures. In Tables 4.5.1 through 4.5.3 are presented the temperature data for all of the cells. For each cell are shown the maximum, minimum and average temperatures for the air and the access well, and the internal temperatures at depths of 4, 10 and 16 ft below the finished surface elevation. All of these readings are correlated with the date on which they were taken and the total elapsed time in days following the completion of each cell.

During the year, Cell A at mid-depth experienced a range of but 11 deg. F, from 64 in the winter to 75 in the summer, a high insufficient to expect any great amount of bacterial activity. The frequent application of water apparently serves to cool the landfill mass.

The same may be said of Cell B, wherein a range of but 15 deg. F was experienced, from 66 in the winter to 81 in the summer.

In Cell C, the temperature of the upper level dropped during the first 3

TABLE 4.5.1

Temperatures in Cell A

Date	Elapsed Time Since Cell Completion (days)	Per Cent Humidity		Temperatures, °F						
				Air*			Access Well	Below Finished Elevation, Ft		
		*Air	Access Well	Max	Min	Avg		4	10	16
1966										
1-08	541	36		72	41	52	62	58	69	68
1-13	545	21		74	42	57	67	63	73	76
2-10	573	58		62	34	46	68	60	72	71
2-17	580	24		68	36	50	66	60	72	70
2-24	587	53		69	42	52	64	62	72	74
3-03	594	29		60	28	42	67	62	72	72
3-10	601	49		72	39	53	66	63	72	73
3-17	608	30		82	38	58	67	64	72	73
3-24	615	44		77	50	60	67	66	72	77
3-31	622	18		96	52	71	68	66	72	74
4-06	628	50		77	45	58	68	67	72	74
4-16	638	48		75	45	67	69	68	72	77
4-21	644	36		76	42	58	69	68	72	77
4-28	651	39		80	44	59	70	69	72	77
5-05	658	75		74	52	59	71	70	72	77
5-12	665	69		81	50	61	72	70	73	75
5-19	672	54		89	47	62	72	70	72	74
5-26	679	87		65	55	59	73	72	72	75
6-02	686	68		83	43	58	73	73	73	79
6-09	693	74		72	56	61	74	73	72	75
6-15	698	63		83	56	66	74	75	73	78
6-23	706	56		88	50	68	74	75	73	75
7-13	726	38		92	46	66	77	77	74	80
7-21	734	63		81	54	62	84	78	74	84
8-02	746	53	91	86	60	70	76	79	74	76
8-11	755	61		92	60	70	76	80	75	81
8-18	762	47		84	60	71	80	80	74	81
8-26	770	43		98	54	70	77	80	74	80
9-01	776	62		77	60	68	77	80	74	80
9-09	784	34	98.5	95	60	73	77	80	74	81
10-06	811	78	83.0	81	52	62	74	75	72	74
10-20	825	26		75	48	59	74	73	72	74
11-01	837	11	91.0	74	44	56	73	74	72	73
11-10	846	59		68	42	51	73	77	73	64
11-27	858	72		61	37	48	73	80	73	68
11-29	865	55	99	56	41	47	73	78	73	68
12-08	874	72		60	38	48	61	71	64	60
12-15	881	32		65	46	58	62	72	65	60

* Data From Pomona Weather Bureau

TABLE 4.5.2

Temperatures in Cell B

Date	Elapsed Time Since Cell Completion (days)	Per Cent Humidity		Temperatures, °F						
				Air*			Access Well	Below Finished Elevation, Ft		
		*Air	Access Well	Max	Min	Avg		4	10	16
1966										
1-08	541	36		72	41	52	69	67	81	-
1-13	545	21		74	42	57	71	68	83	-
2-10	573	58		62	34	46	69	67	82	-
2-17	580	24		68	36	50	71	66	82	
2-24	587	53		69	42	52	72	66	82	
3-03	594	29		60	28	42	72	66	82	
3-10	601	49		72	39	53	73	66	80	
3-17	608	30		82	38	58	74	66	80	
3-24	615	44		77	50	60	77	67	81	
3-31	622	18		96	52	71	77	67	80	
4-06	628	50		77	45	58	77	68	80	
4-16	638	48		75	45	67	79	69	80	
4-21	644	36		76	42	58	78	69	80	
4-28	651	39		80	44	59	79	69	79	
5-05	658	75		74	52	59	81	72	81	
5-12	665	69		81	50	61	80	73	82	
5-19	672	54		89	47	62	80	73	80	
5-26	679	87		65	55	59	80	73	80	
6-02	686	68		83	43	58	76	74	80	
6-09	693	74		72	56	61	76	73	79	
6-15	698	63		83	56	66	82	75	80	
6-23	706	56		88	50	68	80	74	79	
7-13	726	38		92	46	66	82	77	79	
7-21	734	63		81	54	62	83	77	80	
8-02	746	53	84	86	60	70	83	78	79	
8-11	755	61		92	60	70	84	79	80	
8-18	762	47		84	60	71	81	79	82	
8-26	770	43		98	54	70	84	81	81	
9-01	776	62		78	60	68	82	81	81	
9-09	784	34	81	95	60	73	81	81	80	
10-06	811	78	89.6	81	52	62				
11-01	837	26	95	75	48	59	80	74	81	
11-10	846	11		74	44	56	68	73	77	
11-22	858	59		68	42	51	73	72	78	
11-29	865	55		56	41	47	74	71	77	
12-08	874	72		60	38	48	59	70	76	
12-15	881	32		65	46	58	60	68	76	

* Data From Pomona Weather Bureau

TABLE 4.5.3

Temperatures in Cell C

Date	Elapsed Time Since Cell Completion (days)	Per Cent Humidity		Temperatures, °F						
				Air*			Access Well	Below Finished Elevation, Ft		
		*Air	Access Well	Max	Min	Avg		4	10	16
1966										
1-08	516	36		72	41	52	97	111		
1-13	521	21		74	42	57	97	108		
2-10	549	58		62	34	46	97	99		
2-17	556	24		68	36	50	99	95		
2-24	563	53		69	42	52	101	93		
3-03	570	29		60	28	42	101	93		
3-10	577	49		72	39	53	101	92		
3-17	584	30		82	38	58	101	90		
3-24	591	44		77	50	60	104	92		
3-31	598	18		96	52	71	104	91		
4-06	605	50		77	45	58	117	91		
4-16	615	48		75	45	67	119	91		
4-21	620	36		76	42	58	116	92		
4-28	627	39		80	44	59	117	93		
5-05	634	75		74	52	59	119			
5-12	641	69		81	50	61	119			
5-19	648	54		89	47	62	122			
5-26	655	87		65	55	59	119			
6-02	662	68		83	43	58	119			
6-09	669	74		72	56	61	111			
6-15	677	63		83	56	66	117			
6-25	685	56		88	50	68	117			
7-13	703	38		92	46	66	116			
7-21	711	63		81	54	62	119			103
8-02	723	53		86	60	70	118			103
8-11	732	61		92	60	70	118			112
8-18	739	47		84	60	71	118			113
8-26	747	43		98	54	70	117			113
9-01	753	62		78	60	68	119			114
9-09	761	34	96	95	60	73	117			114
10-20	802	78	97	81	52	62	127			108
11-01	814	26	96	75	48	59	122			107
11-10	823	59		68	42	51	117			110
11-22	835	72		61	37	48	112			105
11-29	842	55	98	56	41	47	112			104
12-08	851	72		60	38	48	98			102
12-15	858	32		65	46	58	90			100

* Data From Pomona Weather Bureau

months, while the blower was shut down for repairs, from 111 to 91 deg. F. Then, with restarting of the blower, the temperature rose gradually to a high of 114 deg. F. The temperature started to decline with the coming of cool weather and was 100 deg. F at the close of the year. The effect of increasing the blower "on" time on December 1 and discontinuing recirculation of cell gas on December 19 has not yet shown up.

Thermistors in Cell C at mid-depth and bottom levels were lost some time ago. To obtain bottom temperatures, a thermometer immersed in a water bath was suspended in the access well. As shown, the thermometer readings are consistently higher than the thermistor readings at the upper level. This condition should exist since the air is introduced at the bottom of the cell and greatest oxidation will occur at that level. When Cell C was cored, those core samples which appeared unusually warm were checked with a thermometer immediately upon their being brought to the surface. These spot temperatures are recorded in the logs shown in Table 4.5.4 and are seen to be considerably higher on occasion than the temperatures routinely taken by thermistors.

Thermometers were also suspended in the access wells of Cells A and B, and they do a fair job of confirming thermistor readings.

TABLE 4.5.4

LOG OF CORES FOR CELLS A, B AND C

Cell and Core No.	Elapsed Time Since Cell Completion Days	Distance Below Top of Cell Ft	Observation
A-1	766	2	Moist sand and dirt - no odor
		4	Paper moist and legible - grass decomposing - plastic soft - mild odor
		6	Wood very moist - grass brown - strong odor
		8	Paper moist - grass green
		10	Cloth very moist and decomposing - no odor
		12	Grass green - metal clean and shiny
		14	Decomposed paper - metal clean
		16	Cloth unaffected
		18	Newspaper pulpy
		20	Bottom temperature 78 deg F
			Coring time 55 minutes
A-2	766	4	Cool moist dirt - mild odor
		6	Wet paper and grass
		8	Newspaper pulpy
		10	Refuse decomposed
		12	Grass green - metal clean and shiny
		14	Plastic unaffected
		18	Grass moist and mushy
			Coring time 35 minutes
B-1	766	2	Dirt only
		4	Moist legible paper - no odor
		8	Moist legible paper - cloth deteriorated
		10	Metal shiny
		12	Some decomposition of newspaper
		14	Rubber and moist wood unaffected
		16	Core temperature 84 deg F - mild odor
		18	Refuse dry - metal clean and shiny
		20	Cloth decomposing
			Coring time 45 minutes
B-2	766	4	Moist green grass - odor mild
		6	Paper moist but unaffected
		8	Refuse wet and mushy - grass slimy
		10	Grass green
		12	Metal clean and shiny
		16	Metal clean and shiny
		18	Cloth and plastic unaffected
		20	Moist clay - odor mild
			Coring time 30 minutes

(Continued on Page 25)

TABLE 4.5.4 Continued

LOG OF CORES FOR CELLS A, B AND C

Cell and Core No.	Elapsed Time Since Cell Completion Days	Distance Below Top of Cell Ft	Observation
C-1	743	2	Dirt only
		4	Grass decomposing - strong odor
		6	Newspaper decomposing - metal dull - core temperature 102 deg F
		8	Refuse warm and mushy - grass decomposing
		10	Grass and cloth decomposing - plastic unaffected - core temperature 122 deg F
		12	Core temperature 115 deg F
		14	Metal dull - much rotted material - core temperature 128 deg F
		16	Much decomposed material
		18	Nylon decomposed - high temperature 180 deg F
			Coring time 25 minutes
C-2	743	4	Dirt only (drilled in location of former cave-in)
		6	Charred material - milk cartons soft and decomposed - steam visible
		8	Refuse very decomposed - mild odor core temperature 126 deg F
		10	Newspaper charred
		12	Cushion padding decomposed
		14	Grass decomposed - paper soft but legible
		18	Clay bottom - core temperature 140 deg F
			Coring time 18 minutes

5. NEW CELL D

5.1 Construction. The present research program has as one of its announced purposes the construction of a large volume, gas-tight cell to be used for quantitative study of gas production.

Since previous efforts to study gas production by encapsulating a large mass of refuse within an impervious polyethelene membrane failed, it was decided to make a new approach and seal the refuse within a steel enclosure. For this purpose, there was purchased a 10,000 gal underground storage tank, 95' I.D. x 28'0" high, manufactured from 1/4" A-36 steel. To minimize corrosion the tank was given a resinous inside coating and was covered with an asphalt paint on the outside. The tank is shown on Figure 5.1.1.

The tank was installed at a site adjacent to existing Cell C and, in fact, on the site of former Cell D which failed in its purpose. A standard clamshell-type bucket was used to take out the old refuse, sand, and plastic membrane until there had been formed an open pit 28.5 ft deep measuring about 12 ft x 14 ft at the bottom and 36 ft x 36 ft at the top. A 3-ft layer of refuse was placed at the bottom and this in turn was covered by 1/4-in. thick plywood, both to provide a cushion for the tank and protection for the tank bottom. A crane was used to lower the tank into the hole and hold it in a vertical position while an insulating layer of refuse was placed around it. The vertical free-standing tank in its final position extended 3 ft above ground level. Dirt was packed around the above-ground projection to form a sloping berm. The tank was then ready for filling with refuse.

A 6 in. layer of sand was placed in the bottom of the tank. Some 31,090 lb of refuse as delivered to the tank in weighed packers were then placed in the tank. The refuse was typically domestic, having been collected from homes in Pomona. From spot sampling of the refuse, the breakdown by volume was 42.7%

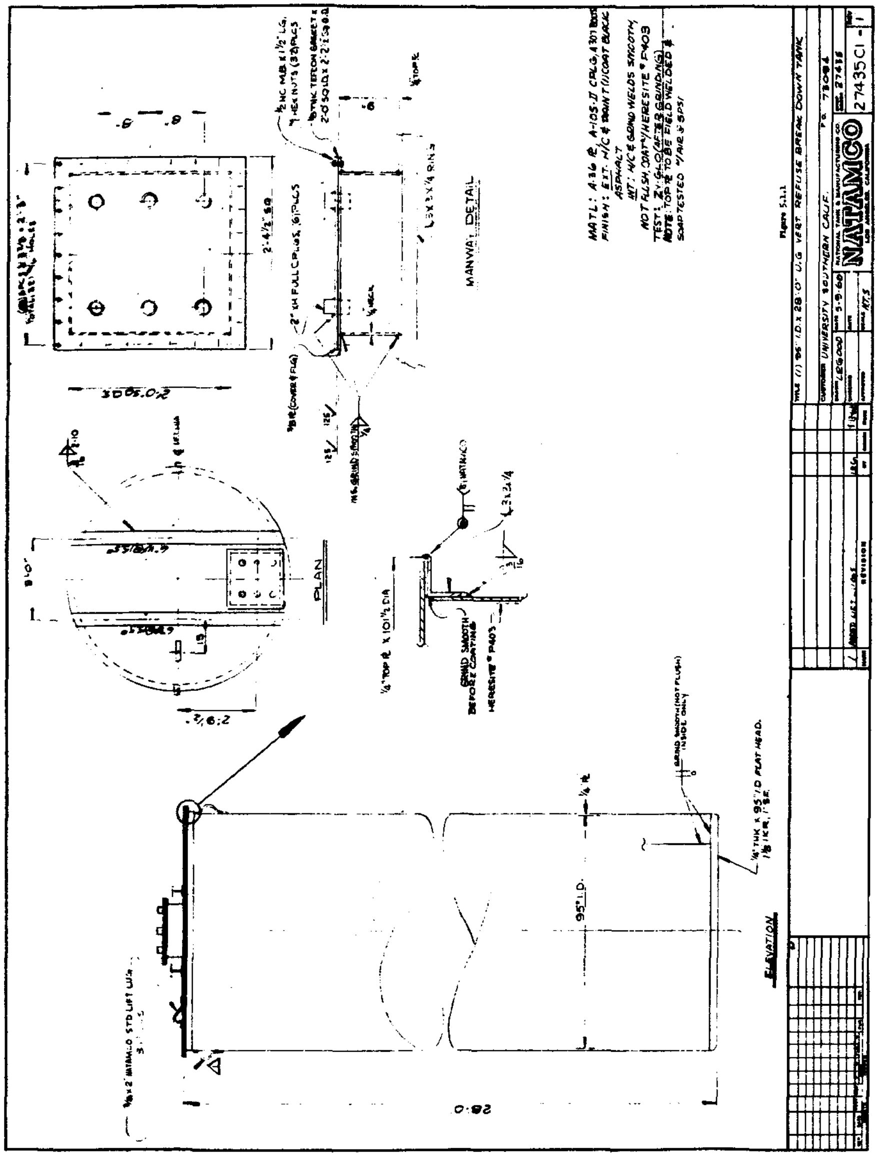


Figure 5.1.1

paper, 38% grass and garden clippings, 3% plastic, 5% glass, 7% metal and 5% dirt. During placement of the refuse, a system of perforated piping was installed to permit withdrawal of gas at top, bottom and mid-depth (or to add water), and thermistors were installed at similar locations. Also during placement of the refuse, sufficient water was added to bring the moisture content to 69.9% on a dry weight basis. The construction summary is presented in Table 5.1.1. Since compaction was limited within the confines of so small an area, the resulting in-place density was a low 634 lb per cu yd.

The top of the tank was sealed by a continuous, external weld. After the cover was welded in place, field personnel entered the tank through a manhole to paint the inside of the weld with a protective sealant. Additional refuse and a top layer of dirt were then laboriously added through the cover manhole to fill the tank. Flexible, neoprene hoses connected the pipes carrying the thermistor leads and the gas pipes to the hatch nipples, and the hatch was then bolted down. A plastic gasket in combination with a liquid sealant were used to make the hatch gas tight.

All joints and welds were brushed with a fluorsene soap solution and the tank was tested by placing it under a pressure of 1 psi by pumping compressed air into it. After holding the pressure for 30 minutes, the pressure was released and the tank was considered sealed under zero pressure, confirmed by a water manometer.

The complete system is illustrated in Figure 5.1.2.

The gas manifold was immediately connected to a wet test cell, later replaced by a gasometer, for measurement of all gas produced by the decomposing refuse.

5.2 Performance. In Table 5.2.1 are presented the performance data covering the six-month period following completion of the installation.

For approximately the first month, the exterior gas manifold was directly

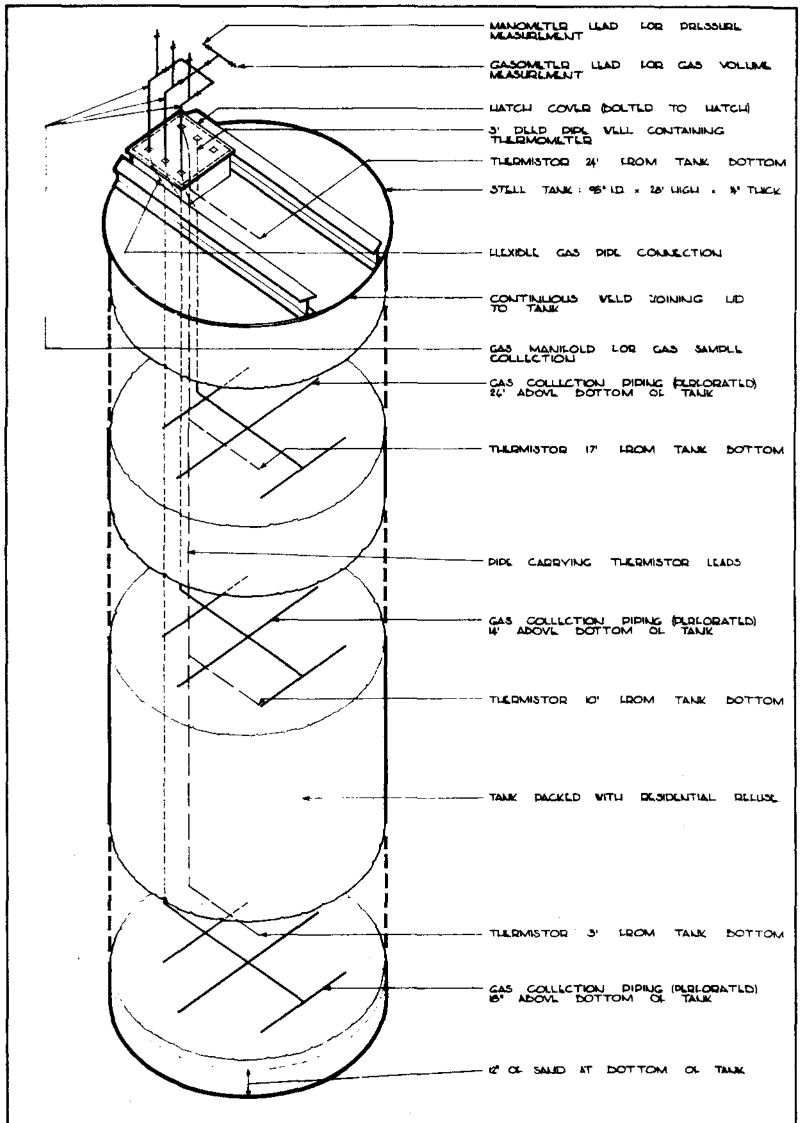
TABLE 5.1.1

Line	Construction Summary for Cell D	
1	Date Started	6-28-66
2	Date Completed	7-07-66
3	Working Days to Place Refuse in Cell	
4	Cubic Yards of Refuse Trucked to Cell[2]	73
5	Pounds of Refuse Trucked to Cell[2]	31,090
6	Delivered Trucked Density, Pounds Per Cu Yd[3]	427
7	Volume of Cell, Cubic Yards[4]	49
8	Fill Density, Pounds Per Cubic Yard[5]	634
9	Gallons of Water Added[6]	415
10	Pounds of Water Added	3,450
11	Pounds of Water Present in Trucked Refuse[7]	7,993
12	Total Pounds of Water in Cell	11,443
13	Per Cent Moisture of Cell, Dry Weight Basis[8]	69.9

Notes:

1. Calculations exclude final fill covers.
2. Actual truck volumes and scaled weights
3. $\frac{\text{Line 5}}{\text{Line 4}}$
4. Determined by field measurements
5. $\frac{\text{Line 5}}{\text{Line 7}}$
6. Measured by water meter.
7. Determined by laboratory tests of representative samples
8. $\frac{(\text{Line 5} \times 34.6\%) + \text{Line 10}}{\text{Line 5} - (\text{Line 5} \times 34.6\%)} \times 100$

   Moisture content of refuse on wet basis = 34.6%



ASSEMBLY DIAGRAM CELL D | 5·1·2

TABLE 5.2.1

CELL D PERFORMANCE DATA

Date	Days Following Completion of Cell	Cumulative Volume of Gas Produced Cu Ft	Cell Pressure In. Water	Temperatures at Locations Below Top of Cell Deg F			
				Bottom	21 Ft	14 Ft	7 Ft
7-08	1	15.68	+12.9	88	100	93	100
7-09	2	34.39	+ 9.2	89	97	93	100
7-10	3	39.28	+ 6.6	88	96	93	97
7-12	5	39.35	+ 2.0	88	96	93	97
7-13	6	39.35	+ 2.3	88	96	93	97
7-14	7	39.42	+ 1.5	89	98	94	97
7-16	9	39.54	0	88	96	--	--
7-18	11	39.68	0	89	99	95	99
7-19	12	40.01	0	89	96	95	97
7-21	14	40.03	0	89	101	97	104
7-22	15	40.06	+ 0.3	85	94	94	95
7-26	19	40.10	---	--	--	--	--
7-27	20	40.10	+ 1.0	--	--	--	--
7-28	21	40.10	+ 0.4	--	--	--	--
8-01	25	40.10	---	--	--	--	--
8-02	26	40.10	---	86	92	94	95
8-04	28	40.11	+ 5.1	--	--	--	--
8-05	29	40.11	+ 3.5	86	92	95	97
8-08	32	40.16	+ 0.4	87	91	96	96
8-11	35	40.20		86	92	94	94
8-12	36	40.28		86	91	94	96
8-15	39	40.30		85	89	94	94
8-16	40	40.34		86	92	94	94
8-18	42	40.34		85	90	94	94
8-19	43	40.34		86	90	94	94
8-22	46	40.34		86	90	94	94
8-25	49	40.34		84	95	94	97
8-26	50	40.34		84	90	93	97
8-29	53	40.39		86	89	93	93
9-01	56			84	90	93	98
9-07	62			85	89	96	92
9-09	64			87	89	92	91
10-13	98			--	--	--	--
10-20	105			87	89	89	88
11-01	117			81	85	88	88
11-03	119			--	--	--	--
11-22	138			80	85	89	83
11-29	145			83	84	89	85
12-08	154			78	83	87	79
12-15	161			78	83	87	78
12-19	165			--	--	--	--
12-28	174			--	--	--	--

Note: Wet Test Cell used to measure gas produced through 8-08
Gasometer used to measure gas produced beginning 8-09
No gas produced after 8-29
450 gal water added to cell 9-07 and 9-08
The cell was under a vacuum after 10-13

connected to a wet test cell. All valves were open, permitting measurement of all gas produced within the cell. The discharge line from the wet test cell was submerged to maintain a positive pressure on the entire system. Within 3 days, 39.3 cu ft of gas had been produced and measured, and this volume proved to be 98% of that which would be produced. During these three days, the internal pressure (in. water) of the cell dropped from the initial reading of 12.0 to 6.5, and then to zero 6 days later. At that time, the wet test cell was permitted to discharge into the atmosphere.

Because gas production had fallen off to almost immeasurable quantities, the wet test cell was replaced after 33 days with a laboratory-built gasometer which would permit storage of gas and more accurate volume determinations. However, by the end of the second month, all gas production ceased.

The tabulated data show a decline in temperature (deg F) at all levels; from 88 to 78 at the bottom, from 100 to 83 at the bottom quarter, from 93 to 87 at mid-depth, and from 100 to 78 at the top quarter. Using the gas collection piping at the top of the cell as a spray system, 450 gallons of water were added on the 62nd day to raise the moisture content of the refuse and improve the environment necessary for bacterial activity. The decision to add water was prompted, of course, by the stoppage of gas production. The addition of water not only did not result in a step-up of gas production, but also served to decrease cell temperatures at a still faster rate and put the entire cell under a vacuum. Negative pressures were first observed in the 98th day and existed until the 145th day. Temperatures remained low through the end of the period covered by this progress report and it is not expected that significant gas quantities will be produced until temperatures come back up to at least 90° F. The high percentage of cellulose packed into the cell will also markedly limit the rate of gas production.

Appendix 8.3

FACTORS CONTROLLING UTILIZATION OF SANITARY LANDFILL SITE

Project Number EF-00160-05

Final Report to

Department of Health, Education, and Welfare

National Institutes of Health

United States Public Health Service

January 1, 1964 to December 31, 1965

Prepared by Principal Investigators

Robert C. Merz, Chairman
Department of Civil Engineering

Ralph Stone
Research Associate

University of Southern California
Los Angeles, California

FACTORS CONTROLLING UTILIZATION
OF SANITARY LANDFILL SITE

Project Number EF-00160-05

Final Report to

Department of Health, Education, and Welfare

National Institutes of Health

United States Public Health Service

January 1, 1964 to December 31, 1965

Prepared by Principal Investigators

Robert C. Merz, Chairman
Department of Civil Engineering

Ralph Stone
Research Associate

University of Southern California
Los Angeles, California

UNIVERSITY OF SOUTHERN CALIFORNIA
SCHOOL OF ENGINEERING
UNIVERSITY PARK
LOS ANGELES, CALIFORNIA 90007

DEPARTMENT OF CIVIL ENGINEERING

March 25, 1966

Mr. Harold B. Robinson, Chief
Research Grants Branch
Division of Environmental Engineering
and Food Protection
Department of Health, Education & Welfare
United States Public Health Service
National Institutes of Health
Bethesda 14, Maryland

Subject: EF 00160-05

Dear Mr. Robinson:

Forty copies of our final report covering the studies made under Grants EF 00160-04 and -05 on the "Factors Controlling Utilization of Sanitary Landfill Sites," are submitted to you with this letter. The privilege of carrying out this work has been very much appreciated, and we hope the information included herein proves useful to those interested in solid waste disposal.

Respectfully submitted,

Robert C. Merz, Chairman
Dept. of Civil Engineering
& Principal Investigator

2. FOREWORD

The Department of Civil Engineering of the University of Southern California, in May 1963, completed a 3-year study of the factors controlling the use of a sanitary landfill site. The purpose of the study was to determine the optimum means by which the most waste can be put into the available volume and at the same time permit shrinkage prediction. Funds were provided by three grants from the United States Public Health Service through assignment from the National Institutes of Health. Copies of the final report are available from the University.

A supplementary grant was provided to continue the study. Four test cells of various sizes were constructed at the Spadra Landfill, Walnut, California, by the County Sanitation Districts of Los Angeles County which has continued to lend its support to the project. The conditions of construction of the cells were varied, and one has been permitted to decompose in an aerobic environment.

This report covers the completed 2-year study extending from January 1, 1964 to December 31, 1965.

The project was under the joint directorship of Professor Robert C. Merz, Chairman, Dept. of Civil Engineering, and Research Associate Ralph Stone. Valuable assistance in the field and laboratory was rendered by Andrew Boyd, Ramon Beluche, Raymond Rodrigue and Roger Olack, Graduate Research Assistants.

3. ACKNOWLEDGMENTS

This research has been supported by the Public Health Service Research Grants EF-00160-04 and -05.

The County Sanitation Districts of Los Angeles County constructed the test cells and provided field assistance when requested. The help of the staff of the Sanitation Districts, and of John D. Parkhurst, Chief Engineer and General Manager, is gratefully acknowledged.

Other individuals who have played important roles in this study include the following:

Mr. John Blatt, Palco Linings, Inc., Indio, California, for supervising the lining of one of the cells with VisQueen film;
Dr. Glen Cannel, University of California, Riverside, for manufacturing and supplying the moisture probes installed in all of the test cells;
Mr. Tom Fellows, Fellows & Associates, Inc., Los Angeles, for providing the sandy silt needed as top cover for one of the cells;
Mr. David C. Henderson, Southern California Edison Company, Pomona, California, for consultative services in bringing power to the research site;
Mr. Paul Ledig, Asgro Seed Company, Azusa, California, for furnishing the Bermuda seed for the test grass plot for one of the cells;
Mr. John McQuade, Pope and Talbot, Inc., San Francisco for furnishing the soil additive "Loamite" which was mixed with native soil to provide cover for one of the cells;
Mr. Wayne C. Morgan, Farm Advisor, University of California Farm and Home Advisors, Los Angeles, for assisting in the analysis of the native soils and procurement of recommended additives;
Mr. G. C. Pooley, Irrometer Company, Riverside, California, for installation of the automatic sprinkler system for irrigation of the grass cover on one of the cells;
Mr. Stuart Shore, Sales Manager, Pacific Clay Products, Santa Fe Springs, California, for providing the Wedge-Lock perforated pipe and fittings needed for supplying air to one of the cells.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ILLUSTRATIONS

4. SUMMARY

Two years were spent in the preparation and study of the landfill cells described in this report. They exist at the Spadra Landfill No. 2, operated by the Los Angeles County Sanitation Districts. The purposes for which these cells were built were:

Test Cell A - Seattle rainfall pattern replication

Test Cell B - Turf development and irrigation

Test Cell C - Maintenance of aerobic environment

Test Cell D - Refuse encapsulation in polyethylene membrane to measure gas production

Summary statements follow.

1. Compaction ratios from 2.1 to 2.2, and an in-place density of 1000 lb per cu yd, were achieved for the test cells.
2. Cell A, receiving the Seattle rainfall equivalent plus an extra 55 in. (for a total of 87 in. of water), did not show percolation into the leach collection cans.
3. Cell B, after receiving 113 in. of applied irrigation water, produced leach in the collection can located 7 ft below the surface.
4. Normal turf development was readily achieved and maintained on Cell B.
5. The greatest settlement, nearly 2 ft in 17 months, occurred in aerobic cell C, whereas the two anaerobic cells A and B settled 0.5 and 0.4 ft, respectively, during the same period.
6. Extensive settlement in cell C produced cave-ins with holes measuring 3 ft by 4 ft that extended to the bottom of the cell. The cave-ins were caused by a combination of oxidation, heavy rainfall and surface flooding.

7. In anaerobic cell A, the major gas constituents by volume have been fairly steady over the past year at 60 percent carbon dioxide and 40 percent methane. Oxygen, hydrogen and nitrogen were present in varying amounts.

8. In cell B, the gas composition was affected by movement of air from cell C when the blower was in operation. The major gas components were carbon dioxide, nitrogen and methane.

9. Cell C was aerobically operated and the gas composition was dependent upon the duration of the blower operation. The chief gas components at the upper level of the cell were nitrogen (70 to 80 percent) and carbon dioxide (10 to 20 percent). Slightly lesser amounts existed at the lower level, but oxygen averaged about 10 percent. Methane was minimal when the blower was in operation.

10. The temperature at the 10-ft depth in anaerobic cell A was about 100 deg F for the first 5 months, and then gradually decreased to 71 deg F over the balance of the test period. The temperature behavior at the bottom depth was similar.

11. The temperature in cell B declined from an early peak of 120 deg to 70 deg F. Although intended to be an anaerobic cell, its performance was influenced by the passage of air from cell C nothwithstanding a compacted, 5-ft wide, continuous earth barrier.

12. The aerobic cell C supported a 193 deg F temperature at mid-depth as much as 174 days following cell construction. Bottom temperatures reached peaks sufficiently high to destroy thermistors. Smoke emanations with fire were noted on a few occasions. The cell temperature was affected by the aeration cycle.

13. Cell D, intended for determining quantitative studies of gas production, was unsuccessful although constructed with extreme care by professional

plastic fabricators. The polyethylene envelope was not able to store gas.

14. Coring and side cutting of the 5 original, 4+ yr old, anaerobic test cells demonstrated that only minor decomposition of the solid wastes had occurred. Moisture analyses on a dry weight basis for numerous core samples ranged from 5.3 to 42.9 percent, considerably less than computed values at the time of construction.

5. THE SANITARY LANDFILL SITE

5.1 Selection. As in the case of the earlier study (see page ii), this investigation was conducted at Spadra Landfill No. 2. This landfill, operated by the County Sanitation Districts of Los Angeles County, is located as shown in Figure 5.1.1, near the City of Pomona at 4125 West Valley Blvd.

5.2 Preparation. Preparation of the site on which the test cells were to be constructed included clearing away of walnut trees, excavation of the cells, placement of access wells, and installation of the facilities required before placement of the refuse.

5.2.1 Cell Excavation. It was decided to position 4 cells in an area adjacent to the entrance to the landfill, as close as possible to the Weighmaster's office as well as a source of power. This area was of a gently sloping nature, so that it was necessary to resort to both cut and fill operations to form the 4 cells. Cells A and B were formed by cutting into undisturbed earth. Cells C and D were formed in well compacted earth. Construction of the cells was undertaken by the District personnel, utilizing bulldozers and scrapers. Cell D, which failed in its purpose, is further discussed in the appendix.

When completed, the 3 test cells were fully below finished grade. End slopes, established to permit easy entry and exit of the equipment, were about one on two, and side slopes were about one on one-half. The result was an in-line series of 3 cells having the appearance of inverted truncated pyramids, with tops and bottoms in essentially parallel planes.

All cells had bottoms measuring approximately 50 ft on a side and tops measuring approximately 70 ft by 130 ft. Their average depth was approximately 20 ft. That portion of each cell utilized for research purposes was the mass rising vertically above the bottom area.

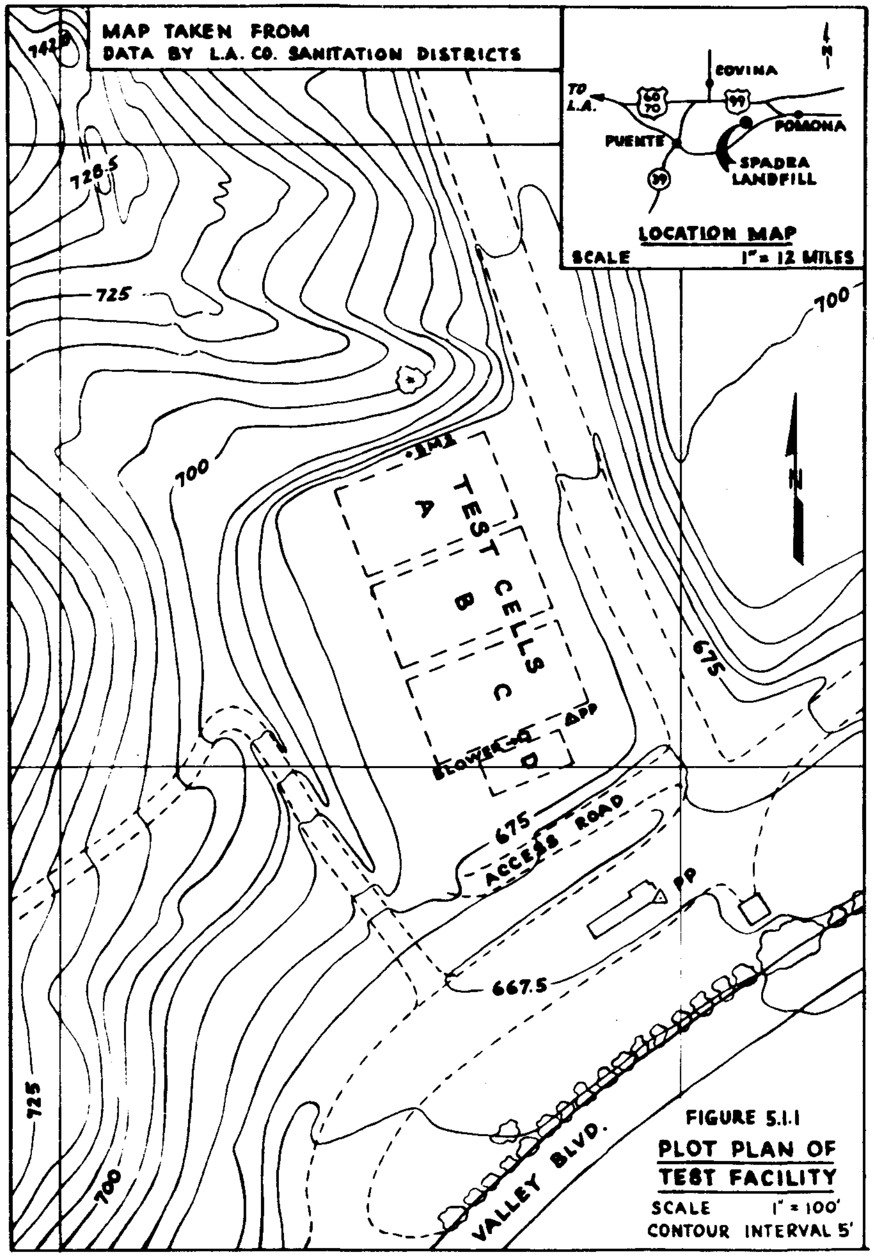


FIGURE 5.1.1
PLOT PLAN OF TEST FACILITY
SCALE 1" = 100'
CONTOUR INTERVAL 5'

5.2.2 Access Well. In the center of each cell there was erected an access well to provide outlets for gas collection lines, leach collection lines, and electrical leads, and a means of human access for observing bottom drainage (if any), the taking of internal humidity and temperature measurements, and collection of leach.

Each access well consisted of a steel pipe 44 in. diameter by 1/4" thick by 18 ft long, with numerous openings cut into the side for admission of the aforementioned conduits emanating from within the cell. The earth bottom of each test cell provided a suitable foundation for the access well. Since the access wells were but 18 ft long, and since it was the intention to carry the cells to a finished depth of 21 ft, it was necessary to build a 3-ft high wooden extension on top of each of them. Each structure was fitted with a hinged, locked cover. Each access well was sealed off from the atmosphere by covering the wooden super-structure with an air-tight, neoprene-coated nylon tarpaulin. All gas conduits and electrical leads were carried outside of the enclosure and housed in a wooden box flush with grade for convenience in taking samples, and so that the internal environment would be unchanged during the sampling process. A 6-in. high concrete and aluminum berm was placed around each access well to prevent surface drainage from reaching the access well.

5.2.3 Power Supply. It was necessary to bring in power from the nearest lines strung along the adjacent highway. New lines were strung from there to a temporary pole provided by the Districts to furnish 6 KW, 220v-3ph current. To serve the research site, a panel board was erected and fitted with control and time clock equipment for the blower, and a transformer to provide the single phase current for the vacuum pump and irrigation controls. Underground lines in rigid conduits carried the single phase current to 4 different locations within the test site.

6. REFUSE AND SOIL

6.1 Refuse Source. All of the refuse placed in the cells originated in the residential districts of the adjoining communities of Pomona, San Dimas, Claremont and LaVerne, just as in the case of the earlier Spadra study.

6.2 Refuse Characteristics. In addition to accepting refuse from only the residential areas of the communities named in the preceding section, further control was exerted to make certain that only typical domestic refuse consisting of paper, grass and garden trimmings, garbage and miscellaneous inert material was placed in the cells. Further, such materials as industrial wastes, lath and plaster, tree logs and stumps, and broken concrete, were generally excluded from the cells. The solid waste placed in the cells was assumed to have the same composition as determined at the start of the earlier project, approximately 65 percent paper, 25 percent grass and garden trimmings, 5 percent garbage and 5 percent inerts by volume. In the laboratory, the average moisture content for the entire mass of trucked refuse was determined to be 31 percent on a wet weight basis (44.8 percent dry weight basis).

6.3 Soil Characteristics. The top soil of the entire Spadra site comprises a thin layer of organic clay. It was skinned off and stockpiled for use elsewhere. The subsoil consists of a decomposed shale. It is this material which was used for final cover on the top of cells B and C.

7. CELL CONSTRUCTION

7.1 Description of Cells. In cell A, the refuse was placed continuously until the full depth (19 ft) was reached. As the refuse was being placed, sufficient water was added to bring the moisture content to 97.4 percent on a dry weight basis. The refuse placed was subjected to the standard compaction procedure. To bring the overall depth to 21 ft, a 2-ft thick earth cover was placed. Since this cell was to be used as a basis for studying the effect of simulated rainfall, particularly with regard to rainfall penetration, it was necessary to provide an earth cover that would permit water penetration. That portion of the earth cover having the same dimensions as the bottom of the cell was therefore imported from a Pomona construction site. Laboratory tests showed the material to be a "sandy silt" with 54 percent passing through a No. 4 sieve and 60 percent passing through a No. 200 sieve. The dry density was 102 lb per cu ft. The coefficient of permeability, assuming 75 percent degree of compaction, was 50 ft per yr. For application of the simulated rainfall, irrigation piping was laid just beneath the top surface to service individually controlled Rain Bird nozzles located one at each corner and one in the center. The amount of water to be applied in simulation of the Seattle, Wash., rainfall is shown in Table 7.1.1.

In cell B, the refuse was placed continuously until the full depth (19 ft) was reached. As the refuse was being placed, sufficient water was added to bring the moisture content to 73.3 percent on a dry weight basis. The refuse placed was subjected to standard compaction procedure. To bring the overall depth to 21 ft, a 2-ft thick earth cover was placed. Since this cell was to be used as a basis for studying the effect of maintaining

Table 7.1.1

Schedule of Amounts of Water To Be Applied To Cell A

(As Related to Rainfall, 1961, Seattle-Tacoma Airport)

Month	Measured Precip. in Inches (U.S. Weather Bureau Info.)	Comparable Water To Be Applied		
		Gallons Per Day	Minutes of Rain Bird Operation	
			Per Month	Per Week
January	7.71	12,012	540	135
February	9.11	14,193	638	160
March	4.45	6,933	312	78
April	2.35	3,661	165	41
May	3.07	4,783	215	54
June	0.54	841	38	9
July	0.75	1,168	53	13
August	0.82	1,278	57	14
September	0.46	717	32	8
October	3.27	5,095	229	57
November	4.67	7,276	327	82
December	5.32	8,289	372	93

a high quality, golf course type turf, particularly with regard to penetration of irrigation water, it was necessary to provide a top soil favorable to turf growth. This was done by mixing "Loamite," a lignin-organic base material containing approximately 45 percent lignin, 85 percent organic matter and one percent nitrogen, with the native topsoil. The amount used was 10 percent by volume. An automatic sprinkler system was installed to insure that the turf would be properly irrigated. An "Irrometer" system was installed, consisting of two pairs of tensiometers tied in electrically with a solenoid valve. The tensiometers were installed in pairs, one 3 in. below the surface and the other 6 in. below the surface. When an unsatisfactory soil-moisture relationship was reached at any of the four tensiometers, irrigation would automatically begin and continue until the proper soil-moisture condition was obtained at all tensiometers. Bermuda seed was selected and chicken guano was used as a fertilizer to help produce the turf. The irrigation piping was laid just beneath the top surface, and individually-controlled Rain Bird nozzles were located one in each corner and one in the center.

Before the refuse could be placed in cell C, a system of piping by which air could be admitted to the completed cell was installed. This system consisted of 4-in. dia VC perforated Wedge-Lock pipe laid in trenches 12 in. deep by 12 in. wide. The network was made up of 3 parallel 48-ft lines on 24-ft centers crossed at right angles by 7 lines on 6-ft centers. The outside periphery of the network was a closed loop. A near-vertical 4-in. galvanized steel line was installed to convey the air from the blower mounted at ground surface to the cell aeration system. The refuse was then placed continually until the full depth (19 ft) was reached. As the refuse was being placed, sufficient water was added to bring the moisture content to 80.0 percent on a dry weight basis. The refuse was subjected

to standard compaction procedure. To bring the overall depth to 21 ft, a 2-ft thick top cover was placed. To prevent movement of forced air through the earth cover and into the atmosphere, an impervious membrane was stretched over the cell one foot below the surface, i.e., at mid-depth of the cover. The membrane used was a white, 6-mill thick polyethylene. It was expected that movement of air through the cell would tend to dry out the refuse. For this reason, a network of perforated 1/2-in. dia PVC spray pipe was laid on top of the refuse, immediately under the top cover. The layout used was similar to that described for the air piping. So that the cell gases could be recirculated during blower operation, a 6-in. dia VC Wedge-Lock pipe was laid on top of the cell, connecting the housing on top of the center access well to the blower intake. The wooden extension to the center access well for this cell was constructed so that it could be reduced easily in height since considerable settlement of the cell surface was expected. A Buffalo Forge Company industrial exhauster was selected for supplying air to the cell. The blower was rated at 1000 cfm against a 6-in. static pressure at 2345 rpm. The blower's inside surfaces were treated to prevent corrosion. A valved manifold was provided at the intake to mix fresh air with recirculated gases in any desired proportion. A time clock was wired into the electrical system so that the operating cycle of the blower could be varied. A plan view of the 3 cells with their relationship to the surrounding terrain may be seen in Figure 5.1.1.

7.1.1 Volumes. Only refuse trucks (packers) of known volume were permitted to unload their refuse at the test site. The volumetric capacity of each packer was obtained from the municipality which owned it.

The volume of each excavation in which refuse was to be placed was surveyed and computed through use of the prismoidal formula.

7.1.2 Weights. Each truck that entered the Spadra site was weighed.

The Weighmaster issued a receipt on which was recorded the truck number, the total weight, the tare weight, and the net tonnage of refuse carried by the truck. The truck was then routed to the test site. The field representative of the research staff was stationed at the site to direct the unloading of each truck and placement of the refuse. The representative also recorded the receipt number and the truck number as it unloaded, and at conclusion of the day's work the entire listing of receipt numbers was checked against the Weighmaster's record to make certain that only those tonnages were included on the record that actually reached the test site.

A bulldozer and scraper was normally used to transport and level the earth that was to be used for top cover. The permeable soil cover for cell A was imported by truck as described previously.

All of the water used in the construction of the refuse cells was metered. From the known gallonage, the weight of the water added was computed.

7.2 <u>Construction Summary</u>. All of the data pertaining to the cell construction are presented in Table 7.2.1. On line 6 of the table, the density of the refuse as delivered to each cell is shown and is seen to be uniform. On line 7 are presented the volumes of the excavations. On line 8 are shown the calculated cell densities. These densities were virtually the same for all cells.

The working time required to build the 3 cells was longest for cell C. Many man days of hard, physical labor were required for placement of the aeration lines and related equipment.

The compaction ratio is usually considered to be the trucked volume of the refuse divided by the in-place volume of the same refuse. A recent survey of sanitary landfill practices, conducted by the Solid Wastes Engineering Section of the ASCE Committee on Sanitary Engineering Research,

TABLE 7.2.1

Cell Construction Summary

Line	Cell Data	Cell A	Cell B	Cell C
1	Date Started	6-15-64	6-25-64	7-15-64
2	Date Completed	7-14-64	7-14-64	8-07-64
3	Working Days to Replace Refuse in Cell	11	12	15
4	Cubic Yards of Refuse Trucked to Cell[2]	7,195	7,449	7,202
5	Pounds of Refuse Trucked to Cell[2]	3,482,340	3,649,980	3,442,560
6	Delivered Trucked Density, Pounds Per Cu Yd[3]	484	490	478
7	Volume of Cell, Cubic Yards[4]	3,468	3,495	3,291
8	Fill Density, Pounds Per Cubic Yard[5]	1,004	1,044	1,046
9	Gallons of Water Added[6]	151,071	85,547	99,969
10	Pounds of Water Added	1,259,932	713,462	833,742
11	Pounds of Water Present in Trucked Refuse[7]	1,079,525	1,131,494	1,067,194
12	Total Pounds of Water in Cell	2,339,457	1,844,956	1,900,936
13	Percent Moisture of Cell, Dry Weight Basis[8]	97.4	73.3	80.0

Notes:

1. Calculations exclude final fill covers.
2. Actual truck volumes and scaled weights
3. $\frac{\text{Line 5}}{\text{Line 4}}$
4. Determined by field measurements
5. $\frac{\text{Line 5}}{\text{Line 7}}$
6. Measured by water meter.
7. Determined by laboratory tests of representative samples
8. $\frac{(\text{Line 5} \times 31\%) + \text{Line 10}}{\text{Line 5} - (\text{Line 5} \times 31\%)} \times 100$

Moisture content of refuse on wet basis = 31%

demonstrated that 70 percent of all operating landfills responding to inquiry achieved a compaction ratio of from 2:1 to 3:1 by various procedures. However, the method of calculation used was generally not specified. *The compaction ratios achieved in the earlier study by this Group by the* various construction techniques employed varied from 1.29:1 to 2.12:1. It is emphasized that the trucked volumes used in determining the ratios represented known, "pre-compacted" values. The compaction ratios achieved in this study were 2.06:1 for cell A, 2.13:1 for cell B, and 2.18:1 for cell C.

7.3 Mensurative Equipment. While the cells were being constructed to their finished surface elevation, it was necessary to install the equipment *which would make possible the measurement of internal and external tempera-*tures, internal moisture and cell settlement, and provide for collection of gas and leach samples. Figures 7.3.1-7.3.3 are diagrams of each cell showing placement of all equipment.

7.3.1 Thermistors. To measure the internal temperatures of each cell, 3 general purpose, bead-type thermistors were buried in the refuse as the cell was constructed. These thermistors were located at distances of 4 ft, 10 ft, *and 16 ft above the bottom surface. The thermistors were selected to operate* in a corrosive atmosphere over the full range of expected temperatures. They and their leads were protected by enclosure in 3/8-in. dia copper tubing. Each thermistor was fitted with 50-ft Teflon-coated leads to reach from the thermistor location into the access well and up to ground surface. A fourth thermistor was installed near the bottom of the access well and was taped to a conventional mercury thermometer for comparison of readings. Even with *these precautions, thermistors were lost, apparently because of corrosion of* leads or because of tearing of leads with settlement. The first losses occurred in cell C at the bottom and mid-depth due to excessive temperatures after 193 days. The last loss occurred in cell B at the bottom depth after

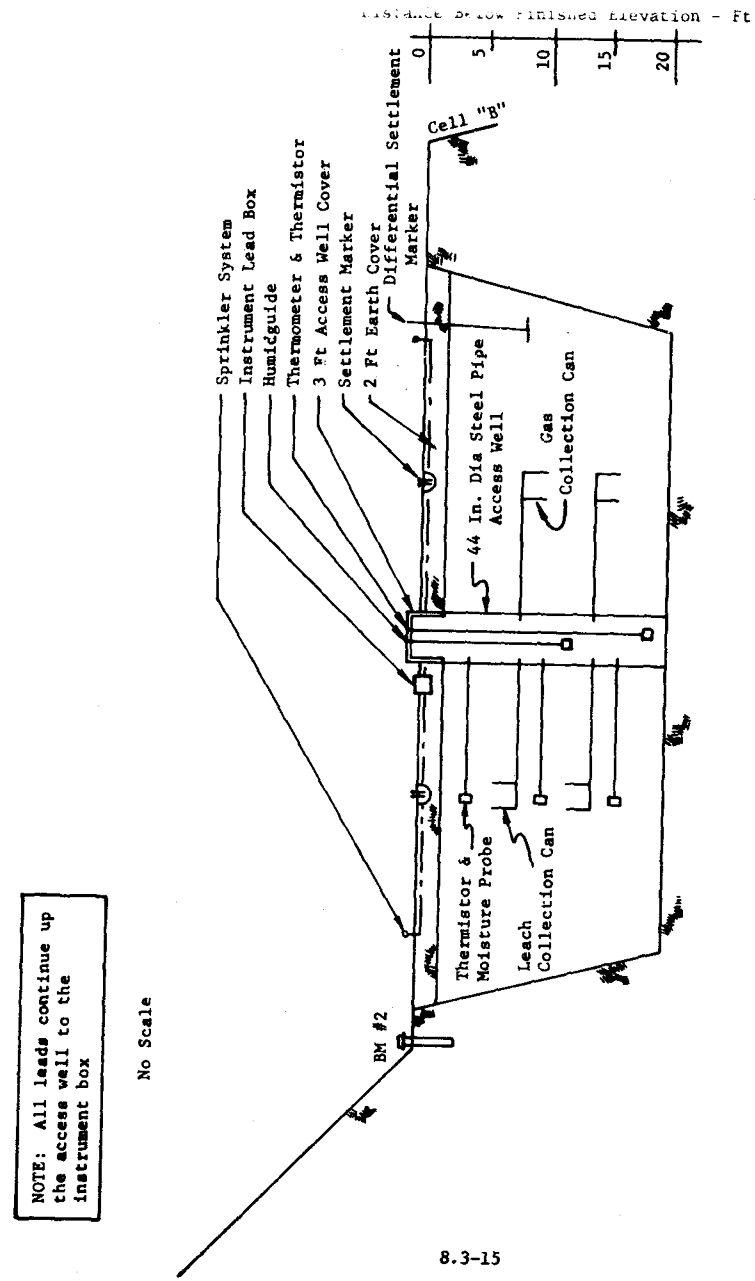


Figure 7.3.1
CROSS SECTION OF CELL "A"

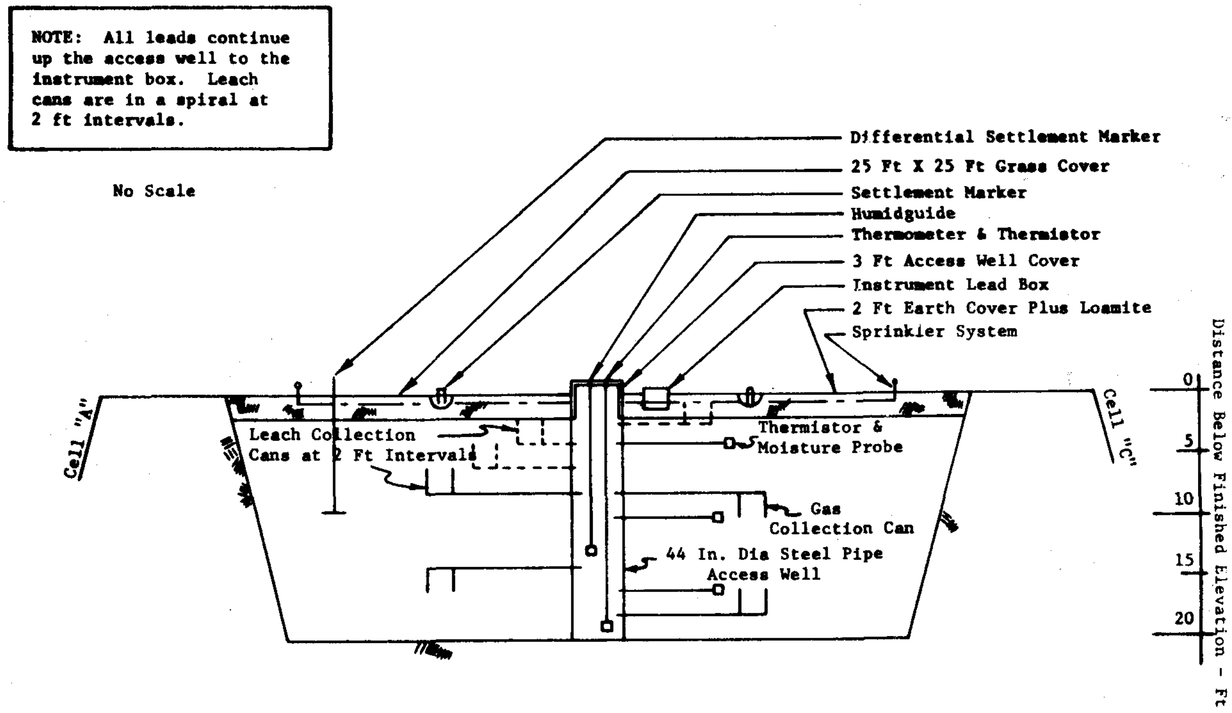


Figure 7.3.2

CROSS SECTION OF CELL "B"

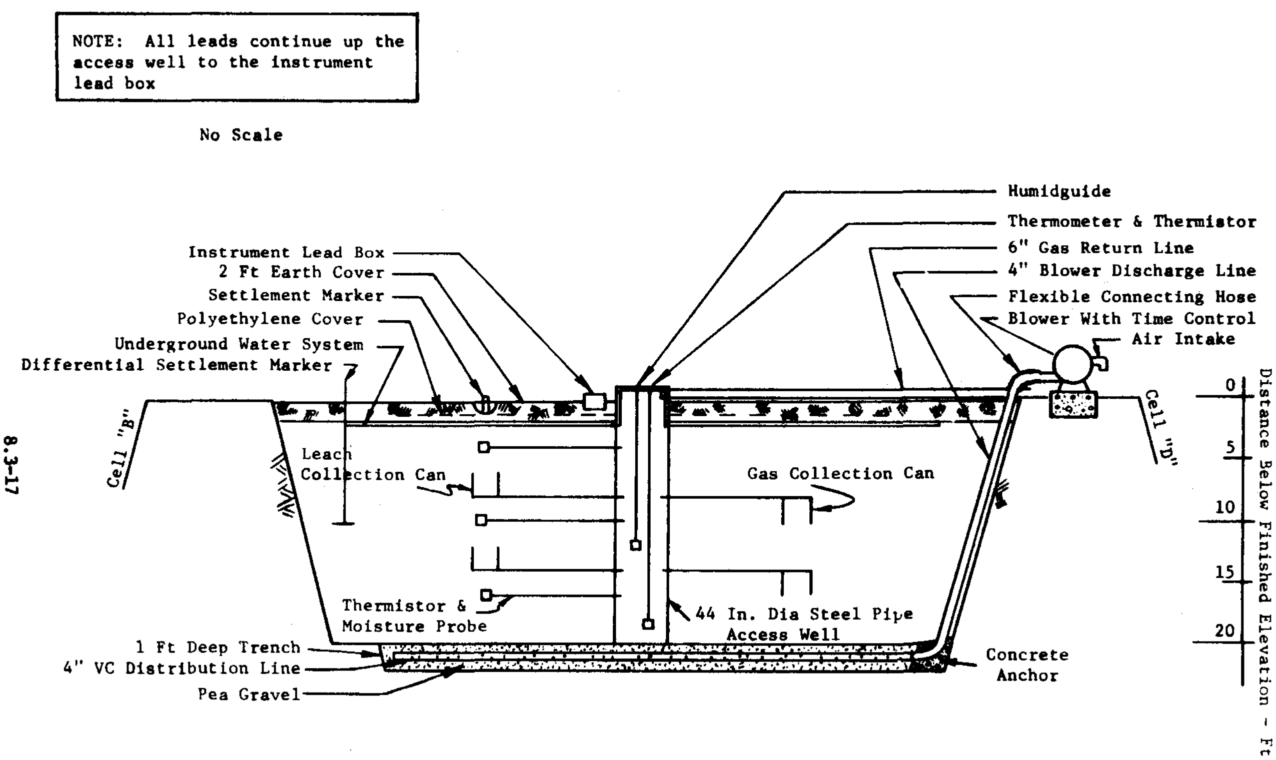


Figure 7.3.3

CROSS SECTION OF CELL "C"

233 days. Temperatures were obtained by measuring the resistance in the thermistor with a "Thermistor Thermometer" and referring the resistance to calibration curves prepared in the laboratory before installation.

7.3.2 Thermometers. An electrically driven recording thermometer using 7-day charts was located with the sensing device mounted in a shaded area at the office of the Weighmaster at the entrance to the Spadra site. The recording thermometer was calibrated against a standard laboratory thermometer, and a maximum-minimum thermometer was installed near it as a constant check on the recorded temperatures.

7.3.3 Moisture Probes. To secure the internal moisture content of each cell, 3 moisture probes were buried in the refuse next to the thermistors as the cell was constructed. The purchased probes consisted of 2 stainless steel, wire mesh, cylindrical electrodes, set concentrically in plaster-of-Paris. Each probe was fitted with a 50-ft lead of heavy duty, laminated wire. The soldered joint was protected with an epoxy resin. It was expected that moisture readings could be obtained by taking readings with a conductivity bridge and referral of the readings to calibration curves prepared by the supplying laboratory. However, for the conditions under which the probes were used, it proved impossible to take readings which could be converted into meaningful humidity valves. Even in the laboratory, calibration readings proved unreliable.

7.3.4 Gas and Leach Collection Cans. As the cells were constructed, half sections of 55-gal steel drums were located within cells A and C, 2 with open end up for the collection of leach and 2 with closed end up for the collection of gas. In cell B, 9 half drums with open end up were installed in a descending spiral pattern between top and bottom of the cell for tracking vertical penetration of irrigation water. Also, 2 half drums were installed with open end down for gas collection. These are hereinafter referred to as

"leach collection cans" and "inverted collection cans." To protect the cans against corrosion, they were given a bitumastic coating before placement. Copper tubing was used to convey any leach and the expected gas from the cans to the center access wells. Leach lines were valved at entrance to access wells. Gas lines were carried on up to ground surface where they terminated in compression stop cocks housed in a wooden box flush with grade.

The cans were installed within the fill with the copper outlet tubing so positioned as to allow for future settlement. Gas samples were obtained at distances of approximately 6 and 12 ft above the bottom. The take-off tubes from the leach collection cans were at the same distances above the bottom. No gas collection lines were lost.

7.3.5 Gas Analysis. All gas analyses were made in the laboratory utilizing a Beckman GC-2 gas chromatograph, modified to provide both silica gel and molecular sieve columns, and a Sargent Model SR recorder equipped with a Disc integrator.

A standard, glass, gas collector was installed between the terminal of the copper gas line and a portable vacuum pump. To take a sample, the valve on the end of the gas collection line was closed, the pump was started, and the system back to the closed valve was evacuated. The valve was then opened, permitting movement of the gas from the cell into the collection system, and the pump was run for 5 minutes before the sample to be used for analysis was sealed in the gas collector. The 5 minute purge used was determined through experimentation. All timing was done by stopwatch in the interest of uniformity. Less than 24 hrs elapsed between the times of sample collection and sample analysis.

7.3.6 Settlement Bench Marks. A survey monument was established in undisturbed earth at one end of the longitudinal axis of the test cells. Also, 4 survey markers consisting of 2-in. capped pipes set in concrete were established 90 deg apart and 15 ft from the center-line of the access well on the surface of each cell. To measure differential settling within a cell, a steel settlement plate was installed 10 ft. above the bottom within each cell. Each plate was approximately one foot square, to which was welded a 3/4-in. dia steel pipe of sufficient length to reach above the finished surface elevation.

8. CELL ACTIVITY

8.1 External Climatic Factors. Monthly average air temperatures and humidities, and daily rainfalls, were taken from Pomona Weather Station records and recorded in Table 12.3. Daily temperatures and humidities are recorded in Tables 12.8 through 12.10. As shown in Table 12.3, there was no measurable rainfall recorded during the time the cells were under construction. The total rainfall on the test site for the period of study (to December 31, 1965) has been 28.7 in.

8.2 Application of Water. In Table 8.2.1 are shown the amounts of water applied to cell A. It will be noted that unintentional flooding of the cell occurred in December, 1964, when some 53 in. of water were applied. Collection gauges were used to measure irrigation quantities. During the ensuing 6 months very little water was applied other than natural precipitation for it was desired to permit the upper part of the cell to dry as well as possible. Beginning in July, 1965, an effort was made to correlate the total amount of water applied (irrigation plus rainfall) with the required amount in accordance with Seattle rainfall (see Table 7.1.1). Approximately 16 in. were applied which was 0.7 in. more than required. Even with the flooding which took place in December, 1964, (55 in.) plus the water applied since that time (30 in.), no leach was collected.

The Bermuda grass was planted on top of cell B on August 25, 1964. Careful and frequent hand watering was required (normal for any new lawn) until a sturdy stand was obtained. It was refertilized on October 9. It was not until October 16 that the tensiometers could be given control of the watering cycle. The first cutting was made on October 30. A third application of fertilizer was made on February 25, 1965. On March 4, a broad leaf weed killer was applied as part of the weed control measure exercised over the entire research site. Since that time, an excellent turf has been maintained. The total irrigation water applied for the period of study was 84.2 in. The total rainfall plus irrigation on cell B was thus 112.9 in. as tabulated in Table 8.2.2. These amounts have produced leach only from the top collection pan. The actual amount withdrawn was about 100 ml of a typical dark green, odorous liquid.

The entrapment of water percolating downward through a medium into a collection pan is not a certainty, and there is always the danger of the pan being bypassed in spite of efforts to preserve the continuity of the medium inside and above the pan. However, since 2 leach collection cans were set, and since leach was appeared in the top can, it is assumed that percolation of the applied water has not yet occurred to a depth of more than 7 ft.

8.3 Settlement. The settlement of the surface of the cells, due to compaction of the refuse, was periodically measured by survey. Settlement was also influenced by the unusually heavy rains of November, 1965. The settlement data are presented in Table 12.4 and Figures 8.3.1 - 8.3.3. They indicate that the greatest settlement, nearly 2 feet in 17 months, has occurred in aerobic cell C. In the 2, full-size anaerobic cells, settlement of 0.50 ft has occurred in cell A and 0.40 ft has occurred in cell B. Cell C developed several longitudinal settlement fissures adjacent to the natural earth, approximately 30 ft long and 1/2 in. wide. These fissures were filled with earth and were not a particular problem.

Cave-ins in cell C did prove to be quite a problem. The first occurred in October, 1965, simply as the result of natural oxidation. The cave-in produced a hole in the cell measuring 3 ft by 4 ft and extending to the bottom. Two more cave-ins followed, one on November 26 and one on December 11, but these were hastened by the very unusual rains of that

TABLE 8.2.1

Actual Amounts of Water Applied to Cell A

Month	Water Applied		Rainfall	Total Water Applied, In.		Water Required, In.	
	Gal	In.	In.	Monthly	Cumulative	Monthly	Cumulative
1964							
September			.01	.01	.01	0.46	0.46
October			.23	.23	.24	3.27	3.73
November			1.77	1.77	2.01	4.67	8.40
December	82550	52.98	2.12	55.10	57.11	5.32	13.72
1965							
January	-	-	0.95	0.95	58.06	7.71	21.43
February	2063	1.33	0.30	1.63	59.69	9.11	30.54
March	2903	1.86	1.90	3.76	63.45	4.45	34.99
April	776	0.50	6.98	7.48	70.93	2.35	37.34
May	-	-	0.07	0.07	71.00	3.07	40.41
June	-	-	0.03	0.03	71.03	0.54	40.95
July	1136	0.73	0.50	1.23	72.26	0.75	41.70
August	1278	0.82	-	0.82	73.08	0.82	42.52
September	-	-	0.83	0.83	73.91	0.46	42.98
October	-	-	-	-	73.91	3.27	46.25
November	-	-	8.88	8.88	82.79	4.67	50.92
December	-	-	4.19	4.19	86.98	5.32	56.24

Note: The "water required" is taken directly from Table 7.1.1

TABLE 8.2.2

Actual Amounts of Water Applied to Cell B

Month	Water Applied Gal	Water Applied In.	Rainfall In.	Total Water Applied, In. Monthly	Total Water Applied, In. Cumulative
1964					
July					
August					
September	15,000	9.63	0.01	9.64	9.64
October	10,283	6.60	0.23	6.83	16.47
November	5,477	3.52	1.77	5.29	21.76
December	6,209	3.99	2.13	6.12	27.88
1965					
January			0.95	0.95	28.83
February	3,167	2.03	0.30	2.33	31.16
March	8,111	5.21	1.90	7.11	38.27
April	1,800	1.16	6.98	8.14	46.41
May	16,187	10.39	0	10.39	56.80
June	7,659	4.92	0.03	4.95	61.75
July	22,151	14.22	0.50	14.72	76.47
August	14,052	9.02	0	9.02	85.49
September	7,142	4.58	0.83	5.31	90.80
October	12,525	8.03	0	8.03	98.83
November	1,336	0.86	8.88	9.74	108.67
December	0	0	4.19	4.19	112.86

period. These cave-ins occurred at the periphery of the cell and served as funnels to channel surface runoff to the bottom of the cell. The result was an inundation of all aeration lines. Backfilling with clean earth repaired the cave-ins.

A method of comparing cell settlement is to use a rate measurement rather than a total measurement. From the tabulated figures in Table 12.4, those of Table 8.3.1 were computed and are graphed in Figures 8.3.1 - 8.3.3. Data for the blower cycle has been added to the settlement graph for cell C. These plainly indicate that during the first 5 months following completion of construction, the aerobic cell surface had the greatest rate of settlement, reaching a maximum of 0.39 ft per month. This compares with cells A and B having a maximum rate of 0.05 ft per month. At the end of 10 months, the rate of cell settlement was negligible and remained so for several months. Most recently, the rate has increased to about 0.05 ft per month in all cells. (Note: for two months, the cell C blower was off due to heavy rainfall flooding.)

Settlement under cells A, B and C was measured by means of the differential settlement plates described in Section 7.3.6. The total settlement figures for the bottom half of each cell are shown in Table 12.4. The settlement of the bottom half of cell A and cell B lagged behind the settlement of the top half by 0.10 ft. The differential settlement between the top half and the bottom half of cell C was 0.26 ft. In other words, the lower portion of the cell settled 1.59 ft resulting in increased "equivalent" density of the bottom fill material. The upper portion of the cell followed the lower portion down and actually compressed 0.26 ft additional to give a total surface settlement of 1.85 ft. Thus, the density of the upper portion of the fill material was virtually unchanged. It is expected that this differential would become greater as the depth of fill

TABLE 8.3.1

Rates of Cell Settlement			
Time Increment	Rate of Settlement of Surface in Feet per month		
	Cell A	Cell B	Cell C
First Month	0.04	0.02	0.09
Second Month	0.03	0.02	0.12
Third Month	0.08	0.02	0.15
Fourth Month	0.04	0.03	0.26
Fifth Month	0.05	0.05	0.39
Sixth Month	0.04	0.03	0.25
Seventh Month	0.02	0.02	0.18
Eighth	0.02	0.02	0.07
Ninth	0.04	0.04	0.04
Tenth	0.02	0.03	0.08
Eleventh	0.02	0.01	0.01
Twelfth	0	0	0.02
Thirteenth	0.01	0	0.02
Fourteenth	0	0	0.04
Fifteenth	0.01	0.02	0.04
Sixteenth	0.04	0.05	0.05
Seventeenth	0.04	0.04	

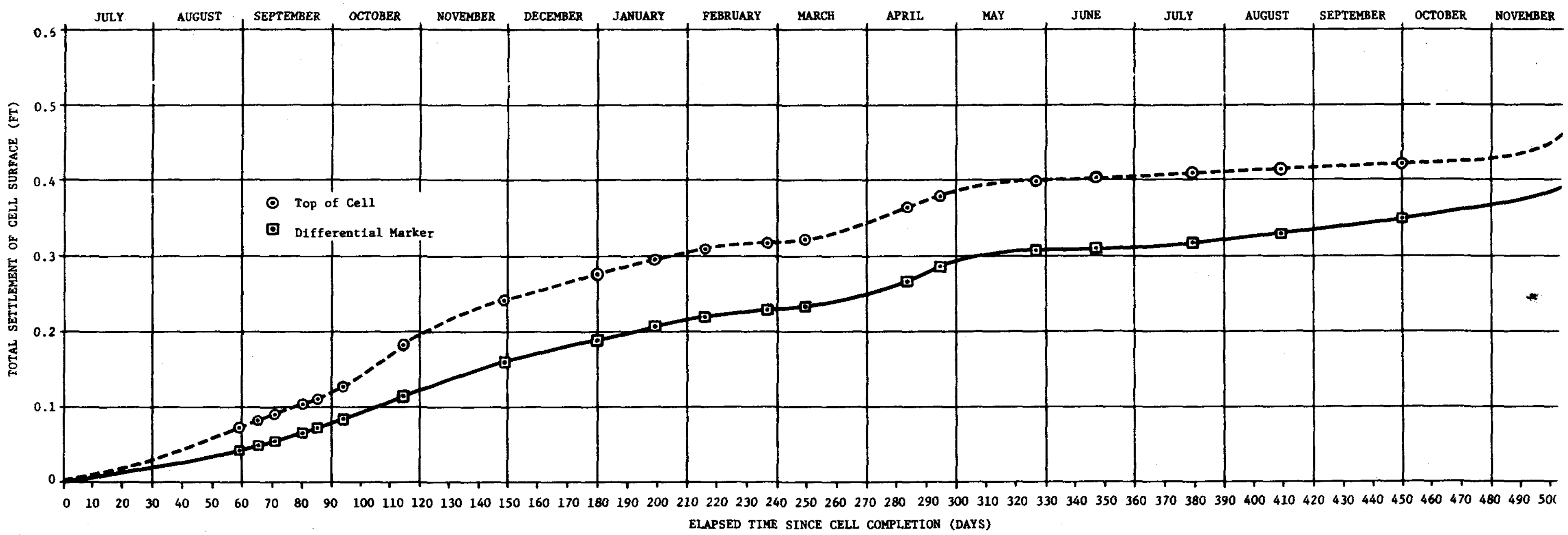


Figure 8.3.1

Surface and Mid-Depth Settlement of Cell A

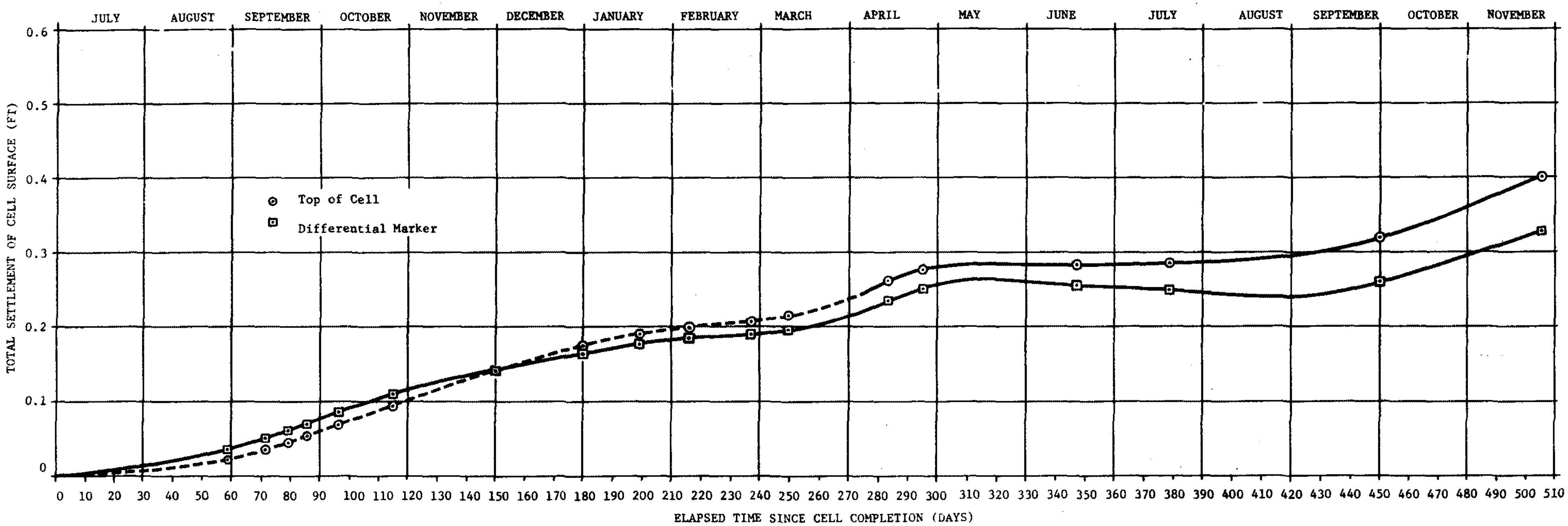


Figure 8.3.2

Surface and Mid-Depth Settlement of Cell B

A

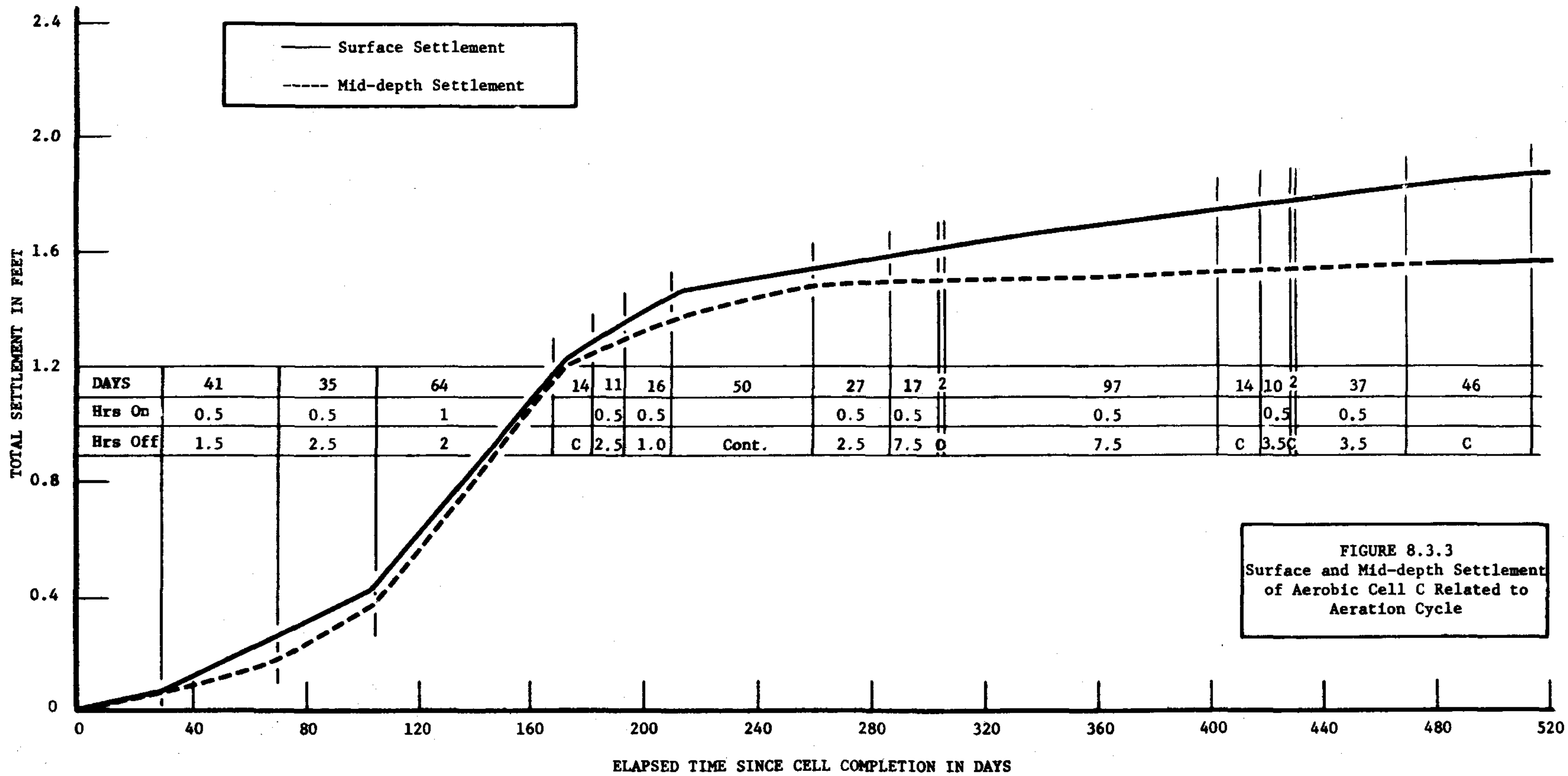


FIGURE 8.3.3
Surface and Mid-depth Settlement of Aerobic Cell C Related to Aeration Cycle

A

B

increased and/or as the settlement plate location is lowered.

8.4 Gas Production. In cell A, the chief component of the gas has been carbon dioxide at top and bottom levels. This gas component decreased rapidly at the start, and then tapered off to a fairly steady 60 percent over the last year. Methane increased rapidly at the start, and then less rapidly to a fairly steady 40 percent over the last year. Since cell A was operated under anaerobic conditions with liberal application of water, these quantities are not considered unusual. Oxygen, hydrogen and nitrogen were all present in varying minor amounts. Graphs of the tabulated data are presented in Figures 8.4.1 and 8.4.2. Gas components which measured less than 3 percent by volume were in general omitted from the graphs. Also, seemingly inconsistent high or low spot values were not plotted.

Cell B was constructed also to operate under anaerobic conditions, and it was separated from cell A by a 5-ft thick wall of undisturbed earth. However, with the blower in operation, a slight billowing of the tarpaulin covering the center access well could be seen, and later on the odor of decomposing organic material was noticeable when one was standing on cell B. It was thus evident that some of the air being sent into cell C was moving through the earthen barrier into cell B. The analyses shown in Table 12.6 present no orderly pattern such as those of cell A; on the contrary, all components fluctuated throughout the test period. Carbon dioxide, methane and nitrogen were the major components. Because of the passage of air into cell B, oxygen was always present and in significant quantities. Graphs of the tabulated data are presented in Figures 8.4.3 and 8.4.4. Information concerning the blower operation has been included on these two graphs for explanatory purposes.

The gas composition data for cell C cannot be generalized. In this cell, intermittent aeration and accompanying recirculation of the gas produced

within the cell was practiced. Also, fresh make-up was added at all times, usually by positioning the flap valve in the intake line at 45 deg. With the blower in operation for extended periods, the chief gas components by volume at the upper level were carbon dioxide (10-20 percent) and nitrogen (70-80 percent), and at the lower level were carbon dioxide (8-15 percent), nitrogen (70-75 percent) and oxygen (5-15 percent). These ranges were due to the facts that the blower was operated on varying on-off cycles and the air was admitted through the piping system underlying the cell. The blower was off at times either by choice when oxidation would proceed too rapidly and fire would break out, or by reason of breakdown of equipment. The heavy rains of November, 1965, caused motor failure necessitating removal and repair, and it was found that by December the methane was rising rapidly at the lower level and to a lesser extent at the upper level, accompanied by a decrease in nitrogen. Oxygen almost disappeared at the upper level, but held up at the lower level to a surprising degree. Graphs of the tabulated data are presented in Figures 8.4.5 and 8.4.6. Information concerning the blower operation has been included on these 2 graphs for explanatory purposes.

The maximum and minimum concentrations of all gas components at the 7-ft and 13-ft depths appear in Table 8.4.1. For cells B and C, these figures per se can be misleading since a low or high value of any constituent would depend upon the blower being off or in operation. A summary of blower operation appears in Table 8.4.2 and should be referred to when the gas analysis tables are being studied.

The internal gas pressure of all cells was measured several times during the test period, using a water manometer connected to the gas lines. This was done under various conditions of temperature and blower operation, and before and after gas sampling. The maximum pressure ever found was 0.80 in. in cell A on August 24, 1965. Other maxima were 0.60 in. in cell B on June

TABLE 8.4.1

Maximum and Minimum Gas Components by Volume in All Cells

Gas Component	Cell A		Cell B		Cell C	
	Max	Min	Max	Min	Max	Min
7 Foot Depth						
N_2	16.0	0.1	75.9	0.4	83.3	0.9
CO_2	95.4	55.2	4.4	T	77.3	3.6
CH_4	43.3	1.0	43.6	0.2	14.0	0.2
H_2	0.4	0.0	0.2	0.0	1.0	0.0
O_2	5.7	0.1	5.3	T	17.8	0.3
13 Foot Depth						
N_2	17.6	0.1	81.2	1.9	84.2	23.9
CO_2	96.3	54.0	8.3	0.1	61.6	6.1
CH_4	45.9	0.7	42.9	0.2	27.1	0.2
H_2	0.2	0.0	0.3	T	0.4	0.0
O_2	4.4	T	8.3	0.5	15.7	0.8

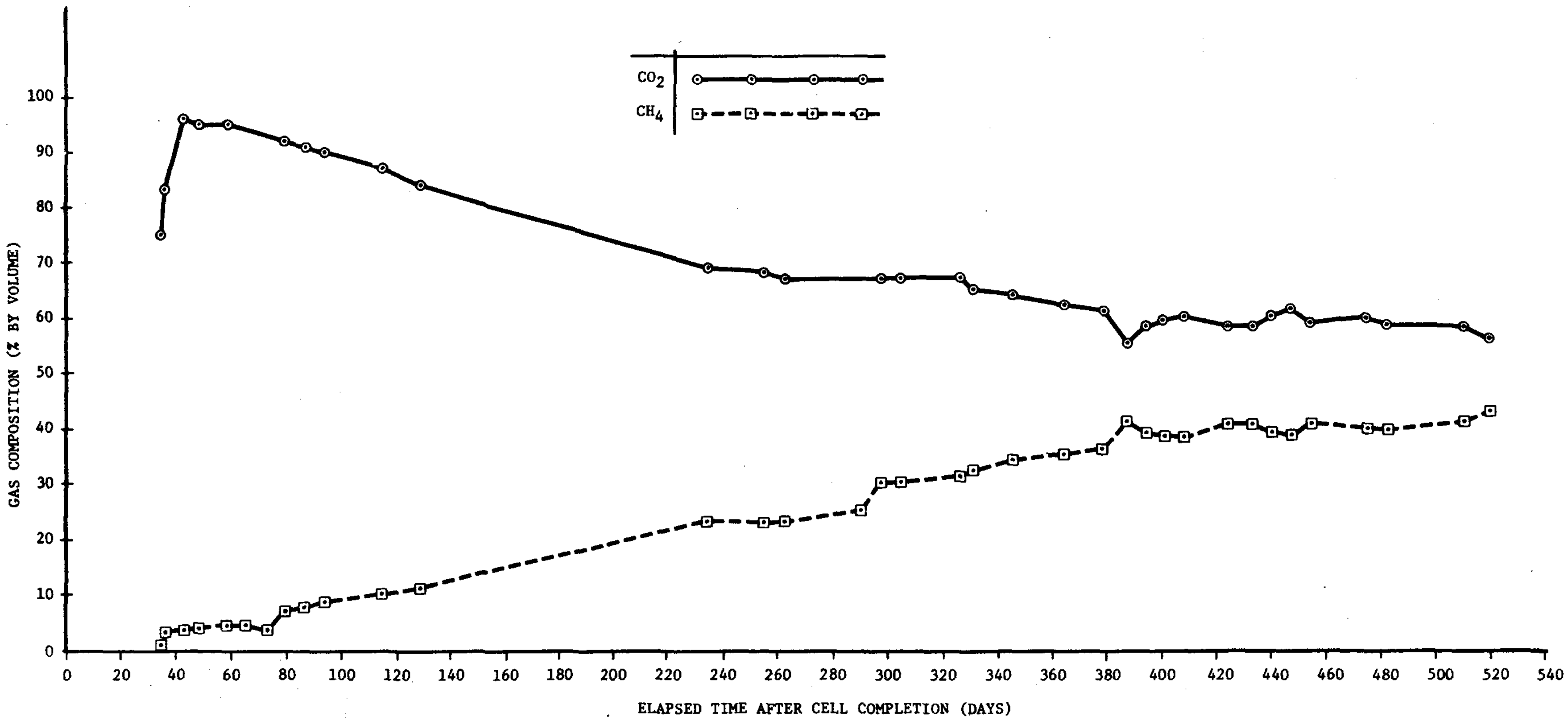


Figure 8.4.1 - Variation in Gas Composition with Time in Cell A
From Inverted Collection Can at 7-Ft Depth

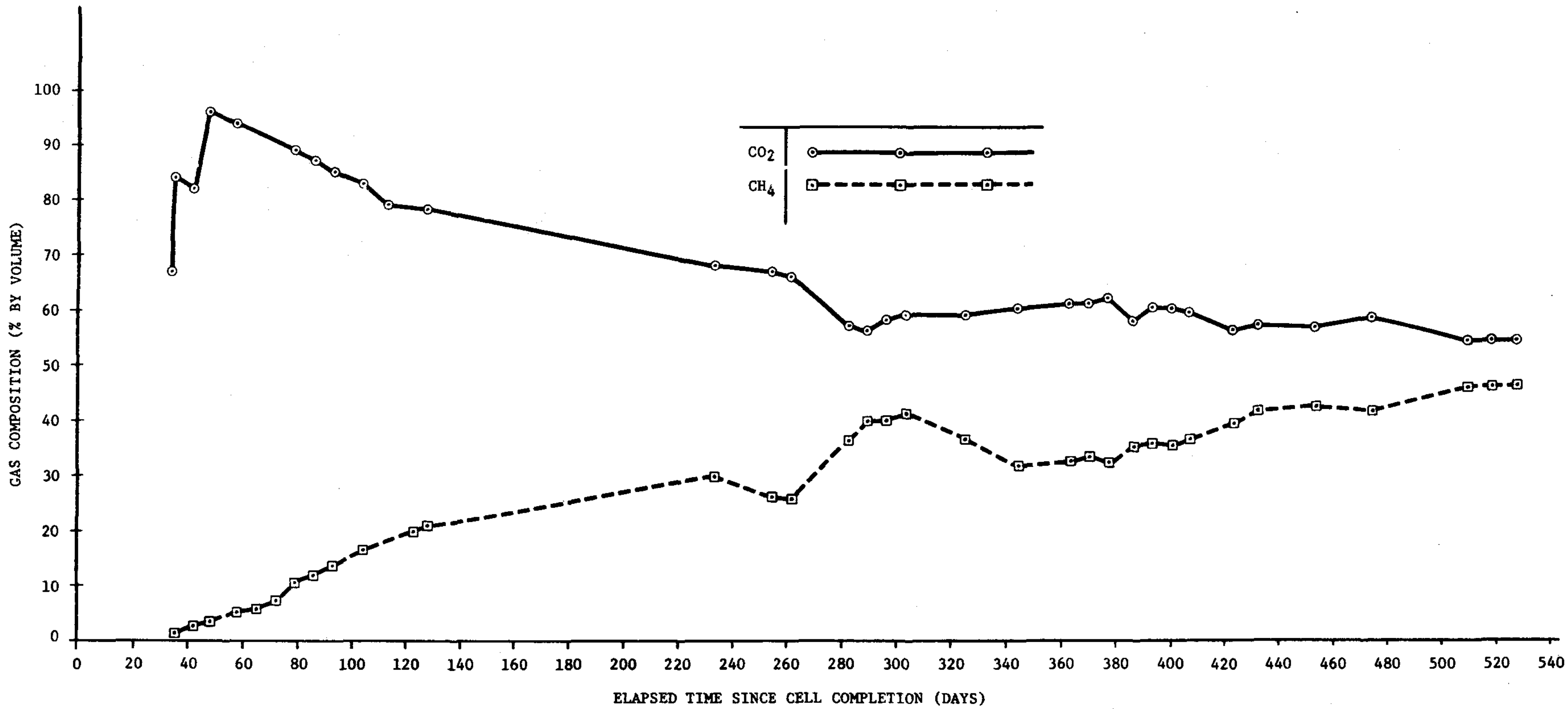


Figure 8.4.2 - Variation in Gas Composition with Time in Cell A
From Inverted Collection Can at 13-Ft Depth

Refer to Table 8.4.2 for Correlation
with Blower Operation

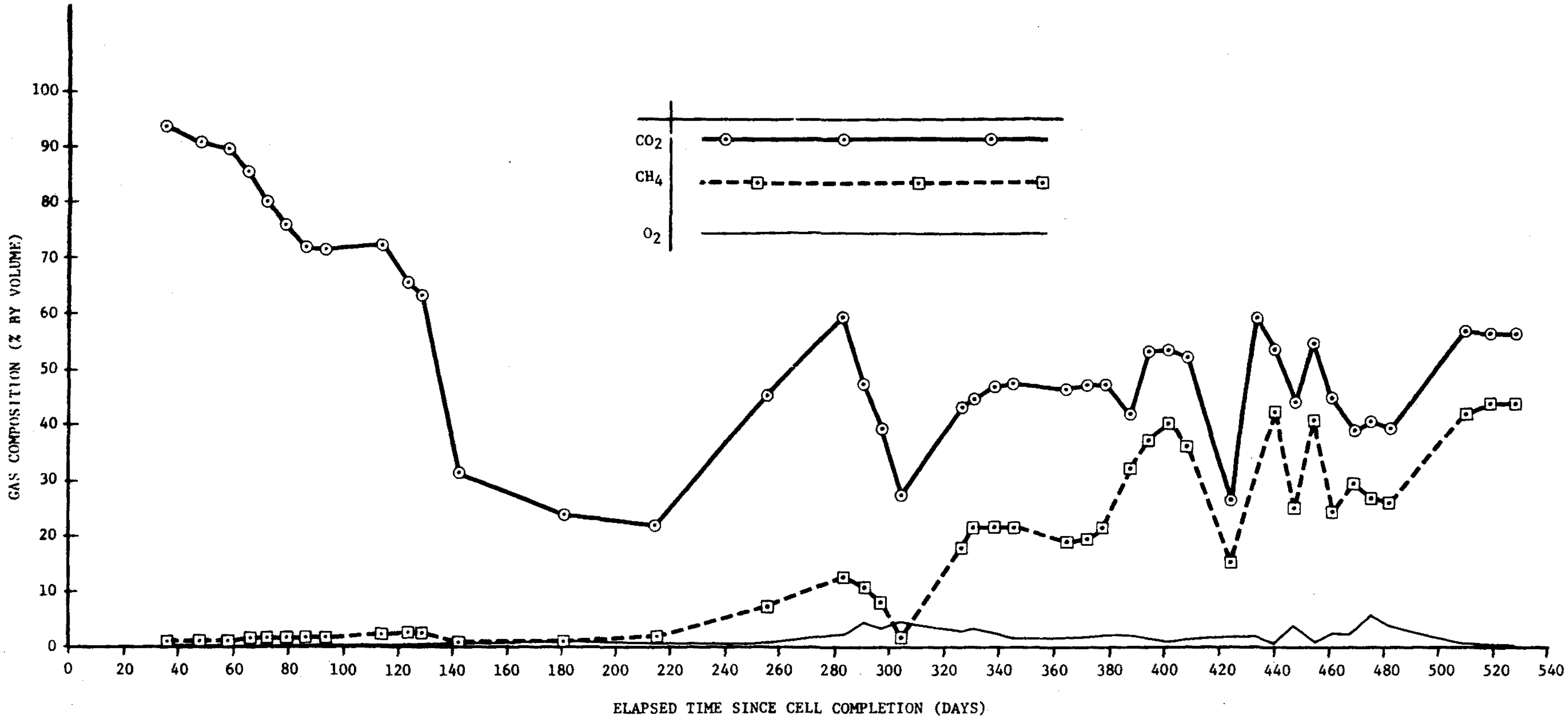


Figure 8.4.3 - Variation in Gas Composition with Time in Cell B
From Inverted Collection Can at 7-Ft Depth

7

B

Refer to Table 8.4.2 for Correlation
with Blower Operation

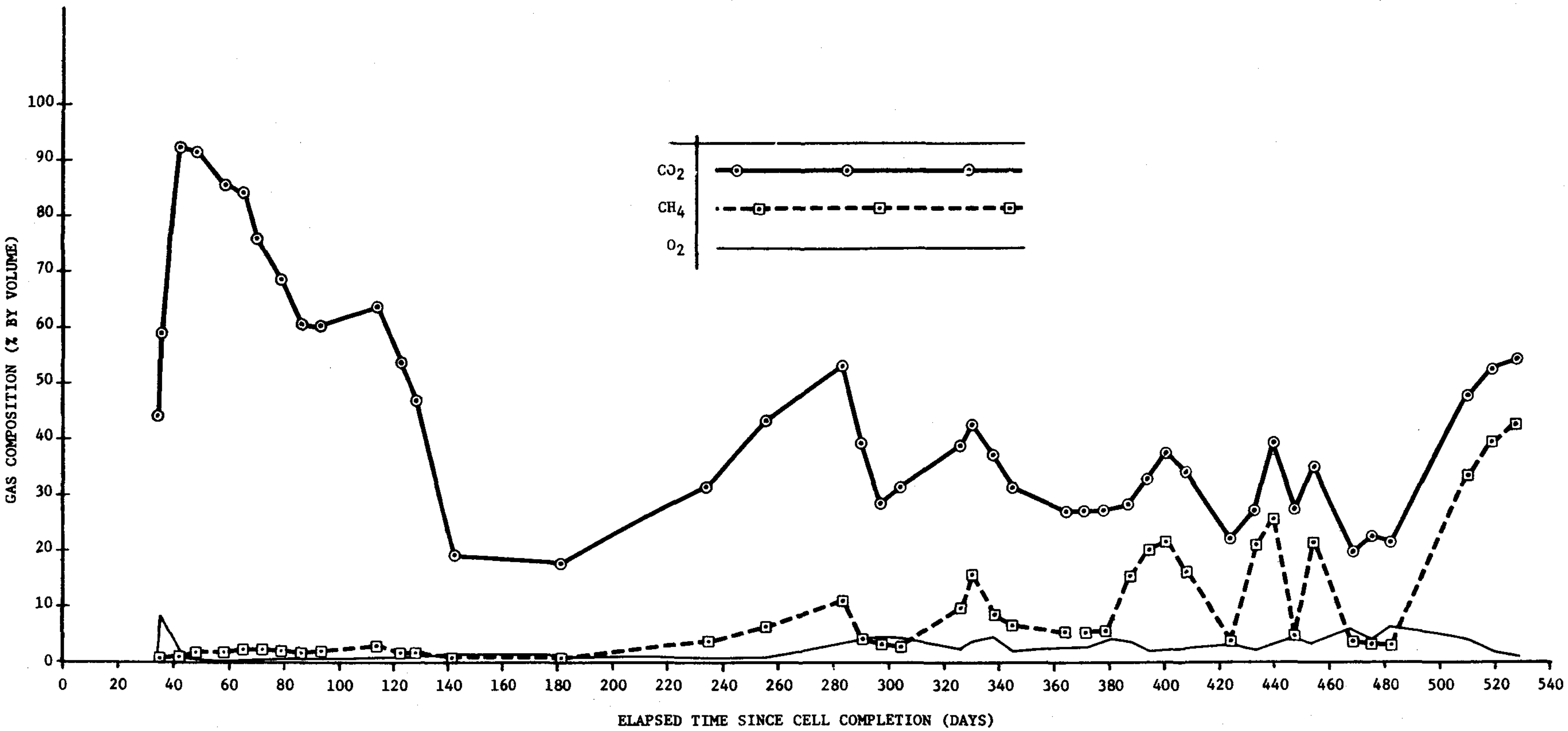


Figure 8.4.4 - Variation in Gas Composition with Time in Cell B from Inverted Collection Can at 13-Ft Depth

B

Refer to Table 8.4.2 for Correlation
with Blower Operation

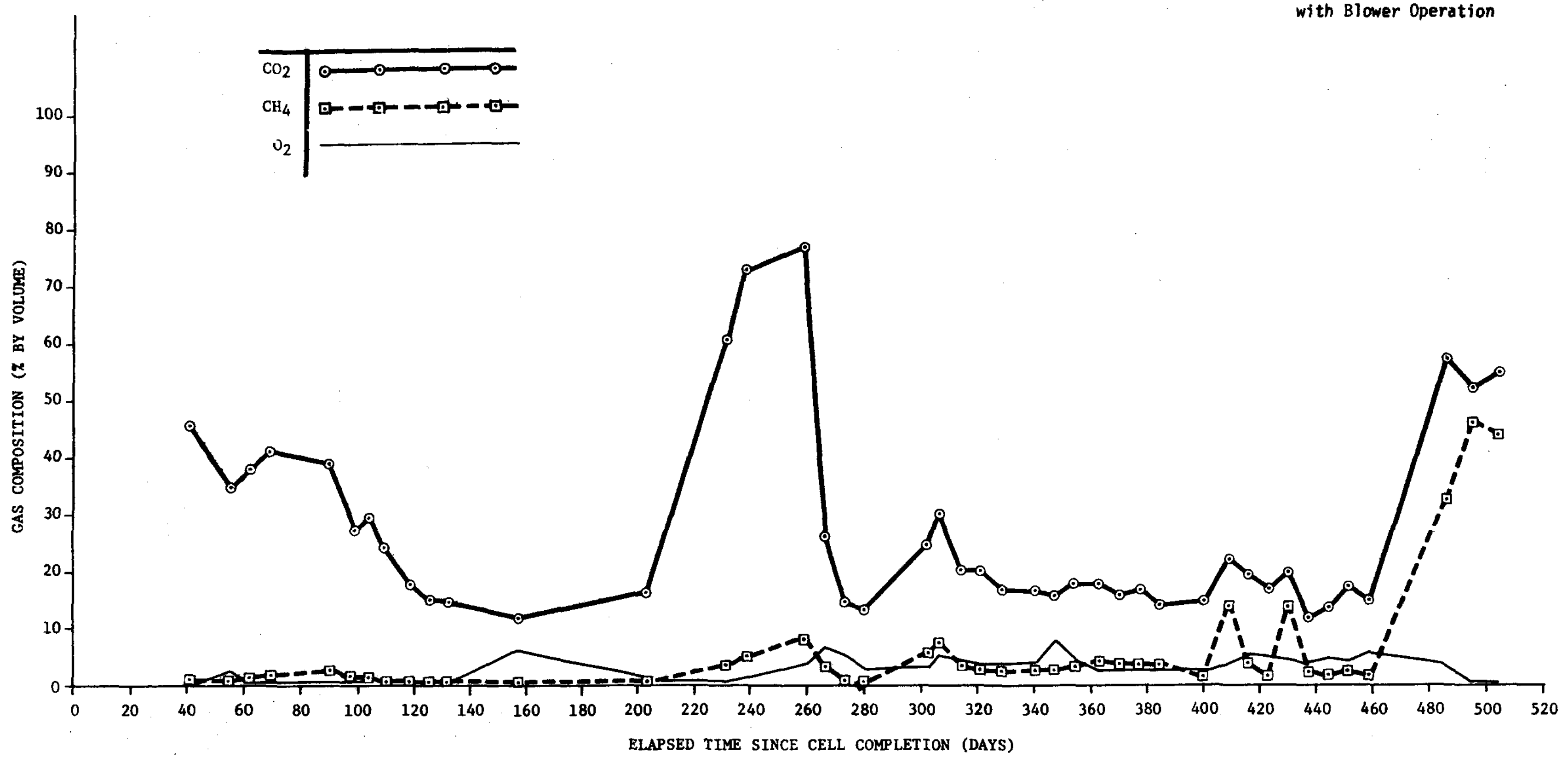


Figure 8.4.5 - Variation in Gas Composition with Time in Cell C
From Inverted Collection Can at 7-Ft Depth

Refer to Table 8.4.2 for Correlation
with Blower Operation

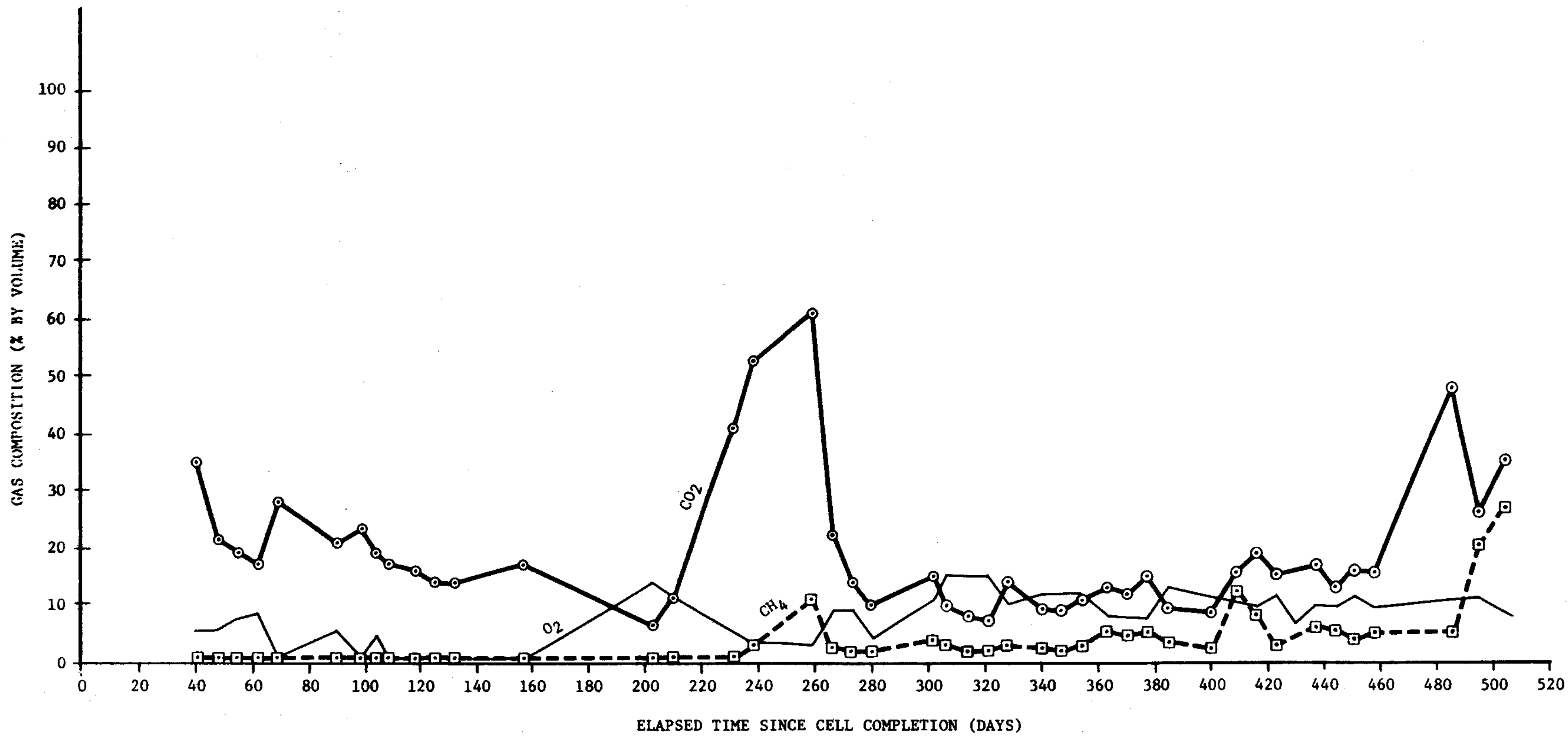


Figure 8.4.6 - Variation in Gas Composition with Time in Cell C
From Inverted Collection Can at 13-Ft Depth

TABLE 8.4.2

Summary of Blower Operation, Cell C

Elapsed Time in Days Following Completion of Cell		Blower		Blower Cycle		Remarks
A and B	*C*	*On*	*Off*	*Hr on*	*Hr off*	
24	0		x			
52	28	x		0.5	5.5	
93	69			0.5	2.5	
128	104			1.0	2.0	
149	125					First observation of effect of blower on cell B.
192	168		x			Odor problem.
206	182	x		0.5	2.5	
217	193			0.5	1.0	
233	209		x			Fire in cell.
283	259	x		0.5	2.5	Replaced blower connections.
310	286			0.5	7.5	
327	303		x			Short in motor.
329	305	x		0.5	7.5	Motor repaired.
426	402		x			Heavy Rains.
440	416	x		0.5	3.5	
450	426		x			Cave-in in C because of fire.
452	428	x		0.5	3.5	Fissure filled.
489	465		x			Heavy rains. Motor damaged.
500	476		x			Cave-in in C because of rain.
508	484					22 in. water bottom cell B.
515	491					15 in. water bottom cell C.
525	511					Cave-in in C. Dec. 31, 1965.

17, 1965, with the cell C blower running, and 1.00 in. in cell C on August 24, 1965, with the blower running.

8.5 Cell Temperatures. In Tables 12.8, 12.9 and 12.10 are presented the temperature data for all of the cells. For each cell are shown the maximum, minimum and average temperatures for the air and the access well, and the internal temperatures at depths of 4, 10 and 16 ft below the finished surface elevation. All of these readings are correlated with the date on which they were taken and the total elapsed time in days following the completion of each cell.

Cell A, which was constructed with a moisture content of 97 percent, was initially cooler than cell B having a moisture content of 72 percent. The 10-ft depth temperature varied between 100 and 103 deg F for the first 5 months and then gradually decreased to 71 deg F. The 16-ft depth temperature, initially some 12 deg cooler, has been roughly equivalent to the 10-ft depth temperature over the past 6 months. At the end of the test period, cell B was maintaining a higher temperature by 6 to 10 deg at both top and mid-depth (probably due to the blower effect).

Cell B, at the 4- and 10-ft depths, has gradually declined from a peak of 120 to 70 deg F. The bottom thermistor failed after 233 days.

The highest temperatures, and the greatest range in temperatures, were experienced in aerobic cell C, as was expected. A peak temperature at the 4-ft depth of 193 deg F was found, which gradually declined to 106 deg F. At the 10- and 16-ft depths, the temperature climbed to heights exceeding 190 deg F after 193 days, resulting in the loss of the thermistors. With fire being experienced in this cell, it is believed the slender teflon leads were destroyed.

In Figures 8.5.1 and 8.5.2 are plotted the variations in temperatures and access wells for cells A and B. Minor, day-to-day fluctuations were not plotted; hence the curves represent temperature trends. Similar curves for cell C are plotted in Figure 8.5.3, plus the information concerning the blower operation. It will be seen that there was usually a temperature rise following the starting up of the blower following a protracted shut down.

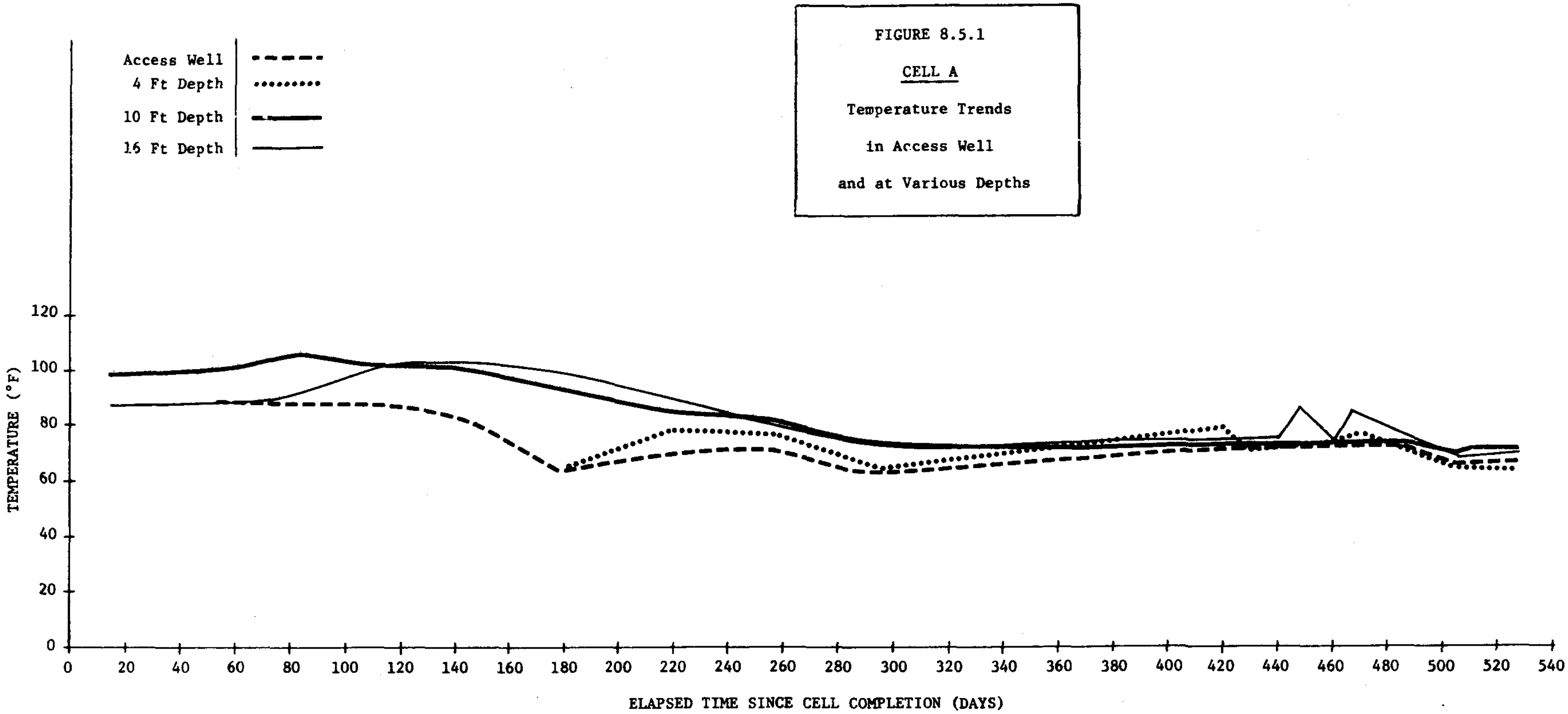


FIGURE 8.5.1

CELL A

Temperature Trends in Access Well and at Various Depths

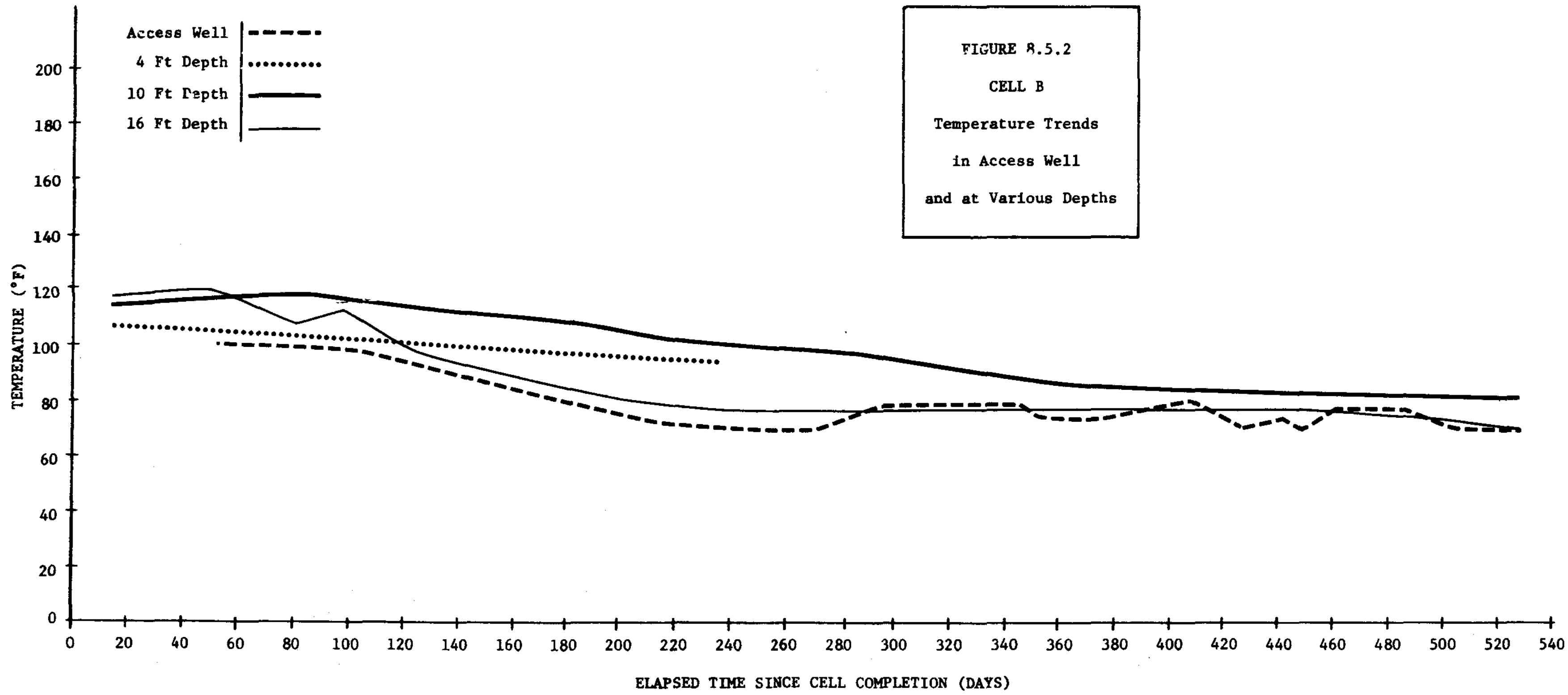


FIGURE 8.5.2

CELL B

Temperature Trends in Access Well and at Various Depths

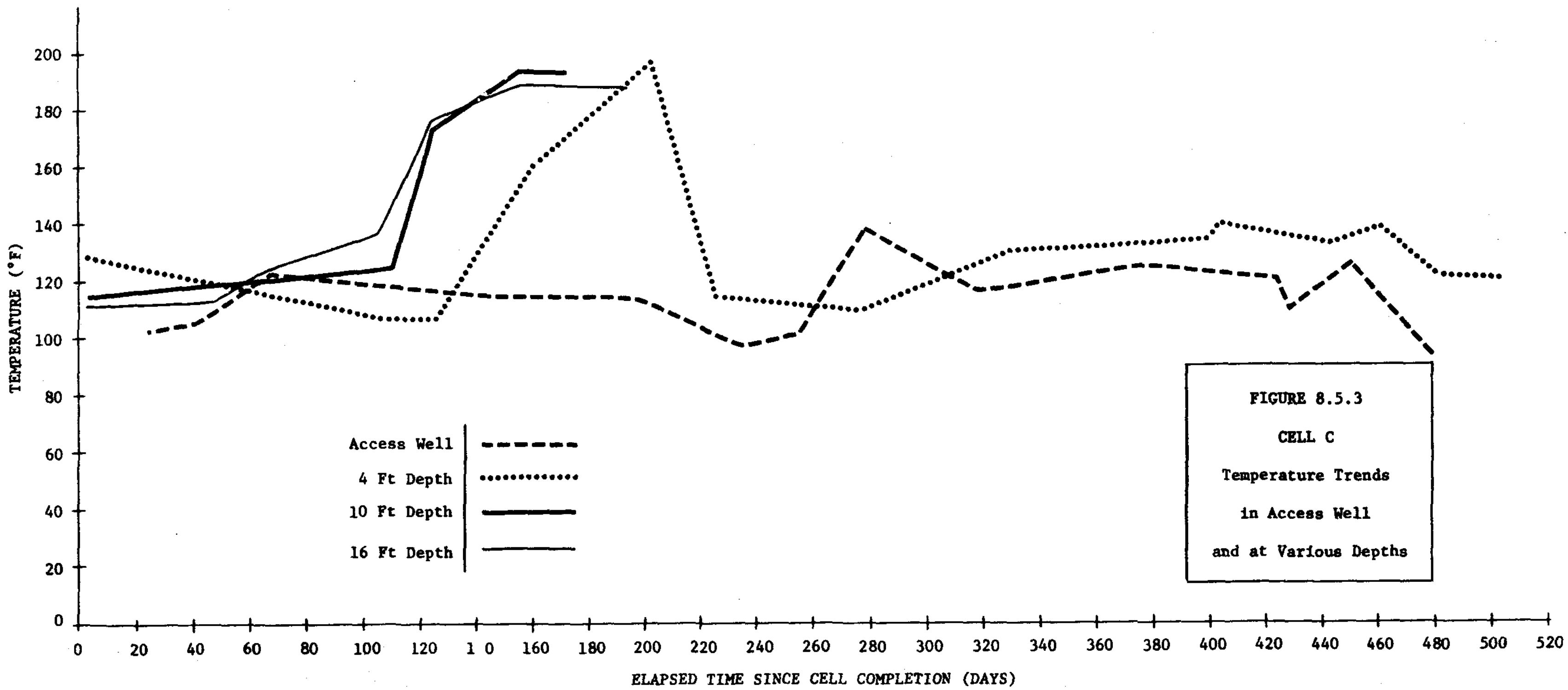


FIGURE 8.5.3

CELL C

Temperature Trends

in Access Well

and at Various Depths

A

10. APPENDIX

10.1 Intended Quantitative Study of Gas Production. As a part of this study, a fourth cell was constructed for the purpose of making a quantitative study of the gas produced during decomposition. The entire amount of gas placed in this cell was to be encapsulated within an impervious membrane. Black, 10-mill thick polyethylene was selected for this purpose. Extreme care was taken to prevent puncturing of the membrane during placement of the refuse. The bottom sheet was laid on a 2-in. thick bed of washed sand and was then covered by a 4-in. thick layer of sand, chuted into place, followed by a 2-ft thick cover of earth. The inclined sides of the cell were protected in a similar manner. Suspended from ground surface and resting against the near-vertical sides of the cell was the membrane sandwiched between layers of 15 lb. felt roofing paper. Plywood, 1/4-in. thick, was laid against the felt roofing paper to protect the membrane during placement of the refuse. All membrane joints were then sealed with mastic and tape by the supplier's representatives. Refuse was then brought and carefully placed, without normal compaction, until the full depth (6.5 ft) was reached. As the refuse was being placed, sufficient water was added to bring the moisture content to 68.3 percent on a dry weight basis. To bring the overall depth to 7.5 ft, a 6-in. thick top earth cover was placed, followed by a 3-in. layer of sand. The covering membrane was then placed on top of the sand and it, in turn, was protected by a second 3-in. thick layer of sand, chuted in place. The covering membrane was joined to the side pieces in the manner described above to complete the capsule. Gas and electrical leads were taken out of the cell through a water-filled U-tube. The leg inside the cell, and the U-section, were made of 6-in. dia

galvanized pipe. The leg which was carried up through the top cover was made of 2-in. dia galvanized pipe, and was also used as a manometer for measuring cell pressure. To prevent debris from entering the system, the leg inside the cell terminated in a reverse bend and the leg outside of the cell was capped with membrane. A seal was provided where the 2-in. leg passed through the top membrane.

The details are recorded here because, in spite of the care taken, the cell was a failure. Gas was able to pass through the membrane, either due to punctures or to the nature of the membrane itself, in sufficient quantity so that no pressure ever built up within the fill nor was any gas ever withdrawn from the fill that could be measured in the wet test cell.

10.2 Examination of Previous Test Site. The 5 cells remaining of the previous Spadra investigation (see page ii) were cored on April 22, 1965, using a power driven, 12-in. auger. The driller's log is reproduced in Table 12.2.1, supplemented by moisture determinations performed on samples sealed in the field and transported to the laboratory. It will be noted that the moisture contents at the time of coring ranged from 5 to 43 percent on a dry weight basis, and were far below those computed at the time of construction.

On June 1, 1965, a bulldozer was used to cut into the side of some of the cells to provide a visual inspection of the refuse in place. In all of the cells so uncovered, newsprint was readable and only minor decomposition had taken place after the initial entrapped oxygen was used up. In cells 2, 3 and 4 were found cuttings from an ivy plant whose leaves had the same green color and whose stems still retained their toughness and strength, indicating no appreciable decomposition. Tin cans were bright and shiny and appeared not to have rusted any from the time they were placed in the cells. Many bottles were found intact. The rubber tires were smashed flat and all life appeared to have gone out of the rubber.

The only noticeable difference between the opened cells was the degree of odor. Cell 2, constructed with 4-ft thick layers of refuse separated by 1-ft thick layers of earth and with water added, was the most odorous. Cell 4, constructed entirely of refuse and with water added, was the least odorous.

TABLE 12.2.1

Log of Core Samples Taken From First Spadra Cells

Moisture Content (Dry Wt) Percent	Cell No.	Elapsed Time Since Cell Completion (Days)	Below Ground Surface Observation Depth--Feet	Observation
	1	1634		2.8 ft earth cover
16.5			3	Partially decomposed - rotten odor
19.7			6	Decomposed - tin can clean
18.1			9	
30.6			12	Clean tin cans - decomposed grass cuttings - damp odorous - read paper
27.8			15	Putrid - damp decomposed paper - some garden trimmings, green
			17-17 1/2	Bottom sample - wet saturated clay
	2	1617		1-1/2 ft dirt cover
17.4			2.3	No odor, decomposed - metal not decomposed
			2-1/2	Fill shakes under rig First putrid odor - tin cans o.k. - paper damp, plastic o.k. - trimmings and paper
				Ran into earth cover at 4 ft
18.6			6	Decomposed
15.0			9	Moist, decomposed garden trim - decomposed paper - plastic o.k. - putrid earthy odor
24.6			10	Earth cover - grey clay
14.8			12	Rags not decomposed - wire o.k., no decomposition - trimmings and paper decomposed - plastic clean - humus-like - putrid odor not too strong

(Continued on Page 50)

TABLE 12.2.1 (Continued)

Log of Core Samples Taken From First Spadra Cells

Moisture Content (Dry Wt) Percent	Cell No.	Elapsed Time Since Cell Completion (Days)	Below Ground Surface Observation Depth--Feet	Observation
			14-1/2	Dirt cover - odor humus - putrid - not bad
24.8			16	Read some newspaper - some rags clean - decomposed grass - clean tin cans
5.3			18	Clean tin cans - minor humus - putrid odor - decomposed garden trimmings - paper
			19	Dirt - bottom of cell
7.4	3	1590		2.3 ft earth cover. No odor
21.6				5 ft Humus - putrid minor - moist - odor
			6	
			7	Dry dirt cover - 1-1/2 ft thick
24.4			9	Clean newspapers - clean tin cans - decomposed leaves, moist wood - strong putrid odor
			10-1/2	Dirt dry - clean paper (dirt and paper 1-1/2 ft thick) - putrid odor - strong
11.1			12	Clean tin cans - some clean paper - decomposed trimmings - clean wire - least decomposed refuse
19.5			15	More humus-like (less odor) - minor clean paper - clean tin cans - clean rags
			15-1/2	Dirt cover (1 ft) - putrid odor - clean plastic - some clean paper - clean tin cans - fill shakes
			16	Undecomposed rubber tire, cloth, newspaper, and plastic
14.5			18	Refuse - hit dirt bottom
			19	Sample of clay dirt - putrid odor

(Continued on Page 51)

TABLE 12.2.1 (Continued)

Log of Core Samples Taken From First Spadra Cells

Moisture Content (Dry Wt) Percent	Cell No.	Elapsed Time Since Cell Completion (Days)	Below Ground Surface Observation Depth--Feet	Observation
	4	1590		0.6 ft dirt cover - no odor
10.4			3	Odor - appears well decomposed - some paper well rotted
16.6			6	Some putrid odor - moist - some plastic - clean tin cans - some nylon stockings - newspaper well rotted
24.3			9	Well rotted - a little paper - some partially decomposed rags - slightly decomposed tin cans - electric wire-plastic; no decomposition
18.8			12	Well rotted paper - dark - tin can partially oxidized - some plastic - nylon stocking greenish color - rubber shoes o.k. - moist paper - sloppy nylon rags - curtain
28.8			15	Humus-like - rubber inner tube o.k.
			17	Some plastic - wet saturated slop
42.9			18	Gumbo - saturated - clay
			19	To solid clay bottom (yellow)
21.9	5	1542		2-1/2 ft dirt cover - no odor
26.6			6	Rotted paper - clean tin cans - plastic - clean - putrid odor
23.2			9	Plastic partially decomposed - glass no decomposition - shiney cans - minor putrid odor - dry, rotted brown paper - wire untouched
28.6			12	Hemp rope o.k. - plastic o.k. - rotted newsprint - tin cans o.k. - milk cartons partially decomposed - putrid odor

(Continued on Page 52)

TABLE 12.2.1 (Continued)

Log of Core Samples Taken From First Spadra Cells				
Moisture Content (Dry Wt) Percent	Cell No.	Elapsed Time Since Cell Completion (Days)	Below Ground Surface Observation Depth--Feet	Observation
21.2	5		15	Decomposed paper - some straw, brownish grey
34.0			18	Dry - not moist
			18-1/2	Wet, saturated clay

The computed moisture contents of these cells at the time of construction were (dry weight basis):

Cell 1	167.1%	Cell 3	32.5%	Cell 5	41.7%
2	51.9%	4	79.5%		

TABLE 12.3

External Climatic Factors							
Month 1964	Day	Inches of Rainfall		Temperatures of			Humidity
		Daily	Cumulative	Ave. Max.	Ave. Min.	Mean	Ave. (%)
June	15	T		78.1	54.9	66.5	48.4
	16	T					
	19	T	T				
July	26	T	T	90.1	60.1	70.1	35.0
Aug.	28	T	T	87.0	62.4	74.7	43.0
Sept.	18	T					
	25	.01	.01	84.3	57.4	70.9	41.0
Oct.	15	T		83.9	58.2	71.1	41.1
	27	T					
	28	.04					
	29	.19	.24				
Nov.	1	T		65.8	45.3	55.6	40.6
	9	.39					
	10	.38					
	12	.13					
	17	.87	2.01				
Dec.	11	T		61.2	44.7	53.0	60.3
	18	.06					
	19	.03					
	20	.43					
	21	.06					
	23	.04					
	24	.03					
	25	T					
	27	1.25					
	28	0.23	4.14				
1965							
Jan.	7	0.45		65.4	43.7	54.6	41.9
	24	0.50	5.09				
Feb.	6	0.28		68.0	43.0	55.4	40.4
	28	0.02	5.39				
March	7	0.39		65.6	46.7	56.0	50.5
	11	0.04					
	12	0.08					
	13.	0.40					
	15	0.30					
	31	0.69	7.29				

(Continued on Page 54)

TABLE 12.3 (Continued)

External Climatic Factors

Month 1965	Day	Inches of Rainfall		Temperatures of			Humidity Ave. (%)
		Daily	Cumulative	Ave. Max.	Ave. Min.	Mean	
April	1	1.88		70.2	48.8	59.5	50.4
	2	0.31					
	3	1.22					
	4	0.22					
	5	0.05					
	7	0.06					
	8	1.14					
	9	0.72					
	10	1.38	14.27				
May		0	14.27	73.1	51.9	62.5	50.4
June	26	0.03	14.30	72.3	54.5	63.4	56.4
July	15	0.05		85.8	58.5	72.2	40.6
	16	0.01					
	29	0.44	14.80				
Aug.		0	14.80	89.5	62.9	76.2	40.8
Sept.	6	0.09		80.4	55.9	68.2	45.8
	17	0.08					
	18	0.50					
	19	0.16					
			15.63				
Oct.		0	15.63	84.5	56.4	70.5	30.9
Nov.	14	0.29		67.2	50.2	58.7	59.0
	15	1.00					
	16	1.10					
	17	0.78					
	18	0.24					
	22	2.20					
	23	1.76					
	24	1.07					
	25	0.44					
			24.51				
Dec.	9	0.20		62.9	42.8	52.9	50.7
	10	0.53					
	12	0.39					
	13	0.02					
	14	0.11					
	15	0.12					
	16	0.09					
	29	2.19					
	30	0.32					
	31	0.22					
			28.70				

TABLE 12.4

Cell Settlement Data

Elapsed Time Since Cell Completion (days)	Total Settlement of Cell Surface in Feet			Total Settlement of Mid-Depth Surface in Feet		
	Cell Number			Cell Number		
	A	B	C	A	B	C
34			0.09			0.08
41			0.13			0.09
48			0.15			0.10
55			0.19			0.13
58	0.07	0.04		0.04	0.03	
62			0.22			0.15
65	0.08	0.02		0.05	0.05	
69			0.26			0.19
72	0.10	0.03		0.05	0.05	
79	0.10	0.04		0.06	0.07	
86	0.14	0.05		0.08	0.07	
90			0.36			0.24
93	0.15	0.07		0.09	0.08	
114	0.18	0.08		0.10	0.10	
125			0.67			0.61
149	0.24	0.14		0.15	0.14	
156			1.09			1.07
174			1.24			1.21
180	0.28	0.17		0.19	0.16	
193			1.33			1.27
198	0.29	0.18		0.20	0.16	

(Continued on Page 56)

TABLE 12.4 (Continued)

Cell Settlement Data

Elapsed Time Since Cell Completion (days)	Total Settlement of Cell Surface in Feet			Total Settlement of Mid-Depth Surface in Feet		
	Cell Number			Cell Number		
	A	B	C	A	B	C
202			1.37			1.30
214			1.47			1.41
217	0.31	0.20		0.22	0.19	
225			1.48			1.40
238	0.32	0.21		0.23	0.19	
249	0.32	0.21		0.23	0.19	
259			1.53			1.47
272			1.55			1.48
279			1.57			1.48
283	0.38	0.27		0.29	0.24	
286			1.58			1.48
296	0.38	0.28		0.29	0.25	
303			1.63			1.51
323			1.62			1.51
327	0.40	0.29		0.31	0.26	
347	0.40	0.28		0.31	0.25	
354			1.66			1.50
378	0.41	0.29		0.32	0.25	
384			1.68			1.49
408	0.41	0.29		0.30	0.24	
426			1.74			1.52
450	0.42	0.31		0.35	0.26	
482			1.85			1.59
506	0.50	0.40		0.40	0.33	

TABLE 12.5

Gas Composition in Cell A

Date	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
8-17-64	34	75.43	5.66	1.02	0.19	17.70	67.23	6.89	0.73	0.20	24.34
8-18	35	83.87	2.33	2.91	0.24	10.64	84.22	3.26	1.73	0.20	10.59
8-25	42	96.24	T	3.52	0.17	0.07	82.93	1.56	2.63	0.14	13.04
8-31	48	95.38	-	4.15	0.24	0.24	96.25	-	3.41	0.17	0.17
9-10	58	95.09	-	4.36	0.24	0.31	94.48	-	5.18	0.17	0.17
9-17	65	75.47	4.11	4.29	0.17	15.96	80.34	2.84	5.69	0.15	10.98
9-24	72						70.83	4.41	7.11	0.09	17.56
10-01	79	92.09	-	6.94	0.24	0.72	89.08	-	10.42	0.10	0.40
10-08	86	91.80	-	7.86	0.24	0.10	87.44	-	12.16	0.07	0.33
10-15	93	90.10	-	8.72	0.24	0.93	85.82	-	13.70	0.09	0.40
11-05	114	87.64	0.01	10.19	0.17	1.99	82.87	-	16.57	0.08	0.48
11-14	123	69.56	0.08	24.52	0.40	5.44	79.36	-	19.70	0.06	0.88
11-19	128	84.68	0.09	11.98	0.15	3.10	77.62	0.03	20.94	0.08	1.33
12-03	142	61.05	0.03	34.15	0.20	4.57	53.99	0.58	42.34	0.08	3.01
3-05-65	234	69.16	0.50	22.69	0.05	7.60	68.08	0.13	29.82	0.02	1.95
3-26	255	67.98	0.12	23.04	0.02	8.84	66.76	0.07	25.89	0.02	7.26
4-02	262	66.66	1.52	23.49	0.02	8.31	66.08	0.72	25.75	0.01	7.44
4-23	283						57.18	1.17	36.35	0	5.30
4-30	290	54.71	3.94	25.14	0.03	16.18	56.63	0.71	39.90	0	2.76
5-07	297	67.17	0.42	30.75	0.03	1.63	58.12	0.43	39.94	0	1.51
5-14	304	67.12	0.52	30.45	0.04	1.87	58.58	0.08	40.98	0	0.36

(Continued on Page 58)

TABLE 12.5 (Continued)

Gas Composition in Cell A

Date	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
6-05-65	326	67.13	0.39	31.17	0.02	1.19	59.07	1.53	36.46	0	2.57
6-09	330	65.20	0.31	32.72	0.03	1.67	59.24	1.63	34.38	0	4.51
6-24	345	63.99	0.41	33.99	0.02	1.59	60.44	1.31	31.53	0	6.72
7-13	364	62.41	0.45	35.08	0.02	2.04	60.84	1.19	32.18	0	5.79
7-20	371						60.80	1.06	32.99	0	5.15
7-27	378	61.38	0.56	35.85	0.02	2.19	61.64	1.19	32.14	0	5.03
8-05	387	55.23	0.74	41.10	0	2.93	57.44	1.29	35.11	0	6.15
8-12	394	58.35	0.47	39.42	0	1.76	60.42	0.61	35.70	0	3.27
8-19	401	59.58	0.32	38.51	0	1.59	59.82	0.77	35.14	0	4.27
8-26	408	59.89	0.35	38.21	0	1.55	59.42	0.70	36.33	0	3.55
9-12	424	57.82	0.30	40.74	0	1.14	56.34	0.85	38.99	0	3.82
9-21	433	58.37	0.30	40.40	0	0.93	57.07	0.27	41.55	0	1.11
9-30	440	60.04	0.19	39.09	0	0.68					
10-07	447	61.27	0.05	38.49	0	0.19					
10-14	454	58.83	0.10	40.71	0	0.36	56.56	0.3	42.12	0	1.02
11-04	475	59.73	0.13	39.71	0	0.43	58.60	0.05	41.17	0	0.18
11-11	482	58.37	0.78	39.46	0	1.39	63.12	0.05	36.64	0	0.19
12-09	510	57.99	0.26	41.01	0	0.74	53.97	0.15	45.52	0	0.36
12-18	519	56.03	0.15	43.28	0	0.54	54.13	0.06	45.60	0	0.21
12-27	528						53.92	0.03	45.93	0	0.12

TABLE 12.6

Gas Composition in Cell B

Date	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
8-17-64	34	-	-	-	-	-	44.41	2.73	0.29	0.06	52.51
8-18	35	94.09	0.12	0.54	0.20	5.05	58.60	8.32	0.74	0.18	32.17
8-25	42	82.75	0.02	1.18	0.22	15.82	92.70	1.12	0.73	0.13	5.31
8-31	48	91.54	0.10	0.87	0.18	7.31	91.66	0.06	1.58	0.25	6.44
9-10	58	89.87	0.03	1.26	0.17	8.67	85.45	0.12	1.82	0.26	12.36
9-17	65	85.72	0.11	1.66	0.15	12.36	84.15	0.14	2.13	0.22	13.36
9-24	72	79.70	0.14	1.76	0.14	18.27	75.85	0.27	2.01	0.17	21.70
10-01	79	76.34	0.26	1.77	0.12	21.51	68.41	0.39	1.53	0.15	29.52
10-08	86	72.09	0.36	1.79	0.16	25.60	60.53	0.47	1.32	0.20	37.47
10-15	93	71.70	0.33	1.87	0.10	26.00	60.23	0.57	1.65	0.20	37.35
11-05	114	72.40	0.29	2.63	0.09	24.59	63.75	0.44	2.47	0.14	33.20
11-14	123	65.72	0.35	2.73	0.10	31.10	53.73	0.62	1.31	0.11	44.24
11-19	128	63.48	0.54	2.53	0.06	33.39	46.95	0.69	1.39	0.12	50.85
12-03	142	31.30	0.74	0.43	0.04	67.49	19.04	1.11	0.29	0.04	79.51
1-11-65	181	23.74	0.95	0.24	0.02	75.05	17.54	1.04	0.20	0.02	81.20
3-05	234	21.46	1.08	1.49	0.09	75.88	31.26	0.72	3.41	0.30	64.31
3-26	255	44.49	0.58	7.03	0.06	47.84	42.93	0.64	5.90	0.03	50.50
4-23	283	59.24	2.19	12.60	0.04	25.93	53.28	3.19	10.83	0.04	32.66
4-30	290	46.95	4.41	10.36	0.03	38.25	38.98	4.34	3.94	0.03	52.71
5-07	297	38.95	3.12	7.84	0.03	50.06	27.91	4.76	2.91	0.03	64.39
5-14	304	26.82	4.92	1.81	0.04	66.41	31.31	4.69	2.26	0.07	61.67

(Continued on Page 60)

TABLE 12.6 (Continued)

Gas Composition in Cell B

Date	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface: 7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
6-05-65	326	42.75	2.74	17.54	0.05	36.87	38.75	2.03	9.39	0.05	49.75
6-09	330	44.67	3.31	21.26	0.04	30.72	42.58	3.39	15.55	0.05	38.43
6-17	338	46.83	2.22	21.42	0.02	29.51	36.96	4.14	8.38	0.02	50.50
6-24	345	47.24	1.36	21.23	0.03	30.14	31.43	1.86	6.17	0.04	60.50
7-13	364	46.16	1.52	18.85	0.05	33.42	27.29	2.34	5.08	0.03	65.26
7-20	371	46.97	1.38	19.14	0.03	32.48	27.57	2.19	5.29	0.03	64.92
7-27	378	47.07	2.04	21.28	0.04	29.57	26.94	3.53	5.45	0.05	64.03
8-05	387	41.74	1.85	31.72	0	24.69	28.15	3.02	15.13	0	53.70
8-12	394	52.98	1.07	37.32	0	8.63	33.35	1.42	20.11	0	45.12
8-19	401	53.17	0.80	39.66	0	6.37	37.66	1.70	21.35	0.06	39.23
8-26	408	52.02	1.30	36.23	0	10.45	34.44	1.91	15.93	0	47.72
9-12	424	26.10	1.62	15.66	0	56.62	21.57	2.76	3.15	0	72.52
9-21	433	58.87	1.68	28.31	0	11.14	27.18	1.95	20.81	0	50.06
9-30	440	53.57	0.63	42.47	0	3.33	39.62	2.43	25.63	0	32.32
10-07	447	43.64	3.81	24.57	0.03	27.95	27.15	4.08	4.78	0	63.99
10-14	454	54.52	0.73	40.95	0	3.80	35.07	2.97	21.30	0	40.66
10-21	461	44.70	2.21	23.67	0.09	29.33					
10-28	468	38.58	2.01	29.17	0	30.24	19.68	5.39	3.27	0	71.66
11-04	475	40.28	5.29	26.67	0	27.76	22.24	3.74	2.89	0	71.13
11-11	482	39.05	3.19	25.53	0	32.23	21.21	6.07	2.89	0	69.83
12-09	510	56.79	0.35	41.77	0	1.09	47.90	3.37	33.40	0	15.33
12-18	519	55.61	0.17	43.62	0	0.60	52.58	1.49	39.57	0	6.36
12-27	528	55.93	0.12	43.59	0	0.36	54.77	0.52	42.86	0	1.85

TABLE 12.7

Gas Composition in Cell C

Date	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface: 7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
9-17-64	41	45.68	0.52	1.03	0.11	52.66	34.76	5.76	0.67	0.05	58.76
9-24	48	-	-	-	-	-	21.26	5.44	0.36	0.05	72.89
10-01	55	34.55	2.84	0.84	0.12	61.65	19.00	7.74	0.36	0.05	72.84
10-08	62	37.84	0.89	1.29	0.14	59.84	17.32	8.53	0.30	0.05	73.80
10-15	69	41.15	0.78	1.82	0.21	56.03	28.70	0.76	0.65	0.07	69.82
11-05	90	39.35	0.76	2.79	0.18	56.92	21.66	5.47	0.87	0.06	71.94
11-14	99	27.82	0.82	1.76	0.09	69.51	23.23	1.05	0.74	0.05	74.93
11-19	104	29.77	0.77	1.47	0.09	67.90	19.58	4.52	0.54	0.01	75.34
11-24	109	24.34	0.99	0.73	0.11	73.83	17.56	1.10	0.16	0.02	81.16
12-03	118	17.58	0.89	0.42	0.05	81.05	16.56	0.90	0.20	0.03	82.31
12-10	125	14.96	0.89	0.33	0.03	83.79	14.74	1.00	0.16	0.02	84.08
12-17	132	14.90	0.89	0.39	0.03	83.79	14.70	0.90	0.20	0.02	84.18
1-11-65	157	11.65	6.34	0.11	0	81.90	17.81	0.91	0.05	0.05	81.18
2-26	203	16.11	1.19	0.30	0.07	82.33	6.08	14.20	0.25	0.03	79.44
3-05	210	3.61	17.81	0.17	0.01	78.40	12.07	11.60	0.96	0.09	75.28
3-26	231	60.40	0.93	3.24	0.78	34.65	41.73	5.17	1.14	0.27	51.69
4-02	238	72.93	1.67	5.01	0.67	19.72	53.41	4.02	2.87	0.44	39.26
4-23	259	77.28	3.12	8.24	1.01	10.40	61.60	3.13	11.39	0.02	23.86
4-30	266	26.57	6.69	3.14	0.04	63.56	22.26	8.73	2.27	0	66.74
5-07	273	14.47	5.08	0.75	0.08	79.62	14.35	9.17	2.08	0	74.40
5-14	280	13.29	2.90	0.48	0.05	83.28	10.79	4.29	2.06	0	82.86
6-05	302	24.51	3.09	5.44	0	66.61	14.90	11.65	4.04	0.02	69.39
6-09	306	29.94	5.17	7.52	0.30	59.80	10.05	15.04	2.91	0.03	71.97
6-17	314	20.04	4.31	3.36	0.13	72.16	8.11	15.67	1.98	0	74.24
6-24	321	19.68	3.78	2.66	0.14	73.74	6.69	11.14	1.96	0	80.21

(Continued on Page 62)

TABLE 12.7 (Continued)

Gas Composition in Cell C

Date	Elapsed Time In Days Following Completion of Cell	Percent Composition by Volume of Gases Drawn from Inverted Collection Can Placed at Indicated Depth Below Finished Surface									
		7 Feet					13 Feet				
		CO_2	O_2	CH_4	H_2	N_2	CO_2	O_2	CH_4	H_2	N_2
7-01-65	328	16.54	4.32	2.39	0.10	76.65	13.80	10.59	3.36	0	72.25
7-13	340	16.48	3.73	2.61	0.10	77.08	9.23	11.90	2.52	0	76.35
7-20	347	15.66	7.78	2.54	0.12	73.90	8.69	11.91	2.28	0	77.12
7-27	354	17.72	4.11	3.09	0.12	74.96	11.04	11.42	3.00	0	74.54
8-05	363	17.83	2.78	4.08	0.12	75.19	12.74	8.47	5.63	0	73.16
8-12	370	15.71	2.78	3.61	0.19	77.71	11.90	11.86	4.86	0	71.38
8-19	377	16.60	2.30	3.24	0.13	77.73	15.25	7.58	5.24	0	71.93
8-26	384	13.38	2.87	3.29	0.08	77.38	9.33	13.02	3.68	0	73.97
9-12	401	14.76	2.16	1.67	0	81.41	8.68	11.73	2.30	0	77.29
9-21	410	21.96	3.76	13.97	0.34	59.97	15.80	10.94	12.21	0	61.05
9-30	419	19.38	5.37	3.78	0.09	71.38	19.13	9.44	8.23	0	63.20
10-07	426	16.72	4.87	1.44	0.75	76.22	15.30	11.43	3.06	0	70.21
10-14	433	19.76	4.13	13.85	0.11	62.15	27.81	6.62	19.33	0	46.24
10-21	440	11.73	3.45	1.99	0	82.83	17.14	9.97	6.19	0	66.70
10-28	447	13.68	4.23	1.54	0.09	80.46	13.01	9.74	5.80	0	71.45
11-04	454	17.18	4.04	2.06	0.01	76.71	16.07	11.17	4.14	0	68.62
11-11	461	14.75	5.84	1.66	0.12	77.63	15.64	9.46	5.55	0	69.35
12-09	489	57.14	2.64	32.26	0.43	7.53	48.56	11.06	5.37	0	46.07
12-18	498	51.99	0.62	45.86	0.14	1.39	26.23	11.64	20.84	0	41.29
12-27	507	54.78	0.26	43.83	0.28	0.85	35.26	8.28	27.12	0	29.34

TABLE 12.8

Temperatures in Cell A

Date	Elapsed Time Since Cell Completion (days)	Percent Humidity		Temperatures, °F						
				Air			Access Well	In Cell at Depths Indicated Below Finished Elevation		
		Air	Access Well	Max	Min	Avg		4 Ft	10 Ft	16 Ft
1964										
7-28	14	34	Not Available	100	59	77			99	88
7-30	16	45		93	57	74			100	88
7-31	17	40		94	55	72			100	88
8-03	20	39		94	58	74			100	88
8-05	22	47		94	61	77			100	88
8-06	23	37		98	67	79			100	88
8-07	24	38		98	59	78			100	88
8-10	27	52		90	62	74			100	88
8-11	28	51		90	64	74			101	88
8-14	31	58		97	63	71			101	88
8-17	34	37		94	52	72			101	88
8-18	35	39		94	54	72			102	88
8-21	38	33		94	57	71			102	88
8-24	41	42		97	59	73			102	88
8-25	42	37		96	58	73			102	88
8-31	48	58		78	52	65			102	88
9-04	52	32		*88	*57		88		103	88
9-10	58	26		*93	*59		89		102	88
9-17	65	57		*76	*59		88		102	88
9-24	72	26		*93	*64		88		102	88
10-01	79	34		*89	*56		89		108	92
10-08	86	34		*90	*65		89		106	91
10-15	93	55		*74	*55		89		104	93
11-05	114	19		86	51	66	88		103	104
11-14	123	35		60	31	43	87		103	107
11-19	128	23		62	32	46	84		113	97
12-01	140	64		66	43	55	84		102	102
1965										
1-10	180	31		76	41	55	62	64	93	101
1-28	198	22		76	40	58	67	72	89	72
2-16	217	18		70	38	50	69	77	87	75
3-04	233	11		76	41	57	68	70	85	88
3-25	254	51		70	42	53	73	77	84	77
4-23	283	42		85	44	62	62	76	73	75
4-30	290	52		84	50	66	64	65	74	71

* Data from Pomona Weather Bureau

(Continued on Page 64)

TABLE 12.8 (Continued)

Temperatures in Cell A

Date	Elapsed Time Since Cell Completion (days)	Percent Humidity		Temperatures, °F						
				Air			Access Well	In Cell at Depths Indicated Below Finished Elevation		
		Air	Access Well	Max	Min	Avg		4 Ft	10 Ft	16 Ft
1965										
5-06	296	52		78	43	57	64	64	73	73
5-13	303	70		70	48	57	64	64	73	74
6-22	343	70		80	54	62	67	70	72	75
6-24	345	61		80	53	63	67	70	72	75
7-01	352	28		97	48	69	67	70	72	73
7-13	364	50		87	54	69	68	73	72	75
7-20	371	43		91	54	69	68	74	72	74
7-27	378	27		94	49	68	69	74	72	75
8-05	387	39		97	56	71	69	75	72	75
8-12	394	37		102	69	82	70	77	73	75
8-19	401	55		90	62	75	72	79	73	82
8-26	408	27		97	54	75	72	79	73	75
9-12	424	36		94	49	68	73	79	73	76
9-21	433	19		90	51	68	69	72	73	76
9-30	440	13	82	93	49	71	70	72	73	75
10-07	447	73	80	76	52	62	72	73	74	86
10-14	454	55		74	57	62	72	74	74	84
10-21	461	12		99	58	78	71	73	74	75
10-28	468	13	79	95	60	76	73	77	75	85
11-04	475	20		*84	*52		73	75	75	75
11-11	482	56		*70	*46		73	74	75	79
12-04	505	18	Buried	64	47	52	65	64	69	68
12-09	510	85	"	*57	*53		66	66	71	68
12-18	519	32	"	*61	*36		67	63	71	72
12-27	528	39	"	67	38	50	67	63	71	70

* Data From Pomona Weather Bureau

TABLE 12.9

Temperatures in Cell B

Date	Elapsed Time Since Cell Completion (days)	Percent Humidity		Temperatures, °F						
				Air			Access Well	In Cell at Depths Indicated Below Finished Elevation		
		Air	Access Well	Max	Min	Avg		4 Ft	10 Ft	16 Ft
1964										
7-28	14	34		100	59	77		117	113	107
7-30	16	45		93	57	74		118	114	106
7-31	17	40		94	55	72		118	114	106
8-03	20	39		94	58	74		119	114	107
8-05	22	47		94	61	77		119	114	106
8-06	23	37		98	67	79		119	116	106
8-07	24	38		98	59	78		119	114	106
8-10	27	52		90	62	74		119	115	105
8-11	28	51		90	64	74		119	115	105
8-14	31	58		97	63	71		120	116	106
8-17	34	37		94	52	72		120	116	105
8-18	35	39		94	54	72		119	116	105
8-21	38	33		94	57	71		118	116	105
8-24	41	42		97	59	73		118	116	104
8-25	42	37		96	58	73		118	115	104
8-31	48	58		78	52	65		119	117	104
9-04	52	32		*88	*57		100	118	116	105
9-10	58	26		*93	*59		100	118	117	103
9-17	65	57		*76	*59		98	114	116	103
9-24	72	26		*93	*64		100	110	118	103
10-01	79	34		*89	*56		98	108		102
10-08	86	34		*90	*65		100	107	119	108
10-15	93	55		*74	*55		98	111	117	102
11-05	114	19		86	51	66	94	101	115	102
11-14	123	35		60	31	43	92	98	115	103
11-19	128	23		62	32	46	88	95	113	100
12-01	140	64		66	43	55	92	92	113	100
1965										
1-10	180	31		76	41	55	80	84	108	96
1-28	198	22		76	40	58	83	80	103	96
2-16	217	18		70	38	50	72	78	102	94
3-04	233	11		76	41	57	69	76	101	94
3-25	254	51		70	42	53	-	76	98	-

* Data from Pomona Weather Bureau

(Continued on Page 66)

TABLE 12.9 (Continued)

Temperatures in Cell B

Date	Elapsed Time Since Cell Completion (days)	Percent Humidity		Temperatures, °F						
				Air			Access Well	In Cell at Depths Indicated Below Finished Elevation		
		Air	Access Well	Max	Min	Avg		4 Ft	10 Ft	16 Ft
1965										
4-23	283	42		85	44	62	80	77	98	-
4-30	290	52		84	50	66	79	75	93	
5-06	296	52		78	43	57	76	75	92	-
5-13	303	70		70	48	57	79	80	96	
6-22	343	70		80	54	62	78	76	88	
6-24	345	61		80	53	63	78	76	88	
7-01	352	28		90	48	69	76	75	86	
7-13	364	50		87	54	69	76	76	86	
7-20	371	43	85	91	54	69	72	76	85	
7-27	378	27		94	49	68	75	77	85	
8-05	387	39		97	56	71	77	77	84	
8-12	394	37		102	69	82	76	77	83	
8-19	401	55		90	62	75	79	73	83	
8-26	408	27	98	97	54	75	79	78	83	
9-12	424	36		94	49	68	71	79	83	
9-21	433	19		90	51	68	72	80	85	
9-30	440	13	88	93	49	71	74	77	83	
10-07	447	73	86	76	52	62	70	78	86	
10-14	454	55		74	57	62	74	78	83	
10-21	461	12		99	58	78	76	75	82	
10-28	468	13	87	95	60	76	75	76	83	
11-04	475	20		*84	*52		77	75	83	
11-11	482	56		*70	*46		78	75	83	
12-04	505	18	87	64	47	52	70	72	81	
12-09	510	85		*57	*53		73	72	82	
12-18	519	32		*61	*36		69	70	81	
12-27	528	39		67	38	50	70	69	81	

* Data from Pomona Weather Bureau

TABLE 12.10

Temperatures in Cell C

Date	Elapsed Time Since Cell Completion (days)	Percent Humidity		Temperatures, °F						
				Air			Access Well	In Cell at Depths Indicated Below Finished Elevation		
		Air	Access Well	Max	Min	Avg		4 Ft	10 Ft	16 Ft
1964										
8-07	0	38		98	59	78		130	113	111
8-10	3	52		90	62	74		129	114	111
8-11	4	51		90	64	74		129	114	111
8-14	7	58		97	63	71		130	116	112
8-17	10	37		94	52	72		128	116	112
8-18	11	39		94	54	72		127	115	110
8-21	14	33		94	57	71		126	116	111
8-24	17	42		97	59	73		124	116	110
8-25	18	37		96	58	73		124	117	111
8-31	24	58		78	52	65		123	118	112
9-04	28	32		*88	*57		104	122	117	110
9-10	34	26		*93	*59		104	120	118	114
9-17	41	57		*76	*59		104	119	119	112
9-24	48	26		*93	*64		113	117	119	112
10-01	55	34		*89	*56		114	118	120	116
10-08	62	34		*90	*65		120	117	119	120
10-15	69	55		*74	*55		122	114	121	124
11-05	90	19		86	51	66	118	109	120	127
11-14	99	35		60	31	43	120	108	125	134
11-19	104	23		62	32	46	118	107	124	134
11-24	109	28		78	47	59	113	106	123	137
12-01	116	64		66	43	55	115	108	128	150
12-10	125	37		68	41	53	116	106	173	177
1965										
1-10	156	31		76	41	55	113	157	193	188
1-28	174	22		76	40	58	116	163	193	187
2-16	193	18		70	38	50	113	157	-	187
2-25	202	27		82	46	61	112	-	-	-
3-04	209	11		76	41	57	113	163		
3-09	214	57		71	42	55	130	167		
3-25	230	51		70	42	53	96	111		
4-23	259	42		85	44	62	107	111		
4-30	266	52		84	50	66	107	108		

* Data from Pomona Weather Bureau

(Continued on Page 68)

TABLE 12.10 (Continued)

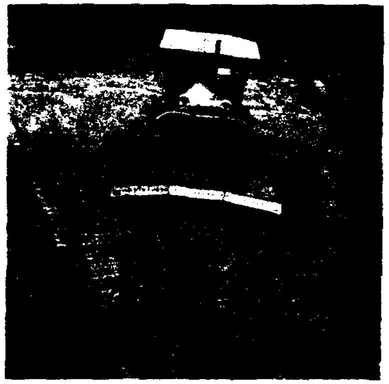
Temperatures in Cell C

Date	Elapsed Time Since Cell Completion (days)	Percent Humidity		Temperatures, °F						
				Air			Access Well	In Cell at Depths Indicated Below Finished Elevation		
		Air	Access Well	Max	Min	Avg		4 Ft	10 Ft	16 Ft
1965										
5-06	272	52		78	43	57	133			
5-13	279	70		70	48	57	136			
6-22	319	70		80	54	62	115			
6-24	321	61		80	53	63	112	127		
7-01	328	28		97	48	69	120	127		
7-13	340	50		87	54	69	115	129		
7-20	347	43	42	91	54	69	120	130		
7-27	354	27	44	94	49	68	116	131		
8-05	363	39		97	56	71	118	131		
8-12	370	37	55	102	69	82	122	130		
8-19	377	55		90	62	75	124	133		
8-26	384	27		97	54	75	122	131		
9-12	400	36		94	49	68	117	133		
9-16	404	67		72	60	64	121	138		
9-21	409	19		90	51	68	95	138		
9-30	416	13	43	93	49	71	117	137		
10-07	423	73	40	76	52	62	121	135		
10-14	430	55		74	57	62	109	134		
10-21	437	12		99	58	78	124	133		
10-28	444	13	40	95	60	76	122	132		
11-04	451	20		*84	*52		124	134		
11-11	458	56		*70	*46		121	138		
12-04	481	18	85	64	47	52	91	120		
12-18	495	32		*61	*36		170	120		
12-27	504	39		67	38	50	159	116		

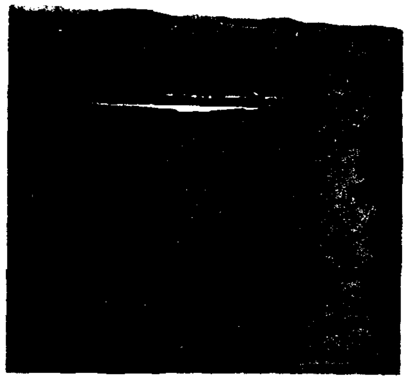
* Data from Pomona Weather Bureau

Photograph 1
Equipment Used For Cell Construction.

Photograph 2
Excavation Of Cells General View.

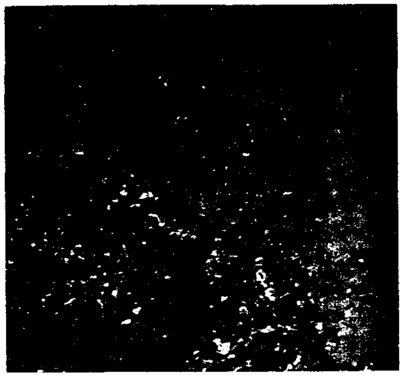


Photograph 3
Excavation Of Cell A.



Photograph 4
Cells B And C Fully Excavated.

Photograph 5
General View Of All Cells
Fully Excavated.



Photograph 6
Start Of Cell A.

Photograph 7
Watering Of Cell A During
Construction.

Photograph 8
Cell A At Mid-construction.

Photograph 9
Placing Upper Half Of
Cell A Access Well.

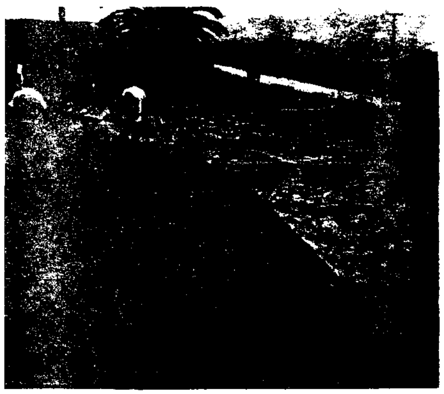
Photograph 10
Cells A And B Filled
Cell C Receiving First Load.

Photograph 11
Placing Earth Cover On
Cells A And B.

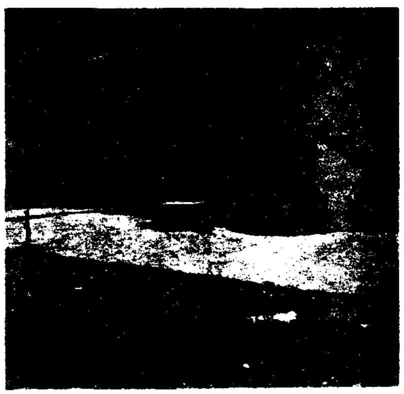
Photograph 12
Floor Of Cell C Showing
Aeration Trenches And
Inlet Pipe From Blower.

Photograph 13
Setting Access Well In
Cell C.

Photograph 14
Underground Sprinkler,
Cell C.



Photograph 15
Laying Top Membrane,
Cell C.



Photograph 16
Top Membrane In Place,
Cell C.

Photograph 17
Covering of Top Membrane,
Cell C.

Photograph 18
Access Well Extension.

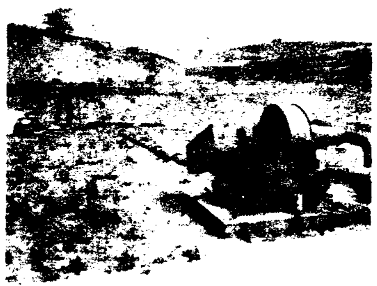
Photograph 19
Access Well Extension
Corner Detail.

Photograph 20
General Instrumentation,
All Cells.

Photograph 21
Gas Collection Drum.

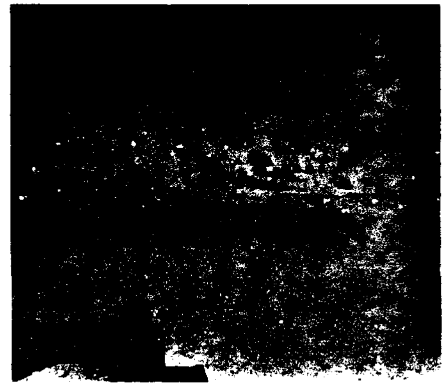
Photograph 22
Collecting Gas Sample.

Photograph 23
Blower Serving Cell C
Recirculation Line In
Foreground.

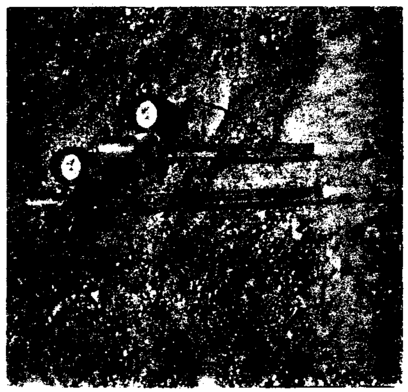


Photograph 24
Blower Serving Cell C
General View.

Photograph 25
Panel Board.

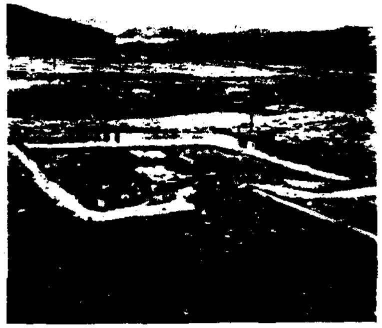


Photograph 26
Finished Cells, C In
Foreground.



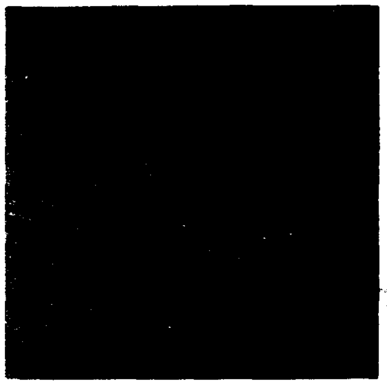
Photograph 27
Irrometers Used In Cell B.

Photograph 28
Watering Cell B After
Seeding.



Photograph 29
Cell C After Settlement, Showing Modified Air Inlet Pipe And Water Barrier Constructed Around Center Access Well.

Photograph 30
Subsurface Irrigation Supply Line to Cell C.



Photograph 31
Settlement Crevices At Cell And Natural Ground Boundary.

Photograph 32
Cave-in In Cell C.

Photograph 33
Differential Settlement
Between Cells B And C As Indicated By Car Position.

Photograph 34
Grass Cover On Cell B.

Photograph 35
Opening Of 5-Year Old Test Site.

Photograph 36
Coring Of 5-Year Old Test Site.