METHANE ON THE MOVE:
Your Landfill's Silent Partner

An Administrator's Guide

NATIONAL LEAGUE OF CITIES

IMTF INTERGOVERNMENTAL METHANE TASK FORCE
7475 DAKIN - SUITE 401
DENVER, COLORADO 80221

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METHANE FROM LANDFILLS: HAZARDS AND OPPORTUNITIES

A WORKING SYMPOSIUM

EPA
ENVIRONMENTAL PROTECTION AGENCY
REGION VIII, SOLID WASTE

COLORADO DEPARTMENT OF HEALTH

TRI-COUNTY DISTRICT HEALTH DEPARTMENT

ADAMS COUNTY

INTERGOVERNMENTAL METHANE TASK FORCE

MARCH 21,22,23, 1979
COLORADO WOMEN'S COLLEGE
DENVER, COLO.

NATIONAL LEAGUE OF CITIES

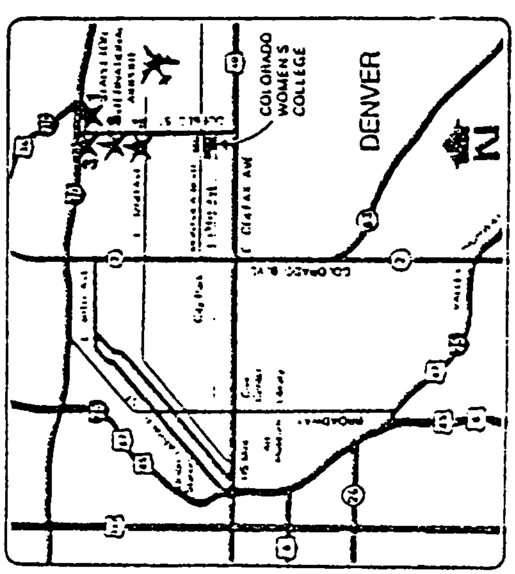
U.S. DEPARTMENT OF ENERGY
DIVISION OF BUILDING AND COMMUNITY SERVICES

ARGONNE NATIONAL LABORATORY

THE JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

LOCATION

Colorado Women's College is located on the corner of Montview Blvd. and Quebec Street, two miles south of Interstate 70 - Quebec Street Interchange, five miles east of downtown Denver, or one mile south of Stapleton International Airport.



If you prefer to stay at a hotel please make your own arrangements. The following hotels are approximately one mile away from the College.

Proximate Lodging:	Address	Phone	Rates
1. Holiday Inn	4040 Quebec	(303) 321-[illegible]	$30-$34/night
2. Ramada Inn	3737 Quebec	(303) 388-6161	$34-$39/night
3. Skyways Inn	3855 Quebec	(303) [illegible]-7301	$24-$28/night
4. Stouffer's Inn	3203 Quebec	(303) [illegible]	$40-$47/night

SYMPOSIUM ON METHANE: HAZARDS AND OPPORTUNITIES

MARCH 21-23, 1979

NAME ______________________ TELEPHONE NUMBER ______________________

COMPANY/AGENCY ______________________ POSITION ______________________

ADDRESS ______________ CITY ______________ STATE ______________ ZIP ______________

WILL YOU STAY AT COLORADO WOMEN'S COLLEGE? ___YES ___NO NUMBER OF NIGHTS ____ x $16.00/$18.00 = ________

WILL YOU ATTEND THE BANQUET ON THURSDAY EVENING? ___YES ___NO (Included in Registration Fee)

WILL YOU GO ON THE SKI TOUR? ___YES ___NO NUMBER OF PERSONS ____ x $14.00 = ______

WILL YOU WANT TO RENT SKIS? ___YES ___NO (Ski rental can be arranged)

WILL YOU WANT TO TAKE THE BUS TOUR TO OBSERVE ALARM AND CONTROL SYSTEMS IN THE DENVER AREA? ___YES ___NO

WILL YOU WISH TO SUBMIT A PAPER FOR INCLUSION IN AN ADMINISTRATORS' HANDBOOK TO BE DEVELOPED BY THE IMTF? ___YES ___NO

WOULD YOU PARTICIPATE AS A PANEL MEMBER IN A WORKSHOP SETTING? ___YES ___NO WHICH ONE(S) ______________

CIRCLE APPROPRIATE WORKSHOPS YOU WISH TO ATTEND. (See list on Page 2)

INSTITUTIONAL 1 2 3 4 5 6 7 8 9 10 TECHNICAL 1 2 3 4 5 6 7 8 9 10

REGISTRATION FEE ENCLOSED $ 25.00
SKI TOUR ________
CWC HOUSING/BOARD ________
TOTAL ENCLOSED ________

CONFERENCE ENROLLMENT AND HOUSING IS LIMITED. REGISTER BY FEBRUARY 15, 1979. REGISTRATION WILL BE ACCEPTED ON A FIRST COME, FIRST SERVED BASIS.

MAIL TO: METHANE SYMPOSIUM
C/O TRI-COUNTY DISTRICT
HEALTH DEPARTMENT
7475 DAKIN ST. SUITE 401
DENVER, COLORADO 80221
428-3343

SYMPOSIUM OBJECTIVES

The objectives for the symposium are to reach those persons at the local and State levels who will have to deal with landfill issues in their communities. Included are:

(1) Sharing of experiences in dealing with methane related problems.
(2) Addressing both institutional and technology-related problems focusing on control and recovery/utilization of methane gas.
(3) Effecting technology transfer in the recovery/utilization of landfill gas.

The symposium is, therefore, structured to define the issues related to the production of methane in landfills and the necessary preliminary concerns that must be resolved prior to entering into a possible recovery stage.

The second day of the symposium will commence with an examination of the issues of control and recovery and then the participants will split into two groups - one focusing on control issues and the other dealing with recovery aspects. That format will continue into the third and final day of the symposium, which also features a tour of landfills where various forms of control and warning systems will be observed.

SYMPOSIUM ATTENDEES

This Symposium is intended for municipal engineers, planners, and local elected officials who are charged with the responsibilities for public health and safety; and who operate or permit local solid waste disposal sites. It will also be appropriate as well as constructive for consulting engineers, engineering design firms, academic people, and managers in government who wish to keep abreast of this developing industry of solid waste disposal, methane control and recovery, and associated problems and opportunities.

REGISTRATION AND FEES

Send in the attached pre-registration form as soon as possible. For your convenience, you may arrive on Tuesday, March 20, after 5:00 p.m. at Dunton Hall, on the Colorado Women's College Campus. The College is located at the corner of Montview Boulevard and Quebec Street; just one mile south of Stapleton International Airport. Otherwise, you may arrive at 8:00 a.m. on Wednesday, March 21, in the Houston Fine Arts Center. Room and board is provided by the College at $16.00 per day per person for a double room and $18.00 per day for a single room including three meals. The program consists of sessions from 8:30 a.m. to 5:00 p.m. Wednesday and Thursday and from 8:30 a.m. to 2:00 p.m. on Friday, with an hour break for lunch.

ACCOMMODATIONS

We suggest that you stay at the Colorado Women's College dormitories which offer both private or double rooms, each with shared baths. Housing is limited at Colorado Women's College, therefore a first come first served policy will be utilized for room reservations. Rates are somewhat higher than those listed above for accommodations not meeting a two day minimum reservation requirement.

WHICH WORKSHOP(S) DO YOU WISH TO ATTEND? PLEASE INDICATE ON REGISTRATION FORM.

INSTITUTIONAL

1. Legal Liability
2. Legal Regulatory
3. Abandoned Landfills
4. New Landfill Planning
5. Hazard Response
6. Public Participation
7. Building Codes/Zoning
8. New Siting Criteria (Design for maximum production)
9. Other ________

TECHNICAL

1. Methane Survey
2. Laboratory Techniques
3. Recovery Technology
4. Control Technology
5. Investigative Techniques
6. Environmental Impacts
7. Market/Risk
8. High BTU Processing Technology
9. Low BTU Processing Technology
10. Other ________

[illegible]

AGENDA

Tuesday, March 20, 1979

5:00 p.m. Early Registration
Dunton Hall, Colorado Women's College

Wednesday, March 21, 1979

8:00 a.m. Registration

Landfill Methane Perspectives:
Environmental Protection Agency (EPA)
Department of Energy (DOE)
Intergovernmental Methane Task Force (IMTF)

Methane Production: How and Why

Conducting Methane Surveys

Investigative/Lab Techniques: Why They Are Needed

Legal: Regulatory/Liability

Abandoned Sites: Tale of Two Cities, Denver/Louisville

Workshops on Topics Presented

Thursday, March 22, 1979

On Line Control Experiences

Recovery and Utilization: Experiences of On Line Projects

Recent Developments in Recovery and Utilization

Guidelines for Decision: Recovery or Hazard Control

New Landfill Design for Control Systems

New Landfill Design for Recovery Systems

RCRA: Landfill Inventory Criteria

Low BTU Processing Technology

High BTU Processing Technology

Public Involvement: New and Old Sites

Workshops on Topics Presented

Banquet

Friday, March 23, 1979

Administrators' Guide

DOE Workbook and Film

Planning for Landfill Sites

The Potential for Recovery and Utilization

Tour of Three Landfill Sites

1:30-2:00 p.m. Wrap-up and Evaluation

Saturday, March 24, 1979

Ski Tour Package to Winter Park

IMTF
INTERGOVERNMENTAL METHANE TASK FORCE
ROOM 400
450 SOUTH 4TH AVENUE
BRIGHTON, COLORADO 80601

STATUS OF WORKBOOK

The Workbook has been prepared from a variety of source documents which are identified in the Appendix.

Due to the time constraints of the individuals involved in the development of this text, no technical editing was accomplished prior to the Symposium. Chapters 1, 2, and 3 are basically in their final form, while Chapters 4, 5, and 6 will require major revision.

Please bear in mind that this is an instructional text and the Symposium is being used as a major critique for the document.

It is requested that each of you fill out the attached critique and provide this to my attention at 8AH-WM, Region VIII EPA, 1860 Lincoln Street, Denver, Colorado 80295.

Gary P. Morgan
Technical Assistance Panels
Program Manager
Region VIII
Workbook Coordinator

CRITIQUE

REGION VIII TECHNICAL ASSISTANCE PANELS PROGRAM ADMINISTRATORS' GUIDE:

METHANE ON THE MOVE: YOUR LANDFILL'S SILENT PARTNER

We are interested in your comments. Please complete this form and return it to the registration desk, or mail to: Gary P. Morgan, 8AH-WM, 1860 Lincoln Street, Denver, Colorado 80295.

1. TYPE OF ORGANIZATION: Consulting Engineers:_____ Planning/Administration:_____
   Federal Agency:_____ State Agency:_____
   Municipal Agency:_____ Industry - (State Type):_____

2. Evaluate the following Chapters according to the criteria listed:

   1 - Excellent 2 - Satisfactory 3 - Unsatisfactory

	COVERAGE OF SUBJECT MATERIAL	READABILITY	FIGURES	TABLES
Chapter 1 Introduction	_____	_____	_____	_____

Liked Most:_____

_____

Disliked Most:_____

_____

Chapter 2 Methane Generation	_____	_____	_____	_____

Like Most:_____

_____

Disliked Most:_____

_____

Chapter 3 Public Impact	_____	_____	_____	_____

Liked Most:_____

_____

Disliked Most:_____

_____

	SUBJECT MATERIAL	READABILITY	FIGURES	TABLES
Chapter 4 Recovery Material	_____	_____	_____	_____

Liked Most: _____

_____

Disliked Most: _____

_____

Chapter 5 Planning	_____	_____	_____	_____

Liked Most: _____

_____

Disliked Most: _____

_____

Chapter 6 Decision	_____	_____	_____	_____

Liked Most: _____

_____

Disliked Most: _____

_____

Were the Topics Appropriate? _____

_____

_____

What Would You Change? _____

_____

_____

Who Would Benefit Most from the Use of this Text? _____

_____

_____

METHANE ON THE MOVE -YOUR LANDFILL'S SILENT PARTNER

An Administrator Guide
developed by the
Intergovernmental Methane Task Force
U.S. EPA Region VIII

Compiled and Edited by
Gary P. Morgan
REGION VIII
TECHNICAL ASSISTANCE PANELS
PROGRAM MANAGER

DISCLAIMER

This administrators guidebook for local decision makers was developed under the Environmental Protection Agency (EPA) Technical Assistance Panels Program. Neither the EPA, the National League of Cities, or the Intergovernmetal Methane Task Force (IMTF) or any of their employee's nor any or their subcontractors or any of their employee's acting on behalf of either:

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b) assumes any liablility with respect to the use of or for damages resulting for the use of any information method or process disclosed in this quidebook.

c) The information within this text was extracted and compiled from many sources and individual experiences. Credit to those sources are identified in the Acknowledgement and Chapter 1.

ACKNOWLEDGEMENTS

This Administrator's Guide was prepared by members of the Intergovernmental Methane Task Force and by several consulting firms who are listed on the following page who have provided information on their specific areas of expertise. The break-out of co-authors and sources for various portions of this Administrator's Guide are as follows:

Primary Sources:

Publications and Articles

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Lockman Associates
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Jeannee Vanoy, Denver Research Institute
Jim Considine, Adams County Planner
Danamarie Schmitt, Adams County Assistant Planner

Forward

This Workbook was designed for city and state officials who have little or no experience with landfill generated methane gas.

The objectives of the Workbook are to reach those persons who will have to deal with landfill issues in their communities. Included are:

(1) Sharing of Intergovernmental Methane Task Force (IMTF) experiences in dealing with methane-related problems.
(2) Addressing both institutional and technology related problems focusing on control and recovery/utilization of methane gas.
(3) Effecting technology transfer relative to the recovery/utilization of landfill gas.

The Workbook is, therefore, structured to define the issues related to the production of methane in landfills and the necessary preliminary concerns that must be resolved prior to entering into a possible recovery stage.

We solicited comments on this potentially serious problem through the participants of the Symposium: Methane from Landfills: Hazards and Opportunities.

Should you have comments on the content or format please follow the directions in Chapter 1.

Disclaimer

FOREWARD

ACKNOWLEDGEMENTS

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- Thermal Measurements
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- Self-Potential Resistivity Measurements
- CO_2 & H_2SO
- Presence of Microbial Presence of Psuedomonas
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2.3.1.4 Ambient Air Temperatures
2.3.1.5 Precipitation
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2.3.1.7 Natural Conduits of Laterial Migration
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2.3.3 Buildings and Structures

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3.2.4 Demonstrations/Training Exercises
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4.2 The Feasibility Study

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CHAPTER 1

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1.2 The Problem Defined (Regional/National)

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1.7 Organization and Content of Guidebook
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Chapter I - Introduction

1.0 Why a Decision Maker's Guide?

During the past decade there has been increasing concern about the environmental and safety impacts of methane gas migrating from open dumps and/or sanitary landfills. In response to these concerns, improved methods have been developed to reduce or mitigate this undesirable migration from the site boundaries as well as protecting those buildings built on closed or abandoned sites. The Administrator's Guide is intended to meet the need of a single document that provides current information about these concerns and developments; particularly with respect to new landfill sitings and current operation of sanitary landfills. Abandoned sites are the ones that cause the most concern in dealing with liability issues as well as being able to take corrective actions to mitigate any undesirable migration. This text will focus on factors that require adoption of methods, requlations, operating procedures to prevent an undesirable safety hazard in and around sanitary landfills and address those social economic impacts of having to put in a control or recovery system.

1.1 Objectives

The objectives of the handbook Administrator's Guide is the same as those presented in the Methane Symposium, "Methane from Landfills - Hazards and Opportunities. Those objectives are to reach those persons at the local and state levels who have to deal with landfill issues in their communities. Included are:

(1) Sharing of Intergovernmental Methane Task Force (IMTF) experiences in dealing with methane related problems in abandoned and new landfill sitings;
(2) Addressing both institutional and technology related problems, focusing on control and recovery/utilization of methane generated gas;
(3) Affecting a technology transfer relative to the recovery/utilization/control of landfill gas.

The text is therefore, structured to define the issues related to the production of methane in landfills and those preliminary concerns that must be resolved prior to entering into a possible recovery stage. The text will address the technical economics, social, and environmental factors that influence landfill siting and future land planning in the Denver metropolitan area that can be applied in areas throughout the continental United States. The Guide is not meant to be a regulatory document; however, the information should be useful to local, state and federal administrators, legislators, policy makers, planners, and other local decision makers involved in the review or approval for siting landfills or controlling the zoning after the landfill sites are closed. This information should also be of interest to citizens who would be affected by any new land development or any proposed new landfill siting.

The guide identifies and highlights information that is considered by industry during their site evaluation process. For example, the sites specific aspects of a landfill are receiving increasing attention from regulators and industry and is particularly affected by the requiremens of the Resource Conservation and Recovery Act of 1976, and some earlier disposal practices from municipal solid waste are no longer acceptable. To assure that the guide will be useful to local decision makers, comments from a steering committee at the symposium were considered for final publication.

1.2 The Problem Defined (Regional or National)

Methane, carbon monoxide, carbon dioxide, and other gases are produced by the decomposition of organic wastes in a landfill. The use of trenches, cells, and cover material in landfills tends to cause lateral migration of these gases from the sites. A sanitary landfill provides vents such as gravel trenches or pipes to enable the gases to escape into the air. On the other hand, drainage tile, utility pipes, and other conduits from buildings enhance the migration of these gases into nearby buildings. When concentrated in enclosed buildings these gases may accumulate to combustion, explosive or toxic (asphyxiation) levels. The migrating gases also frequently poison or asphyxiate vegetation near the disposal site.

1.2.1 Lack of Control - The Symptoms

The problem associated with landfill gas is not in its generation but in its migration or movement. The migration of the gas past the perimeter of the landfill has occurred in many parts of the U.S. and represents a potential health and safety hazard in the form of a fire, explosion or asphyxiation. This explosive nature of the gas has been documented in such cases as:

Winston-Salem, North Carolina (September 1969) - methane migrated from a nearby dump to the basement of an armory where it exploded when a cigarette was lit, killing three men and seriously injuring five others;

Montreal, Canada (1968) - methane gas from a dump ripped apart a swimming pool under construction near the EXPO 67 site; a parking lot built on top of the dump had lamps designed to allow the gas to escape into the air;

Denver, Colorado (1977) - Two men were killed in a storm drain that was under construction some 600 feet from an old landfill that was designated for future development as a light industrial park

(See Table 1.1 for list of some additional documented cases.)

These incidents point out that methane migration from closed, abandoned, or existing landfills are, on a national scale, potentially dangerous gas and leachate generators.

The problem is not, however, limited to the potential fire and explosions, but to the other byproducts:

(A) Odor due to organic acids in gaseous form;

(B) Vegetation destruction due to root kill;

(C) Leachates due to carbonic acids which decrease pH and increase corrosivity;

(D) Differential settlement on or near perimeter of landfill;

(E) Asphyxiation due to atmospheric oxygen displacement by methane (CH_4) and carbon dioxide (CO_2).

Table 1.2

ENVIRONMENTAL IMPACT OF GASES FROM SOLID WASTE DISPOSAL SITES

1. Winston-Salem, North Carolina (September 1969) - methane migrated from an adjacent dump to the basement of an armory where it exploded when a cigarette was lit, killing 3 men and seriously injuring 5 others.

2. Atlanta, Georgia (December 1967) - methane gas from decaying wastes in an adjacent landfill concentrated in the sealed basement of a single story recreation center building (90 ft. X 40 ft. with 50 ft. X 30 ft. addition); a lighted cigarette caused the methane to explode killing 2 workmen, seriously injuring 2 others, causing minor injuries to 4 others, and completely demolishing the building.

3. Montreal Canada (1968) - methane gas from a dump ripped apart a swimming pool under construction near the EXPO 67 site; a parking lot built on top of the dump had lamps designed to allow the gas to escape into the air.

4. Rockford Illinois (1966-67) - methane gas from the Peoples Avenue Landfill migrated to the basement of the Quaker Oats Company production plant necessitating the development of vents to prevent methane to accumulate (methane seeping into the basement would support a flame).

5. Southeast Oakland County, Michigan (1974-75) - methane from a landfill operated by the Southeast Oakland County Incinerator Authority (SOCIA) migrated to nearby homes and accumulated to explosive levels, necessitating the development of a gravel filled trench at the landfill perimeter to enable the gas to vent.

6. Richmond, Virginia (1975) - An apartment next to a landfill exploded as a result of methane accumulations (January 8, 1975). The door and two windows in the living room were blown out, and a woman suffered first degree burns of her hands, while her husband's hair was singed. A subsequent chain of two elementary schools built on landffills showed hazardous concentrations of methane gas and resulted in closure of these schools. j About 1000 families living near the landfills were also threatened, but only one was found to have methane concentrations. All home, however, were advised to keep their windows and closet doors open year-round.

7. Louisville, Kentucky (1975) - explosive concentrations of methane in homes near a landfill resulted in the evacuation of 8 families unitl appropriate venting could be developed.

8. Baltimore County, Maryland - small flash fires at a transfer station construction site resulted from gases from a nearby landfill.

9. Hopkins, Minnesota - explosive concentrations of methane gas from the Hopkins Landfill accumulated in and threatened nearby condominiums and apartments.

10. Anne Arrundel County, Maryland (1975 or 76) - gases from the old Schmuck (?) Dump injured 5 persons, resulting in 4 days hospitalization for two of them.

11. Philadelphia, Pennsylvania - section of the city built on old landfill caused venting problems for homes.

12. Palos Verdes Landfill (L.A. Sanitation Districts) California - major expenditures to prevent migration of gases to adjacent homes.

13. Sheldon-Arletta Landfill (City of L.A.) California - major expenditures to prevent migration of gases to adjacent homes.

14. Shelbyville, Indiana (1976) - incinerator built on landfill is getting explosive concentrations of methane.

15. Sheridan, Colorado (1975) - An explosion occurred in a drainage pipe under construction. The explosion was caused by methane gas from a landfill, ignited by a welding torch. One workman was burned and another injured by flying debris.

16. Sheridan, Colorado (1975) - An explosion occurred in a storm drain pipe that ran through a landfill. The explosion occurred when several children in the storm sewer lit a candle. The resultant explosion burned four of the boys seriously resulting in extensive hospitalization.

17. Commerce City, Colorado (1977) - an explosion occurred in a tunnel being drilled under a railroad right-of-way. The explosion was caused when a worker lit a cigarette which touched off the explosion. j Both of the workmen were killed and four firement were injured.

ASPHYXIATIONS

1. Springfield, Missouri (1973) - a man, working in a shed on a landfill, died as a result of asphyxiation by carbon monoxide produced by decomposing wasdtes; several other employees became ill.

2. Vancouver, British Columbia - two men working in a manhole died from asphyxiation from gases from a landfill.

What complicates the issue is that methane and its associated components are not predictable and are site specific due to geological conditions, landfill operation and other environmental variables. In addition to its unpredictability in production, the gases' migration and movement can change without warning to create a hazardous situation following Murphy's Law.

1.2.2 DOE Seminar at John Hopkins Applied Physics Lab

A methane workshop held at John Hopkins Applied Physics Lab produced the following list of methane associated problems:

(1) A problem exists with respect to the transfer of the technology. Relatively few people are aware of its possibilities. It is recommended that the federal government fund the production of a short (10-15 minute) methane recovery education film. (DOE will complete in early 1979)

(2) Local governmental units have a problem deciding whether or not the technology is appropriate for them. It is recommended that the federal government produce a "decision-makers guide" which provides background information and guidelines to assist local governmental units in their decision making process. Included should be a summary of each landfill methane utilization project currently operating or planned. (This text)

(3) Uncertainty exists with respect to how to optimize methane production from landfills. It is recommended that one or more demonstration projects be funded, hopefully on a federal-state-local cooperative basis, to investigate optimization techniques; (See Appendix A)

(4) Little correlation exists between the laboratory studies which have been completed and the numerous field tests which have been carried out nation-wide. A unifying theory is needed to tie these two areas together. It is recommended that a federal program be implemented to correlate laboratory study results with observed gas generation data; (EPA Cincinnati funding modeling research to tie the two together, 1979)

(5) A problem exists with respect to the design of landfill gas gathering systems. Many designs currently exist, employing different materials and techniques. It is recommended that a series of case histories be written for individual projects. It is further recommended that these case histories be used as one input for the eventual formulation of design guidelines and standards; (Being developed in Headquarters EPA/OSW for publication in late 1979)

(6) A problem exists with respect to overall landfill design and siting. Landfills will be required, in some parts of the United States, for many more years; they must be made better. It is recommended that efforts be undertaken to improve the design and operation of landfills. Recommended approaches include the preparation of a decision-makers guide, implementation of improved civil engineering standards and uniform building codes, and the standardization of conditional use permits which recognize the viability of landfill methane recovery; (Addressed partially in this text and EPA Cincinnati Lab modeling work)

(7) Regulatory restrictions in such areas as health standards and landfill site utilization do not currently recognize the viability of landfill methane utilization. It is recommended that a systematic identification and evaluation of the relevent restictions be carried out at the local, state, and federal levels; (This Text)

(8) The financing mechanisms for landfill methane utilization projects are currently highly uncertain. This stems largely from the fact that the economics of the technology are not well defined. It is recommended that studies to better define the economics of both low-BTU and high-BTU gas utilization be undertaken. One goal of these studies should be to identify appropriate incentives which can be initiated to accelerate the utilization of the technology; (DOE Workbook)

(9) The transfer of information among people currently working with the technology is inadequate. It is recommended that some sort of relatively informal publication, such as a newsletter published quarterly, be started. It is also recommended that the formalization of a technical group, perhaps affiliated with an existing professional society, be examined; (Possible for such an organization as the American Public Works Association, the National League of Cities or the Government Refuse Collection and Disposal Association)

(10) Many unresolved issues currently surround gas ownership and legal liabilities at landfill methane projects. It is recommended that these issues be more clearly defined, and that methods for resolving them be determined. (Partially addressed in this text)

In addition to the preceeding specific problem areas, the workshop produced a list, Table 1.2 of methane problems divided into institutional and technical problems.

TABLE I.2

Technical and Institutional Factors Related to the Utilization of Landfill Methane

TECHNICAL FACTORS	INSTITUTIONAL FACTORS
Need for special drilling equipment	*Financing
*Modelling of generation process	*Who owns gas?
High BTU gas processing technology	*Regulating restrictions
*Gas processing technology	*Educating public
*Modelling of recovery rate	*Public relations
*Field vs. theoretical data	*Technology transfer,
industry	
Well design	to industry and
geographical	
*Gathering system	Define agencies' roles
*Landfill design (optimize CH_4)	Jurisdication of federal
agencies	
Gas enhancement	Pricing
Control technology	Role of utilities
Other withdrawal technology	*Contracting
Operational costs and procedure	Recovery system and
ownership	
Cost estimating	Resistance to use
*Marketing	*Economics
Comparison with other resource	Legal precedents
recovery techniques	*Marketing
Health aspects	*Incentives
*Environmental aspects	Politics
*Testing criteria	Institutional dis-incentives
*Selection	Siting problem
Dynamics of withdrawal	Social impact
Waterwell technology	Agency fragmentation -
Net energy balance	coordination
Risk analysis	Environmental impacts
Marketing products (CO_2)	Minor nature of this - where
Hazard aspect	this fits in overall energy
Ultimate use of landfill	picture
How long will gas last?	Institutional risk
Product liability (warranties)	Training needs
Co-generation (with sludge)	Interplay with RCRA
Agricultural waste	Building codes and zoning
	restrictions
	Use of landfill
	Labor
	*Liability
	Revenue prediction
	Getting financial support
	Finding good consulting firm

Note: Asterisks denote higher priority items.

1.3 The Potential Accident

1.3.1 Safeguards and Response

The facts are quite clear that the methane is generated from all landfills at some level. The question then is, is it in my backyard? The sites listed in the preceeding Table 1.2 demonstrates the need for proper action to be taken in the event of such a disaster. Although seemingly out of context with the guide, this subject is addressed in Chapter I to coincide with its criticality.

1.3.1.1 The Initial Response.

The initial response depends largely on who first discovers the methane problem. Generally the problem is first discovered by the building owner, who detects a strange odor. Although the odor detected is not methane gas, it is landfill generatd companion gases. The common complaint received from building owners is that they smell sewer gas.

The first reaction of the building owner is to notify their public utility company to investigate for a natural gas leak. After investigation by the utility company, it is soon discovered that the odor is not pipeline natural gas. Generally this is where the line of communication breaks down. The proper emergency response people, i.e., fire department or building department, are seldom notified of the problem.

1.3.1.2 Who responds.

Ideally who responds should depend on what agency within local government is best equipped and trained to deal with the problem. Normally the fire department, fire prevention bureau and/or the building department personnel are best qualified to deal with hazardous conditions within a structure.

1.3.1.3 Emergency Equipment.

Out of necessity, the responding agency must be equipped with the basic amount of proper emergency equipment. That equipment should include:

1. Flammable Gas Detector;
2. Low Oxygen Detector;
3. Self-contained Breathing Apparatus;
4. Ventilation equipment;
5. Individual personal safety alarm.

Flammable gas detection equipment is basic and self explanatory (See Chapter 2 for further discussion), however, one must keep in mind that landfill generated gas also travels with 40% to 50% carbon dioxide gas. The volume of both gases together will displace oxygen in sub-surface or confined areas to a very dangerous low level. Therefore, a low oxygen level detector is mandatory in any landfill generated gas investigation. In fact, a Tri-tector is strongly recommended for personal safety! A Tri-tector is designed to detect flammable gas, low oxygen and hydrogen sulfide, all at once and all are landfill generated gases.

Self-contained breathing apparatus is necessary for any sub-surface investigation in order to provide basic personal safety. Oxygen deficient atmospheres have been found in crawl spaces of buildings and in valve and meter vaults.

Ventilation equipment is used to evacuate these sub-surface and confined space once flammable gas atmospheres are found. This equipment should be in the form of explosion proof ventilation fans. These types of fans are normally part of any fire department inventory and are classed as Class I, Division II, Group D explosion proof.

1.3.1.4 Communication/Notification.

Once a methane gas problem has been identified, it becomes necessary to notify the appropriate people. That notification should be proper and legal in form. The burden of notification rests with that governmental unit having jurisdiction. A multiple jurisdictional situation can and sometimes does exist. If that be the case a coordinated notification plan should be established. Governmental units having jurisdiction in a methane gas problem can be in the following forms:

1. Municipal or county fire department;
2. Municipal or county building department;
3. Municipal or county health department;
4. State health department;
5. State fire marshal;
6. Federal or state occupational, safety, and health administration.

The people to be notified should include the owners, operators or leasees of the landfill generating the problem. (See Chapter 3 for examples)

1.3.1.5 Protective Action Guide.

Protective action for the safety of the occupants of any structure subjected to lateral migration of landfill generated methane gas should begin immediately. Each structure must be dealt with on an individual basis, as no two structures are constructed alike. Because of the unpredictable characteristics of landfill generated methane gas a complete survey of each building must be done. Conditions that should be taken into consideration are as follows:

1. Geological and soil conditions;
2. Footing and foundation design;
3. Building ventilation requirements;
4. Meterological conditions;
5. Building occupant requirements.

After the above conditions have been identified, the methane gas problem can be dealt with using sound engineering consideration. Such methods of control utilizing physical barriers, or sub-surface ventilation or monitoring, detection, ventilation and alarm systems, have recently proven successful in methane gas control. Ideally, new construction is the most economically dealt with. However, existing structures are the most common problems found.

The most common system used in the protection of existing buildings is a monitoring and detection, tied to a ventilation and alarm system. Although this type of a system is not 100% building protection, it is primarily used for occupant safety. By setting alarm levels at 10% Lower Explosive Limit (L.E.L.) for ventilation actuation and 20% L.E.L. for alarm, you have insured occupant evacuation prior to reaching dangerous explosive levels. Only after the methane gas level has been reduced below 10% L.E.L., is it safe for the occupants to return to the structure.

1.4 The Intergovernmental Methane Task Force, Denver, Colorado

The Intergovernmental Task Force (IMTF) is an ad hoc committee comprised of representatives from 20 Colorado agencies and five federal agencies interested in landfill associated methane, its control and recovery. The group was formed shortly after two workmen were killed in June 16, 1977, by an explosion of landfill-generated methane inside a large water conduit in Commerce City, Colorado. The agencies involved in the ensuing investigation quickly discovered that little was known about the nature of this hazard and, more importantly, where other potential methane hazards might be located within the State.

As a result, a workshop, sponsored by the Tri-County District Health Department, Adams County and the National Association of Counties, (through an EPA grant), was conducted September 28, and 29, 1977. Persons from fire, safety, planning, health, and other interested agencies met to discuss the situation. Five experts

from other parts of the United States were invited to the workshop to help identify the most pertinent issues surrounding the methane problem and to provide guidance in the development of solutions to the problem as it exists in Colorado.

The primary function of the IMTF, which evolved from the September workshop, has been to address the methane migration problems in the immediate metropolitan Denver area.

In addressing the problem the Task Force sought to:

(1) Joint agency efforts to survey all past and present landfill sites within the State of Colorado for the presence of methane and provide notification of all affected parties as to the presence of the gas and institution of control measures to protect life and property;

(2) The scope of this ad hoc committee has become increasingly larger as it progresses into the depths of the problem. It is with the larger problem of methane migration nationwide that the IMTF has become more involved in due to the numerous requests for assistance from other cities;

(3) The goal then of the IMTF is to provide an information exchange; focused on the hazard and the control of gas migration and the development of new techniques to achieve economic identification and control. An example of this cooperative effort is meetings with officials from the City of Winnepeg, Manitoba, Canada, and Louisville, Kentucky, to discuss methods of control and liabilities arising from the migration of the methane gas;

(4) Bringing together diverse groups of interdisciplinary talent to focus in on the problem; and finally, and perhaps the most important;

(5) Obtaining the cooperation of methane impacted property owners in installing control devices without going through lengthy court actions.

1.4.1 IMTF Goals and Functions

The IMTF primarily through the EPA Region VIII Technical Assistance Panel Program has also been instrumental in soliciting federal and state monies for methane landfill assessments, and control recovery projects. To date, over $448,000 has been granted to various Colorado agencies for use in methane surveys and projects. In addition, the IMTF members have been involved in developing model methane legislation for local and state governments. This includes building and zoning codes, as well as, landfill design and operation criteria.

The IMTF succeeded in its goals by dividing into subcommittees to address the major specific issues of the gas problem. A listing of these committee members are provided in the Appendix C, for your future reference. The major committees are:

1. Legislation (National, State, Local);
2. Research and Technical Aspects;
3. Fire Safety;
4. Building Codes and Standards;
5. Planning and Zoning;
6. Funding;
7. Public Relations;
8. Presentations;
9. Analytical and Monitoring Techniques.

Through these subcommittees the IMTF accomplished the following in one year of effort. Note that the task force meets once a month at various local, state, and federal conference rooms:

1.4.2 IMTF Accomplishments

Chapters 2 and 3 will provide the necessary detail on each of the items listed below.

(A) ISSUE: Construction safety in and around landfills.

OUTPUT: Developed a checklist of safety precautions and worksheet for distribution to local construction companies.

(B) ISSUE: Question of safety in buildings affected by gas migrations.

OUTPUT: Developed an instruction sheet for use by building occupants, on detection and alarm equipment and safety precautions to be observed in methane affected structures.

(C) ISSUES: Lack of knowledge on methane migration.

OUTPUT: A 45-minute slide presentation on the hazard and control of landfill gas was developed and has been presented to various public and private groups (40 occasions).

(D) ISSUE: Lack of State Legislation on landfill gas.

OUTPUT: Developed a comprehensive revision to the Colorado State Solid Waste Act to provide several necessary actions:

(1) Define who is responsible;

(2) Put control in State Health Department vs. County;

(3) Restriction placed on deed to land.

(E) ISSUE: Question of Government responsibility for control of gas migration.

OUTPUT: To take agressive positive action, use the Fire Marshals authority to abate hazards to protect building and occupants. This action is more immediate than that of the Colorado State Health Department.

(F) ISSUE: Lack of funding at state level.

OUTPUT: With inputs from the IMTF, members of the Colorado State Health Department prepared a budget to perform a survey for identifying landfills that have a methane gas problem. The health department almost lost this appropriation twice had it not been for the testimony of IMTF members before the HEW Budget Committees. As a result, $200,000 was set aside to investigate the problem.

(G) ISSUE: No funds available for remedial action at local sites.

OUTPUT: The IMTF prepared a work scope for corrective actions at two sites using innovative technology which was also low in cost. The Colorado State Health Department then forwarded a grant application to OSW through Region VIII. The funds, $50,000 has been committed to but not allocated. Additionally some private industries have incorporated alarm systems following notification which they should be applauded for their morale responsiveness.

(H) ISSUE: Building codes do not address landfill problems or precautions.

OUTPUT: Presentation was made to the International Council of Building Official (ICBO). As a result, the building code will be amended for the 1980 edition to address landfill associated problems when building on or near such a development.

1.5 Intergovernmental Coordination

We have observed that the production and movement of landfill gas is recognized as an environmental problem but not understood. That the control and recovery systems are both straight forward yet costly and not without problems. The solution to the associated methane gas problem is as complex as the problem itself and will requie all the cooperation any community can master in bringing about an equitable resolution.

Intergovernmental coordination is a very important aspect of methane gas management. No one single problem involves so much interplay between the different functions and levels of government. Because of the magnitude of the problem, duplication of effort must be avoided.

Coordination should be done at the local level. The local official, whether municipal or county, has the prime responsibility for preservation of health, safety, and welfare of the citizens of that jurisdiction. He therefore has the primary duty to deal with the methane gas problem. However, out of necessity his actions will involve federal, state, and local units of government. By strict coordination of all of these units of government, conflicting statements and requirements concerning management of a methane gas problem will be avoided.

A committee such as the Intergovernmental Methane Task Force is a representative example of what community cooperation is all about.

1.6 Assignment of Responsibilities

These problems of landfill gas migration frequently transcend governmental boundaries, which suggest that an intergovernmental approach be used. Care must be exercised in this unification to pull together this fragmentation of authority and responsibility which becomes of such a critical importance, in that this awareness of ingenuity doesn't flounder in the sea of special district authorities, utilities, and joint power agreements. Thus, the overall unification should be an organization that is capable of responding to the migration problem.

It becomes very evident early in the process that there are voids in state regulations and local ordinances in directing attention to methane. Some of the voids that were addressed in the Denver, Colorado area by agencies are outlined in the following presentation.

Following is an outline of the responsiblities necessary to adequately address the methane gas migration problem and its associated symptoms.

1.6.1 State

1. Review of landfill plans based on a solid waste act.
2. Has power to disapprove a landfill if it doesn't meet criteria.
3. Enforces state solid waste act.
4. State Health Department has no criteria for methane control at landfills.

5. The state should provde better guidance for county officials regarding the operation and maintenance of landfills. (regulations, guidance, standards, etc.)

1.6.2 County

1. County commissioners have primary responsibility to approve sites in their own county.
2. Has authority to take action against non-compliance sites.
3. Presently most landfill areas are either MC or industrially zoned.

   a. Need to zone areas appropriately with hazards involved
4. The County Commissioners should be more informed relative to landfill/methane gas problems.

1.6.3 City

1. City council has authority over landfills in city only.
2. Under a dual enforcement system county/city and the State Health Department should determine enforcement procedures.

1.6.4 County Health Department

1. Acts in surveillance only for county, city and state
2. Enforcement procedures are usually slow at the county level.
3. How do we notify contractors of methane hazards if they intend to dig in a landfill area?
4. How do we deal with the hazrds associated with methane from existing landfills?
5. Continuation of TCDHD (Tri-County Health) methane investigation to determine sites affected by methane, areal extent of movement from fills, etc. in order to carry out the investigation, the following are needs:

1.6.5 Building and Planning Departments

Building and planning departments take into consideration the hazards of methane from landfills in any land use or building decision.

1. To accomplish this goal TCDHD and appropriate fire officials to inventory on buildings around landfills for the city and provide guidance to monitor and/or control the gas.

2. Building codes do not have requirements for structures on or near landfills (no allowance for methane).

1.6.6 Task Force Approach

A task force be formed to deal with the problem and to evaluate the available data.

1. Evaluate and establish criteria identifying hazard conditions in and around landfills.
2. Investigate and identify enforcement responsibilities and authorities.

1.6.7 Federal (EPA)

Resource Conservation and Recovery Act of 1976 which is developing inventory criteria for sanitary landfills from an environmental standpoint.

1.7 Organization and Content

The material is organized as follows:

Chapter 2. Technical Explanation of Methane Generation

This chapter discusses what takes place in a landfill through aerobic and anaerobic decomposition. It also discusses the migration and movement of landfill gas due to geological and soil conditions. Included in the discussion are the state-of-the art in dealing with both laboratory vs. field equipment in examing the actual vs. the theoretical data that can be accumulated. In addition, the impacts on air, water, and land use will be briefly discussed. Mr. Russ Herman, Raymond Vail Associates, Dr. David Updegraff, Colorado School of Mines, Clarence Lott, Chemist, Colorado State Health Department provided input to this portion of the text.

A look into investigative techniques deals with the methodology in determing in the field the types of equipment used to determine whether gas is present within the boundaries and without the boundaries of a landfill. It deals with simple techniques for evaluating the basic problem and will go into more detail making detailed analysis of the gases. In addition, remote sensing techniques will be discussed and what their limitations presently are and what the projected outlook entails. This chapter will also deal with the laboratory equipment - why the use of laboratory equipment is necessary, how to identify landfill gas from natural gas, and will discuss the trace elements that will be present in landfill gas which may be an inhibitor to a successful recovery process.

Chapter 2 Physical Control -

Additionally, observations of landfill gas hazards and liabilities will be discussed in the context of how we control that hazard by use of passover active systems and how these systems are to be designed and what are the characteristics of these systems. A detailed look at movement of the gas will be analyzed as to natural conduits of migration and as to manmade conduits of lateral migration.

Chapter 3 Methane Management - Training Information Dissemination

The outputs of the Intergovernmental Methane Task Force. These outputs will show how the Task Force, which is an Ad hoc committee, attempted to affect the technology transfer in allowing or disseminating gas information to other local decision makers through the use of slide presentations and training exercises and demonstrations. Principle input was received from Bruce Wilson, Tri-County Health Department, Jeanne Vanoy, Denver Research Institute, Don Kennerson, Raymond Vail and Associates, and Terry Marone, Legal Clerk.

Public involvement on an old site discusses the issues of public relations, notification, presentations, and information dissemination that may be utilized to identify abandoned or closed sites as being health or environmental problems.

Political and social discusses the issues of landfill gas liability as it applies to the fire safety codes, building codes, planning and zoning. This chapter will also investigate state statutes, local regulations, and local ordinances as they apply to the issues of gas generation from landfill.

Chapter 4 Methane Management Recovery

In this chapter we will discuss the markets, the feasibility studies, the incentives, the generation products, and the impacts and barriers to recovering landfill gas as opposed to natural gas. Discussion of the political barriers, sales agreements, the product warranties and liabilities of the by-products in recovering landfill gas. Principle input was from a report supplied by Mr. John Pacey, EMCON Associates, to the IMTF.

Chapter 5 Methane Management Planning Objectives and Guidance
The New Site

The overall emphasis of this chapter will be planning for the future the final end use, and deal with the environmental and legal assessment in establishing new landfill sites. A discussion

of federal envrionmental impacts as to federal regulatory requirements apply to, such as air, water, solid waste, as well as, OSHA and HUD developments. Discussion of the potential impact and control requirements that may be imposed on a new landfill site. Input supplied by Jim Considine and Danamarie Schmitt, Adams County Planners, and Charles Brinkman, EPA Region VIII.

Chapter 6 The Decision Products Conclusions.

Finished context of this chapter will take a look at the alternatives of the previous chapters, taking a look at the risks involved, and the institutional evaluations. An attempt to provide a decision flow chart for decision makers to utilize in determining which course of action they should attempt to take in dealing with their local landfill gas problem.

Appendix. List of References

The Appendix will include all papers presented at the gas symposium in March, as well as, the consultants working on methane, consultants, the Intergovernmental Methane Task Force experiences in Colorado sites, and source documents of the publications referenced in this Handbook.

1.8 Comments and Updating

The information in this handbook was compiled from many sources. It has been carefully reviewed by representatives of government, industry and public interest groups, to eliminate to the greatest possible extent errors or inconsistencies, and to update information obtained from the literature when appropriate. Readers are invited to submit comments to National League of Cities, 1620 I St., Washington, D.C., or U.S. EPA Region VIII, 1860 Lincoln Street, Denver, Colorado 80295, Attn: Mr. Gary P. Morgan. In the future, significant progress is expected to improve waste disposal practices in the impact and mitigation techniques for siting disposal sites. Additionally, the techniques for evaluating and determining the migration patterns of methane gas are inspected to improve. This quide is in loose leaf form so that its usefulness may be extended by future revisions to reflect the results of such progress.

CHAPTER 2

TECHNICAL EXPLANATION OF METHANE GENERATION

2.0 Technical Explanation of Methane Generation
2.1 What Is It

2.1.1 Why is Methane Dangerous
2.1.2 What Takes Place in a Landfill (the problem)

2.1.2.1 Aerobic - Anaerobic Decomposition
2.1.2.2 Composition
2.1.2.3 Movement - Laterial Migration

2.1.3 Environmental Impact

2.1.3.1 Leachate Formation and Migration
2.1.3.2 Gas From Leachate
2.1.3.3 Water
2.1.3.4 Land Use

2.2 How Do We Find It (Investigative Techniques)

2.2.1 Administrative Planning Guide for Surveys
2.2.2 Site Evaluation Plan
2.2.3 Field Equipment Investigation

2.2.3.1 Equipment and Procedures
2.2.3.2 Gascope
2.2.3.3 Bar Hole Punch

2.2.4 Desirability of Lab Techniques/Testing

2.2.4.1 Significance of Analytical Lab Work
2.2.4.2 Quality Assurance
2.2.4.3 Trace Elements (Leachate)
2.2.5.1 Remote Sensing Techniques

- Seismic
- Map Permeability Zones
- Infrared Scanning
- Thermal Measurements
- PH & EH Measurements
- Self-Potential Resistivity Measurements
- CO_2 & H_{2SO}
- Presence of Microbial Presence of Psuedomonas
- Methanica

2.3 What Do You Do With It (controls)

2.3.1 Methane Movement

- 2.3.1.1 Cover Material
- 2.3.1.2 Surrounding Soil
- 2.3.1.3 Gas Pressure and Generation Rate
- 2.3.1.4 Ambient Air Temperatures
- 2.3.1.5 Precipitation
- 2.3.1.6 Barometric Pressure
- 2.3.1.7 Natural Conduits of Laterial Migration
- 2.3.1.8 Man Made Conduits of Laterial Migration

2.3.2 Gas Control Technology

- 2.3.2.1 Barriers
- 2.3.2.2 Passive Static Vents
- 2.3.2.3 Power Vents

2.3.3 Buildings and Structures

2.3.4 Success

- 2.3.4.1 Effectiveness
- 2.3.4.2 Managability

2.3.5 Criteria for Selection

2.3.6 Impacts

- 2.3.6.1 Environmental
- 2.3.6.2 Compatibility
- 2.3.6.3 Construction

2.0 The Methane Fermentation: Updegraff

Technical explanation of methane generation

2.1 What is it?

2.1.1 Why is Methane Dangerous?

Methane is highly explosive in concentrations between 5 and 15 percent by volume in air. However, this is only a general range and varies with site specific conditions. Some of the more important parameters include the amount of oxygen (O_2) and carbon dioxide (CO_2) in the surrounding atmosphere. In laboratory tests conducted by the U.S. Bureau of Mines, the methane explosive range varied appreciably within the accepted range of 5 to 15 percent as illustrated in Figure 2.

The atmosphere is primarily composed of a mixture of nitrogen (78%), oxygen (21%), and very small (1%) amounts of other gases. From laboratory test results,[2] it has been shown that an explosive boundary or envelope can be experimentally established. Figure 3 illustrates the relation between quantitative composition and flammability of mixtures of methane, air, and nitrogen. It shows, for example, that the mixture

	Percent
Methane	12
Oxygen	2
Nitrogen	86

cannot form an explosive mixture with air, whatever the proportions used, whereas, the mixture,

	Percent
Methane	9
Oxygen	12
Nitrogen	79

although not itself explosive, may form a series of explosive mixtures with air. This envelope of explosivity is very small as shown on the graph.

In addition to the impacts of the surrounding atmosphere's composition, the possible influence of pressure, temperature and large amounts of water vapor on the explosive limits of methane in air cause the predictability of hazards difficult in this dynamic state of affairs. The question of why more methane explosions are not evident at landfills, in summary, remains at this time.

2.1.2 What takes place in a landfill?

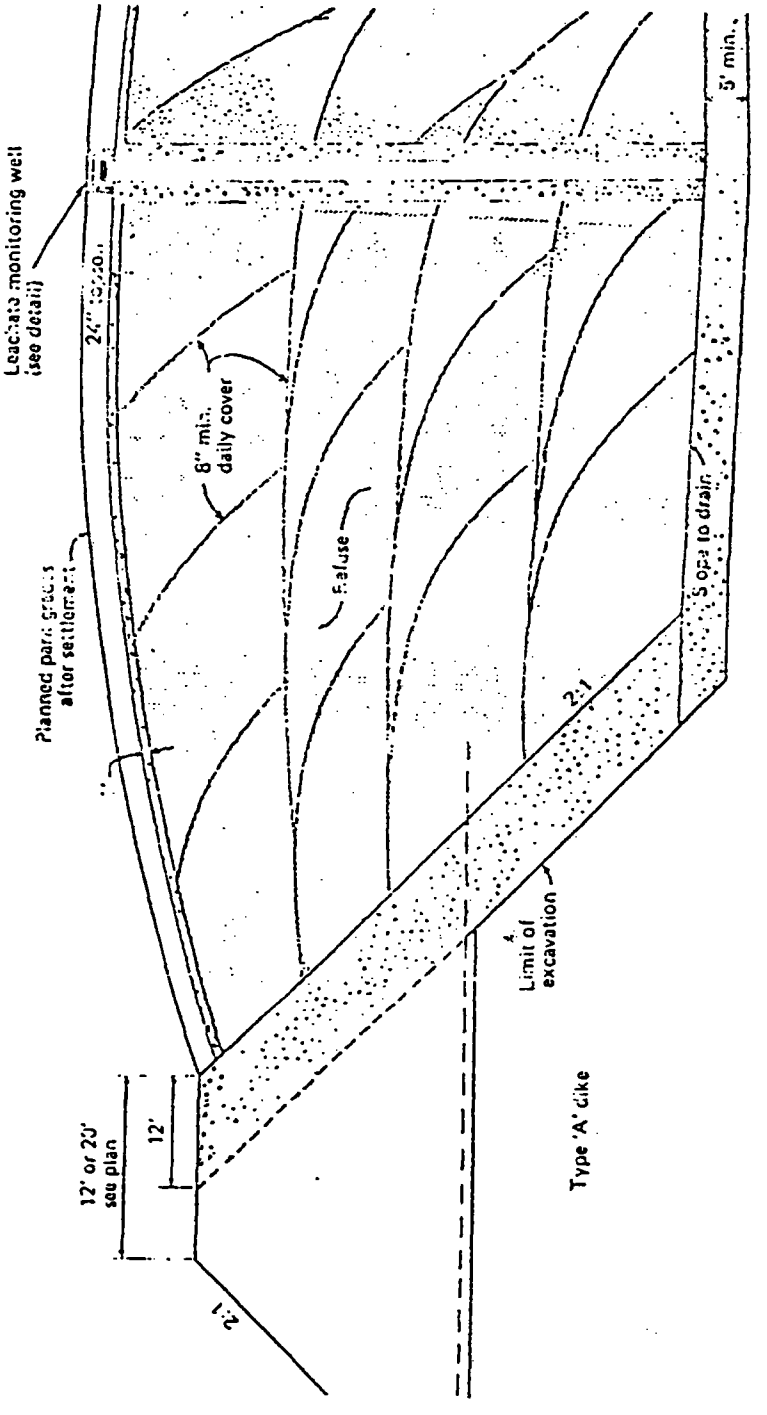
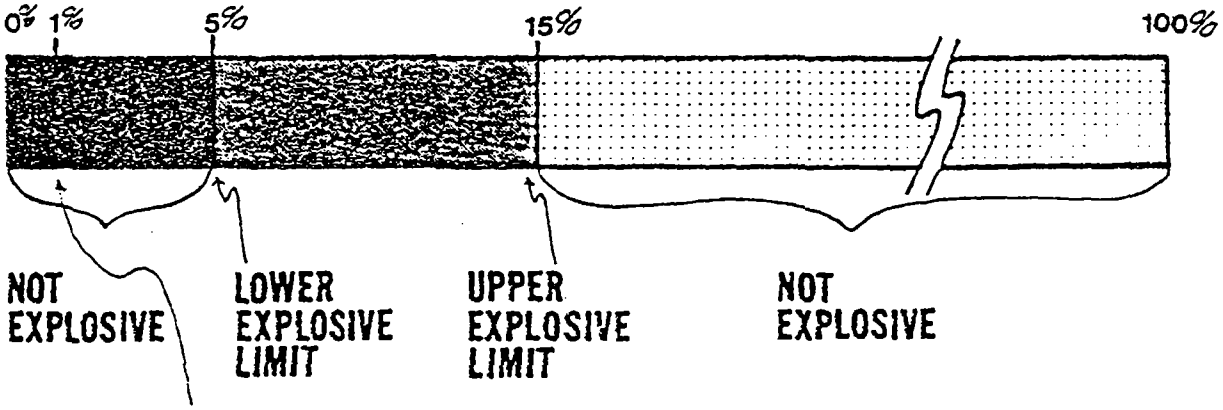


Fig. 2.3 Typical Sanitary Fill

DANGER OF LANDFILL GAS

METHANE



OXYGEN

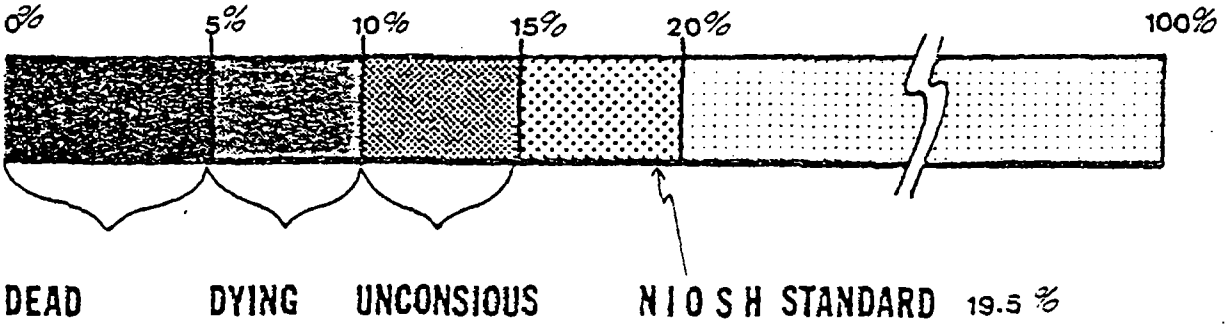


Figure 2.16

Figure 2.1a

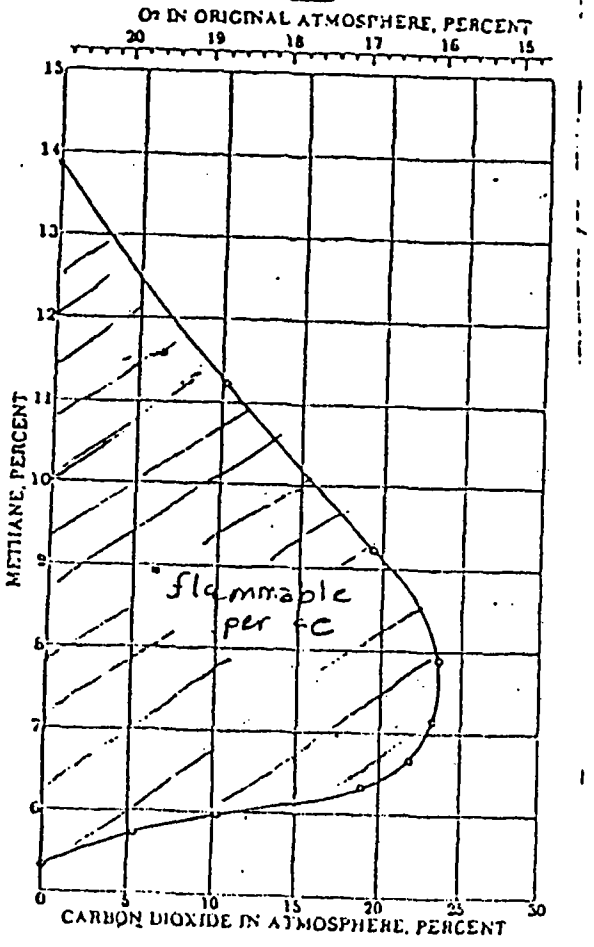
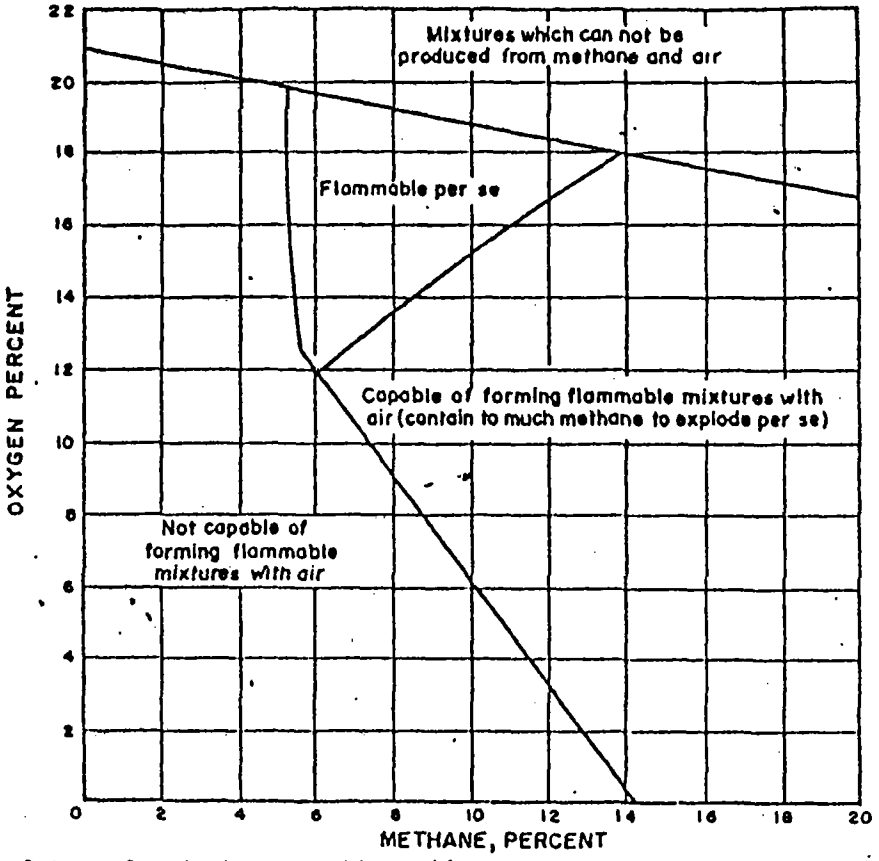


FIGURE 3 2.2

LIMITS OF INDIVIDUAL GASES AND VAPORS



Relation Between Quantitative Composition position and Flammability of Mixtures of Methane, Air, an Nitrogen

2.1.2.1 Aerobic and anaerobic decomposition.

Whenever natural organic matter is buried it is transformed by the action of microorganisms into a variety of simpler organic materials. Organics that decompose to methane include solid waste, refuse, sawdust, wood, and agricultural residues, in either landfills or natural sources such as peat bogs, tar pits, coal or oil deposits. The final stage in the anaerobic degradation of organic materials is methanogenesis, and the products of this reaction are methane and carbon dioxide. This was well known long before the development of the sanitary landfill as a means of disposing of solid wastes. Methane is produced in organic rich sediments beneath the sea as well as in freshwater marshes, ponds and lakes. The ghostly will-o-the-wisp, known to our prehistoric ancestors, was due to the burning of marsh gas bubbling up from swamp sediments. The bacteria causing methane production, a group called the methanogens are perhaps the most strictly anaerobic bacteria know. Thus, no methane can be produced except in strictly anaerobic environments, meaning a complete absence of oxygen.

Since municipal solid waste, even when compacted into a landfill, is extremely porous, a freshly filled, compacted and covered landfill contains a large amount of air which is 21% oxygen. No methane production can take place until this oxygen is removed. The removal is carried out by aerobic and facultative microbes. Since municipal solid waste contains garbage, which is rich in all kinds of microorganisms as well as water and all of the nutrients required for their growth, microbial growth will begin at once. Approximately half of the total dry weight of municipal solid waste is paper, which is nearly pure cellulose. Cellulose is an excellent nutrient for several species of fungi and bactria. Cellulose is a polymer of glucose, and the decomposition of the insoluble, fibrous cellulose leads to the production of the water soluble sugar, glucose. Glucose is an excellent nutrient and energy souce for a much wider assemblage of microorganisms that cellulose, and it is readily degraded under either aerobic or anaerobic conditions. Under aerobic conditions it may be completely oxidized to carbon dioxide and water, according to the equation:

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \underset{\text{carbon dioxide}}{6CO_2} \quad \underset{\text{water}}{6H_2O}$$

This type of reaction explains what happens to the oxygen in a landfill. Assuming that the waste is well compacted and well covered with an impermeable clay soil, and that the bottom and sides of the landfill are also of relatively impermeable clay sediment there will be little migration of either gases or liquids into or out of the landfill.

The composition of landfill gas undergoes an evolutionary process as the waste experiences, first aerobic decomposition (characterized by the presence of free oxygen), and then anaerobic decomposition (lack of oxygen) environments. This evolution develops in four phases as discussed below.

Aerobic

This phase, may take from a few months to a year. Eventually the landfill becomes completely anaerobic, and contains not only a great deal of cellulose, since only a small portion of the cellulose will have been decomposed by aerobic organisms, but will also contain an enormous variety of breakdown products of cellulose glucose and other organic materials.

The phase of anaerobic digestion, carried out by many kinds of bacteria working together now begins. The process may be divided into three phases.

Anaerobic Non-Methanogenic

The digestion of high molecular weight insoluble materials and their conversion into simpler water-soluble materials. For example, cellulose is converted into glucose, proteins are converted into amino acids, and fats into glycerol and fatty acids. In this stage, significant amounts of carbon dioxide and some nitrogen and hydrogen are produced.

Anaerobic Methanogenic - Unsteady

During this stage gas production and composition approach steady-state conditions. During this steady-state condition, the percentage of methane gas may range from 50 to 60 percent; carbon dioxide, from 40 to 50 percent with traces of other gases. Figure 2.3 depicts landfill gas production vs. time. The methanogens convert these materials into carbon dioxide and methane, as illustrated in the following equations:

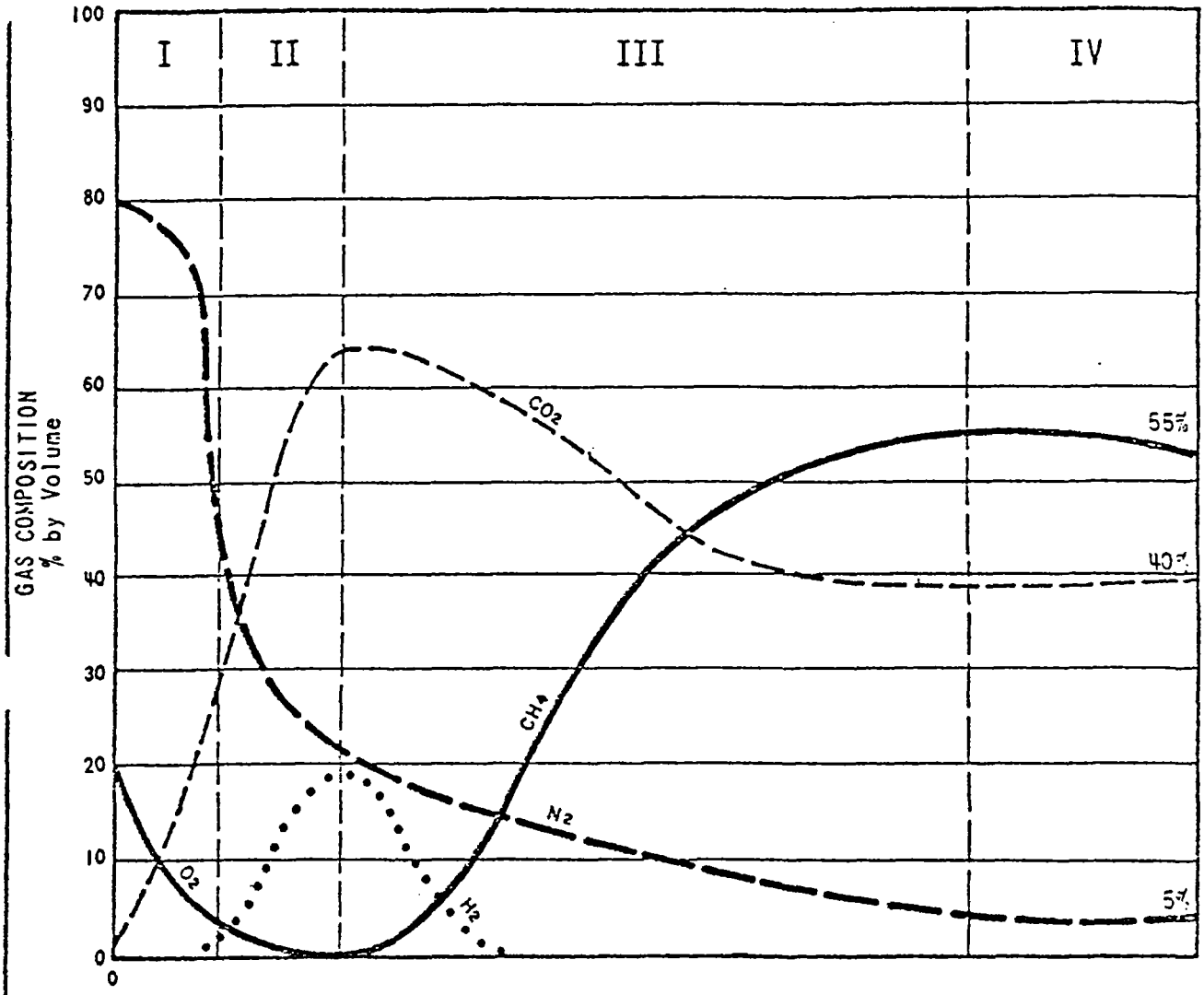
$$CH_3COOH \rightarrow CO_2 + CH_4 \quad (1)$$

acetic acid — carbon dioxide — methane

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \quad (2)$$

carbon dioxide — hydrogen — methane — water

How propionate and acetate get converted into methane and carbon dioxide remains largely unknown, but the may be converted first to carbon dioxide and hydrogen, since all methanogens are able to carry out the formation of methane from carbon dioxide and hydrogen.



I. Aerobic

II. Anaerobic, Non-Methanogenic

III. Anaerobic, Methanogenic, Unsteady

IV. Anaerobic, Methanogenic, Steady

EMCON

EVOLUTION OF TYPICAL LANDFILL GAS COMPOSITION

PROJECT No. 309-1.1 | FIGURE No. A1

FIGURE 2.3a

GAS COMPOSITION OF A TYPICAL LANDFILL

TIME INTERVAL	VOLUME %		
MONTHS	N_2	CO_2	CH_4
0 - 3	5.2	88	5
3 - 6	3.8	76	21
6 - 12	0.4	65	29
12 - 18	1.1	52	40
18 - 24	.4	53	47
24 - 30	.2	52	48
30 - 36	13	46	51

Figure 2.3 b

The methanogens are very sensitive to temperature, and prefer a warm environment. Some have an optimum growth temperature of 35 to 45°C, while others, the thermophiles grow best at 60 to 70°C. Thus, the landfill environment is ideal, because the aerobic decomposition phase preceding the anaerobic digestion phase produces a great deal of heat. This is due to the oxidation of organic materials by the aerobic organisms, and may cause the temperature to 35°C or more. Table 2.1 shows optimal conditions for decomposition.

TABLE 2.1
OPTIMAL CONDITIONS FOR ANEROBIC DECOMPOSITION

Anaerobic Conditions	No Oxygen (Air)
Temperature	85 - 100° F (29 - 37° C)
pH	6.8 - 7.2
Moisture Content	Greater Than 40 Percent
Toxic Materials	None
Production	.05 - 7.0 SCF/pond

2.1.2.2 COMPOSITON

As observed, biological decomposition of the organic matter in refuse results in the production of gaseous products. The major constituents of landfill decomposition gas ar carbon dioxide and methane with lesser amounts of nitrogen, and traces of ammonia and hydrogen sulfide may also be produced. Carbon dioxide is a colorless, odorless, non-combustible gas, highly soluble in water. Carbon dioxide can be dissolved in water and can cause increased hardness or corrosive conditions.[5] Several studies have been made of gas production from reguse landfills in the Los Angeles area following suspicion that CO_2 dissolving in the groundwater degraded the quality of the groundwater underlying a disposal area. Sufficient information is not yet available to indicate the specific conditions (size of the disposal area, porosity of underlying soils and proximity to groundwater leading to the absence or presence of this problem). Average landfill gas compositions are identified in Table 2.2 and 2.3:

TABLE 2.2
AVERAGE LANDFILL GAS COMPOSITION

(percent by Volume)

Component	Range	From Mountainview, CA Site
Methane	50.50 - 54.17	
Carbon Dioxide	35.70 - 44.04	
Nitrogen	9.52 - 1.52	
Oxygen and Argon	2.74	
Oxygen	0.03	
Water Vapor	1.50	Not Reported
Hydrogen	0.04 - 0.23	
Ethane	Trace - 0.01	

LANDFILL GAS COMPOSITION AT EAST 52nd & DAHLIA

TABLE 2.2

OFF SITE ppm		ON SITE ppm	
METHANE	61,306 (6.1%)	METHANE	491,055 (49.1%)
CARBON DIOXIDE	45,000 (4.5%)	CARBON DIOXIDE	495,000 (49.5%)
ETHANE	4.2	ETHANE	26.4
ETHYLENE	13.2	ETHYLENE	50.0
PROPYLENE	0.6	PROPYLENE	24.4
PROPANE	0.5	PROPANE	4.6

2.1.2.3 METHANE GAS MIGRATION

The migration of gas beyond the landfills and into the surrounding soils or overlying structures occurs by two basic processes; convection, movement in response to pressure gradients; and diffusion, movement from areas of higher gas concentration to regions of lower concentration. Gas flow is greater through materials with large voids and soils having high permeability such as: sands; gravels; and lesser through soils of low permeability. (See Figure 2.5)

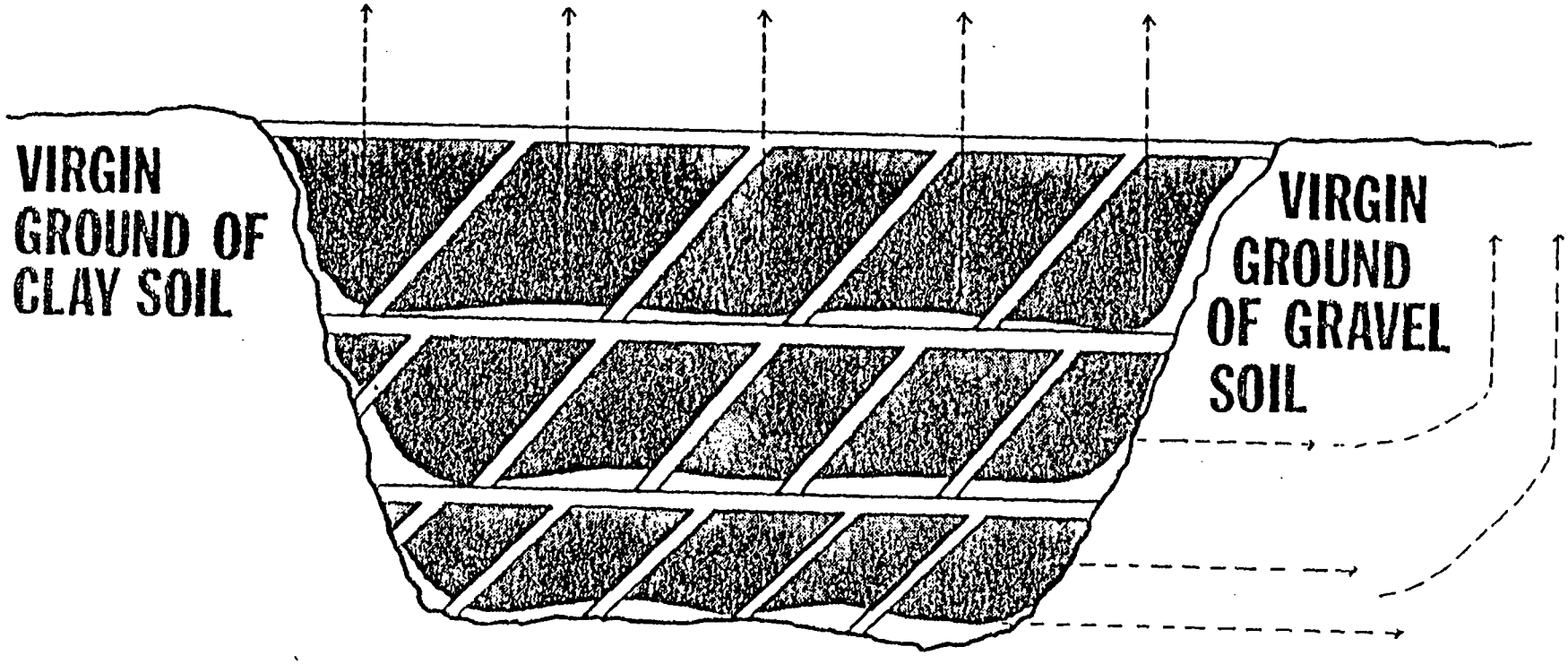
Gas migration from landfills, therefore, is partly dependent on the geological environment of the site. In general, a landfill constructed in a sand-gravel environment experiences greater vertical and lateral movement of gases than one built in a clay environment. Gas migration is also restricted by methane's relative insolubility in water. The presence of a groundwater table beneath a disposal site may inhibit the depth of gas migration. Being lighter than air, methane gas tends to rise and exit through a landfill cover. A cover of clay, which is relatively impermeable, restricts vertical gas migration and increases lateral migration potential.

Climatic conditions may reduce the permeability of the soil, thus, restricting the passage of gas through the cover. For example, sufficient rain or frost will render any type of soil less permeable, encouraging the lateral migration of the gas. In addition to decreasing the permeability of surface soils, rainwater and melted snow may infiltrate the refuse and stimulate the rate of waste decomposition and gas production. The combination of decreased permeability of the cover and increased gas production can cause a significant increase in lateral migration of the gas during the rainy season.

The gas produced within a landfill must escape through vertical or lateral migration. The Sydrogeologic environment and construction of a particular site determines the direction in which the gas will exit.

2.1.3 Environmental Impacts

Landfill construction, until very recently, was carried out with little or no consideration for pollution hazards. For example, old gravel pits on the banks of streams and rivers are often used as landfill sites. The sediments beneath and surrounding these landfills were highly porous and permeable sands and gravels. Thus, leachate could migrate freely downward into the groundwater supply, and laterally into surface streams. The toxic hazards of such leachate migration remain unknown, but may be considerable and will interfere with the lands end use. Groundwater pollution surely represents a hazard to the many families who derive their drinking water from shallow wells.



METHANE PATHWAYS

FIGURE 2.5

The most obvious problems, however, are those attendant upon building on top of or adjacent to landfill. Earth subsidence offers a major problem to builders, and the fire and explosion hazards from migrating methane are ever present. Means of dealing with these problems will be discussed in detail elsewhere.

2.1.3.1 Leachate Formation and Migration.

Landfill leachate is a foul-smelling dark-colored water solution resulting from aerobic and anaerobic decomposition of substances originally present in the landfill, and from gradual solution of other organic and inorganic materials in the resulting liquid. Leachate may be strongly acidic as a result of microbially produced acids such as acetic acid, propionic acid, butyric acid and valerric acid. Such an acidic solution is capable of dissolving many materials which will not dissolve in ordinary groundwater. The few chemical analyses which are available indicate that leachates contain a wide variety of organic materials derived from industrial products, some of which may by dangerously toxic. Toxic concentrations of heavy metals, mercury, cadmium and copper for example, have been detected in some leachates. Microbes present in soils and sediments have been shown to produce methylmercury (CH_3Hg^+) from mercury, mercurous ions or mercuric ions, a more toxic form of mercury which concentrates in fish to levels toxic to humans who consume the fish. A similar microbial methylation process probably also takes place with cadmium, lead and tin.

The pollution of groundwater from leachate, discussed above, surely represents a hazard which should be investigated whether gas is, or is not detected.

2.1.3.2 Production of Gas from Leachate.

Another problem caused by leachate migration is microbial methane formation from leachate at a distance from the original landfill. The methanogens are very sensitive to acid, and will not produce methane from highly acid leachate. The acid will be neutralized if the leachate migrates through rocks containing calcareous sediments, and the methanogens will then grow and produce gas. This gas may reach the surface at some area where it will constitute a fire or explosion hazard, for example in the basement of a building.

Odor may present a nuisance rather than a hazard, since hydrogen sulfide concentrations would not be expected to reach toxic levels.

2.1.3.3 Air

2.1.3.4 Land Use

On a level of lesser concern from the safety point of view, migrating landfill gas may cause significant damage to vegetation. Both carbon dioxide and methane may harm vegetation by high gas temperatures (up to 150 F) and by displacing oxygen from the root zone. The specific effects of landfill gas on vegetation will depend on the plant's sensitivity to carbon dioxide and methane, oxygen depletion, and elevated temperatures.

2.2 INVESTIGATIVE TECHNIQUES - HOW DO WE FIND IT

Until recently, the real and/or potential hazards of landfill disposal sites to land utilization and public health have been largely ignored. However, the increasing number of documented incidents linking landfill disposal sites to groundwater contamination by leachate and the numerous fires and explosions attributed to gas migration has stirred widespread concern over the health and safety aspects of disposal sites.

It is the purpose of this discussion to address the problem of assessing the magnitude and extent of gas migration from landfill disposal sites. The suggestions and guides provided herein are intended to assist those engaged in or planning such investigations. In addition, these guides and suggestions should find application in the evaluation of the effectiveness of systems employed to limit, control, or eliminate gas migration.

2.2.1 ADMINISTRATIVE PLANNING GUIDE FOR SURVEYS

The assessment of real or potential gas migration from landfill disposal sites is a problem of unsuspected complexity. It is vitally important that administrators and staff planners have a genuine understanding and appreciation for the magnitude of the problem in terms of:

1. Manpower requirements;
2. Technical support requirements;
3. Investigation costs;
4. Hazards of gas migration;
5. Equipment requirements;
6. Time involvement;
7. Expertise requirements.

All too often gas migration investigations are arbitrarily and haphazardly initiated and terminated as a result of a lack of understanding and appreciation of these factors. Investigations handled in such a manner usually result in the insufficient, inaccurate, or irrelevant data and information for the purpose intended.

Investigations of landfill disposal sites are either of two fundamental types:

1. Disclosure investigations, which determine:

   (a) presence or absence of gas production;
   (b) presence or absence of gas migration;
   (c) source of gas present

2. Interpretative investigations, which determine:

   (a) magnitude and extent of gas migration;
   (b) magnitude of gas production;
   (c) effectiveness of control systems;
   (d) establish real or potential hazards;
   (e) enforcement or compliance studies.

The selection of the type of investigation to be conducted must be made carefully. The type of investigation selected will have a profound effect on the scientific and economic impact of the data and information collected and the budgetary requirements for supporting the investigation.

Before any site investigation is instituted, the following criteria should be established:

1. Define need for investigation;
2. Define type of investigation;
3. Establish priorities for each site;
   in terms of health and safety hazards.

Once these criteria have been determined, an assessment of the available resources should be completed. An inventory of both personnel and technical capabilities is in order and should include the following information:

1. Inventory of Personnel
   a. Number available
   b. Training and experience
   c. In-house of field capability

2. Inventory of Technical Capabilities

   a. Capability for desired analysis
   b. Equipment status
   c. Field operation capabilities
   d. Other sources of desired capabilities

2.2.2 SITE EVALUATION PLAN

The assessment of the magnitude and extent of gas migration at existing landfill disposal sites is a difficult task. Although gas migration is known to occur, the parameters influencing this phenomenon ar poorly understood and have not been extensively studied. Therefore, while a COOKBOOK approach might seem to be desirable, it cannot be justified at the present time in view of the lack of knowledge concerning the various parameters and the site specific characteristics of landfill disposal sites.

A very general outline of a model plan for the evalution of a disposal site is presented on the next page. (Table 2.4) This model is designed for alteration or modification in accordance with site information, site specific characteristics, or investigation objectives to yield the most cost-effective study possible.

TABLE 2.4
SITE EVALUATION OUTLINE

I. Objectives

1. Type of investigation
2. Scope of investigation
3. Purpose of investigation

II. Site Evaluation

1. Initial assessment

   a. Nature of waste
   b. Physical extent of site
   c. Waste treatments
   d. Fill procedures
   e. Rate of fill
   f. Age of fill
   g. Liners and covers
   h. Topography and geology
   i. Local land use
   j. Hydrology of the area

2. Detailed technial evaluation

   a. Sample site selection
   b. Sample site preparation
   c. Sampling equipment
   d. Sample collection
   e. Sample analysis

III. Data Evaluation

1. Hazard potential
2. Monitoring requirements
3. Effectiveness of controls

The initial assessment of a disposal site involves the collection of a considerable amount of general information regarding the location, use, and status of the site. This data base is quite useful for the classification as to the type of disposal site, present or future potential hazards, likely hazardous materials present, priority assignment for study, and guides the selection of sample collection points.

The types of wastes disposed of in landfill sites vary widely from site to site. Among the major determinants of the waste types accepted at any individual disposal site are waste types generated in the general locale, the regulatory agency involved, the landfill operator, and the economics of the operation.

As the contaminants to be derived from the disposal of wastes is dependent upon the types of wastes, a determination should be made to ascertain, both current and historically, the types of wastes accepted at the site. The waste types can range from reactive hazardous industrial wastes to essentially inert glass.

Although there is no consistent system of classification of waste types, a number of general types are recognized. First, residential wastes which contain food, paper, cans, bottles, etc. Secondly, industrial wastes which contain chemicals, oils, cleaners, process by- products, reactive materials, etc. Agricultural wastes which contain pesticides, manure, agricultural chemicals, etc. Fourthly, another large volume waste material is sewage sludge. Details on the probably source of the wastes, such as a refinery, chemical plant, pesticide facility, food processor, etc., is quite helpful in determining the contaminants to be expected from the disposal site.

Another important factor in assessing the magnitude and extent of contaminants either as gases or leachate is the physical size of the disposal site. This information is essential in the selection of both the number and location of sample sites.

The type of treatment given to the wastes at a disposal site is important in assessing the contaminants to be expected from the wastes. For example, a site at which most of the combustibles are incinerated, such as wood, paper, and solvents, would not be expected to be a major gas generator. While a disposal site at which such materials are simply buried would be expected to generate methane and carbon dioxide in significant quantities.

The procedures used at a fill are another important consideration. The segregation of waste types both prior to disposal or in placement in the fill area are examples. The procedures used at a disposal site and the treatment of wastes are intimately related and must be considered when evaluating potential contaminants.

The rate of fill is important from the economic standpoint to the fill owner or operator. Of equal importance; however, is the contribution of the fill rate to estimating or anticipating gas migration problems.

The age of the fill in a disposal site is of interest for several reasons. First, the composition of gases generated by a disposal site varies with its age. Secondly, the time over which a site will generate gases can be estimated. Thirdly, the age of the fill will determine to some extent the scope and type of monitoring necessary.

The topography and geology of a disposal site are major factors in the magnitude and extent of gas migration and generation. The types of soils determine the case with which the gases can migrate vertically or laterally. Surface topography determines to some extent the quantity of water which reaches the buried materials and thereby influence the rate and volume of gases generated.

Data on the present or anticipated use of a landfill disposal site shopuld be collected in the initial assessment. This information is useful in determining the type of monitoring needed, the extent of monitoring required and an estimation of the hazard to health and safety of the occupants or users of the site.

The technical evaluation of a landfill disposal site involves careful planning and attention to detail at each stage of the investigation. While the type of investigation can be classified as being either a qualitative or quantitive study, this is only an indicator of the breadth of the data to be collected. These types will not be discussed separately as the techniques used are common to both types and are readily exchangeable. It should be pointed out that despite the level of technology available, NO RESULT IS ANY BETTER THAN THE SAMPLE COLLECTED.

Sites to be used for the collection of samples must be selected with considerable care to insure that a representative picture of the magnitude and extent of any gas migration is obtained. Potential sampling sites include surface loctions, subsurface sites, buildings, excavations, and manholes. These sampling sites may be on-site, off-site, and/or perimeter locations. Other site selection criteria include the geology, topography, man-made structures and utilities, soil conditions, watertable, and climatic conditions.

The major portion of sample site preparation is directed at obtaining truly representative samples of the gases in or migrating from a disposal site. The preparation is directed at obtaining truly representative samples of the gases in or migrating from a disposal site. The preparation techniques range from the relatively simple bar-hole punch to that of a rotary drilling rig with the subsequent placement of drill hole casings. The choice of techniques will significantly influence the economics of the study. By the same token, the extent of site preparation influences the reliability of collecting a representative sample of the gases.

2.2.3 Field Investigation

After becoming involved with a landfill generated methane gas problem it becomes evident that all old landfill sites must be identified. This is a tremendous task, as very little is known about abandoned or closed

landfill sites, one must rely on older residents of the community in order to establish the boundaries, depth, or type of refuse that had been placed in those sites. Another method of locating these old sites is by use of aerial photographs, one can plot the formation, use, and abandonment of these landfill sites. A complete flammable gas survey must be made, not only of the site itself, but any area covering 1,000 feet beyond the perimeter of the site. The extent and amount of methane gas migration must be established in order to safeguard any structures that are subjected to the gas problem. After these closed sites and their approximate boundaries have been established, construction activities on and surrounding these sites should be regulated. The reasons for construction regulations are very apparent. A mechanism should be designed to alert the public that may be planning such construction activities. A good focal point for this alerting mechanism could be the county or municipal building and zoning departments. In this manner the methane gas problem can be brought to the attention of the responsible people prior to any construction activity.

A study should consist of two general approaches - a survey and a field investigation.

To complete the landfill methane gas survey, the following procedures were followed as closely as possible:

1. Visually inspect site for signs of litter, differential settlement and odor, to attempt to define the landfill limits (boundaries).

2. Discuss site with residents in the area as an aid to establish landfill location, period of operation, and operational practices.

3. Review aerial photographs taken at various time periods to determine surface changes (see Figure 2.6 as an example).

4. Interview the landfill operator, if possible, to obtain information such as: type of refuse deposited; water table elevation, depth of refuse; compaction methods; cover material placed; etc.

5. Interview local planning and health department personnel to determine conditions of approval and complaint history.

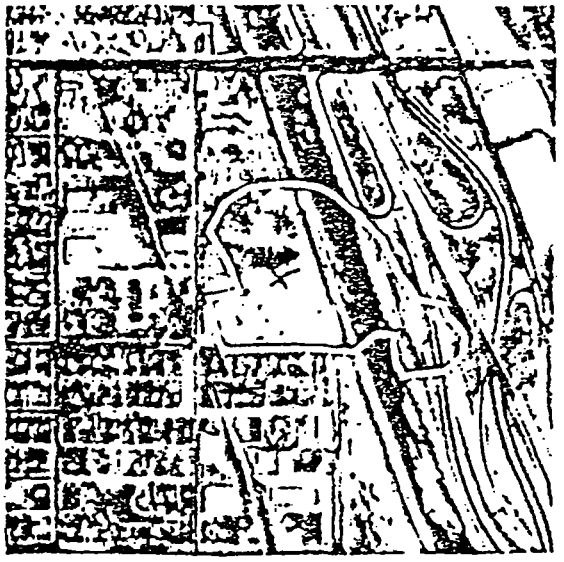
6. Obtain tax assessor maps to establish previous owners and existing owners.

7. Interview public service agencies and utility companies to determine utility line locations and any additional site data.

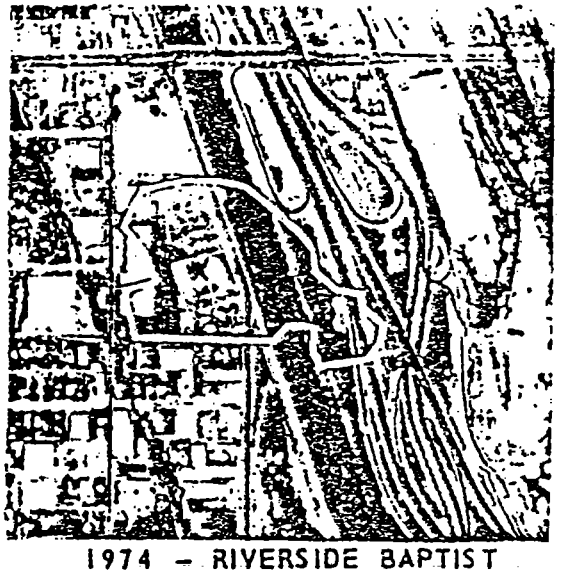
After available site information gathering was completed, the landfill boundary established, and major utilities located, the following field investigation procedures were established:

1. Survey on-site structures at foundations, in basements, in crawl spaces under floors, and at cracks in the structures to determine possible gas concentrations.

1949 – SHOWING GRAVEL PIT & S. PLATT RIVER



1963 – SITE CLOSED (S. PLATT STREAM BED MODIFIED BY I-25)



1974 – RIVERSIDE BAPTIST CHURCH BUILT DIRECTLY OVER FORMER LANDFILL

AERIAL SITE REVIEW TECHNIQUE

2.8

2. Survey utility trenches, manholes, drain inlets, and valve boxes.

3. Measure and record methane gas readings at locations indicated with bar-punch or hand-auger holes for measurement through the landfill cover, parking lot pavements, and at the site boundaries.

2.2.3.1 EQUIPMENT AND PROCEDURES

Gas measuring instruments such as the MSA Gascope have eliminated much of the guesswork in detecting the presence of flammable gases or vapors. Before the development of these sampling devices, it is necessary to collect a sample of the suspected atmosphere and return it to a laboratory for analysis. This required the services of experienced technicians and a considerable investment in laboratory equipment. By the time the analysis is completed, the concentration of the suspected atmosphere can change considerably.

Today's compact and simplified combustible gas indicators - both the portable and the continuous or permanently installed type have a wide field of application. They are used for measuring hazards created by the presence of flammable gases with air; in oil refinery service, public utility operations, distilleries, paint and varnish plants, iron and steel mills, marine service, as well as, for use by municipalities in investigating fire hazards, testing sewers and manholes, and checking for gas hazards in sewage disposal plants. The sampling devices can be classified according to their function of measuring either combustible gases, toxic gases, or oxygen. More than 225,000 combustible gas analyzers are currently in use. (List of field equipment Table 2.5)

2.2.3.2 MSA GASCOPE

To identify the presence of methane gas, migration patterns and pathways and the hazards to public health and safety, the Mine Safety Appliances (MSA) Gascope, Model 53, was selected. This gascope is essentially two instruments built into a common case. Meter readings are given in two ranges, 0 to 100% LEL (lower explosive limit) and 0 to 100% gas. When in the % LEL position, the measurement is accomplished by catalytic combustion on the surface of a catalytic (hot wire) filament. As heat generated by combustion on the hot wire takes place, it provides variable resistance to a dual readout. The hoter the wire becomes, the higher the LEL reading. Figure 2.7 shows meter reading various methane in air concentrations. The LEL, as the name implies, is the lowest point at which methane will explode (approximately 5% methane gas). The explosive range of methane gas is 5 to 15% by volume in air as described in Figure 2.8.

For mixtures above the LEL, the measurement is made by measuring the relative thermal conductivity of the sample compared with air by means of a thermal conductivity meter.

Table 2.5

GAS INSTRUMENTATION AND EQUIPMENT

Emcon Associates maintains a variety of gas instrumentation used in detecting and continuously monitoring gas generation in the field, as well as in measuring relevant parameters, including composition, temperature, and pressure of the landfill gas. Gas instrumentation and equipment include the following:

FIELD INSTRUMENTATION

Johnson - Williams (Bacharach Instrument Co.) Oxygen/Combustible Indicators

Model MHPK

Oxygen	0% to 25%*
Combustible Gas	0% to 5%
	0% to 100%

Johnson - Williams Gas-Pointers

Model H

Combustible Gas	0% to 5%*
	0% to 100%

Johnson - Williams Super Sensitive Combustible Gas Detectors

Model SS-P

Aromatic Hydrocarbons	0 to 1,000 ppm
Combustible Gas	0% to 5%

Johnson - Williams Combustible Gas Indicators

Model TLV Sniffer

Combustible Gas	0 to 100 ppm
	0 to 1,000 ppm
	0 to 10,000 ppm

Bar Hole Drivers and Fiberglass Probes

- For shallow field surveys with the above instruments

* Percent refers to percent by volume in air

TABLE 2.5 (cont'd)

Test Caps
- For use with permanent gas monitoring probes

Fyrite Carbon Dioxide Indicators

Dwyer Magnehelic Differential Pressure Gages
Inclined Manometer
- For measuring internal landfill gas pressures, relative to atmospheric pressure.

Electronic Digital Thermometers
- For measuring gas temperature within probes and wells

Portable Gas Chromatograph
- For analyzing gas composition

Gas Sampling Bottles

Hand Vacuum Pumps
- For gas sampling

Battery-Operated Pump
- For gas sampling

Pitot Tubes
- For measuring gas velocity in well casings and pipes

Portable Motors and Blowers
- For gas extraction testing

Various Hand and Power Tools
- For installation of gas monitoring probes and extraction wells

TABLE 2.5 (CONT)

Enmet Portable Gas Detectors

Model CG5-10

- Personal safety monitoring equipment with visible and audible alarms - for detecting combustible (methane) and toxic (hydrogen-sulfide and carbon monoxide) gases and oxygen deficiency.

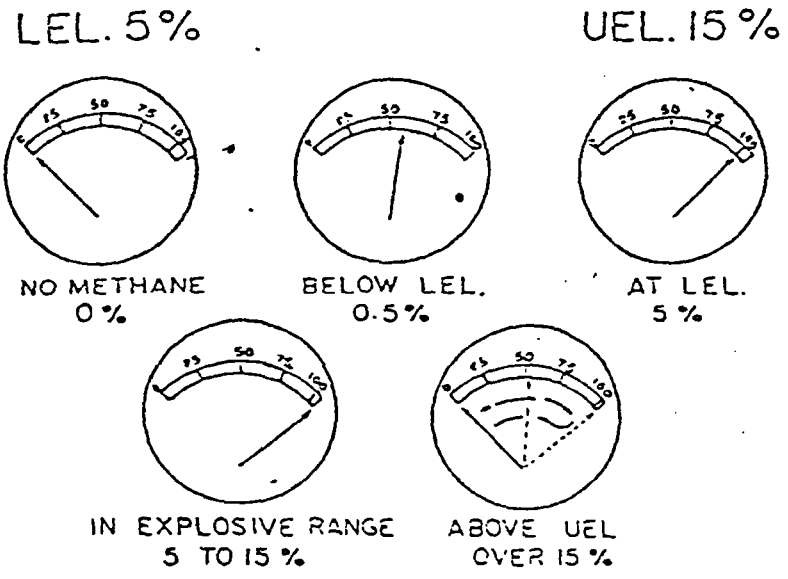
LABORATORY EQUIPMENT

Varian 90-P Gas Chromatograph with strip chart recorder

- For analyzing gas composition

Infra-Red Industries 702 Nondispersive Analyzer

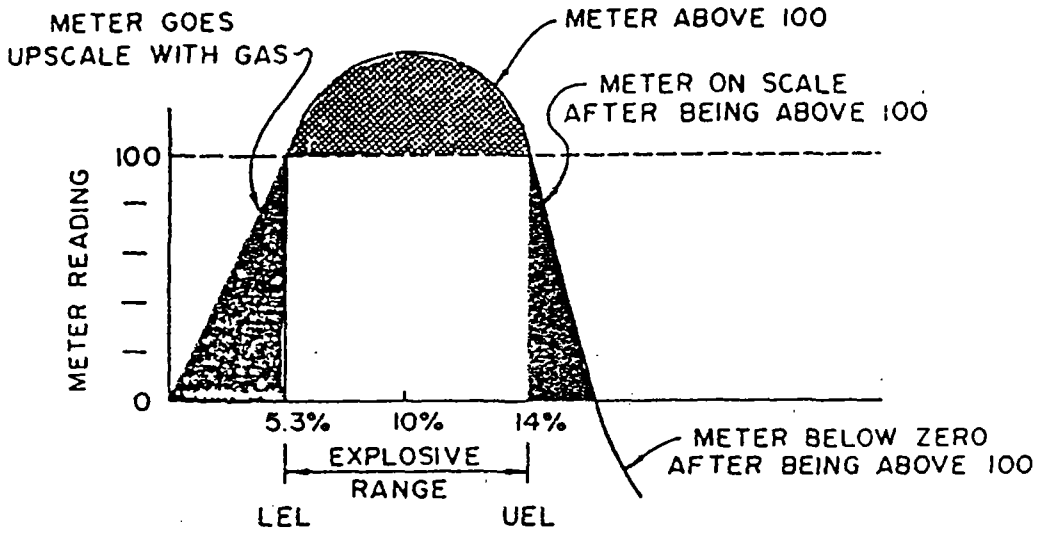
- For methane and carbon dioxide determination



METER READINGS AT VARIOUS METHANE IN AIR CONCENTRATIONS [8]

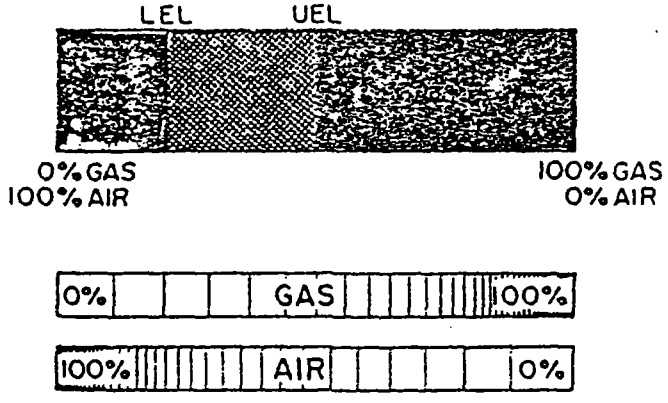
FIGURE 11

HOT WIRE GAS DETECTOR RESPONSE TO METHANE



RELATIONSHIP BETWEEN L. E. L. METER READING
AND COMBUSTIBLE GAS CONCENTRATION

EXPLOSIVE LIMITS



RELATIONSHIP BETWEEN LEAN AND RICH GAS MIXTURES

2.8

FROM PUBLICATIONS
MINE SAFETY APPLIANCES CO.

Measurement of the combustibles in the atmosphere is direct for the full range of the instrument without resorting to dilution of the sample with air. The MSA Gascope was precalibrated by the manufacturer and checked several times with the use of a gas chromatograph to determine the effects of various gas concentrations ($CO_2N_2O_2$) on the explosivity of methane and the monitoring meter. Figure 2.6 illustrates on a representative basis for this instrument that N_2 and O_2 decreases while CO_2 increases with a corresponding increase in CH_4 as the pressure drops. This figure also illustrates the relationship between direct meter readings of methane and gas chromatograph analysis. As depicted, the difference in readings is minor up to about 25% gas. This difference increases as the MSA Gascope measured methane 10 to 15% higher at 30% methane gas concentratins and above.

LIMITATIONS

The full range of the Gascope is limited to those combustibles which are in the gaseous state at the temperature of the instrument, such as hydrogen, natural gas, methane, and manufactured gas.

The Gascope is specifically calibrated for the gas with which it is to be used.

The Gascope is unsafe for use on acetylene or hydrogen in pure oxygen. It is, however, suitable for use in detecting hydrogen or acetylene in air mixtures.

The Gascope is not suitable for testing high boiling point hydrocarbons which have vaporized in ovens, and will condense in the instrument flow system at room temperature.

When an atmosphere contaminated with leaded gasoline is tested with a Gascope, the lead produces a solid product of combustion which upon repeated exposure, may develop a coating upon the catalytic filament resulting in a loss of sensitvity. To reduce this possibility, an inhibitor-filter is available for insertion in place of the normal cotton filter in the instrument.

Silanes, silicones, silicates, and other compounds containing silicon in the tested atmosphere may seriously impair the response of the instrument. Some of these materials rapidly poison the detector filament so that it will not function properly. When such materials are even suspected to be in the atmosphere being tested, the instruments must be checked frequently.

2.2.3.3 BAR HOLE PUNCH

The bar-hole punch is a simple device consisting of a solid metal rod to which is attached a weighted sleeve for driving the rod

into the ground and extracting the same. This device is relatively small and easily handled by a two-member team. However, the sampling site prepared by this device has a number of disadvantages.

First, the depth of penetration is seldom greater than three feet and the diameter of the hole is limited to a maximum of approximately one inch. The resulting volume available for sample collectin is quite small.

Secondly, atmospheric contamintion of any sample is highly likely due to the collection of too large of sample volume.

Thirdly, the sampling site is only temporary due to no casing and subsequent wall crumbling and hole closure.

The use of a drilling rig has many advantages over a bar-hole punch.

First, The diameter of the hole can range to several inches and the depth can be extended to the bottom of the fill.

Secondly, The hole can be protected with casing and the casing capped to prevent atmospheric contamination.

Thirdly, The diameter and depth of the hole allows a greatly increased sample volume. The disadvantages of a drilling rig include a larger crew, higher per sampling site costs, relatively large physical size, and lower rate of sample site preparation.

The sampling equipment available for the collection of gas samples can be divided into three basic types. See Figure 2.8-1. Although there are numerous variations available in the equipment design, the classification is based on the sample container preparation before sampling and the pressure at which the sample is collected and maintained. These types are:

Category	Preparation	Pressure
Type 1	Non-evacuated	Atmospheric
Type 2	Evacuated	Atmospheric
Type 3	Evacuated	Above Atmospheric

Type 1 devices utilize the flushing of the sample container with the sample gases to displace the air or previous sample contained therein. After displacement has been completed, the container is then sealed to retain the sampled gases. Advantages of Type 1 devices include simple operation; minimal power required, such as hand-operated pump; and relatively low per unit cost. The disadvantages of Type 1 devices include large volumes of sample gases are required for flushing; small sample volume available for analysis; and potential of incomplete flushing of sample device.

Type 2 devices are commonly used to collect gas samples for subsequent laboratory analysis. The use of this sampling device involves the prior evacuation of the container by a vacuum pump, and the opening of the sampling port at the sampling site to draw in the sample gases. The sampling port is then closed. This sampling device has the advantage of no external power requirements; simple operation; sample volume required is equal to volume of the container; and relatively low per unit cost. A major disadvantage is that a small sample volume is available for analysis.

Type 3 devices utilize an evacuated sample container connected to a pump capable of producing pressures in excess of atmospheric. This type of device has the advantage of providing a large volume of sample for analysis. The disadvantages include a required external electrical power source, transportation of pressurized containers, and a higher per unit cost.

All of the aforementioned devices can be and are fabricated from a wide variety of materials. Consideration must be given to the type of container material preferred based on parameters such as potential alteration of sample compositon due to diffusion through the container walls or reactivity of the gases with the materials of construction. The ruggedness required of the sampling device must also be considered in terms of mode of transportation, storage, field use, and analysis.

One of the major points on which the technical evaluation of the disposal site hinges is the collection of truly representative samples. The collection of gas samples is difficult due to the case with which the sample can be contaminated with atmospheric gases and the colorless state of most gases. Therefore, the individual collecting gas samples must be very aware of the points of potential contamination and adhere strictly to an established collection procedures. This same individual must readily recognize the consequences of using devices which require sample volumes in excess of that available, such as found in a bar punched hole.

The analysis of samples is a subject requiring far more detail than can be made available here. A general discussion will be made concerning the techniques available and the technical expertise required for data interpretation. The field analysis of samples can be completed using either gross monitoring instruments such as explosimeters or by employing highly sophisticated analytical instruments such as a gas chromatograph or gas chromatograph/mass spectrometer. The degree of information detail required for the study will dictate the techniques employed. The more common analytical techniques used in the analysis of gases included infrared analysis, gas chromatography, and anumber of older techniques such as the Orsat method. The operation of instruments such as explosimeters, LEL meters, etc., require a minimum of training while the more highly sophisticated instruments require a highly trained chemist both to operate and interpretate the data obtained from such instruments.

The data evaluation following a site evaluation should allow a reasonable definition of the hazard potential from gas migration. This definition of the potential hazard will by the nature of the problem be based on the gas composition data. The composition data must be evaluated very carefully as to the hazard it presents based on observations of the hazards presented or known for similar gas compositions.

The finding of significant gas migration from a landfill disposal site will almost always mandate some degree of monitoring. This monitoring will be necessitated by either protecting human life or evaluating the controls being employed to control the gas migration. Each site will require its own unique monitoing system which may range from periodic samples to a continuous sampling system.

2.2.4 LABORATORY DESIRABILITY

The technical investigation of a landfill disposal site is confronted with a number of unique questions which cannot be readily answered by using field portable equipment. If a laboratory is not readily available, it is suggested that the necessary capabilities be secured for detailed analysis through contract services, etc.

The source of the gas is the first question which must be answered. The prewsence of natural gas pipelines passing near or through a fill area must be eliminated as a possible source of methane. The identification of the source of the gas requires analyses for compounds unique to the source, many of which are present at trace levels. Other potential sources of gas include sewer lines, marshes, chemical processing, and other industrial sources.

The question of whether the landfill gases contain other gases which are hazardous such as hydrogen sulfide, phosgene, vinyl chloride, and numerous others, require the analyte capabilities usually only found in a laboratory. This question becomes rather important when investigating a disposal site where industrial chemicals or processing wastes are/or are thought to be internal.

2.2.4.1 SIGNIFICANCE OF ANALYTICAL LAB WORK (TRACE ELEMENTS)

The analytical procedures and techniques presently employed in the laboratory for the determination of the hydrocarbons and fixed gases in the landfill gas samples are being prepared for review and comments by the subcommittee.

The analyses presently being determined on a semi-routine basis include methane, ethane, propane, n-butane, i-butane, ethylene, propylene, carbon dioxide, nitrogen, carbon monoxide, and oxygen/argon combined. Although some technical difficulties were experienced in the first attempts to determine the fixed gases, these have been rectified and the techniques are undergoing a continual refinement.

The chemist should be thoroughly trained in the techniques and instrumentation of gas analysis.

The list of compounds to be alerted for in analyzing landfill gas are as follows:

Hydrocarbons:

Ethane	Propane	ISO. Butane
N. Butane	ISO Pentane	N. Pentane
Hexane	Heptane	Octane
Nonane	Delane	Undecane
Benzene	Toluene	Xylene

Other Compunds of Interest:

Ethylene Chloride	Carbonyl Sulfide	Sulfur Dioxide
Trichlor Ethylene	Perchlor Ethylene	Chlorobenzene
Dichlorobenzene		

Table 2.6
LEACHATE ANALYSIS

Time requirement:

Into laboratory within 24 hours of sampling. Keep sample cool at all times.

Bottle Requirements;

1 - 1/2 gallon plastic

1 - 1 liter with nitric acid preservative

1 - 250 ml with sulfuric acid preservative

Sample will be analyzed for:

BOD_5
COD
Ammonia nitrogen
Nitrite nitrogen
Nitrate nitrogen
Ortho-phosphate
Conductance
Total Alkalinity
Free carbon dioxide
Potassium
Cadium
Copper
Zinc
Baron chlorine

Other parameters as situation dicates by discussion with laboratory.

2.2.4.2 QUALITY ASSURANCE

The data collected during the hours of a disposal site investigation must bring with it a reasonable degree of assurance of relibility. This assurance can only be provided through a quality assurance progrm. Such a program need not be a highly involved and expensive situation. The program used for quality assurance should test both the function and response of the equipment. The equipment should be checked using standards which closely approximate the actual samples encountered. Further, the equipment should be checked under conditions as close to the actual use conditions as possible. It must be pointed out that such a program is prone to overkill and such must be prevented.

2.2.4.3 Trace Elements (importance of)

2.2.5 REMOTE SENSING TECHNIQUES

A variety of remote sensing techniques have been investigated as to their value and application to the problems of locating old, active disposal sites and assessing the magnitude and extent of gas or leachate migration. These techniques have met with varying degrees of success due undoubtedly, at least in part, to the site specific characteristics of the fill.

These techniques which may have application to defining the magnitude and extent of gas migration include infrared scanning, multi-spectral photography, presence of Pseudomonas Methanica, and vegetation stress. There are undoubtedly other techniques which are worthy of consideration.

Infrared scanning offers some potential in that this technique will locate the areas showing significant thermal radiation. It should find application, especially, in those loctions in which there is a low density of man-made structures. Such structures may present difficulties due to their thermal radiation masking tht of the fill area.

Multi-spectral photography offers potential application to the gas migration problem and fill area definition. The use of IR film will delineate any thermal radiating areas. Other spectral film types allows the identification of vegetation types and vegetation stress.

The testing of surface soils for the presence of Pseudomonas Methanica may prove to be another technique for defining the migration of landfill gases. This aerobe requires the presence of methane for its metabalism.

Vegetation stress study is an approach which is easiy overlooked by the usual technical personnel. Yet, this technique may prove to be one of the more productive. A number of studies have been done in which the effects of gas migration are seen in terms of vegetation stress and vegetation kill. This technique does; however, stand in need of further refinement if it is to be applied in a general sense.

2.3 METHANE GAS - WHAT DO YOU DO WITH IT

In landfills, methane is usually produced in concentrations above the explosive range; therefore, it almost always passes through the explosive range when diluted with air. Fortunately, in most cases, an energizer such as an open flame is not present as methane gas passes through combustion/explosive ranges, and combustion is averted. Nevertheless, the numerous instances on record of fires and explosions resulting from landfill produced methane serves to warn that gas migration can lead to tragic consequences.

Fire and explosion can be the tragic results of uncontrolled methane combustion. The potential for hazard is heightened by the ease with which methane may migrate subterraneously, often to significant distances, through permeable media such as porous soils, trench backfills, and utility or drainage corridors. Public safety may be endangered if migrating methane accumulates in a poorly ventilated area and subsequently achieves combustible or explosive concentrations.

2.3.1 Methane Movement

Methane from landfills will normally migrate upward through the decomposing organics and outward through the cover soil, diffusing into the atmosphere; but when upward movement is impaired, the gas will diffuse laterally along subsurface paths of least resistance until it finds a vertical path to the atmosphere.

The factors affecting the movement of methane are quite varied. Some of the factors identified to date are:

A. The type of cover placed on the landfill;
B. The type of surrounding soil;
C. The amount of gas produced by the landfill;
D. The ambient air temperature;
E. The precipitation;
F. Barometric pressure;
G. The presence of natural or man-made conduits;
H. The presence of natural or man-made barriers.

2.3.1.1 Cover Material

During the sanitary landfilling process, soil layers 6 in. (15 cm) or more thick are compacted over the accumulated refuse; as the fill progresses, alternate layers of solid waste and soil cover are built up. When the soil layers consist of compacted clays and silts, they present a substantial barrier to the vertical passage of methane; this relative impermeability is increased when the compacted soil becomes saturated with water. The resistance of an overlying layer of fine-graned soil can be sufficient to cause the methane generated beneath it to migrate laterally.

Many of our landfills have a clayey, well compacted cover with surrounding soils of gravel. This forces more of the methane laterally since less can leave through the surface of the fill. Natural phenomia may also make the landfill cover less permeable to the gas by saturating the surface with water or freezing the surface over.

When sub-freezing temperatures occur, water that has percolated into the pore spaces between grains of sediment may freeze, forming an additional barrier to the upward passage of landfill gases and encouraging lateral subsurface gas movement.

2.3.1.2 Surrounding Soil

Highly permeable soil (clean sands and gravels) adjacent to a landfill can provide paths of least resistance for gas migration when overlain by layers that restrict the gas's upward flow. Similarly, the gas can travel toward areas of lower pressure, moving through jointing and weathering cracks in apparently solid bedrock.

2.3.1.3 Gas Pressure and Generation Rate

Since methanogens can produce high gas pressures by the generation of methane, it is not feasible to solve the problem by constructing a gas-tight landfill. Although no research has been done to determine the maximum pressures exerted, it is not unlikely that pressures sufficient to lift the soil overburden might be produced.

2.3.1.4 Ambient Air Temperature

We have also found increasing amounts of methane in our lateral probes during hot weather as well as low barometric pressure situations. The reasons for this phenomia are not fully understood since air temperature should not substantially affect the internal temperature of the fill. Optimal anaerobic gas production ocurs when landfill tempeatures are between 90 and 95°F. Lower temperatures will reduce the metabolic rates of the methanogenic bacteria while higher temperatures may provide non-methanogenic bacteria a selective edge. As a result, generation rates are almost always less than maximum, especially for fills located in colder climates. In addition, seasonal fluctuations in temperatures may also produce variations in gas production rates. There is some supposition that the increase may be due to a heating of the grounds surface and thereby causing more gas migration on the grounds surface.

2.3.1.5 Precipitation

The gas production rate of most solid wastes generally increases with an increase in moisture content. The methane content of gases produced has also been observed to increase with increases

moisture content. Studies have shown that methane concentrations can vary from almost negligible in fills without water to greater than 50 percent in fills that are saturated. It should be noted that even though higher moisture contents generally promote methane generation, rapid application of large quantities of water may hamper methanogenic activity.

2.3.1.6 Barometric Pressure (See Figure 2.9)

2.3.1.7 Natural or Man-made Conduits

Natural and man-made conduits are frequently present around our landfills. In fact, most injurious explosions that have been reported, were caused by these methane pathways. In one case, a storm sewer carried the gas from the landfill which was ignited by a candle. Another methane conduit was formed by a water conduit and another by a steel drain culvert. Any such man-made structure placed near or in a landfill may carry the methane gas substantial distances from the landfill. In fact, many of our higher concentrations of gas found on our survey were found in water meter pits by houses. This poses definite dangers to utility companies that run pipes near landfill areas. These pipes must be sealed with a gas tight collar upon leaving the fill in order to prevent this migration.

Cracks or leaks in subsurface utility structures or tunnels can provide migration routes for landfill gases. Significant methane concentrations are common in sanitary sewer manholes, catch basins, and other subsurface utility structures near sanitary landfills.

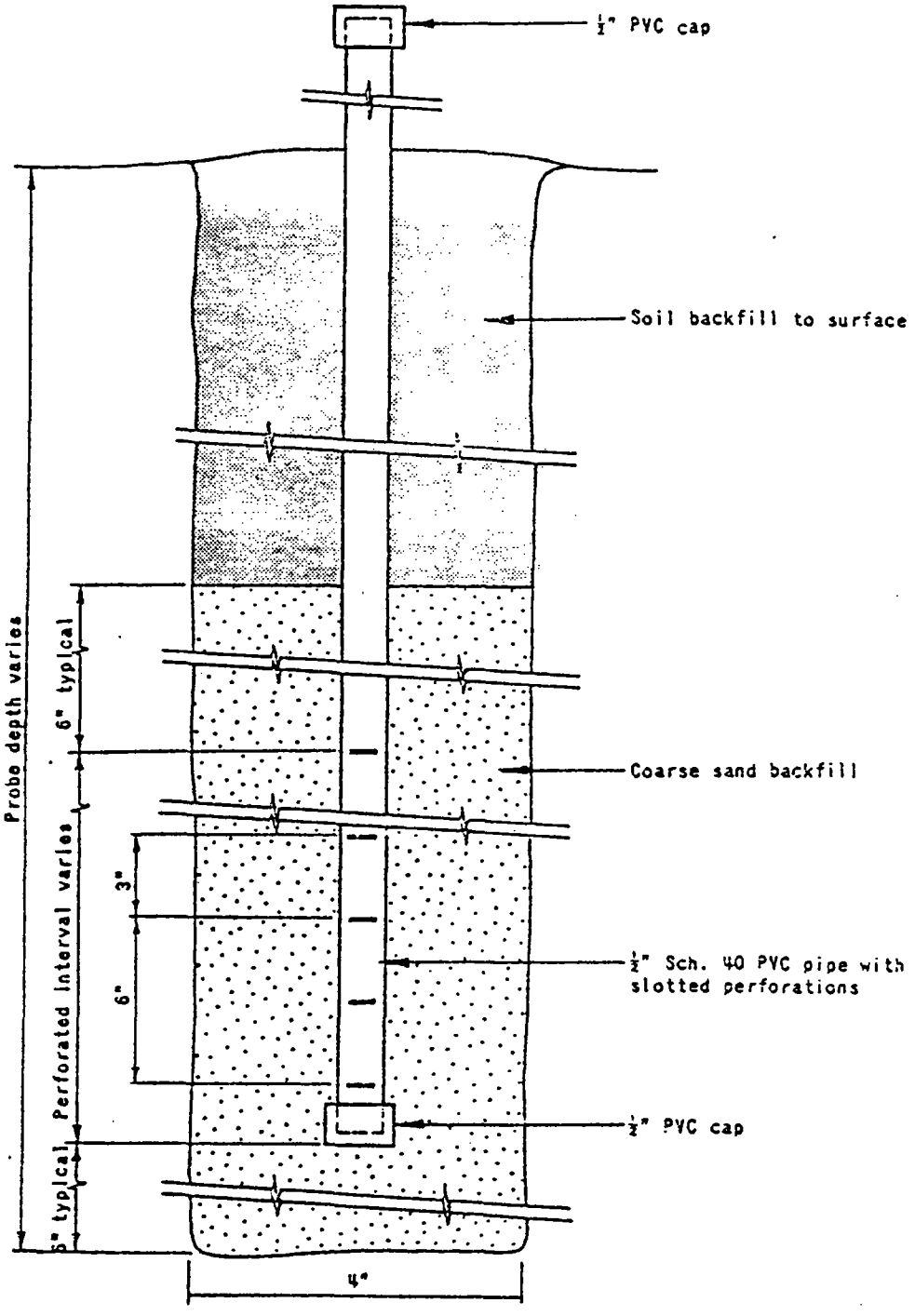
Manmade structures can provide a conduit for methane gas migration. Asphalt pavement, concrete foundations and floor slabs, storm drains and sanitary sewer lines, lawns and other surface structures can confine gases and promote lateral migration.

Natural conduits may be formed by gravel lenses or more porous soils radiating out from the landfill. These lenses may cause higher gas concentrations in specific areas.

Cracks, fissures, and voids resulting from sanitary landfill differential settlement can reduce subsurface gas pressures in their immediate vicinity. Not only do these cracks and structural discontinuities provide avenues along which methane may migrate, they also promote migration of gases to areas of reduced pressure. Further, gases can become concentrated in such areas, thereby creating an underground fire hazard at the landfill.

2.3.1.8 pH

Another environmental factor which affects landfill gas production is pH. Methanogenic bacteria are highly specialized organisms



NOTES:

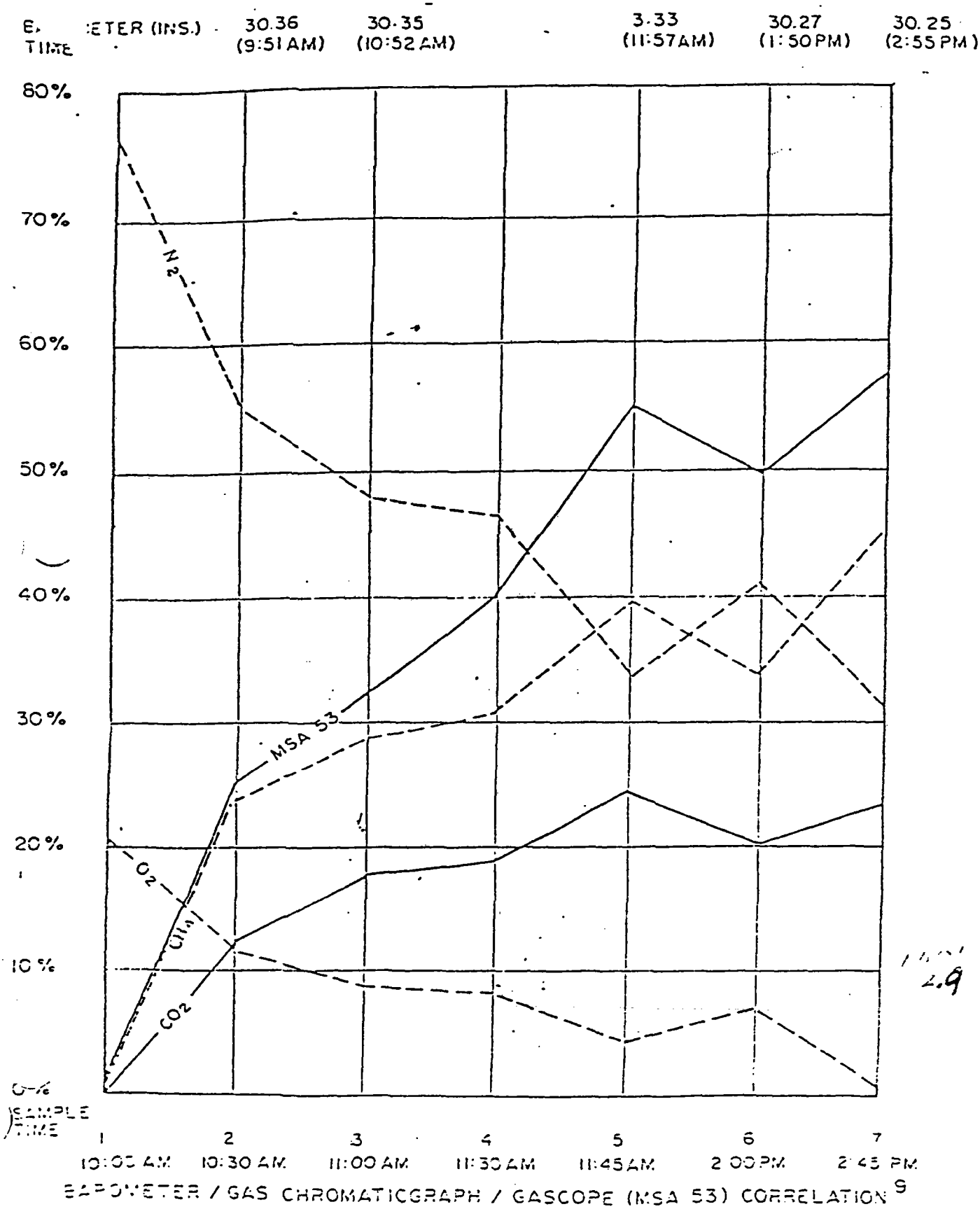
1. Probes in refuse use 2" Sch. 40 PVC pipe.
2. Solvent weld all PVC connections except top cap.
3. Perforations are field slotted with a saw to a depth of 1/4 to 1/3 the pipe diameter. Perforations on opposite sides of the probe are staggered 3" longitudinally.

EMCON ASSOCIATES

GAS MONITORING PROBE - DETAIL

PROJECT No. 309-1.1 | PLATE 9

Figure 2.8-1



BAROMETER / GAS CHROMATICGRAPH / GASCOPE (MSA 53) CORRELATION

which need a pH near 7.0 to produce optimal amounts of methane. These organisms are severely inhibited when the pH is outside the range of 6 to 8, while non-methanogenic bacteria can tolerate more acidic conditions, down to about pH 5.2.

2.3.1.9 Natural or Manmade Barriers

Natural and man-made barriers may be formed from clay deposits, railroad tracks, etc., that present a more dense soil condition between the landfill and the virgin soil. These barriers may vary however and tend to mask the problem. For instance the barrier may show little methane on the surface near the barrier, but have a high methane concentration at ten feet down. This gas may again come to the surface well beyond the barrier.

We are sure that many other factors that affect the lateral movement of methane gas exist and have not yet been identified. We have found however that the largest amounts of methane are found on hot summer days immediately following a storm. The highest readings are also found next to a landfill with a tightly compacted top and natural gravel soils surrounding it.

2.3.2 Gas Control Technology

There are two basic approaches to controlling the migration of methane from closed, abandoned or operating landfill: impermeable barriers and ventilation systems. Each system or combination of systems is effective, but adequate control depends upon the many site specific conditions.

There are many different types of landfill gas control systems in use today. These systems fall into fairly distinct groups or combinations thereof. They are:

A. Barrier Systems - Placement of impervious liner materials to block or seal flow of gas.

   Located: a) at landfill boundary
            b) beyond landfill boundary

   Material: a) impervious liner material
             b) granular materials

B. Passive ventilation systems - Placement of granular materials in a trench for either gas venting or collection

   Located: a) at landfill boundary
            b) beyond landfill boundary

C. Power extraction systems - Evacuation and venting of gas through use of wells and gas piping systems.

   Located: a) within boundary of landfill
            b) at and beyond boundary of landfill
            c) combination of a) and b)

In the establishment of new sites, accurate data on gas production rates and gas migration patterns will not be readily available. The qualitative nature of the assumptions made with respect to these factors suggest that monitoring of the effectiveness of the mitigation measures employed would be advisable. Design of a gas control system should contain provision for modification should the system prove ineffective because of inadequate design data.

The potential hazards created by migrating landfill gas may not always warrant the installation of an elaborate control system. For example, only a portion of the landfill surface or its adjacent area may require control measures. In such cases, specific features may be incorporated into the designs of structures, utility lines or other facilities, often at a cost lower than that of a large-scale landfill control system.

2.3.2.1 Barrier Systems (See Figure 2.10)

Barrier systems are most frequently utilized on landfills that are in the process of being filled. They may be constructed of natural substances or manmade substances.

A combination of gravel-filled trench (refer to Figure 5) and barrier membrane provide an effective passive system if the trench depth is reasonable. In this instance, the trench is dug, and a membrane is placed across the bottom and up the wall away from the landfill. Gravel; is then used to backfill the trench; a vent pipe may or may not be included. A shallow depth landfill and high water table typify conditions for this fairly common system.

These barrier systems are normally installed prior to, or during the actual filling of the site. Subsequent installations are often costly, less extensive than required, and occasionally impossible to accomplish. Installation after fill completion might be limited to trenching in the area requiring protection and to inserting a membrane into the trench, followed by backfilling. In order to effectively stop gas movement the barrier must extend from an impermeable layer such as groundwater, bedrock, etc. to the surface of the ground, or be a continuous liner covering the entire area to be filled.

The installation of a barrier system must be carefully carried out so as not allow any breaks or tears in the barrier. This is especially important in installing man-made liners since sharp objects and mishandling can cause numerous breaks and tears.

Natural soil barriers such as a saturated clay may furnish a highly efficient barrier to gas migration, provided the soil is kept saturated. The natural substances may also leave portals for the passage of gas if they are installed incorrectly or allowed to dry and form cracks across the surface or perimeter of the fill.

The effectiveness of barrier systems seems to vary from site to site. One site in the Denver area shows low-level gas penetration beyond the limits of the landfill (clay, streams, etc.) show no

BARRIER SYSTEM

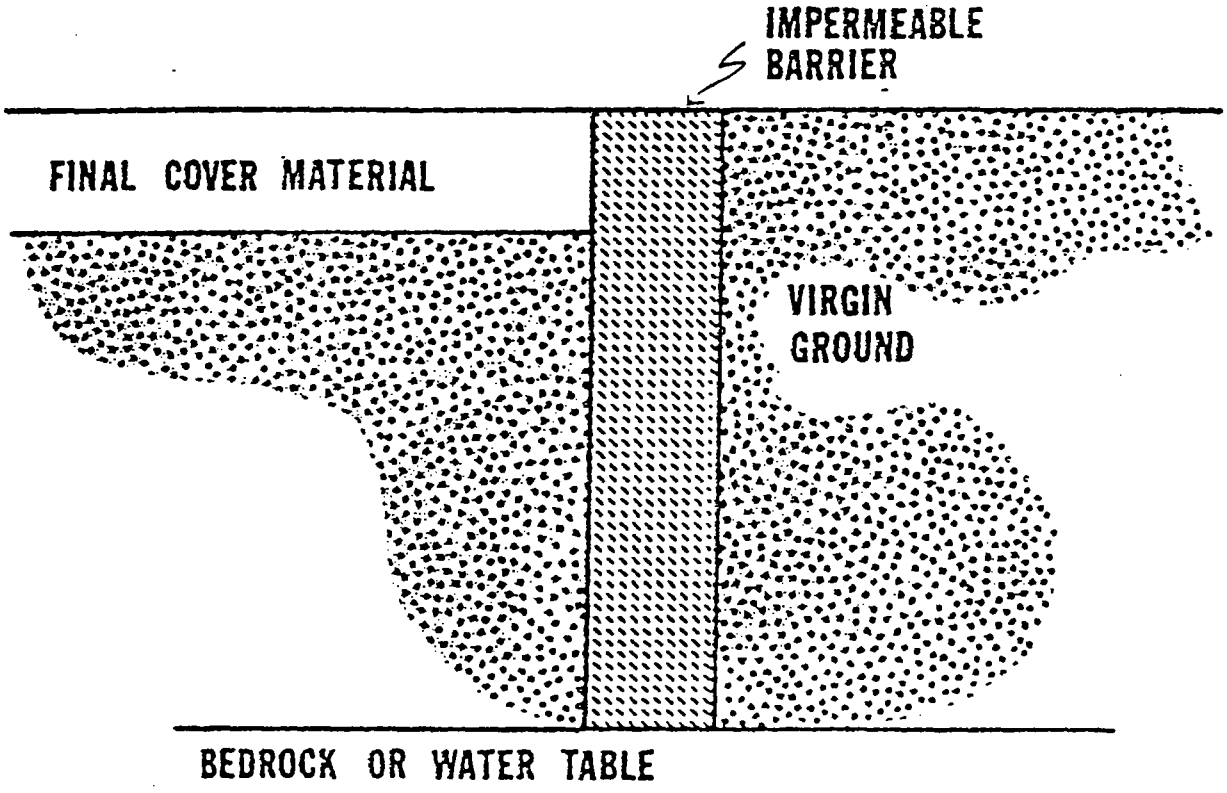


Figure 2.10

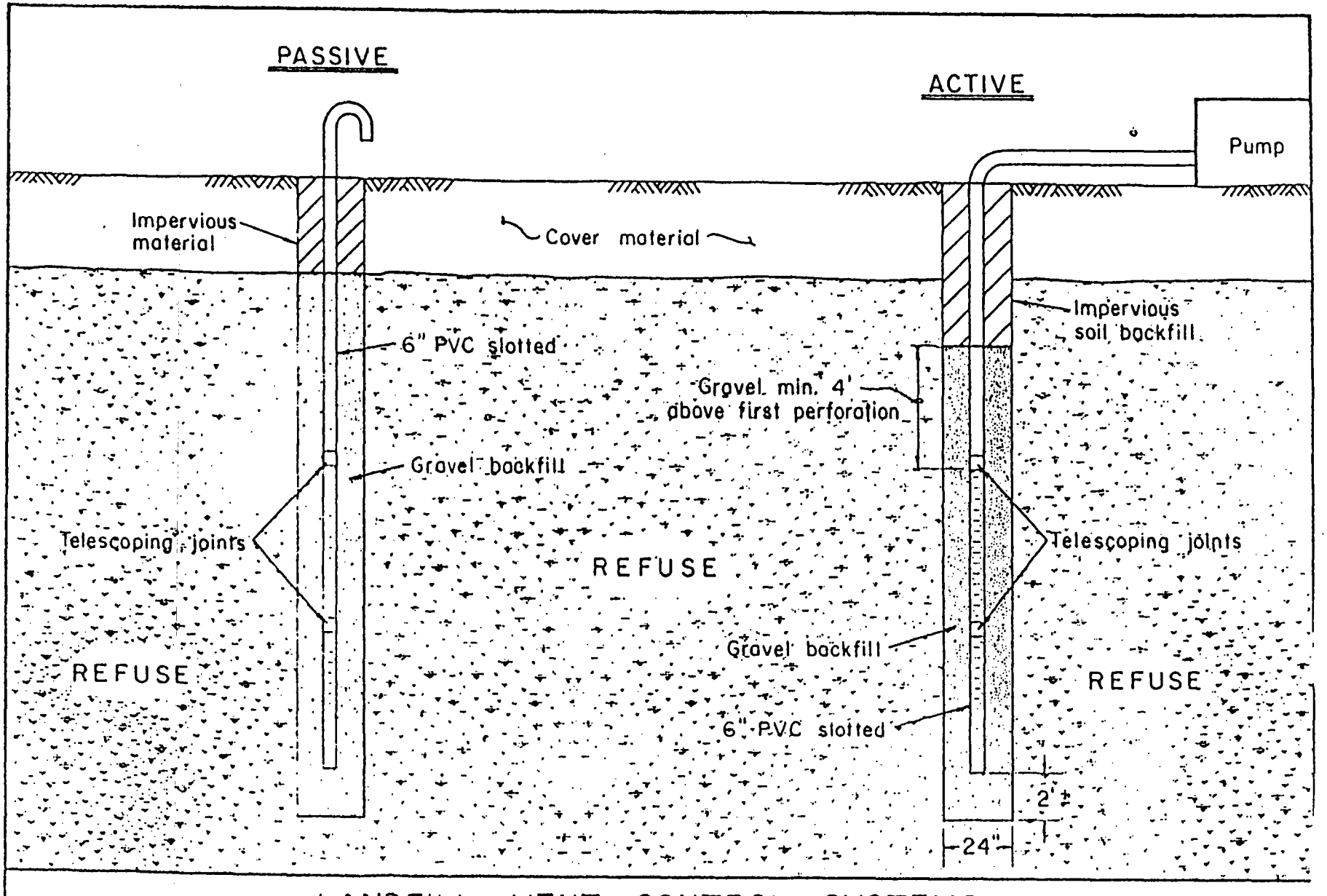


FIGURE 2.12

LANDFILL VENT CONTROL SYSTEMS

gas movement that we can detect. We feel that gas penetration studies should be conducted on any material considered for a barrier system before installation.

The relative cost of a barrier system varies with the stage of the operation, the substances utilized, and geology of the site. Generally speaking, if the system is installed before or during operation of a reasonably shallow fill, it is the least expensive method. This is especially true when one considers the maintenance and upkeep of the other types of control systems. On a landfill that has already been filled, however, the cost of excavation may make this type of system far more expensive and therefore as a remedial system, it probably will be less feasible than the other two types.

2.3.2.2 Passive Ventilation Systems (See Figure____)

Passive ventilation systems have been utilized on existing and proposed landfills include: gravel filled trenches, perimeter rubble vent stacks and combinations thereof. Passive venting systems rely on naturally occurring pressure or diffusion gradients to induce exhaust. The passive systems rely on highly permeable material, such as gravel, placed in the path of the gas flow. Since the permeable material offers a path more conducive for gas flow than that of the surrounding medium, flow is redirected to a point of controlled release. Passive systems can be effective in controlling convective gas flow, less so in instances of diffusive flow; and there are instances of their being ineffective.

This type of system consists of a layer of more permeable material between the landfill and the surrounding soils. This material may be crushed rock, gravel, sand, etc., or it may consist of perforated pipe put into the ground at specific intervals or both. Our experiene with this type of system has proven it to be far less efficient in stopping the movement of landfill gas than the other systems. Since the gas moves by convectin as well as pressure, it appears to move right through the material via diffusion and into the surrounding soils. If snad is used as the porous material, relatively few fines should be included, to insure ease of gas flow (e.g., not more than 5% passing No. 100 sieve). Well rounded pea gravel can be used for the passive vent if the trench is excavated in and backfilled with refuse, because refuse would not ravel into the pea gravel as natural soil would. However, anyone intending to excavate in refuse should be aware of and take precautions against potential hazards from fire or toxic gases, and the likelihood of malodors. A 4-inch PVC schedule 40 perforated pipe would be laid in the porous material at a depth of five feet below ground surface. To protect against plugging of the passive vent during freezing conditions, the synthetic membrane would be folded over the top of the sand or gravel near the surface. Hooded vent stacks would extend through the membrane at 200-foot intervals and would be connected to the underground perforated header pipe. The vent/barrier trench method of gas

migration control was considered whenever practicable (i.e., whenever groundwater was within 25 feet of the surface).Such factors as rain, snow, etc., may clog the surface of the passive vent and stop gas migrating upwards thereby allowing the gas to continue on through the surrounding soil.

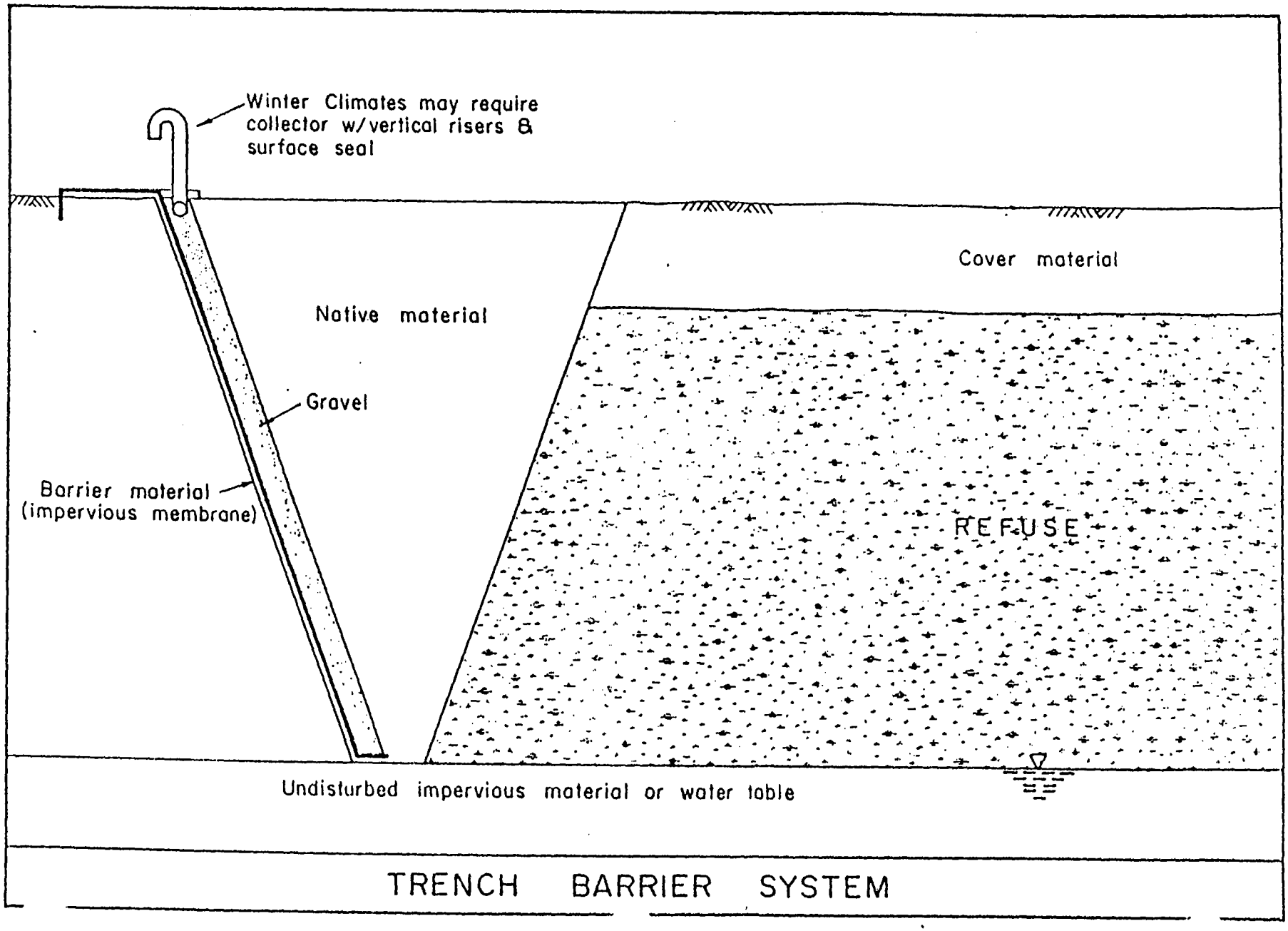
Due to this low-level of efficiency, the passive vent system is frequently combined with a barrier system. In this case the permeable material is placed between a barrier system and the fill. The vent/barrier trench system would consist of a trench along or just outside the perimeter of a landfill, dug to a depth sufficient to key the system into the groundwater table, unfissured bedrock, or some other material impermeable to the flow of methane gas. A barrier membrane would then be laid across the bottom of the trench and up the trench side opposite the landfill. (See Figure 2.11)

Our experience with this type of system suggests that it is only as good as the barrier system. We therefore do not recommend a passive ventilation system without at least a good barrier system to support it. Construction of such a system utilizes a control trench which is limited by the backhoe equipment. In this instance, the trench is dug and a membrane is placed across the bottom and up the wall away from the landfill. Gravel is then used to backfill the trench; a vent pipe may or may not beincluded. A shallow depth landfill and high water table typify conditions for this fairly common system.

2.3.2.3 Power Extraction (See Figure 2.12)

Power extraction systems appear to be the most efficient system to install in previously filled on late life operating landfills. Active systems almost always include wells placed at intervals and connected to a manifold which is in turn connected to a pump. The pump creates a negative pressure in the system which develops into a "gradient" barrier. The main advantage of this type of system is that it provides a positive displacement of gases and thereby prevents the buildup of adverse pressures.

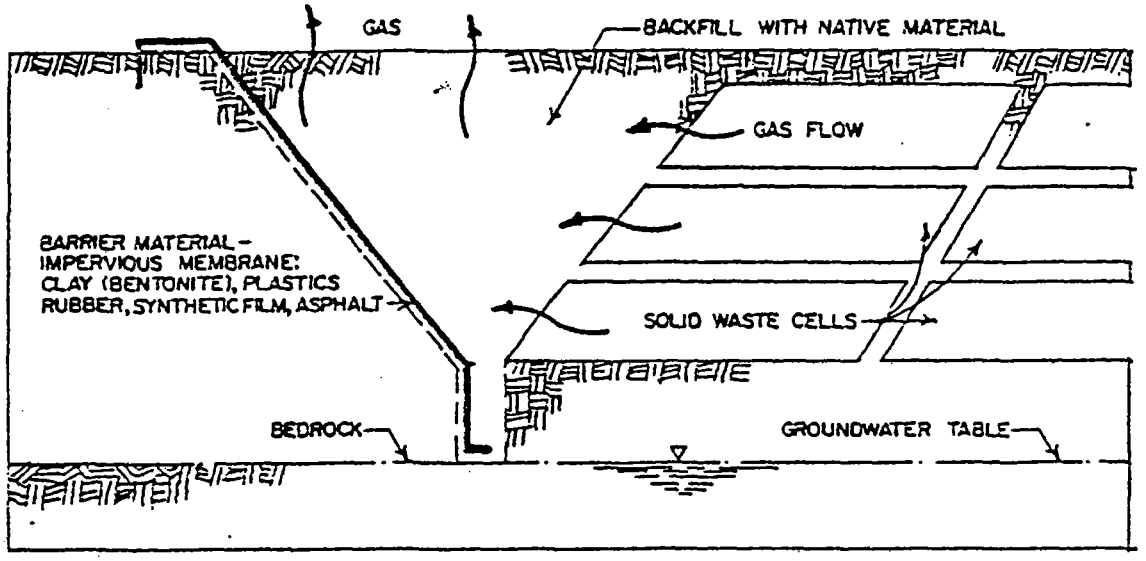
In many cases, a final system which utilizes one or more of the features listed in the prior discussion has been installed. This provides a system of maximum efficiency with a minimum of disadvantages. Systems can be installed prior to completion of the fill as a preventative measure or after completion in response to the development of a particular problem. Most systems installed to date are intended to alleviate or prevent a particular problem which had already developed. However, more and more systems are being installed as part of the original design. This is due in part to the increasing technology which is making it easier to predict potential problems prior to their actually occurring. Very few of these systems have as yet been proven in actual field use. Systems containing only passive elements have the advantage of being low in cost, both in the initial capital expenditure and in the annual maintenance and operation costs,



TRENCH BARRIER SYSTEM

FIGURE 2.11

BARRIER MATERIALS



while systems which utilize active elements are probably more effective. In either case, each system should be designed to be the most effective while still providing adequate protection under the site specific conditions.

Gases collected by exhaust systems ar generally disposed of by direct stacking, by incineration, or by passage through various sorption media. Gases from passive vent systems usually are allowed to discharge directly to the atmosphere; in certain cases, the gases are combusted, as in "tiki torches". In all instances uncombusted gas must be exhausted at a location where it is not subject to careless ignition, generally in a protected enclosure or above normal reach. Malodors associated with uncombusted gas may distate some form of odor control; ignition represents the simplest and most effective malodor control.

This type of system consists of a number of wells put into the landfill into which a vacuum is induced. The vacuum pulls the gas out of the wells and into a manifold system and then to a discharge point. The wells themselves are made by drilling a hole into the landfill or the surrounding soil with an auger, caisson, or bucket drill. A perforated pipe is then lowered into the hole to a depth of from 2/3 to 3/4 of the depth of the fill, and the rest of the hole filled with a fairly porous material (gravel or rock). The top of the hole around the pipe is sealed with cement or clay and the pipe connected to a manifold system with a valve. The manifold system then goes to a vacuum pump and into a flaring system.

The number of wells necessary for any particular landfill depends on many different factors such as: The density of the fill or surrounding soils, the number of acres of landfill, the depth of the fill, etc. It is therefore a site specific number that must be designed for the particular fill in question. Some sites have used a radius of influence of 150 feet and others greater or lesser distances and achieved relatively good results. The wells arre spaced at intervals along the perimeter margin of the landfill. Wells are located either interior to the edge of ill or external to it, in the surrounding native soils. Selection of location is site-specific and dependent upon cost, benefit and perrformance criteria. The wells are connected by manifolding to an exhaust blower which creates a vacuum drawing gas from thewell field. The gas flow direction in the volume of refuse or soil influenced by eac well is toward the well, effectively controlling migration. Alternatively, to enhance the control ability of a trench system, a collection pipe can be placed in a gravel-filed trench and then connected to a vacuum exhaust system. A pipe would be installed with perforations from the bottom of the casing to within 10 feet of ground surface. Coarse rock backfill would be placed around the perforations, and the upper 10 feet would be sealed from surface inflow of air by placing a concrete seal and impermeable backfill material. The wells would be connected by a header system. A centrifugal blower would apply a partial vacuum

to the header system and wells, drawing gas through the soil or refuse surrounding the wells and collecting it in the header. Exhaust from the blower would be ignited in a flare to control malodors.

Another factor determining the number of wells is whether or not gas recovery is considered. Since the power extraction system removes the gas from the landfill in a controlled manner, recovery of the gas for energy purposes is possible. In a recovery system the operator wants to extract as much landfill gas as possible without pulling air into the system, therefore a large number of wells is necessary.

The power extraction system is one of the most efficient systems if properly designed and installed. It is especially important as a remedial device used on abandoned landfills. Our experience shows that within a very short time after activation of the system, methane levels in the surrounding soils decrease dramatically. The cost of this system is also extremely competitive with the other systems. This type of system does, however, require more maintenance than the other systems.

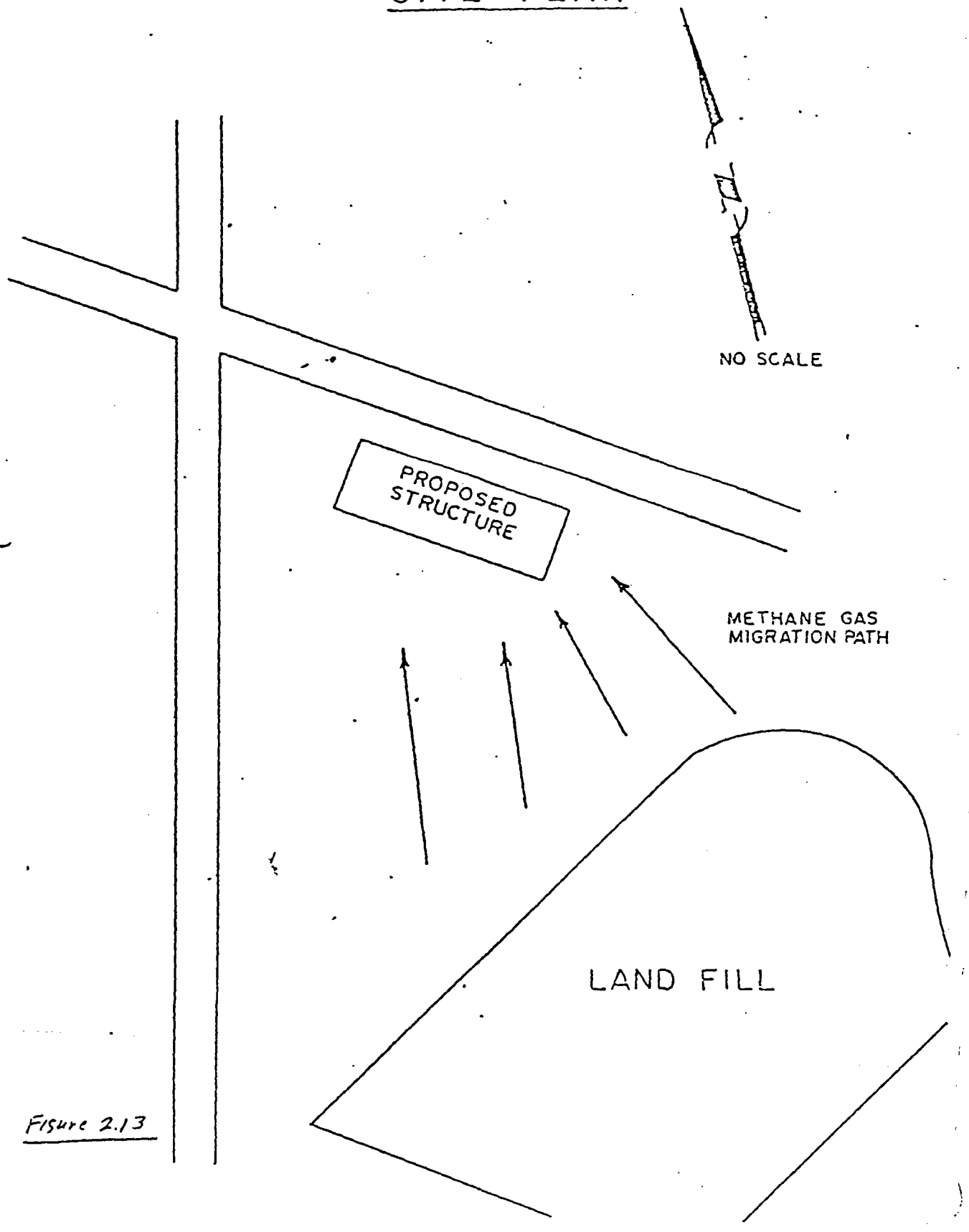
2.3.3 Building and Structures Protection on the Landfill

For buildings and other structures such as the one depicted in close proximity to a landfill with lateral methane gas migration in Figure 2.1.3, protective design features may range from simple to fairly complex. An example of one such gas control system is illustrated in Figure 14. A very basic feature of this example, is the impervious membrane between the slab and subgrade in buildings with slab on grade floors. A more effective system is provided by a permeable blanket with exhaust pipes between membrane and subgrade, permitting passive or active exhaust venting of the intercepted gas. Utility lines entering a structure must always be properly sealed. A broken drain line could be a direct connection of the landfill gas.

An additional feature which further adds to system credibility is a thin layer of permeable material between the membrane and slab with methane gas probes and an automatic methane gas sensors alarm system. The probes can be monitored and the alarm can trigger an event when the methane gas concentration exceeds a selected value.

Building codes generally incorporate requirements for good ventilatin and undoubtedly have precluded many methane-related incidents from happening. Nevertheless, many homeowners or building operators are unaware of the potential problem and unknowingly block the vent system, thereby creating a gas hazard. Buildings immediately over the landfill are particularly suspect, as cracks in the soil cover, settlement of the building, and resultant rupture or cracking of slabs may allow gas to flow into the building. Building codes should require that developments adjacent to a landfill require a predetermined distance dependent largely on the gas perrmeability of the soils in the buffer zone to provide adequate safeguards for the life of the structure nd include operation, maintenance, and monitoring of any protective system.

SITE PLAN



Fisure 2.13

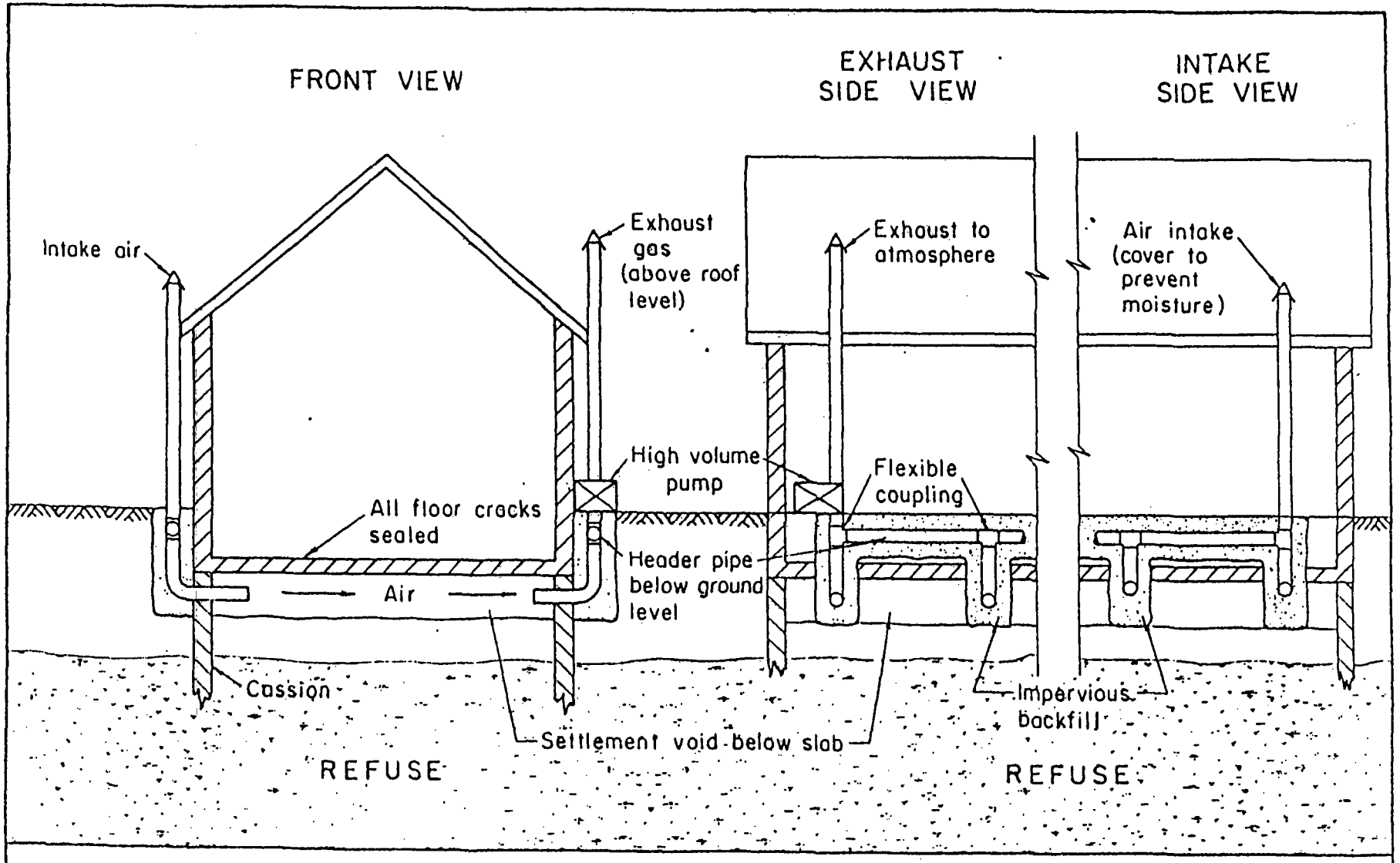


FIGURE 2.14

POSITIVE BUILDING GAS CONTROL SYSTEM
ON LANDFILL WITH DIFFERENTIAL SETTLEMENT

2.3.4 Success

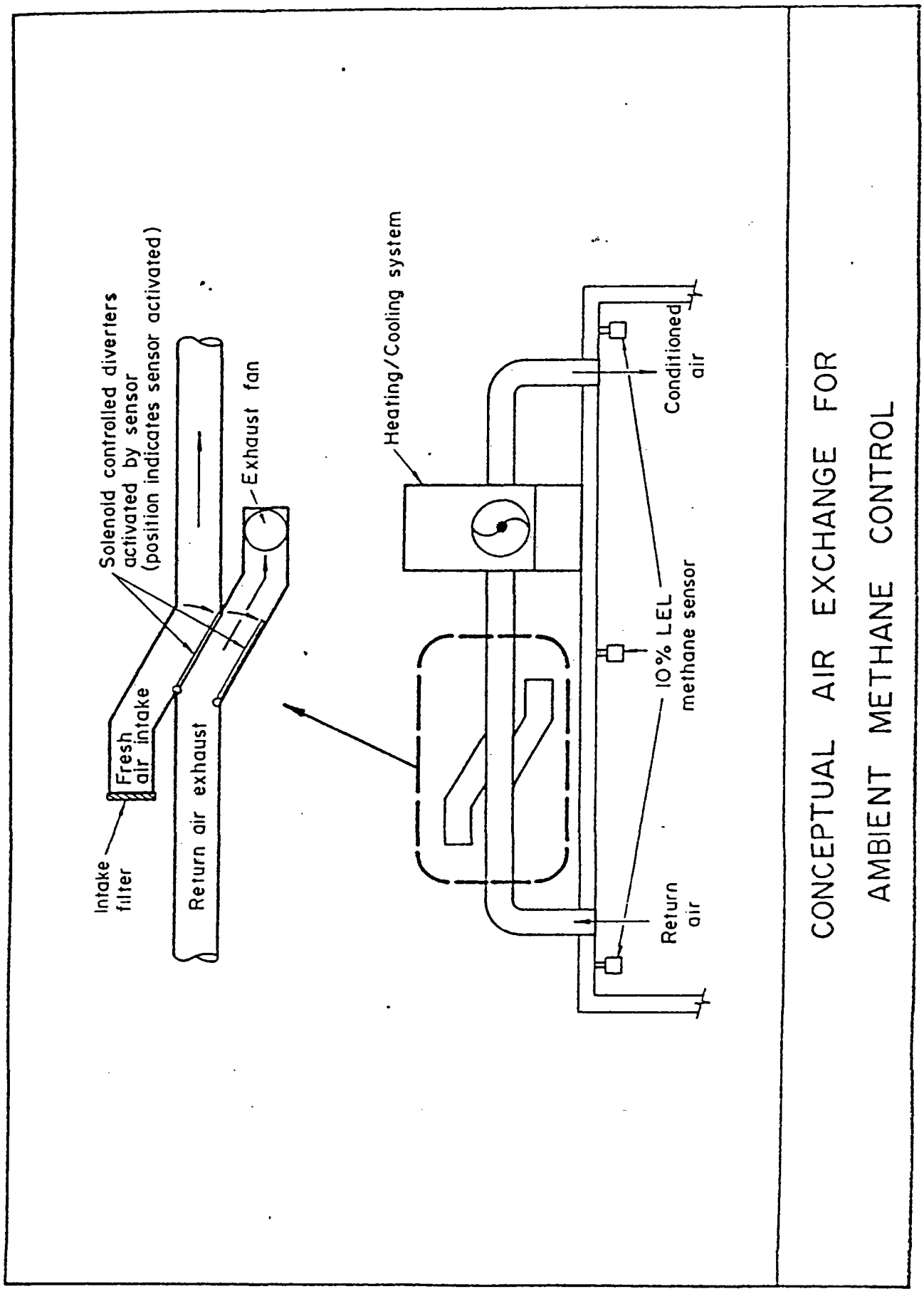
The success of any of the migration control systems described must be continuously appraised throughout the gas production life of the landfill. In installed protection systems, probes may be permanently placed at suitable locations in the interval between the migration control system and the facilities to be protected. These probes may be monitored on a frequent schedule either by gas sampling and analysis, or by in-site gas detectors connected to an alarm system. Subfloor protection systems also must incorprate similar apartatus for measurement of gas concentrations above the protective layers.

Alarm systems are considered as to the type of environment for which their protection will be designed. The main component of these alarm systems will be a combustible gas sensor. These sensors would function by detecting methane gas concentrations at a present leve. When this present level is achieved, the sensor would then complete either an alarm circuit, a ventilation circuit or both (refer to Figure 2.15). Most of the combustible gas sensors on the market today are set at a threshold of either 10 to 20 perrcent of the lower explosive level (0.5% to 1.0% gas by volume in air), thereby, reducing the possibility of explosive levels in the immediate vicinity of the sensor. A system flow chart as represented by Figure 2.16 depicts the more sophisticated systems being utilized in larger buildings in the top frame and in the bottom frame, a less sophisticated system being for use in residential units.

2.3.4.1 Effectiveness

Effectiveness in controllability refers to the reliability and ability to control gas migration. This evaluation distinguishes between initial and future effectiveness. Future effectiveness of a control method is related to the system's maintainability. Generally simple systems are the most maintainable; so the impermeable barrier and natural ventilation systems are given the highest ratings. The trench with impermeable barrier systems receives the best rating because the impermeable barrier would probably provide an acceptable level of methane control even if the porous material in the trench became clogged with sediment from surface drainage.

Two additional factors should be taken into account, however. First, ease of detecting and repairing failures is an important consideration. In this regard, the natural ventilatin and impermeable barriers systems rank lower than the forced ventilation system. Second, short periods of down-time, likely with mechanical forced-ventilation system, would not be significant interms of effectiveness. Conversely, with the other systems the longer poeriods of undetected partial failure would cause a greater reduction in effectiveness.



CONCEPTUAL AIR EXCHANGE FOR AMBIENT METHANE CONTROL

FIGURE 2

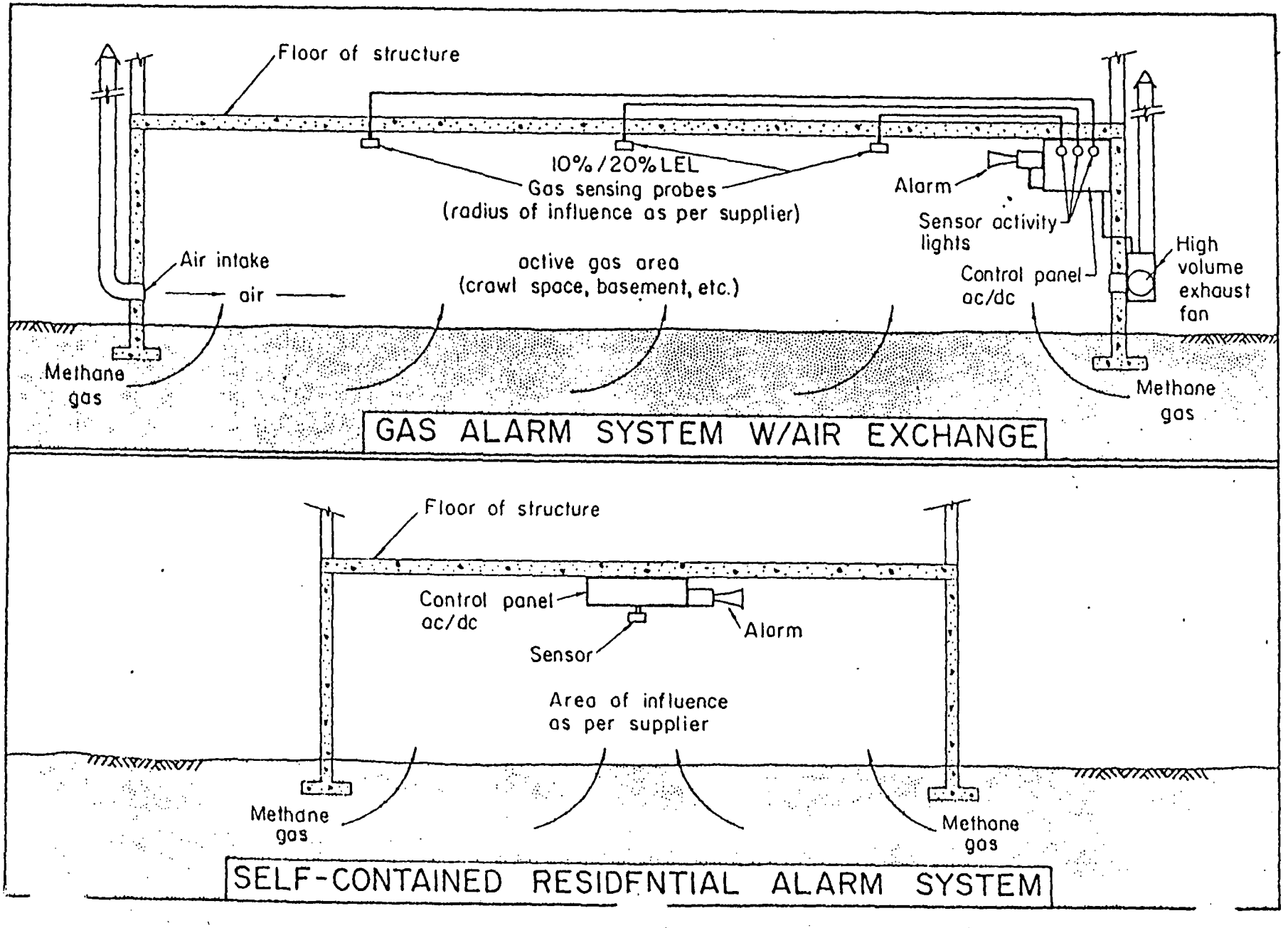

Floor of structure
10%/20% LEL
Gas sensing probes
(radius of influence as per supplier)
Alarm
Sensor activity lights
Air intake
air
active gas area
(crawl space, basement, etc.)
Control panel ac/dc
High volume exhaust fan
Methane gas
Methane gas
GAS ALARM SYSTEM W/AIR EXCHANGE
Floor of structure
Control panel ac/dc
Alarm
Sensor
Area of influence as per supplier
Methane gas
Methane gas
SELF-CONTAINED RESIDENTIAL ALARM SYSTEM

FIGURE 2

2.3.4.2 Manageability

Manageability of a gas control system can be thought of as its adaptability to modification of operations as required by changes in gas migration monitoring data. Manageability is a measure of a system's flexibility to respond to changing circumstances. This flexibility can be thought of in two ways:

First, as controllability in operating the system as initially installed;
Second, as the availability of contingency plans for physical modification of the initial system should it prove inadequate to control gas migration.

Manageability, therefore, is the system's ability to be operator-adjusted for maximum effectiveness. Substantial cost savings will result if a system can be controlled to maintain maximum effectiveness with reduced gas flow rates.

High controllability is inherent in forced ventilation systems. Natural ventilation systems and impermeable barriers offer little or no controllability (after initial installation) and therefore require costly renovation should they be ineffective.

2.3.5 Criteria for Selection

Subjectivity necessarily enters into the selection of factors to be considered in evaluating conrol alternatives, the weighting of those factors, and the scoring of alternative control methods under each factor. Each of the gas migration control alternatives considered can be evaluated on the basis of several factors. The factors were weighted according to the importance each should have in influencing the choice of a control plan. For a given landfill, each control alternative can be assigned a score under each factor; the score reflects the degree to which the control alternative meets the objective of the factor. The factor weight represents the maximum score that any alternative could receive under that factor. The total of all factor weights (therefore, the maximum possible total score for any control alternative) was arbitrarily made to equal 100 points. The following is a list of factors that may be considered in evaluating control alternative, together with their factor weight:

Factor	Factor Weight
Cost	30
Effectiveness	28
Initial	12
Future	16
Manageability	20
Controllability	8
Availability of Contingency Plans	12
Environmental Impact	10
Malodor	4
Noise	2
Aesthetics	4
Compatability with Surroundings	10
On Site	5
Off Site	5
Disturbance During Construction	2
TOTAL	100

You can make your own list with your subjective ratings. The point is you need such a list to narow down the choices.

2.3.6 Impacts

2.3.6.1 Environmental Impacts of Control Systems

Environmental effects being considered in this evaluation include malodor, noise, and aesthetics. A vent/barrier trench system would be completely silent. Some odorous gases would issue from the vent stacks of this system, and aesthetically, the vent/barrier trench system is very unobtrusive; the vent stacks are the only manifestation of its presence.

With a control well system there are noises associated with operation of the blower/burner facility. Ignition of the exhaust gases effectively controls malodors, and aesthetically, the well control system is also fairly unobtrusive, but the blower/burner facility is obvious and might be considered unsightly.

2.3.6.2 Compatibility with Surroundings

Compatibility of a gas control system with its on-site and off-site surroundings includes its impact on future land use and on property values. In addition, compatibility with the on-site surroundings includes the effects the control system may have on

existing landfill operations. Impact on property values would be the same for either a well control system or a vent/barrier trench system. Effect on the value of on-site land is negligible since individual structures would have to include protection from landfill gas even if a perimeter control system were installed. Any system could cause an increase in the value of off-site land by eliminating the landfill gas hazard; but since both systems effectively control off-site migration, the potential increase in property values should be equal.

2.3.6.3 Disturbance During Construction

Installation of a vent/barrier trench system requires extensive excavation and backfilling, and this system was awarded no points for minimizing disturbance during construction. A control well system requires well drilling operations, some excavation for protection of the header pipe, and may require some earthwork during site preparation.

Control Sys. ..	Description	Ad..ntages	Disadvantages
Trench with granular backfill	Along all boundaries to completely enclose each site. Gravel backfill greater than 1/4 inch. Depth: 20 feet or to groundwater table or bedrock, whichever is less	Low cost at depths up to 12 feet. Little maintenance is required. The granular backfill provides a highly permeable region with venting to the air to allow low resistance passage of gas.	Costs escalate rapidly at depths over 20 feet. The barrier may not be effective if pervious natural soil layers exist on the outside of the membrane. Gas could migrate and/or diffuse across the barrier. Difficult to construct at depths over 30 feet, and impractical to construct over 45 feet. Not controllable.
Trench with impervious membrane	Along all boundaries to completely enclose each site. Impervious membrane. 30 mil. thickness Depth: to groundwater or unfissured bedrock.	Low costs at depths between 12 and 30 feet. The membrane cvan provide a positie seal and be a barrier against gas and leachate. Little maintenance is required. Granular backfill on the landfill side of the membrane allows methane gas to vent to the air.	Costs become exceptionally high below 30 foot depth. The barrier my not be effective unless it extends into the groundwater table to eliminate gas migration beneath the membrane. Difficult to construct at depths over 30 feet, and impractical at over 45 feet. Not controllable.
Natural induction wells with subsurface collector pipes	Perimeter and interior spaced sme as foced induction wells. Depth: same as above.	Can install wells to depths over 100 feet. Can install collector pipes at varying depths. Can cover a large area of landfill surface using interconnecting collectors between wells. Negligible maintenance and operating costs.	Extensive piping and well systtem is needed at high cost. Reliability and effectiveness may be unsatisfactory since this system basically combines the trench and well systems. Not con= trollable

Control System	Description	Advantages	Disadvantages
Natural induction wells	Perimeter and interior spaced same as forced induction wells. Depth: same as above	Can install at depths over 100 feet. Can cover a large area. Negligible maintenance and comparatively low operating costs.	Localized venting of methane. Large number required to achieve control of migration. Is uneconomical. Reliability and effectiveness have been inadequate. Not controllable.
Low-flow and high flow forced induction wells with surface collection ducts	perimeter wells--space 100 feet on center. Interior wells--space 200 feet on centers. Duct collectors. blowers for forced induction burner for odor control. Depth: 20 feet or to groundwater or to bedrock, whichever is least.	Very reliable and effective at controlling gas migration from landfills. provides positive controlled removal of methane gas. Can be used as a barrier around the landfill perimeter by spacing close enough to provide overlapping negative pressures.	Relatively costly. Requires maintenance and periodic inspection. High-flow has greater power and maintenance cost than low-flow system.

CHAPTER 3

PUBLIC IMPACTS

3.0 Public Impacts
3.1 Public Involvement

- 3.1.1 Notification
- 3.1.2 Public Meetings

3.2 Training/Information Dissemination Techniques

- 3.2.1 The Methane Audience
- 3.2.2 Information Types
- 3.2.3 The Communication Media
  - 3.2.3.1 Slide Presentation
  - 3.2.3.2 Films
  - 3.2.3.3 Video Tape
  - 3.2.3.4 Press Releases (samples)
  - 3.2.3.5 Training Exercises/Demonstrations
- 3.2.4 Demonstrations/Training Exercises
- 3.2.5 Technology Transfer

3.3 Political and Social Controls

- 3.3.1 Landfill Gas Hazard Liability
- 3.3.2 Legal Liability - Who Is Responsible
- 3.3.3 Statutes and Regulations
- 3.3.4 State Health Regulations
- 3.3.5 Local Ordinances
- 3.3.6 Who Owns Gas
- 3.3.7 Deed Restrictions
- 3.3.8 RCRA Legal
- 3.3.9 Fire Safety Codes
- 3.3.10 Building Codes and Standards
- 3.3.11 Planning/Zoning

3.0 Public Impact

Without a doubt the public will be impacted by the discoveries of methane movement in close proximity to residences, schools, industrial and commercial buildings. It is important that the publics' involvement be well founded based on logical and technical facts and not a reactionary movement based upon fear. It is essential that public officials identify the hazard as to its magnitude and true dangers. To avoid such fear, public officials must undertake a very positive notification and information dissemination campaign.

3.1 Public Involvement

Public relations plays an important part in any methane management program. The public must be informed of the problem using sound documented information. The problem should be presented as to its cause, origin, life expectancy, potential and corrective measures in dealing with the problem. The purpose of a public relations program is to negate any panic that may arise in the public's point of view. The fact that there is methane gas in, under and around a building, does not necessarily mean that an explosion potential exists and that required physical precautions must be taken in order to preclude the possibility for an explosion or fire.

A public relations program should be aimed at both the private and public sector of a given community. It should be pointed out that methane gas generated from solid waste landfill sites were created by the public at large from their own waste generation and therefore is a public health and safety concern.

3.1.1 Notification

Public awareness of the total problem is essential to an effective accident prevention program. The one thing to avoid is mass hysteria on the part of the public by misinformation and scare tactics. Tables ___ and reflect forms of official notification used by some local government agencies to notify the public.

3.1.2 Public Meetings

By conducting open informative meetings the general public can be informed of the total problem. Part of the misconception surrounding landfill generated gases is a complete understanding of how the gases travel and collect. This kind of information must be given to the public in order that they fully understand the explosive fire and aphyxiation potential possessed by the gas.

There are many vehicles for assembling public meetings. One of the most available, but seldom used, are the communities service clubs, such as Kawanis Club, Lion's Clubs and Rotary Clubs. These service organizations often present community special interest programs and would welcome such a safety oriented informational program.

Other areas of public involvement are civic oriented groups such as P.T.A.'s and senior citizen groups. These types of groups are always looking for community involvement type of programs.

Last, but not least, are public meetings involving the political community. These meetings include city council and boards of county commissioners. It is most important to keep legislative authorities of any community informed as to the extent of the landfill problem. It is they who will fund the necessary programs and pass the required legislation that will control the problems.

3.2 Training/Information Dissemination Techniques

The need has been identified and illustrated in the previous sections, that the information gathered from research or investigations into landfill-associated methane be disseminated quickly, accurately, and by the most effective communication medium. This is important in order to create and/or maintain a positive attitude about investigative control and recovery efforts, to promote new technology as it develops so that others may share the benefits, and to enable individuals and communities effected by the investigations to take appropriate action.

This Section will identify potential information users, explore what type of information is pertinent, and will suggest ways that this information can be best presented.

3.2.1 The Methane Audience

There are six primary users of information concerning methane generated by domestic landfills:

(1) Public Officials; (discussed in 3.1.2)

(2) Elected Officials;

(3) Landfill Owners/Operators;

(4) Methane-affected Individuals/Property Owners;

(5) Professionals, eg., Consultants, Engineers;

(6) Researchers/Academicians;

(7) News Media (for redistribution to the general public).

Public officials who might request or need information concerning landfill-associated methane include individuals from local, state, and federal departments of health, safety, land-use planning, and others. They need information to determine the best way to investigate methane accidents, to develop methane-related legislation, to assess liabilities associated with methane from landfills, or to help interpret newly generated data.

Elected officials at all levels of government could also use this information to find the most suitable administrative and legislative remedies for the methane problem.

Landfill owners and operators will be especially interested in methane survey data generated from their particular site. Not only will this give the owner/operator a better idea of the risk involved at his or her facility, but also, in the surrounding area. Survey information can also be used to assist in the design of methane control and methods to safeguard life and property.

Those individuals who own methane-affected property adjacent to the landfill will need accurate and up-to-date information so that preventative measures can be taken to protect their interests and potential liability.

Engineering/consulting firms need the information to effectively design control and monitoring systems that will help to protect life and property now and in the future.

The researcher/academician may be interested in the information for use in developing new methods of methane control and recovery or possibly to better understand the methane phenomenon.

Information may be transmitted to the newsmedia (broadcast and print) in two ways:

(1) By the controlled release of information through a press release or press conference by an agency or firm for a specific reason. Usually such a release will include information which requires wide dissemination to a large audience. For example, notifying the public about methane problems which can develop near landfills would be necessary to protect property owners, builders, contractors, maintenance workers, etc.;

(2) Information may be released when the media initiates its own investigation into a particular site or problem.

3.2.2 Information Types

The basic types of information to be disseminated are:

(1) General information about landfill associated methane, potential or actual hazards, and methane control and recovery;

(2) Information derived from investigations at specific sites;

(3) Proprietary information regarding control or recovery techniques.

General Information

It is not recommended or warranted that the general public be given information that is too technical. Specific investigative data that the public cannot interpret could be confusing and might cause unnecessary fear and a negative reaction. General descriptions defining methane generation, investigations and control and recovery methods would be appropriate. Whereas, a more knowledgeable audience would expect and appreciate more detailed data. It should be remembered that any information release could

lead to an unfavorable reaction by the public and/or other persons involved. It should also be remembered that no matter how much care has been taken to prepare the communication and information flow, there will probably be someone who is not satisfied, or will misinterpret the basic facts. Therefore, it is important that whoever is chosen to disseminate the information anticipates all possible negative and positive reactions that could occur from the release of the information and is prepared to handle them properly, if they should occur.

Investigative Information

In presenting investigative data regarding a specific site it is best to notify those parties directly involved (property owners, site owners/operators) first, if possible, so they may take appropriate action. Then, if there is a specific request for the information by someone else (e.g., the media) it will not come as a surprise to those affected. In some cases, it may be possible to refer any inquiries to the affected parties so that they may release the information as they choose.

Proprietary Information

Proprietary information provided by private engineering/consulting firms should never be discussed without prior approval of the firm. In most cases this agreement is worked out during contractual negotiations. This is of special importance in the newly evolving field of methane recovery since development of new recovery systems can cost a firm millions of dollars to develop. Every effort should be made to protect this confidential information. Examples of written communications are given in Tables 3.1, 2,3,4 and 5.

3.2.3 The Communication Media

A variety of communication mediums can be utilized to disseminate information to individuals, groups, or the public in general. If used efficiently they can be effective tools to carry out public relations efforts and technology transfer. Each medium has unique qualities and applications. Some of the more commonly used methods include:

1. Slide presentations (35 mm);
2. Film (16 mm, 8 mm, and Super 8 mm);
3. Video tape;
4. Press release;
5. Training exercises/demonstrations.

In the following discussion each technique will be briefly analyzed as to its advantages and disadvantages and recommendations will be given for its use. No matter what method is chosen, the message should be presented in a clear and concise manner and should be designed to meet the needs and technical background of the particular audience members.

3.2.3.1 Slide Presentations

Slide presentations can be an effective way of presenting information to large or small audiences and can be used in a television broadcast as well. Individual or a series of 35 mm slides can be used to illustrate points in an oral presentation which are normally difficult to describe. Helping the audience to visualize the inner workings of a methane extraction system, for example, can be easily accomplished with a slide showing a cross-section of the system; or, comparison of gas composition data from several extraction wells can be better understood when presented in slide form than with a lengthy verbal explanation.

A slide show is a flexible presentation technique that can be tailored to the individual audience. Shots of local landfills, for example, can be inserted to bring a show "home" to a particular audience. Depending upon the situation, the speaker can shorten or lengthen the presentation by simply increasing or decreasing delivery speed and detail. Recordings can be made to accompany your own show and at very little cost. But, a taped message is less flexible than a speaker's verbal accompaniment.

A do-it-yourself slide show is fairly inexpensive once the basic equipment (i.e., 35 mm camera, projector and screen) has been purchased. The cost of the film, flash, and developing is minimal. And, if necessary, the show itself can be reproduced at a very low cost for use by others. In contrast, professionally made slide shows with accompanying sound track and narration on tape and which require special projection equipment can be very expensive costing as much or more than a professionally produced short film.

By following a few simple rules, your slide show can be an effective communication tool. In developing a slide presentation it is recommended that it be kept to the point and should be interesting to the viewer throughout. It is wise to write a basic script prior to taking pictures to insure that there is continuity to the information dissemination goals of the speaker rather than trying to fit a presentation to whatever slides might be available. The slides should not duplicate what is said, but should complement or accentuate specific points expressed verbally. The slide show should be carefully edited and only those slides that are pertinent to the presentation should be included. Resist adding those unique shots that are exciting to look at, but don't really relate to the subject.

The use of charts and graphs make data presentation easier while a few carefully selected newspaper pictures and articles can add reality to a presentation. A newspaper headline, "Two Men Killed in Landfill Associated Methane Accident" would help to dramatize the potential gravity of the problem. Avoid putting too much data on one slide. It is better to divide the data on two or three slides in order to give the viewer the feeling that the

information is not too complicated. Blank (exposed) slides can be inserted between slides so that as the speaker talks on areas that do not require illustration, the audience will not be distracted by a previous slide.

Most slide shows should be relatively short as audience members tend to lose interest if a presentation is longer than 15 minutes. A question and answer period iks usually appropriate after such a presentation.

To help make the slide show run smoothly, the speaker should take the time to practice with the equipment and to perfect timing. Be sure that there is an extra bulb for the projector and that extension cords are available. Extra long projector control switches are also helpful if the speaker must be away from the projector during the presentation.

A slide presentation has been developed by the Intergovernmental Methane Task Force regarding the methane hazard as it exists in the Denver Metropolitan area. The information to be presented about a methane gas problem should be technically correct, but not too technical in nature. All aspects of the problem should be presented; starting with how methane gas is produced, how methane gas migrates, and how to control the problem.

A slide program using local landfills and buildings that have experienced a methane gas problem, seem to work best. By utilizing local conditions, the public seems to identify more rapidly with the problem. Another method of information dissemination is sharing of information and experience by holding joint meetings with other authorities having jurisdiction such as Colorado's Intergovernmental Methane Task Force (IMTF). An aggressive, informed, combined activity is the quickest way to solve a problem. Information about this slide show is available from:

Chairman
Intergovernmental Methane Task Force
450 S. 4th Avenue
Brighton, Colorado 80601

3.2.3.2 Films

A film, whether it be 16 mm, 8mm, or super 8 combines the impact of sight, sound, and movement with added dimensions of color music and drama to encourage audience response. Other than a live presentation, film and video tape productions are the only mediums that can provide all of these life-like effects and extras. Film can illustrate time and sequence factors that are necessary to perform specific actions. For example, a film can show actual methane monitoring and survey techniques while a slide or series of slides can only show a portion of the event.

As opposed to a slide show and many other audio-visual techniques, film presents a message that cannot be compromised by the presenter's mood, delivery, technique, or knowledge of the subject. A film can attract the sustained, exclusive attention of the audience for the length of the message.

While film is usually the first and most desirable choice of many persons with an information dissemination purpose, the presenter must weigh carefully the benefits of film - its potential use, and audience and budget allowance - before deciding on this unique medium.

Producing a film is very expensive, requires an experienced and creative team to produce an effective product and takes a much longer time to make than a slide show. In most cases a film company must be hired to write a script, do the filming, editing, and sound recording of narration, background music, and special effects. A film may take months to produce and cost $1,000 or more per minute of film.

Once a film is complete it cannot be easily changed or modified. If the subject of the film is, new methane recovery techniques, it may be outdated before the film is even finished.

It is recommended that any film produced be adaptable for television presentation. Local television stations will frequently use short films or film clips on subjects of local interest. The tele- vision medium offers the opportunity for much broader exposure of the filmed message. If a film is to be used by television broadcastors, be sure to have extra copies of the film for this purpose. If it is to be used for public service announcements via television, cassettes can be prepared in timed sequence (30, 60 second, etc.), to meet the station's individual public service announcement requirements. These can also be made on video tape.

3.2.3.3 Video tape

Video tape is fast becoming one of the most popular ways of disseminating information and entertainment to the public. The recent dramatic increase in the availability of low-cost video tape-recordings equipment has made it much easier for individuals and public and private groups to own and operate this valuable communication tool.

At this time, a video tape camera can be rented for approximately $250/day for color and purchased for $2,000. A black and white camera costs $65/day and purchased for $1,500 Video tape cassette players can be rented for $65 per day and purchased for approximately $1,000 - $1,500 (Rental prices are reduced for multi-day use). This price range would allow individuals or groups to make use of this type of equipment.

Video tape, like film, incorporates the benefits of sound, color, motion, and drama, but produces an instant product that can be edited, if desired, in a short time and that can be very effective in delivering certain types of messages. Video tape is somewhat less polished than film, but it can be produced at much less cost, is easily reproduced, and can be erased and reused.

For certain applications, a script should be followed so that the presentation is smooth and has a "professional" look. Following a script can also eliminate unnecessary editing.

Because video tape recording is so versatile and easy to use, it can be very effective in both controlled or uncontrolled productions. It is an excellent tool for use in training sessions where participants can see instantly how well they have performed certain tasks. Improve- ments can be made and actions retaped with the option of allowing com- parisons between the two sequence. Because tape is fairly inexpensive, used tape can be saved or erased and be used again at a later time. Video tape equipment can record lectures, speeches, panel discussions, and demonstrations for reshowing at a later date to participants and other interested parties.

Video tape recording equipment is very simple to operate and can be used by almost anyone following a few simple instructions. It should be noted that editing equipment does require considerable experience to make smooth and fast changes to a completed tape.

The Environmental Protection Agency is in the process of developing a video tape which will be available in the near future on the landfill-associated methane problem. Please contact the Solid Waste Program of the Region VIII Office of EPA for further information regarding this tape (telephone 303/837-2221).

3.2.3.4 Press Releases

A press release is a written message that is used to disseminate information to the news media - newspapers, radio, and television, for redistribution to the public. Information regarding an important meeting, demonstration projects and their results, new policies, or a new grant are commonly announced in this way.

If used by the media, a news item may get wide distribution to the public where slide presentations, films, and video tapes may not. A press release allows for tight control over the information released which is an important advantage if you are releasing results of a methane survey of a landfill in an especially sensitive area.

A press release does not have the same type of impact as a film with its sound and sights, but a press release can be very effective in a number of ways, especially if a relevant photograph is included. A picture of a methane recovery system, for example, can be used to complement a short release on a new recovery

technique. Photographs should have appropriate captions and identifications taped to the back. Most newspapers prefer 8" x 10" black and white glossy prints. Television stations prefer photographs with a matt finish. Check with the news editor of the newspapers and television stations you will be sending your photographs to in order to find out what their special requirements might be.

In using a press release it is recommended that you:

(1) Have an up-to-date list of local news editors;

(2) Know when to release the information. Be aware of press and broadcast deadlines;

(3) Be sure the release is timely, interesting, and above all, newsworthy;

(4) Do not overuse the press release;

(5) Follow-up with a phone call to the media representatives to remind them of the meeting date, etc. Do not ask when or if the release will be used;

(6) Be familiar with the content and format of each outlet. Tailor the release to the medium - write news stories for newspapers and articles for publication, etc.;

A press release can be used to create a positive public attitude about an organization, project, or community effort so that if future problems should occur, the public will frequently have a more confident attitude regarding the capabilities and credibility of a group or projects worthiness. Frequently, concern about public image is not considered until after a problem arises. By providing the public or interested parties information in advance through responsible use of the press release, negative reactions may be diminished or avoided entirely should a sensitive situation occur.

3.2.4 Demonstrations/Training Exercises

One of the most effective training methods to transfer information or technology to others is to conduct a demonstration or training exercise where a process is witnessed first- hand, or where participants actually take part in the event.

While this technique can be very successful, it requires time and effort to properly prepare for each session. One must arrange for equipment, a meeting place, transportation, provide equipment and other supplies, extend invitations and follow-up, arrange for sufficient support staff and a proficient communicator and technology expert to conduct the demonstration/training exercise.

But, despite the effort, hands-on experience is often the quickest and most efficient way to communicate specific information. For example, methane survey techniques can be demonstrated easily and successfully in the field using a gas meter to monitor the methane levels at various locations. The on-site demonstration enables the trainee to use proper equipment in a natural environment under supervised and controlled conditions.

3.2.5 Technology Transfer

This exchange of information will allow others with common interests to proceed from the most current standpoint, saving man-hours and dollars that would have been expended to discover an answer that was already known.

There are many ways that technology transfer can occur: through published reports in industry periodicals; in the mass media; through organization newsletters, seminars, workshops, demonstrations; and by word of mouth on an individual basis. But, no matter what way is used, it is the process of exchanging ideas that perpetuates the growth of technology and stimulates further communication.

This workbook, which will be used during the first national working symposium entitled, "Methane from Landfills - Hazards and Opportunities," is a technology transfer effort by the IMTF with contributions by symposium participants. The symposium will bring people together to discuss the many aspects of the methane situation, to complete this workbook and, at the same time, a communication network will begin to build naturally as the symposium takes place. Names will be exchanged, and interests will be aroused regarding projects in other areas. Technology transfer will occur during the workshop and will continue as correspondence and reports are exchanged between participants.

Technology transfer is being promoted heavily by state and local governments, industry and business, universities, special interest groups, and individuals who recognize the need for a sharing of information. The federal government has taken a very active leadership role in the promotion of technology transfer.

It is our hope that this workbook will help to eliminate repetitive research and stimulate continued advancements in methane control and recovery process.

3.3 Political and Social Controls

3.3.1 Landfill Gas Hazardous Liability

The liability question of landfill-associated methane gas fires and explosions is not clear. To our knowledge no case has been allowed to

complete the judicial process due to out-of-court settlements, etc. We do know, however, that several of the law suits filed on accidents occuring in the Denver area were directed to almost everyone connected with the landfill.

In the suit filed due to the death of one of the workmen at the 48th and Holly landfill, the suit named the following entities:

A. The landfill owner(s);

B. The landfill filler;

C. The city with jurisdiction.

D. The pipeline construction company.

E. The Colorado Occuptation Health and Safety Administration.

These entities cover about every agency having any jurisdiction or ownership on the property.

These suits have also been for extremely large amounts of money. The suit at 48th and Holly asks for $4.5 million in damages and penalities. Another suit has asked for about $15 million for the injury of four children in an explosion.

The Attorney General's office of Colorado has stated that the responsiblity for the methane generation of a fill is the responsiblity of the present owner of the fill. This becomes quite confused as the number of owners increases. In some areas, a subdivision has been placed on the fill, resulting in many owners for one landfill area. In these cases attaching liability in a court of law may be impossible.

We feel that the liability attached to government agencies is primarily that of identification of the problem coupled with notification of those parties affected. If government does not adequately warn individuals of a problem that they know exists a definite liability exists. We also feel that orders to correct the situation and follow-up visits to insure that these orders are adhered to must be given in order to prevent government from becoming involved in future lawsuits.

3.3.2 Legal Liability - Who's Responsible

Methane from landfill sites can cause both personal injuries and property damage. The determination of who is responsible for methane related hazards can aid in resolving what legislative and regulatory controls are needed to ensure that the danger is being controlled and that the burden for such control is allocated equitably.

Responsibility for methane hazards when a landfill is in operation rests primarily with the landfill operator. When damage or injury occurs the operator can be held liable for the negligent operation of the landfill.

Under this theory the operator is not liable for all damage resulting from methane but is only liable when the damage results from a failure to use reasonable car in the operation of the landfill. Whether or not reasonable car is used depends on such factors as the foreseeability to the operator that such damage might result. Practices in the industry relating to methane control may indicate the standard of care which will be imposed on the landfill operator although courts will often impose a higher standard if they feel industry customs are not reasonable in light of the danger the industry presents. Government regulations can also be an indication of the care required of a landfill operator although courts may impose a higher standard or care if they find the operator should have knowledge of additional dangers.

There are certain circumstances under which a landfill operator can be held absolutely liable for damages resulting from methane. Under the theory of nuisance the landfill operator can be held responsible for damage regardless of any lack of care in the operation of the landfill.

A nuisance is a condition on land which unreasonably interferes with the rights of another. An action for private nuisance is usually brought by one whose property rights are interfered with. If personal injury occurs rather than property damage, an action for public nuisance can be brought by the injured person against the landfill owner or operator. Since nuisances usually involve conditions on land, a nuisance action is often brought against the owner of the property on which the nuisance is located. However, if the landfill operator rather than the landowner is responsible for the creation of a nuisance, the operator can also be held liable.

Negligence need not be proven in a nuisance action. Rather the value of the competing interests are weighted to determine if the offensive condition is unreasonable considering such factors as the location of the landfill in relation to populated areas. In the absence of proof of negligence, the acts creating the nuisance must be intentional. In most jurisdictions, the act is intentional if there is knowledge that it has caused harm in the past and nothing was done to abate the harm.

Once a landfill has been closed, responsibility for landfill gas hazards rests primarily with the owner of the land which was previously used as a landfill. If ownership of the landfill has changed hands after the landfill has been closed it is difficult to hold the present landowner liable for any damage caused by landfill gases which have migrated from the landfill site. The present landowner would have to be negligent in some respect and this would be difficult to prove since the landowner probably has little knowledge of landfill gas hazards.

There is a possibility that the landfill operator or owner could still be held liable for any methane related damage once the landfill has been closed on the basis that the owner or operator created a dangerous condition that is a nuisance. If the closed landfill could still be considered a nuisance, the creator of the nuisance could be held liable even though the landfill site ownership has been transferred.

Government has legal responsibility of the to control methane hazards whether the landfill is publicly or privately owned, the nature of government regulation of landfills and the extent to which the sovereign immunity doctrine applies in the state where the landfill is located.

In most jurisdictions a municipality or county has the responsibility of operating a publicly owned landfill without creating a nuisance. The liability of a local governmental entity for creating or maintaining a nuisance is usually the same as that of a private operator. The landfill must be operated without causing an unreasonable invasion to the rights of others.

Whether or not a state, county or municipality can be sued for negligence depends on whether the doctrine of sovereign immunity has been abrogated in a particular state. Sovereign immunity is the doctrine which prohibits state governments from being sued without their consent. Counties are also immune from suit under this doctrine. However, the doctrine only applies to municipalities when they are performing functions which are deemed to be governmental. Generally the operation of a landfill is considered to be a governmental function. This is especially true if a state statute specifically gives a municipality the duty to operate solid waste disposal facilities.

If a municipality is assuming this duty voluntarily and if substantial revenue is derived from the disposal of solid waste, courts are more likely to find that the muncipality is not performing a governmental function but rather that the function is proprietary. In Koontz v. Winston-Salem, 280 N.C. 513, 186 S.E. 2d 897 (1972), a North Carolina case which involved injuries resulting from a methane-related explosion, the Supreme Court of North Carolina held that the operation of a landfill by the city was a proprietary function for which the city could be held liable for negligence in the landfill's operation and maintenance. The North Carolina court found that the operation of the landfill was a proprietary function largely because the city was receiving payment from the use of its landfill by users outside the city and that this extra use of the city's landfill was a duty the city had assumed for its own benefit and which was not imposed on the city by the state statute.

In approximately 23 states the sovereign immunity doctrine has been abrogated. In these states governmental liability for the operation an maintenance of a publicly owned landfill is close to that of an operator of a privately owned landfill. In many of these states, however, the courts will refuse to impose negligence liability on state and local governments when the only duty owed by the governmental unit is a duty to the general public. The duty to ensure that landfills are being operated safely is usually a duty to the general public and unless a special duty of the governmental unit is found toward a particular person, there will be no governmental liability for negligence. A special duty to a particular person is not easily found and will depend on factors such as whether the area in which the injury occurred was open to the general public and whether any special protection was expressly promised.

Liability is usually not imposed for a failure to enact regulations or pass legislation dealing with methane hazards. Governmental actions which involve discretion and basic policy decisions are usually not reviewable by the courts. There is an argument, however, that the state has a duty under its police power to enact legislation protecting the health of the public. Once legislation or regulations dealing with solid waste disposal sites are enacted, courts are more likely to impose a duty upon local governments to see that such sites do not constitute a hazard to the public health. However, when local government officials have discretion as to whether or not to take any action regarding methane hazards, there is probably not a legal duty to take such action.

3.3.3 Statutes and Regulations

Many problems related to landfill gases are dealt with ineffectively without any methane specific legislation or government regulation. Legal liability only results when damage or injury occurs. Knowledge of this liability will often cause landfill owners and operators to take action to prevent methane damage but there is no assurance that such action will be taken. Methane also continues to be a problem after a landfill is closed. Since the landfill is no longer in use it is very difficult to hold any person liable for any damage. Purchasers of land which was previously used as a landfill often have no notice of the previous use. Without any notice of methane dangers, it is impossible to hold anyone liable for damage. The purchasers of the land themselves may be in danger if they have no notice of methane hazards. If a subdivision is built on or near a closed landfill site, each individual landowner has the responsibility of protecting his own property from damage but there may be no way for any individual landowner to effectively vent his own tract of land to prevent any danger to himself from methane.

Many states have enacted statutes which give state agencies some control over solid waste disposal sites. Usually a state agency, such as the department of health or environmental conservation, is given authority to promulgate regulations concerning solid waste disposal. However, few statutes deal specifically with methane control. Ideally state statutes should deal with control of landfill decomposition gases to provide for some uniformity throughout the state and to make certain that all landfills in the state are subject to some type of control. Statutes or regulations should provide for the monitoring of landfill sites for methane and should also give state or local agencies the power to require that landfill operators and owners alleviate any methane hazards. The following is a model state provision dealing with methane control. It could also be adapted to state regulations if legislative authority already exists giving a state agency power to enact such regulations.

MODEL STATUTORY PROVISION FOR THE CONTROL OF LANDFILL DECOMPOSITION GASES

(1) The state department of health shall have the power to determine which solid waste disposal sites present a potential danger to surrounding areas from the presence and movement of landfill

decomposition gases. The state department of health shall initially monitor such solid waste disposal sites to determine if an actual hazard from the gases exists.

(2) If the state department of health finds levels of landfill decomposition gases which it deems to be hazardous, it shall require the landfill operator and owner to take such measures as determined necessary by the state health department to alleviate the danger.

(3) The solid waste disposal site operator and owner shall provide for the continued monitoring of the site after the state health department determines an actual hazard exists and the monitoring shall continue until the state health department determines that the monitoring is no longer necessary. Periodic reports of the monitoring shall be submitted to the state health department at intervals determined by the department.

(4) No person shall establish or continue to operate a solid waste disposal site without the submission of a plan to provide for the venting, control and monitoring of landfill decomposition gases should such measures be required by the state health department.

(5) All persons seeking approval of an application for the operation of a solid waste disposal site shall submit a proposed plan for the ultimate use of the site to the municipal and county officials in which the site is located. The operator shall operate the site in a manner consistent with the goals of the plan. Such a plan shall include a proposed methane control system which will prevent hazards from methane to any foreseen development within the area surrounding the landfill site.

(6) The design and location of a proposed solid waste disposal site shall be based on the consideration of geological data so as to minimize the off-site migration of landfill decompostion gases.

In addition to the requirements for the monitoring of landfills sites and future planning for landfill sites, some provision is necessary to ensure that someone is responsible for site care in the long term. Methane barriers or ventings systems can fail to work properly years after the site has been closed. A provision should be included which will hold the landfill owner responsible for any hazards resulting from methane after the landfill site is closed and for a reasonable time after the closure.

Different problems are posed when develpment has already occured on or in dangerous proximity to a closed or operating landfill. States can enact provisions under their police power which give them power to regulate closed landfill sites or require that some measures be taken to abate any hazards from methane. Certain areas where the hazards are particularly dangerous and where individual landowners do not have the financial resources to alleviate the dangers can be condemned. However, a less expensive and perhaps more efficient means to deal with this problem may be to establish a tax assessment district with powers to acquire rights of way and to control the methane. In this way the cost can be spread out in the area that needs to abate methane hazards and the efforts will be concentrated in one entity.

3.3.4 Proposed State Health Department Regulations

(a) No person shall establish or continue to operate a solid waste disposal site without the submission of a plan to provide for the venting, control and monitoring of landfill decomposition gases should such measures be required by the state health department.

(b) All persons seeking approval of an application for the operation of a solid waste disposal site shall submit a proposed plan for the ultimate use of the site. If the site is located within a municipality the plan shall be submitted to the municipal officials. If the site is located in the unincorporated areas of a county the plan shall be submitted to the county commissioners. The operator shall operate the site in a manner consistent with the goals of the plan. Such a plan shall include a proposed methane control system which will prevent hazards from methane to any foreseen development within 1000 feet of the solid waste site.

(c) The design and location of the proposed solid waste disposal site shall be based on the consideration of geological data so as to minimize the off-site migration of landfill decomposition gases.

Proposed Legislation to Grant Health Department Authority Over Closed and Abandoned Landfill Sites.

(a) The state health department shall have authority over closed and abandoned solid waste disposal sites to monitor for the presence and movement of landfill decomposition gases. The state department of health may also require that the owner of the closed or abandoned landfill site take measures deemed necessary by the state department of health to prevent the hazardous off-site migration of such gases.

3.3.5 Local Ordinance

The local health departments may assume the authority of the state health department, upon approval of the state health department, over closed and abandoned solid waste disposal sites as set out in paragraph (a).

3.3.6 Who Owns the Gas?

Methane is produced naturally from the decomposition of waste material. Consequently traditional oil and gas theories apply to methane produced from landfill sites. Whoever owns the mineral rights to a piece of land also owns the rights to the methane under that tract of land. This is true unless the gas rights to a tract of land are expressly excluded from the grant of the mineral rights. There are two different theories dealing with the ownership of gas. The ownership in place theory puts the ownership of the gas in whomever owns the land under which the gas lies. The ownership of the gas can be transferred just as mineral rights are transferred. Under the nonownership theory the gas does not belong to anyone until someone gains possession of it. Therefore, there is no ownership of the gas until it is taken from the ground. However, a right to search for the gas and reduce it to possession can be transferred. Under either theory the rule of capture applies. This provides that no

matter if the gas migrated off of someones else's land, whoever reduces the gas to possession owns it. As applied to methane, in order to convert the methane gas to use, the mineral rights to the landfill or a portion of the landfill must be acquired.

A provision should also be included providing that a notation of the existence of a landfill site be recorded in the office of the register of deeds in the county recording office where the site is located. This would provide notice to subsequent purchasers of possible hazards from the landfill site which would have to be taken into account in developing the land. Such notice could also be used to alert public utilities to the danger of placing utility lines in some areas.

3.3.7 Deed Restrictions

Proposed Legislation to Provide for Notice on the Deed and Contract of Sale of Solid Wste Disposal Site

(a) The deed to any parcel of land which has been previously used as a solid waste disposal site shall contain notice that the parcel of land has been used as a solid wst disposal site.

(b) The contract for the sale of any land which has been previously used as a solid waste disposal site shall contain notice that the parcel of land has been used as a solid wste disposal site and that the land is subject to the authority of the state health department for the purposes of the control of landfill decomposition gases.

3.3.8 The Resource Conservation and Recovery Act of 1976 states in Section 7003 (IMMINENT HAZARD):

> "...upon recept of evidence that the... disposal of any solid waste...is presenting an imminent and substantial endangerment to health...the Administrator may bring suit on behalf of the United States...or...take such other action as may be necessary".

Should steps to remedy the hazardous situations not follow expeditiously, it may be incumbent upon the Agency to act in accordance with this provision of the Law.

3.3.9 Fire Safety Codes

3.3.10 Building Codes and Standards

3.3.11 Planning/Zoning

Table 3.1

INTERGOVERNMENTAL METHANE TASK FORCE
LANDFILL - ASSOCIATED METHANE
FACT SHEET

BACKGROUND

In 1968, the State of Colorado banned the burning of trash to alleviate the air pollution problem. The resulting trash was then buried in landfill sites unburned. From the decomposition of this trash came another environmental problem - methane.

THE METHANE PROBLEM

Methane is the byproduct of anaerobic (without oxygen) decomposition of organic material by certain methanogenic organisms. In a landfill situation, this gas builds up in high concentrations, disperses into the surrounding environment and can pose severe safety and health problems. If trapped in a confined space with sufficient oxygen present and a source of ignition, an explosion can occur. Another hazard involves asphyxiation. In high concentrations, the gas can displace oxygen and cause suffocation of those individuals exposed to it.

METHANE RELATED ACCIDENTS

In the metro Denver area, methane migration from landfills has caused two deaths and several serious injuries.

1. March 26, 1974, Englewood, Colorado, 3 workmen seriously injured in methane gas explosion while constructing a storm sewer adjacent to dumping area.

2. August 18, 1976, Sheridan, Colorado, 6 children seriously burned in methane blast while exploring a storm sewer culvert located near a landfill site.

3. June 16, 1977, Commerce City, Colorado, 2 killed, 4 injured in a methane gas explosion while constructing a water conduit line near landfill site.

LANDFILL GAS COMPOSITION

MAJOR COMPONENTS:	1.	Methane	CH_4 - odorless - non-toxic
	2.	Carbon Dioxide	CO_2 - odorless - non-toxic
MINOR COMPONENTS:	1.	Hydrogen Sulfide	H_2S - rotten egg odor - toxic
	2.	Ethylene	
	3.	Propylene	

In landfills, methane concentrations as high as 60% are commonly found.

EXPLOSIVE LEVELS

1. 5-15% methane by volume in air is the explosive range.

MIGRATION

1. Methane (landfill gas) can migrate vertically through the soil and dissipate into atmosphere.

2. Methane (landfill gas) can migrate laterally through porous soil (sand, gravel) around a fill and leave the fills boundaries.

WHERE CAN IT BE FOUND

1. Buildings
2. Pipes
3. Excavations
4. Manholes
5. Up to 1,000 feet from a fill area in non-fill soil

HOW TO CONTROL IT

Major controlling techniques include:

1. Trench Vents - trenches are continuously cut around the landfill and filled with course gravel. Such vents may vent naturally to the atmosphere or may undergo forced convection by mechanical pumping into or out of the trench.

2. Pipe Vents - similar to trenches except that they are placed at intervals around the landfills. Normally some type of convective flow must be used if such pipe vents are to be effective.

3. Barriers - constructed similarly to trench vents except that the trenches are filled with saturated compacted clays or other impervious liner materials.

4. Hybird Systems - a combination of trench vents backed by impervious barriers. The trench vent may or may not involve forced flow.

The costs involved in the construction, maintainance and operation of these control devices vary widely and it is important to optimize design to reduce cost and increase effectiveness.

BOTTOM LINE

Landfill gas (methane) can become a tragedy or become an untapped potential source of energy, helping man.

REV:3/1/78

TABLE 3.2

CONSTRUCTION SAFETY IN AND AROUND ABANDON LANDFILLS

For construction on a known landfill area, the following steps should be taken to prevent injury:

1. A combustible gas indicator must be utilized at all times during trenching or drilling, or when construction occurs within 10 feet of an open excavation.

2. When trenching or drilling deeper than 2 feet into the fill, or in the presence of detectable concentrations of methane, the soils are to be wetted and the operating equipment shall be provided with spark-proof exhausts.

3. Foam fire extinguishers will be provided on all equipment working in the landfill.

4. Personnel within or near an open trench or drill hole will:
   a) Be fully clothed
   b) Wear shoes with non-metallic soles
   c) Wear an organic vapor mask
   d) Wear a hard hat and safety goggles or glasses.

5. Exhaust blowers should be on hand to be used in cases where trenches may show a build-up of methane or a lack of oxygen.

6. Smoking should not be permitted in any area within 500 feet of the excavation.

7. An attempt should be made to keep personnel away from a downwind proximity of any open trench, unless the trench is constantly monitored and declared safe.

8. The operator of trenching equipment should wear an organic vapor and acid gas respirator while operating the equipment in or astride any trench.

9. Before personnel are permitted to enter an open trench, the trench should be carefully monitored for methane and oxygen sufficiency. The personnel should also be provided with a continuous methane and oxygen monitor in their work area as long as they are in the excavation.

For construction near area (within 1000 ft.) of a known landfill area, the following safety precautions should be taken:

1. The areas under construction must be checked with a combustible gas indicator before excavation to determine if methane is in the area.

2. Any excavations must be monitored for methane and oxygen deficiency if personnel are to be sent in. This must be carried out continuously unless the presence of methane in the area can definitely be ruled out.

3. Should methane gas be found in the area, those precautions applicable to digging in the landfill shall also apply to this situation.

Table 7.3

Safety procedures to adhere to when working in landfill generated gas atmospheres.

1. Personal monitoring equipment.

   (a) Tri-techtors a must
   flammable gas
   low O_2
   toxic gas

2. At least one monitor for each work party.

3. All appliances used in landfill generated gas atmospheres, must be explosion proof, i.e., class I, Division I, group C, ord, as per the 1978 NEC.

4. Ventilation a must/minimum of 2500 CFM. Should be increased as excavation of area becomes larger.

5. Entrance into utility line access manhole covers should be done with extreme caution. Sparks can occur from metal manhole covers and rings.

6. Always sample the air in a manhole or confined space with a detector, before entering.

7. If flammable vapors or low oxygen atmosphere conditions prevail, ventilate before entering.

8. Never allow smoking, or open lights in or near excavations or confined spaces.

TABLE 3.4

Gentlemen:

MONITORING OF LANDFILL GAS PROBES FOR PRIVATE SITES

Please be informed that Section III-O-1 of the Minimum Regulations for Sanitary Landfills in the City of Los Angeles as amended by the Board of Public Works on December 7, 1973, states:

> Permittee shall furnish monthly a report signed by a responsible testing company of readings at each of the test holes placed at 300-foot intervals around perimeter of site indicating the amounts of gas or gases present. Said test holes shall be made accessible to authorized representatives of the Board of Public Works for any tests considered necessary and the expense thereof shall be borne by the Permittee."

In conformance with said Regulation, it is your responsibility to ensure that:

1. Monthly gas analyses are performed. You may contract for this service directly with the City's Bureau of Standards or have it performed by a responsible State approved testing laboratory. Reports shall be submitted by the 15th of the following month.

2. You receive a copy of the test results directly from your testing laboratory, and

3. You forward a copy of these results with your monthly report as described in your 1978 permit conditions, to the Bureau of Sanitation, Room 1410, City Hall East, 200 North Main Street, Los Angeles, 90012.

The first reports will be due no later than Aoril 15, 1978. Should you have any questions concerning this request, please contact Mr. Kenneth Kasner on 485-5347.

City of Richmond
Department of Public Safety
Office of the Director

501 North 9th Street, Richmond, Virginia 23219
703 • 649-3621

December 5, 1975

Dear Resident:

As you are aware, notices were distributed in your neighborhood in July and August advising residents to take precautions against the possible accumulation of methane gas. Although we know of no change in the general migration of methane gas in the area, this is to remind you that the need for ventilation is even greater during cold weather. Accordingly, you are again advised to take the following precautions:

1. All basements and crawl spaces should be opened for natural ventilation.

2. All living areas should be ventilated. Where forced air ventilation is not provided, our consultant's staff advises that windows should be opened at least one inch, preferably from the top. Storm windows should also be opened at least one inch. Closet doors should be left open as well.

3. Should you have any questions concerning methane gas in your building, or should you note any unusual odors, please call 649-1111 immediately.

Concentrations of methane gas may be odorless and are not usually dangerous in a well vented area. According to the independent consultant, it is most important that your home, apartment, dwelling or other structure be kept well ventilated at all times.

As a step to alleviate the problem, City Council has authorized initial funding for the establishment of a gas control system. In the meantime, we sincerely appreciate your cooperation in the following the above safety precautions.

Jack M. Fulton
Director of Public Safety

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City of Richmond
Department of Public Safety
Office of the Director

501 North 9th Street, Richmond, Virginia 23219
703 • 649-5621

July 3, 1975

Dear Resident:

According to information furnished by an independent consulting firm, there appears to be reasonable evidence of concentrations of methane gas in an area of approximately two blocks outside of the perimeter of the Falls Street Landfill.

Therefore, you are advised to take the following precautions:

1. All basements and/or crawl spaces should be opened for natural ventilation.

2. Any unusual odors should be reported immediately to 649-9111.

3. All living areas should be ventilated. This means that windows should be left open and closet doors should also be left open.

Concentrations of methane gas are not usually dangerous in a well vented area, according to the independent consultant. Therefore, it is most important that your home or apartment be kept well ventilated at all times.

Your cooperation is sincerely appreciated.

Jack M. Fulton
Director

JMF/wjl

J L Parks
1602 Tyler St.

Los Angeles County

sory structure not intended or used for human occupancy and not exceeding 400 square feet in area nor 12 feet in height.

g. When the work involves the repair of single family residences and accessory buildings where the cost of such repair exceeds 25 percent of the value of the existing building or involves the replacement of such structures where the loss to be replaced was due to causes other than landslide, settlement, or slippage. Before a permit is issued the owner shall:

(1) Record in the office of the Department of Registrar-Recorder (1) a statement that he is the owner and that he is aware that the records of the County Engineer indicate that the property is subject to a physical hazard of a geological nature and (2) an agreement relieving the County and all officers and employees thereof of any liability for any damage or loss which may result from issuance of such a permit. This agreement shall provide that it is binding on all successors in interest of the owner and shall continue in effect until the County Engineer records in the office of the Department of Registrar-Recorder a statement that he finds such hazard no longer exists.

(2) Submit calculations and plans for the proposed reconstruction prepared by a registered civil engineer and designed to minimize damage while accommodating the amount of vertical and horizontal displacements which he determines are probable or which have occurred since the original structure was built, whichever is the greater.

→ (c) Fills Containing Decomposable Material. Permits shall not be issued for buildings or structures regulated by this Code within 1000 feet of fills containing rubbish or other decomposable material unless the fill is isolated by approved natural or man made protective systems or unless designed according to the recommendation contained in a report prepared by a licensed civil engineer. Such report shall contain a description of the investigation, study and recommendation to minimize the possible intrusion, and to prevent the accumulation of explosive concentrations of decomposition gases within or under enclosed portions of such building or structure. At the time of the final inspection, the civil engineer shall furnish a signed statement attesting that the building or structure has been constructed in accordance with his recommendations as to decomposition gases required herein.

Buildings or structures regulated by this code shall not be constructed on fills containing rubbish or other decomposable material unless provision is made to prevent damage to structure, floors, underground piping and utilities due to uneven settlement of the fill. One story light frame accessory structures not exceeding 400 square feet in area nor 12 feet in height may be constructed without special provision for foundation stability. ←

(d) Conditional Use. Work required by this Section as a condition for the use of the site shall be performed prior to the connection of the utilities or occupancy of the building.

SEC. 309 — GEOLOGICAL ENGINEERING REPORTS

The Building Official may require a geological or engineering report, or both, where in his opinion such reports are essential for the evaluation of the safety of the site. A geological report shall be prepared by a certified engineering geologist licensed by the State of California. The report shall contain a finding regarding the safety of the building site for the proposed structure against hazard from landslide, settlement, or slippage and a finding regarding the effect that the proposed building or grading construction will have on the geologic stability of property outside of the building site. An engineering report shall be prepared by an engineer experienced in soil mechanics. When

Necessary Changes to SWD S&F Regulations for
Methane Landfill Gas Control and
Hazardous Waste Disposal Control

I. Section 2(2)N. Redefine "Hazardous material and toxic substances" to read "are liquids, gases, or solids which can be dangerous to man, animal, and plantlife."

II. Section 4, add,

1. "The design of a solid waste disposal facility shall be such as to minimize dangers from the production and migration of landfill decomposition gases. No person shall operate a solid waste disposal site and/or facility without the submission to the Department and subsequent approval of a plan to provide for the monitoring and control of landfill decomposition gases. The design and location of any proposed solid waste disposal site or that portion of an existing site not utilized shall be based on the consideration of geological and hydrological data so as to minimize the uncontrolled off-site migration of landfill decomposition gases. The design of a control system shall limit off-site migration of flammable gas not to exceed the applicable LEL standard.

III. Section 6.C Five new subsections with relettering.

6h. A landfill decomposition gas monitoring system which will indicate the presence or absence of uncontrolled off-site migration of landfill decomposition gases.

6i. A list of all materials that will be accepted for disposal at the site or facility including types of industrial hazardous materials and toxic substances, and their estimated volumes (annual).

6j. Segregation of materials for disposal which are not compatible or require special handling due to their chemical or physical nature.

6k. Procedures for implementing other aspects of the design.

6l. Other matters which the Department determines are important for the protection of public health, safety, and the environment.

IV. Section 7. Add new subsection.

C. Upon closure of a site used for solid waste disposal, the County Clerk and Recorder should note on the appropriate property records

that the parcel of land has been used as a solid waste disposal site. Any contract for sale of any land which has been previously used as a solid waste disposal site, for it to be duly recorded in the county files, should contain a notice that the parcel of land has been used as a solid waste disposal site. Such notation in both the contract for sale and the county records should state that special precautions may be required due to decomposition gas production and migration and the storage of potentially hazardous materials or toxic substances.

V. Section 8. Completely rewritten.

8a. Upon a determination that a solid waste disposal site or facility is not being operated in compliance with the Engineering Report Design Criteria, the approved Operational Plan, or these regulations, the operator shall be informed of the nature of the alleged violation or violations by registered mail. Within 30 days of the receipt of the letter of citation the operator shall submit a written response to the Department specifying the actions taken or a plan of action to be taken to bring the site or facility into compliance with regulatory requirements stated herein.

8b. In the case where a variance from the provisions of these regulations is requested and deemed appropriate and where the protection of public health, safety or the environment is not jeopardized, a variance may be granted by the Department.

8c. In the case where a variance from the regulatory requirements is not authorized by the Department, an administrative hearing shall be scheduled. If an operator fails to bring the solid waste disposal site or facility into substantial compliance with the regulatory provisions of these regulations and 30-20, Part 1, CRS, 1973, the operator shall be deemed to be in violation of the law and these regulations and the "Certificate of Designation" shall be subject to suspension, revocation or injunction as provided in 30-20-113, CRS, 1973, and other such penalities as provided in 30-20-114, CRS, 1973. The Department shall keep the Certificate of Designation issuing authority informed on the compliance status of all solid waste disposal sites and facilities within their respective jurisdictions. Upon a determination as provided for in d), above, Section 9 of these ragulations, or in the case of violations of 30-20-102, CRS, 1973, the Department shall officially request the local government at interest to take the appropriate action under the provisions of Title 30, Article 20, Part 1, CRS, 1973.

VI. Section 9. Complete new section.

Section 9. Determinations.

9a. Mine wastes disposal sites, new or abandoned, shall be evaluated for a determination of the existence of a public nuisance upon a complaint or indication by the state or local government that a public nuisance might exist. Significant degradation of the environment under the environmental regulations of the state shall be due and justifiable reason for declaration of a public nuisance by the Department.

9b. Landfill decomposition gases in an occupiable structure or appurtenance in excess of 20% of the Lower Explosive Level (LEL) as indicated by appropriately calibrated measuring devices shall constitute a determination of a potential health hazard warranting notification by state and local government, or municipal agencies to the parties responsible for taking corrective or preventative measures to preclude existence of the potential hazard for that structure or appurtenance.

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Sec. 6-61. Barbed wire.

Barbed wire or similar materials may be used at a height of not less than six (6) feet above grade within commercial or industrial districts, as defined by the city zoning ordinance, within the city. (Ord. No. 8-1959, § 4, 5-18-59)

Secs. 6-62—6-69. Reserved.

Article IV. Building on Fills*

Sec. 6-70. Permit required; application; contents; plans and specifications.

(a) *Permit required.* No person, firm, partnership, or corporation shall erect, construct, enlarge or alter any building or structure in the city on land previously used for a sanitary landfill or on fills containing rubbish or other decomposable material, or cause the same to be done, without first obtaining a special permit for construction on a fill from the building official.

(b) *Application.* To obtain a permit for construction on a fill, the applicant shall first file an application therefor in writing on a form furnished for that purpose. Every such application shall:

(1) Identify and describe the work to be covered by the permit for which application is made;

(2) Describe the land on which the proposed work is to be done, by lot, block, tract, and house and street address, or similar description that will readily identify and definitely locate the proposed building or work;

(3) Indicate the use or occupancy for which the proposed work is intended;

(4) Be accompanied by plans and specifications as required in subsection (c) of this section;

*Amendment note—Ord. No. 8-1972, § 1, adopted April 10, 1972, amended this Code by adding Art. IV, §§ 8-70—8-72. Effective date provisions were omitted from codification.

(5) State the valuation of the proposed work;

(6) Be signed by the permittee, or his authorized agent, who may be required to submit evidence to indicate such authority;

(7) Give such other information as reasonably may be required by the building official.

(c) *Plans and specifications required.* With each application for a permit for construction on a fill, two (2) sets of plans and specifications, prepared and designed by an engineer or architect licensed by the State of Colorado to practice as such, shall be submitted.

(d) *Information on plans and specifications.* Plans and specifications shall be drawn to scale upon substantial paper or cloth and shall be of sufficient clarity to indicate the nature and extent of the work proposed and show in detail that it will conform to the provisions of the building code of the City of Sheridan, and all relevant laws, ordinances, rules and regulations. The first sheet of each set of plans shall give the house and street address of the work and the name and address of the owner and person who prepared them. Plans shall include a plot plan showing the location of the proposed building and of every existing building on the property. Computations, stress diagrams, and other data sufficient to show the correctness of the plans, shall be submitted when required by the building official.

(e) *Engineering reports.* In order to evaluate the potential hazard to a structure from landslide, a settlement, slippage, gas production or gas movement from a fill, an engineering report prepared by a licensed professional engineer shall be submitted evaluating the safety of the site. This report shall include:

(1) A gas movement survey conducted at the site of the fill assessing the present gas penetration and the potential gas penetration as well as the possibility of occurrence of any gas hazards;

(2) Recommendations for preventing the accumulation of decomposition gases within or under enclosed portions of the proposed building or structure;

(3) Recommendations for preventing damage to structure, floors, underground piping and utilities due to uneven settlement of the fill. (Ord. No. 6-1972, § 1, 4-10-72)

Sec. 6-71. Review of application, plans and specifications; issuance, duration of permit.

(a) *Issuance of permit.* The application, plans, specifications and reports filed by an applicant for a permit shall be checked by the building official. Such plans may be reviewed by other departments of the city to check compliance with the laws and ordinances under their jurisdiction. If the building official is satisfied that the work described in an application for permit and the plans filed therewith conform to the requirements of other pertinent laws and ordinances, and that the structure is designed to provide proper ventilation beneath and in the structure, or constructed on a foundation either naturally impervious or so created through design and construction, so that explosive gases can not be trapped or accumulated in or under the structure, and the structure can not be damaged by uneven settlement of the fill, he shall issue a permit therefor to the applicant.

When the building official issues the permit, he shall endorse in writing or stamp on both sets of plans and specifications "APPROVED". Such approved plans and specifications shall not be changed, modified or altered without authorization from the building official, and all work shall be done in accordance with the approved plans.

(b) *Expiration.* Every permit issued by the building official under the provisions of this Code [article] shall expire by limitation and become null and void if the building or work authorized by such permit is not commenced within sixty (60) days from the date of such permit, or if the building or work authorized by such permit is suspended or abandoned at any time after the work is commenced for a period of one hundred and twenty (120) days. Before such

work can be recommenced, a new permit shall be first obtained so to do and the fee therefor shall be one-half (½) the amount required for a new permit for such work, provided no changes have been made or will be made in the original plans and specifications for such work; and provided, further, that such suspension or abandonment has not exceeded one year. (Ord. No. 6-1972, § 1, 4-10-72)

Sec. 6-72. Permit fee.

A fee for a permit for construction on a fill is one hundred dollars ($100.00), and shall be paid to the building official upon filing of the application. The fee is nonrefundable and is in addition to a building permit fee. (Ord. No. 6-1972, § 1, 4-10-72)

Secs. 6-73—6-79. Reserved.

ARTICLE V. MECHANICAL CODE*

Sec. 6-80. Adoption of code.

The Uniform Mechanical Code, 1973 Edition thereof, published by the International Association of Plumbing and Mechanical Officials, at least three (3) copies of which have been certified as true copies by the mayor and city clerk, and are now on file in the office of the city clerk, is hereby enacted and adopted by reference as the mechanical code of the City of Sheridan, and the same is hereby incorporated herein. In the event of conflict between the provisions of such mechanical code and the provisions of this Code of Ordinances, state law and city ordinances, rules and regulations, the provisions of this Code of Ordinances, state law and city ordinances, rules and regulations shall prevail and be controlling. (Ord. No. 6-1974, § 1, 2-26-74)

*Editor's note—Ord. No. 6-1974, § 1, enacted Feb. 26, 1974, amended Ch. 6 by adding Art. V, §§ 6-80—6-87, as herein set out.

COLORADO DEPARTMENT OF HEALTH
Water Quality Control Commission
4210 East 11th Avenue
Denver, Colorado 80220
Adopted: November 21, 1976
Format changed: January 4, 1977

7.1.0 GUIDELINES AND CRITERIA FOR REVIEW OF SOLID WASTE DISPOSAL FACILITIES FOR WATER QUALITY CONTROL SITE APPROVAL

7.1.1 AUTHORITY: Sections 25-8-202(1)(c) and 25-8-205(1)(c), C.R.S. 1973, as amended.

7.1.2 INTRODUCTION:

(1) Under certain geological conditions, the burial of solid wastes presents a high potential for chemical and bacteriological pollution of ground and surface water. Observations of groundwater pollution from sanitary landfills have indicated that if a sanitary landfill is intermittently or continuously in contact with groundwater, the groundwater can become grossly polluted and unfit for domestic or other use. Proper site selection combined with good design and operation of the sanitary landfill can normally eliminate the possibility of either surface or groundwater pollution.

(2) The purposes of this publication are:

(a) To specify minimum technical information required for Division review of applications for solid waste disposal sites; and

(b) To limit values for certain factors upon which an evaluation of such applications may be made by reviewing authorities. When the term "shall" or "must" is used, it means a mandatory requirement insofar as confirmatory action by the Division is concerned. Other terms such as "should, recommended, preferred" and the like indicate discretionary use on the part of the Division.

(3) Factors which must be considered in the selection of a site include topography, climatology, geology and hydrology. Singly or in combination, these factors may preclude some locations as solid waste disposal sites due to the possibility of pollution of underground and/or surface water. Since the possibility of actual pollution of the waters of the State may depend upon the interrelationship of the factors above, it is not possible to specify criteria for every factor at every site. The suitability of a location for a solid waste disposal

site will, therefore, depend upon the conditions unique to each site. Each site will be evaluated on its own merits, taking account of the protective features of the design.

(4) If an applicant presents to the Department an application for a landfill site which, while not specifically complying with all mandatory limitations herein contained, complies with the objectives of these criteria, the Division may approve such site with such conditions as the Division may consider appropriate. Although applicants are encouraged to develop innovative approaches to the design of the facility, practices which have stood the test of time are preferred. Some of these are:

(a) Locating the site outside the flood plain at a safe distance from streams, lakes, wells, and other water sources;

(b) Avoiding sites above subsurface formations that may conduct leachate from the landfill to water sources, i.e., fractured limestone;

(c) Using an earth cover that is nearly impervious;

(d) Providing surface drainage facilities to prevent surface water entering the site.

7.1.3 SITE ANALYSIS AND LANDFILL DESIGN:

Technical information on site conditions and details of landfill design accompanying a site application shall be prepared by a professional person qualified by training and experience who shall attest, by signature, to the accuracy of data submitted, and the competency of analyses and designs proposed.

7.1.4 INFORMATION ON SITE:

Data to be submitted shall include but not be limited to:

(1) The general climatology of the area, including but not limited to: average annual precipitation, monthly distribution of precipitation, frost depth and average snow depth and water content.

(2) A scaled map of the area showing surface contours (2 ft. interval), location of streams, lakes, reservoirs, intermittent streams, roads, water wells and buildings with 1/2 mile of the proposed site and the location of the proposed site.

(3) Geological information shall include a log and physical description of the soil down to the bedrock formation, depth and thickness of all formations from the surface to and including the first aquifer, amount and direction of dip of surface and subsurface formations, faults or fractures.

(4) Surface water hydrology shall include but not be limited to: estimated maximum rate and direction of surface runoff through the site on 50-year frequency; historical flow of surface streams, ditches, drains, canals within 1/2 mile of the site; and pertinent hydrologic data on lakes or other surface water bodies within one half mile of the site.

(5) Groundwater hydrology shall include data on water table elevation and its annual fluctuations; piezometric surface and gradients in vicinity of the site; and hydraulic conductivity of all major strata between the land surface and bedrock (or to 30 feet depth).

7.1.5 DESIGN INFORMATION AND CRITERIA:

(1) Sanitary landfills shall be constructed in such a way as to prevent surface or groundwater from entering or leaving the landfill. Protective works for surface waters shall be designed for peak discharge expected with fifty-year frequency.

(2) Design shall show that saturation will not occur in the formation at the bottom of the landfill. Otherwise, an impermeable barrier shall be provided.

(3) Landfills shall not be located adjacent to stream, lakes, reservoirs, unless protective dikes are provided or natural barriers exist to prevent washing of the material into the waters of the State.

(4) Where dry arroyos are selected for disposal sites, the design must provide a positive means of preventing washing of the solid wastes downstream in periods of runoff based on the fifty-year peak discharge. Where dry arroyos are used, the disposal site should be in the upper end of the drainage basin.

(5) Construction details shall show the elevation of the bottom of the fill site in relation to the first aquifer, the present surface contours, the final cover and surface runoff diversions during operation and after completion and closing of the site. If an artificial seal (membrane, clay, asphalt liners, etc.) is proposed, detailed specifications on materials and installation

shall be provided. Construction and operation procedures shall be given, which preclude puncturing by hydrostatic pressures or equipment or hydrostatic uplift damage.

(6) Where a water table exists within 7.0 feet of the bottom of the disposal site, a monitoring well for ground water sampling shall be provided within 100 feet downstream from the site in relation to the direction of flow of groundwater. The well shall be cased with non-corrosive material, perforated through its contact with groundwater, and with a lock cover provided. The casing shall be a minimum of four inches in diameter.

(7) Construction and operation shall be such that flow of water through fill is prevented. Cover material shall be impervious and compacted to provide a tight surface seal of material which will not crack when dry. It shall be free of putrescible materials and large rocks, stones or other objects. Final surface grade shall compensate for expected settlement of the fill, provide runoff of surface water and prevent ponding on the fill area. Diversion ditches and dikes shall be provided on the upslope sides of the disposal area to divert surface runoff around the site both during operation and after the site is closed.

federal register

Part 254
FRIDAY, OCTOBER 21, 1977

ENVIRONMENTAL PROTECTION AGENCY

Office of Solid Waste

PRIOR NOTICE OF CITIZEN SUITS

[6560-01]

SUBCHAPTER I—OFFICE OF SOLID WASTE

[FRL 802-4]

PART 254—PRIOR NOTICE OF CITIZEN SUITS

AGENCY: Environmental Protection Agency.

ACTION: Final regulations.

SUMMARY: The Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, authorizes suits by private citizens to enforce the Act. These suits may be brought where there is alleged to be a violation by any person (including (a) the United States, and (b) any other governmental instrumentality or agency, to the extent permitted by the eleventh amendment to the Constitution) of any permit, standard, regulation, condition, requirement, or order which has become effective under the Act, or a failure of the Administrator to perform any act or duty under the Act which is not discretionary with the Administrator. These actions are to be filed in accordance with the rules of the district court in which the action is instituted.

The Act further requires that certain notification requirements must be met before any action may be commenced. These regulations outline the procedures to be followed and prescribe the information to be contained in the notices.

EFFECTIVE DATE: November 21, 1977.

FOR FURTHER INFORMATION CONTACT:

Mr. Jeffrey L. Hilliker, EPA, OSW, Management and Information Staff (WH-562), 401 M Street SW., Washington, D.C. 20460, 202-755-9173.

SUPPLEMENTARY INFORMATION: On page 37214 of the FEDERAL REGISTER of July 20, 1977, the Environmental Protection Agency published proposed regulations for section 7002 of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of

1976 (40 CFR Part 254). These regulations are intended to advise prospective litigants of the procedures to be followed in notifying alleged violators of any of the provisions of the Act. The notification requirements of section 7002 are intended to provide alleged violators a time period within which to rectify any violations of the Act so they may avoid litigation if at all possible.

The three comments which were received advocated either additional language or revision of existing language. As discussed below, two of these suggestions were rejected as requiring too stringent a notification procedure and the third was adopted due to its clarifying nature.

DISCUSSION OF COMMENTS

One commenter requested that the words "site manager" be substituted for the words "managing agent" in § 254.2 (1), line 6. Since this phrase is more descriptive of the individual to whom notice should be delivered than the proposed language, the recommended change was made.

The same commenter further requested that a new § 254.4(a) be added as follows:

(a) With respect to any notice sent pursuant to §§ 254.2(a)(2) and 254.2(3) a copy of that notice shall also be mailed to the private individual(s) or corporation(s) named in or affected by the notice, or alleged in such notice to be responsible for any violation.

This suggestion was rejected for the reason that it would be unduly burdensome to require a complainant under section 7002 of the Act to determine all persons who might be affected by an alleged violation of the Act, and to notify them.

A second commenter suggested that the following words be inserted in § 254.3(a):

the exact nature of the activity alleged to constitute a violation, *the information and/or data upon which the allegation is based,* * * *

The insertion of the first phrase was rejected because the proposed wording of this section already requires the complainant to divulge sufficient information to the alleged violator to identify the activity alleged to constitute the violation. The insertion of the second phrase was rejected because the procedures required by these regulations merely constitute preliminary notification of an intent to sue. If and when a suit is actually filed, facts of a more specific nature such as the information and/or data upon which the allegation is based will be required to be alleged under the Federal Rules of Civil Procedure. Such formal requirements, however, should not attach until the district court obtains jurisdiction over the matter.

Accordingly, 40 CFR Chapter I is amended by adding a new Part 254, reading as follows:

Sec.
254.1 Purpose.
254.2 Service of notice.
254.3 Contents of notice.

AUTHORITY: Sec. 7002, Pub. L. 94-580, 90 Stat. 2823 (42 U.S.C. 6972).

§ 254.1 Purpose.

Section 7002 of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, authorizes suit by any person to enforce the Act. These suits may be brought where there is alleged to be a violation by any person (including (a) the United States, and (b) any other governmental instrumentality or agency, to the extent permitted by the eleventh amendment to the Constitution) of any permit, standard, regulation, condition, requirement, or order which has become effective under the Act, or a failure of the Administrator to perform any act or duty under the Act, which is not discretionary with the Administrator. These actions are to be filed in accordance with the rules of the district court in which the action is instituted. The purpose of this part is to prescribe procedures governing the notice requirements of subsections (b) and (c) of Section 7002 as a prerequisite to the commencement of such actions.

§ 254.2 Service of notice.

(a) Notice of intent to file suit under subsection 7002(a)(1) of the Act shall be served upon an alleged violator of any permit, standard, regulation, condition, requirement, or order which has become effective under this Act in the following manner:

(1) If the alleged violator is a private individual or corporation, service of notice shall be accomplished by registered mail, return receipt requested, addressed to, or by personal service upon, the owner or site manager of the building, plant, installation, or facility alleged to be in violation. A copy of the notice shall be mailed to the Administrator of the Environmental Protection Agency, the Regional Administrator of the Environmental Protection Agency for the region in which the violation is alleged to have occurred, and the chief administrative officer of the solid waste management agency for the State in which the violation is alleged to have occurred. If the alleged violator is a corporation, a copy of the notice shall also be mailed to the registered agent, if any, of that corporation in the State in which such violation is alleged to have occurred.

(2) If the alleged violator is a State or local agency, service of notice shall be accomplished by registered mail, return receipt requested, addressed to, or by personal service upon, the head of that agency. A copy of the notice shall be mailed to the chief administrator of the solid waste management agency for the State in which the violation is alleged to have occurred, the Administrator of the Environmental Protection Agency, and the Regional Administrator of the Environmental Protection Agency for the region in which the violation is alleged to have occurred.

(3) If the alleged violator is a Federal agency, service of notice shall be accomplished by registered mail, return receipt requested, addressed to, or by personal service upon, the head of the agency. A copy of the notice shall be mailed to the Administrator of the Environmental Protection Agency, the Regional Administrator of the Environmental Protection Agency for the region in which the violation is alleged to have occurred, the Attorney General of the United States, and the chief administrative officer of the solid waste management agency for the State in which the violation is alleged to have occurred.

(b) Service of notice of intent to file suit under subsection 7002(a)(2) of the Act shall be accomplished by registered mail, return receipt requested, addressed to, or by personal service upon, the Administrator, Environmental Protection Agency, Washington, D.C. 20460. A copy of the notice shall be mailed to the Attorney General of the United States.

(c) Notice given in accordance with the provisions of this part shall be considered to have been served on the date of receipt. If service was accomplished by mail, the date of receipt will be considered to be the date noted on the return receipt card.

§ 254.3 Contents of notice.

(a) *Violation of permit, standard, regulation, condition, requirement, or order.* Notice regarding an alleged violation of a permit, standard, regulation, condition, requirement, or order which has become effective under this Act shall include sufficient information to permit the recipient to identify the specific permit, standard, regulation, condition, requirement, or order which has allegedly been violated, the activity alleged to constitute a violation, the person or persons responsible for the alleged violation, the date or dates of the violation, and the full name, address, and telephone number of the person giving notice.

(b) *Failure to act.* Notice regarding an alleged failure of the Administrator to perform an act or duty which is not discretionary under the Act shall identify the provisions of the Act which require such act or create such duty, shall describe with reasonable specificity the action taken or not taken by the Administrator which is claimed to constitute a failure to perform the act or duty and shall state the full name, address, and telephone number of the person giving the notice.

(c) *Identification of counsel.* The notice shall state the name, address, and telephone number of the legal counsel, if any, representing the person giving the notice.

Dated: October 17, 1977.

DOUGLAS M. COSTLE,
Administrator.

[FR Doc.77-30718 Filed 10-20-77;8:45 am]

CHAPTER 4

RECOVERY

4.0 Recovery*

The energy recovery process og gas withdrawal from constructed sanitary landfills promises to produce only 10 to 15% of the energy available by direct burning of municipal waste. This decomposition gas is a resource which is now being completely wasted and which contributes to air and water pollution; it still offers a potential economical source of fuel which is worth considering.

In earlier years when dumps were undergoing the conversion to sanitary landfills, there was some reluctance on the part of disposal site operators to discuss or acknowledge the existence of landfill generated gas. The gas, however, can be controlled by properly engineered systems and combined with the national energy situation, has awakened much interest in the industry for turning this dubious characteristic of sanitary landfills into a useful asset.

Gas generation in landfills is site specific and production may range from a few years to hundreds of years in certain environments which carries with it a joint liability. Potential gas production quantity alone does not determine whether the effect of gas production will be significant, however, the quantity of gases present at a given time will be more dependent upon the rate of the decomposition process. This rate can be generally expressed as: rate = (k) x (organice content of wastes). The magnitude of the proportionally constant, k, is dependent on several factors. The most important factors which affect this term are the moisture content of a landfill and temperature.

*Principal input to this section taken from papers presented to IMTF from Mr. John Pacey, EMCON Associates.

Recovery of methane from landfills is feasible but practical engineering considerations may limit production to only a fraction of the theoretical maximum. The practical engineering problems occur both in the collection and refining must be resolved in explorating this waste produced fuel gas. Many variables occur in the operation and those facilities in operation have produced less than the design capacity of the facility.

4.1 Incentives

Some would say that recovery is the current approach to dealing with an undesirable product such as solid wastes. Recovery should not only be considered in its own merits but on the economy of the cost of the control systems for the hazardous liability vs. that portion necessary to recover the gas. The positive view proposed is that the cost of a control system must be considered as a sunk cost to cover liabilities. Thus the incremental cost to recover the gas should be an important factor in the decision because it is a supplemental to the initial investment in the control system, to receive income from the sale of the collected gas.

This incremental cost as a minimum would include an increase in the gas collection system, a processing plant and a direct use or gas transmission system, and most important factor, a long-term contract.

The success of such a project, of course, hinges on a number of factors including, but not limited to, the following:

(1) obtaining a buyer for the gas;
(2) securing an adequate sales contact;
(3) obtaining sufficient capital and an adequate line of credit;
(4) obtaining pipeline right-of-way;
(5) meeting regulatory requirements for environmental security and legal actions;
(6) having gas sales rights;
(7) comprehensive testing for the quantity and quality of gas;
(8) obtain permits;
(9) public support.

Landfill gas has many variables associated with it which will result in a need for a compliance feasibility study and mandate analysis.

4.2 The Feasibility Study

4.2.1 Gas Quantity

Experts in the field of gas recovery differ in their assessment of the quantity of gas recoverable from a given volume of refuse. The rate of gas recovery from operating as well as recently closed land fills ranges from a low of 0.02 cubic feet of methane per year per pound of refuse (40 cubic feet per year per ton) to a high of 0.12 cubic feet per year per pound (200 cubic feet per year per ton)

For comparative purposes, the pertinent data for other recovery projects are presented in Table _____.

As previously noted, the important parameters affecting methane production include refuse composition, moisture content, level of oxygen present, environmental pH, nutrient availability, alkalinity, temperature, toxicity. The ability to enhance production is related to successful management of these parameters in a practical and cost-beneficial manner.

One means of increasing production is to change the composition mix by increasing the organic content of its waste. This may be achieved by sewage sludge addition, removal of ferrous ad nonferrous metals, separation of heavy and light material, and use of less cover soil; the total theoretical production per unit volume will increase accordingly.

Although a gas ehancement program may require additional management and increased costs, it offers some significant advantages, including (1) increases quantity of methane per unit volume of refuse, and (2) shorter time frame of production. This latter feature correlates with a shorter decomposition time, therefore, earlier end-use potential of the land, and shorter time frame for a hazard control program.

The need for methane enhancement relates to the community need for natural gas; as the supply of gas dwindles, the demand will increase. Thus, gas enhancement programs will depend o community need and the public's willingness to supprt the concept.

4.2.2 Gas Quality Incentives

Moisture content, level of oxygen and availability of nutrients affect the efficiency and time-rate of decomposition and, hence, the gas production and gas quality. The most efficient moisture content for methane production is achieved when the landfill is near saturation; therefore, moisture management is very important. Certain heavy metals are toxic to bacteria, and oxygen is toxic to all methane-forming bacteria and to some organic acid-forming bacteria; hence, exclusion of these substances must be managed. Nutrient availability, although usually adequate, is far more effective if constantly circulated, such as occurs in a recirculation program.

The recovered gas should be nearly saturated, and consist of 40% to 50% methane; 40% to 50% carbon dioxide; and contain less than 5% of other gases, principally nitrogen and oxygen. This flow stream should be valid for 15 years or more following steady state methane production.

Carbon dioxide is generated in the landfill in approximately the same percentage as methane 45 to 55 percent); therefore, one of the major efforts in upgrading methane gas quality is to separate the carbon dioxide from the methane.

A number of solvent treatment systems are available, including Methyl Ethanol Amine - Diethanol Amine Absorption (MEA-DEA), Diglycolamine (DGA), Hot Potassium Carbonate, propylene Carbonate, Seloxol, and Fluor Solvent. All of these systems utilize a liquid solvent that has an affinity for carbon dioxide, hydrogen sulfide and, in some instances, water. The solvent has minimal affinity for methane; thus the methane is effectively separated from the other gases.

Dry adsorbent systems can also be used where molecular sieve, activated charcoal or other appropriate adsorbents remove the contaminants. As an example, the molecular sieve has a microscopic honeycomb structure that traps (adsorbs) molecules according to their size and polarity. Some molecules, including carbon dioxide, hydrogen sulfide and water, are more readily adsorbed than othrs such as methane, thus allowing the landfill gas contaminants to be selectively removed. In all instances, the solvent or adsorbent is regenerated and rcycled, the latter being regenerated through vacuum evacuation and/or thermal regeneration. The resulting contaminated gas or solvent is freed and discharged in an environmentally safe manner. Each of the process should be evaluated on its own merit, with special consideration for the economics, environment constraints and process reliability. For each individual prospective project this, in turn, must be weighed against other utilization mode alternatives. Research is presently ongoing in this area to build a cheaper efficient CO_2 filter.

4.2.3 Economic Feasibility

One of the major factors in the search for a buyer is questions of low BTU vs. high BTU. There is much to be said for the low BTU considerations. The low BTU has much in its favor such as:

1. The modular low BTU gas facility is the lowest capital investment alternative.

2. Gas sales can be negotiated strictly on supply and demand.

3. Landfill gas recovery projects operating at this time are overcapitalized and/or over-designed for the available gas that can be recovered.

4. The collection system and other components of the modular unit can be designed for much higher capacity at a minimum cost. Such a system could be easily modified for higher capacity or conversion to a gas purification facility or some combination of the two.

5. The modular unit could be skid-mounted and would thus have a high salvage/resale value should unforeseen events necessitate termination of the project.

6. Higher capital cost programs such as the expanded low BTU program or a pipeline quality purification facility could be negotiated at a time when natural gas prices are much higher (and hence demand greater).

7. The modular approach to developing recovery facilities shoudl more than pay for itself within a relatively short period of time.

What are the alternatives to the problem methane generating landfill with regards to operation? Some of the major options are:

a. Establish your own recovery program based on the preliminary findings of the feasibility study.

b. Entertain a parternship-type arrangement.

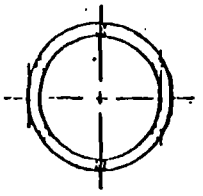
c. Lease the landfill for commercial gas extraction.

TABLE 3

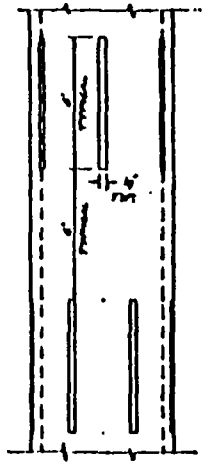
LANDFILL GAS RECOVERY COMPARISON DATA

Landfill Name	Year Fill Began	Year Fill Completed	Refuse In Place (tons x 10^6)	Surface Area (Acres)	Average Thickness of Refuse (ft)	Predicted Methane Extraction Rate (cfm)	Annual Methane Production per Pound of refuse* (ft^3/lb/yr)
Azuza Western Azuza, CA	1953	Still Filling	6.6	55	120	900	0.04
Bradley Sun Valley, Ca	1960	Still Filling	8.3	60	120	1300	0.04
Coyote Canyon Irvine, CA	1964	1981 (est.)	21.6	400±	NA	3300	0.04
Hewitt Los Angeles, CA	1962	1975	6.2	60	100	1000	0.04
Mountain View Mountain View, CA	1975±	1975±	0.8	20	40	350	0.12
Palos Verdes Rolling Hills Estates, CA	1957	1975	3.8	31.5	100	700	0.05
Scholl Canyon Glendale, CA	1963	1974	4.7	45	90	400	0.02
Sheldon Arleta Los Angeles, CA	1962	1974	3.0	36.4	85	1000	0.09

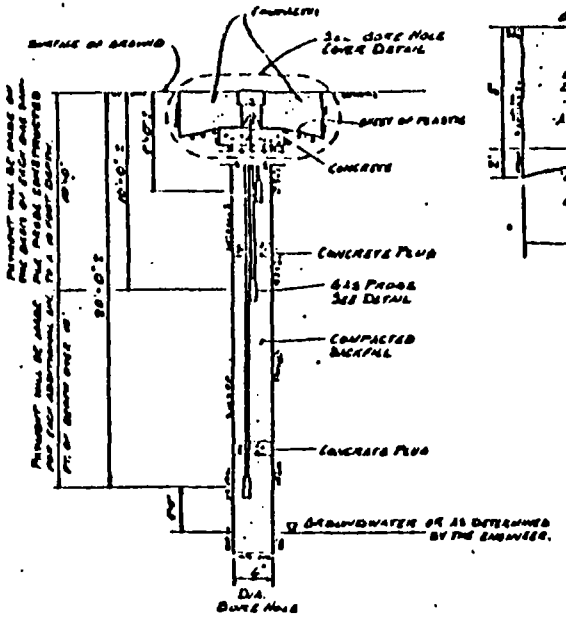
*Figures based on published or latest available data, including personal communication.



PLAN



TYPICAL PERFORATION DETAIL
No Scale



TYPICAL GAS SAMPLE PROBE INSTALLATION
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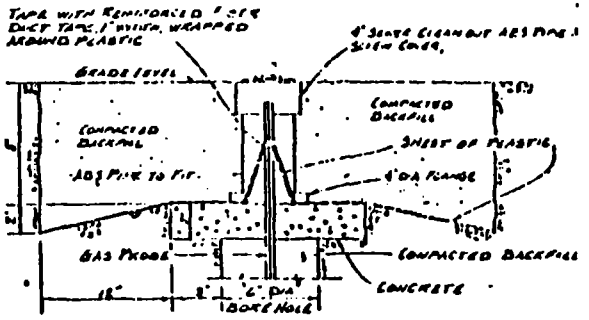
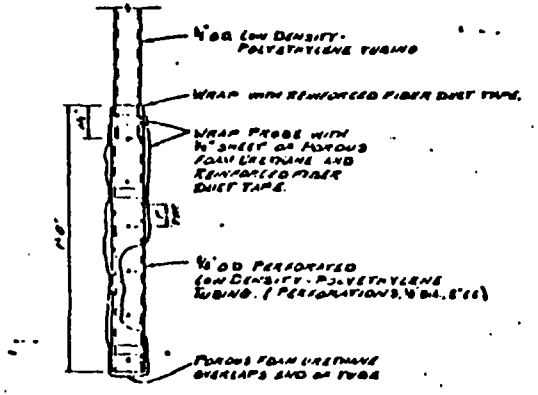
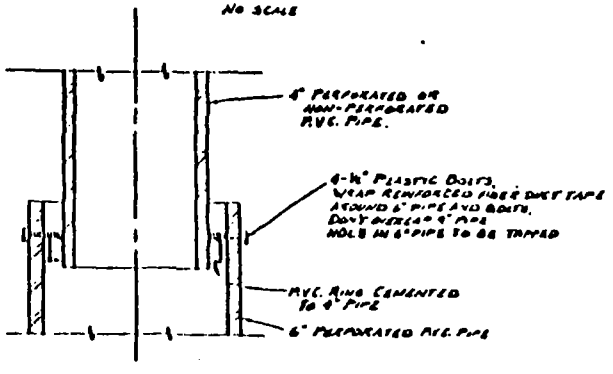
Not Included in Contract



BORE HOLE COVER DETAIL
No Scale
Not Included in Contract



GAS PROBE DETAIL
No Scale
Not Included in Contract



COUPLER DETAIL
No Scale

TAL. 2

COMPARATIVE GAS RECOVERY DATA
DENVER AREA LANDFILLS

Landfill	Surface Area (Acres)	Average Depth (ft)	Volume (cu.ydsx10^6)	Refuse In Place (tonsx10^6)	Predicted Methane Extraction Rate (cfm)	Estimated Annual Methane Production Rate[1] Per Pound of Refuse (ft^3/lb/yr)
Adams County 60th	72	16	2.0	1.1	165	.04
Western Paving 61st	30	25	1.2	0.7	105	.04
P.I.I.-62nd 62nd	45	25	1.8	1.0	150	.04
B.F.I.-64th 64th	85	25	3.4[2]	1.9[2]	285	.04
48th & Holly	100	40	6.4	3.5	525	.04
Arapco	104	30	5.0	2.8	420	.04
Mile High	90	35	5.0	2.8	420	.04

1. Production rate might be as much as 2 to 3 times that indicated depending on many factors. P.I.I. apparently can yield on a sustained basis in excess of 350 cfm.
2. Anticipated volume and tonnage.

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TABLE A-1

LANDFILL GAS COMPOSITION DATA

LANDFILL	Methane %	Carbon Dioxide %	Nitrogen %	Oxygen %	Other %
Azuza Western Azuza, CA	50	50	-	-	-
Bradley Los Angeles, CA	50	50	-	-	-
Hewitt Los Angeles, CA	45	55	-	-	-
Mountain View Mountain View, CA	44	34	21	1	-
Palos Verdes, Rolling Hills, CA	53	43	3	-	1
Scholl Canyon Glendale, CA	40	51	7	2	-
Sheldon Arleta Los Angeles, CA	55	45	-	-	-
P.I.I. Denver, CO	45	55	-	-	-
G.R.O.W.S. Morristown, PA	46	53	1	-	-

established at 2 percent.

With the above findings and control criteria in mind, a number of alternatives were reviewed. The three most promising were then selected for comparison purposes. The three candidate systems are graphically shown in Figures 9-11 and include: (1) control well system, (2) combined control well-vent/barrier trench system, and (3) an extraction well-process-sale system. These three systems were then analyzed on a matrix basis, whereby they were compared on numerous parameters. A discussion of the matrix evaluation system is presented in Appendix E. While the system is somewhat subjective, it nevertheless addresses many of the relevant considerations.

TABLE 1

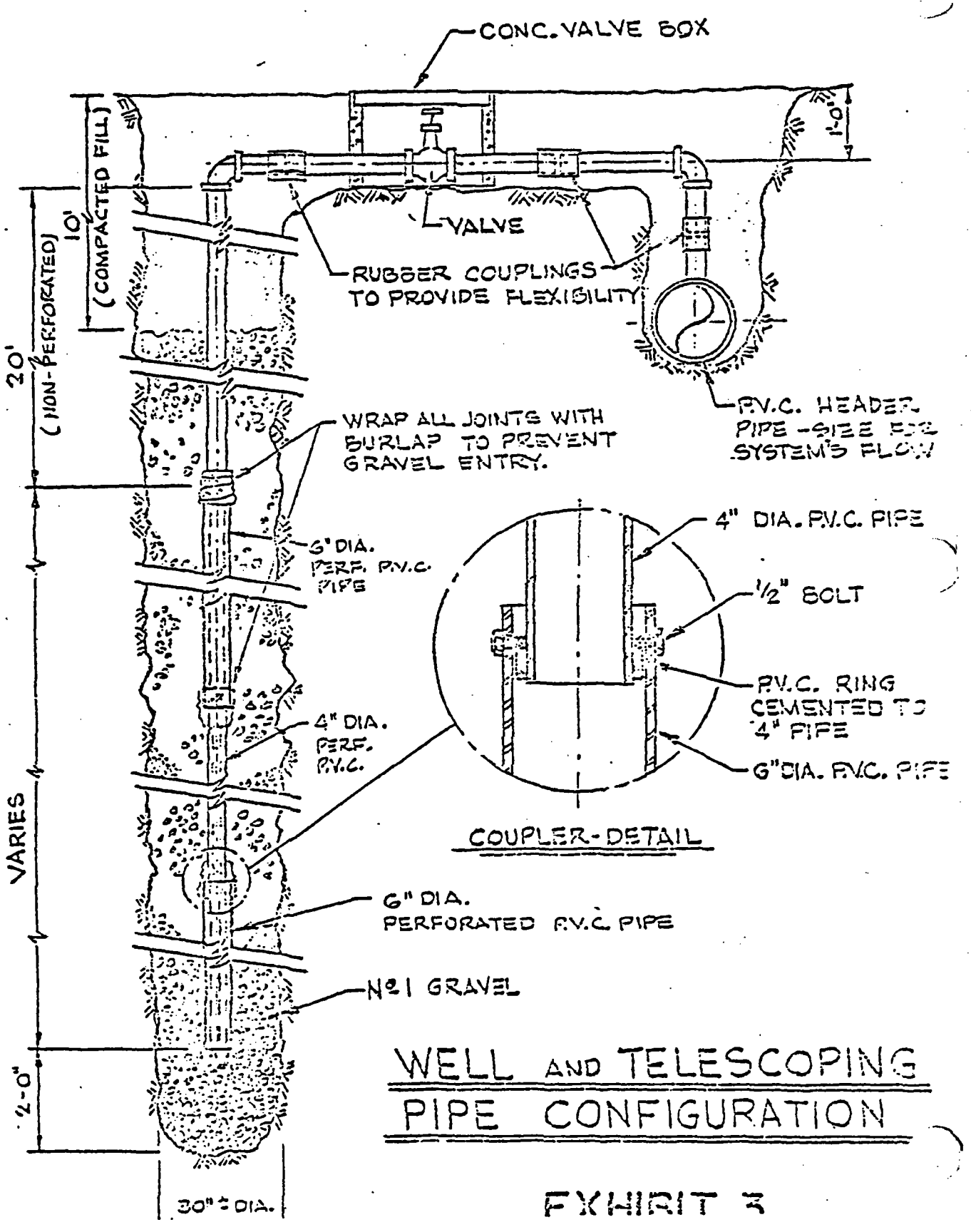
COST OF GAS CONTROL ALTERNATIVES

	COST($)						
	48th and Holly - Site A			48th & Holly-Site B		Arapco	
	Control Alt. I	Control Alt.II	Control Alt. III	Control Alt. I	Control Alt. II	Control Alt. I	Control Alt. II
Engineering							
Office	10,000	15,000	11,000	1,000	3,000	5,000	6,000
Field	21,000	31,000	23,000	3,000	6,000	10,000	12,000
Construction	207,000	306,000	229,000	25,000	62,000	104,000	124,000
Contingencies (20%)	48,000	70,000	53,000	6,000	14,000	24,000	28,000
TOTAL CAPITAL	286,000	422,000	316,000	35,000	85,000	143,000	170,000
Annual Operation and Maintenance[1]	39,000	29,000	26,000	7,000	-	24,000	18,000
Annual Monitoring	3,000	3,000	3,000	500	500	3,000	3,000
Present Worth of Annual Operation and Maintenance	239,600[2]	178,200[2]	235,400[3]	43,000[2]	-	147,500[2]	162,900[3]
Present Worth of Annual Monitoring	18,400[2]	18,400[2]	18,400[2]	3,100[2]	3,100[2]	18,400[2]	18,400[2]
TOTAL PRESENT WORTH[4]	544,000	619,000	570,000	81,000	88,000	309,000	351,000

1. Current cost of annual operation and maintenance.
2. Based on uniform annual costs over a ten year period and a 10% annual interest rate (assumes cost inflation is balanced by decrease in operation and maintenance cost due to slowing rate of landfill settlement, and by decrease in monitoring cost due to lessening frequency of monitoring as background data is established and gas production rate diminishes).
3. Based on a ten year period, 10% annual interest rate, and 8% annual cost escalation.
4. Total capital cost plus present worth of annual O & M plus present worth of annual monitoring.

APPENDIX I - STATES WITH POLLUTION CONTROL REVENUE BOND ENABLING LEGISLATION

1. ALABAMA - Allows for industry, not public utility
2. ARIZONA
3. ARKANSAS
4. CALIFORNIA
5. COLORADO
6. CONNECTICUT
7. DELAWARE
8. FLORIDA
9. GEORGIA
10. HAWAII
11. ILLINOIS
12. INDIANA
13. IOWA
14. KENTUCKY - May need special inclusion for public utility
15. LOUISIANA
16. MAINE - Public utility not specifically included
17. MARYLAND
18. MASSACHUSETTS - Public utility not specifically included
19. MICHIGAN
20. MINNESOTA
21. MISSISSIPPI
22. MISSOURI
23. MONTANA
24. NEVADA
25. NEW HAMPSHIRE - Public utility not included
26. NEW JERSEY - Allows for solid waste facilities
27. NEW MEXICO
28. NEW YORK - Public utility not specifically authorized
29. NORTH DAKOTA
30. OHIO
31. OKLAHOMA
32. OREGON - Questionably possible for public utility
33. PENNSYLVANIA
34. RHODE ISLAND
35. SOUTH CAROLINA
36. SOUTH DAKOTA
37. TENNESSEE
38. TEXAS
39. UTAH
40. VERMONT - Public utility not included
41. VIRGINIA - Public utility not authorized
42. WASHINGTON
43. WEST VIRGINIA
44. WYOMING

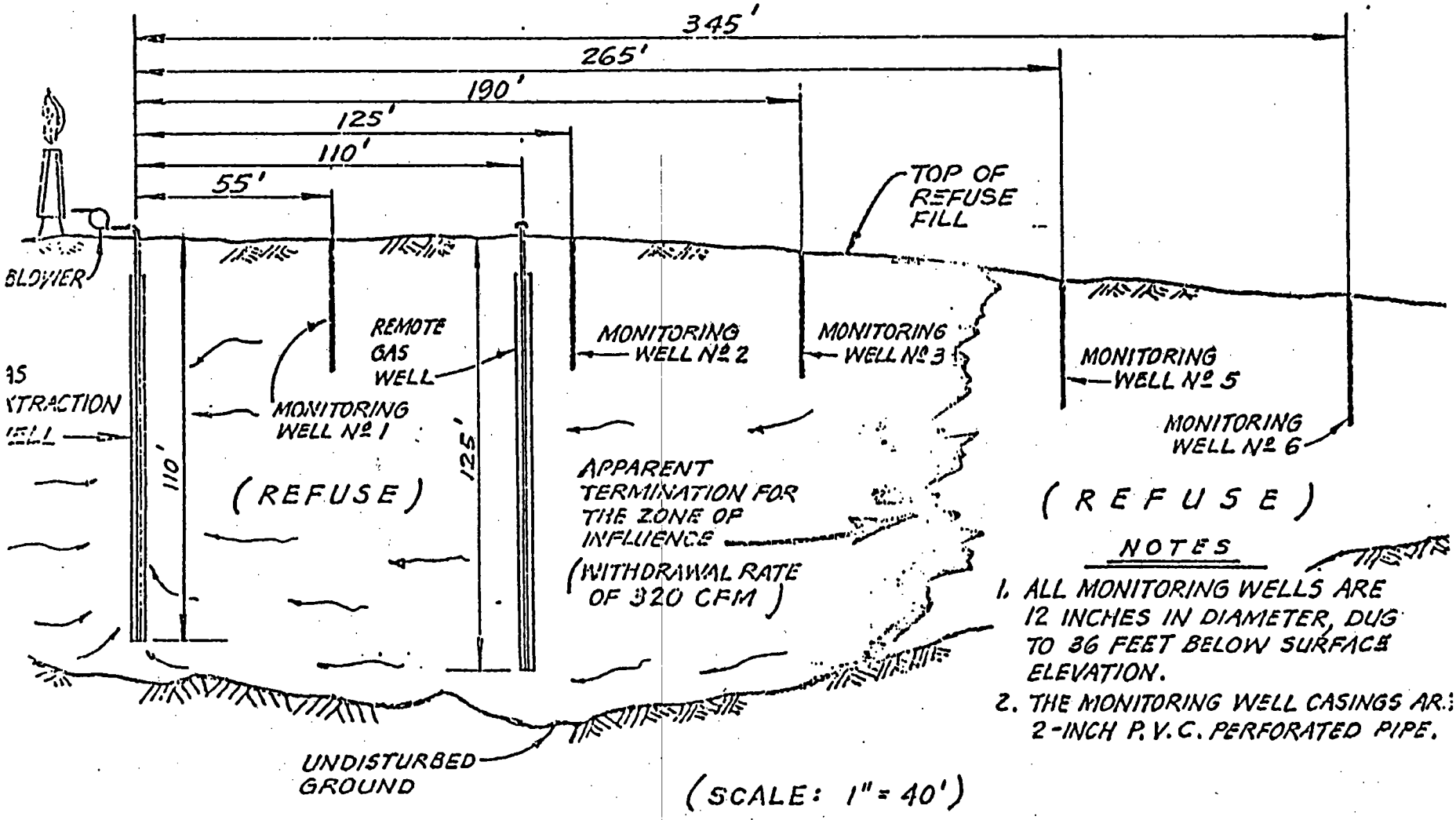


WELL AND TELESCOPING PIPE CONFIGURATION

EXHIBIT 3

INFLUENCE AREA STUDY

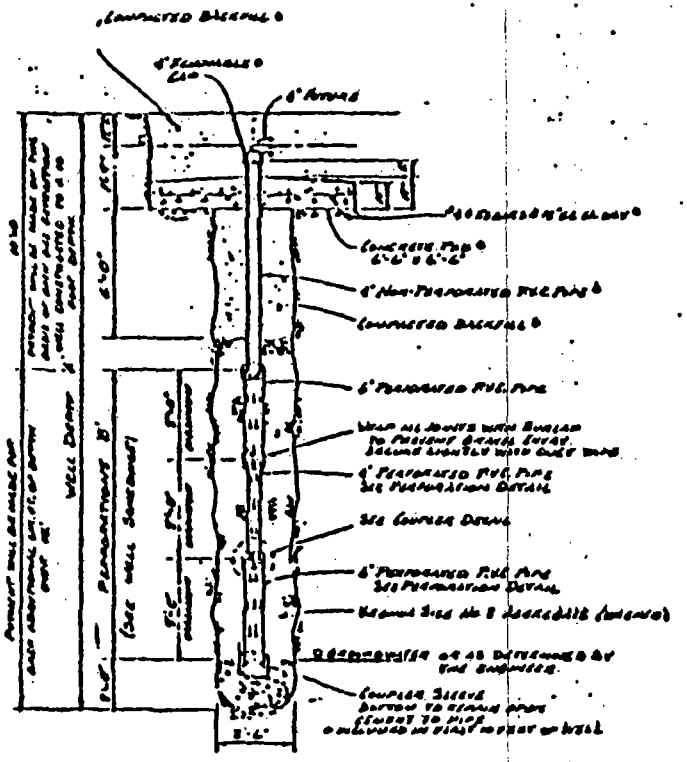
MONITORING WELL LOCATIONS AT PALOS VERDES LANDFILL



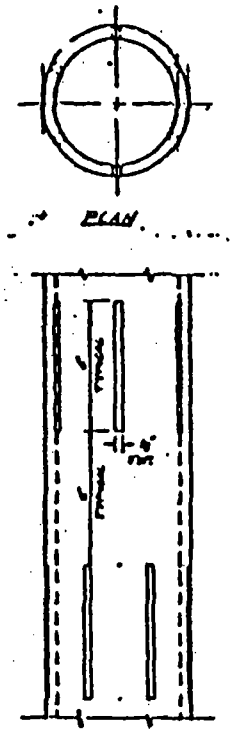
NOTES

1. ALL MONITORING WELLS ARE 12 INCHES IN DIAMETER, DUG TO 86 FEET BELOW SURFACE ELEVATION.
2. THE MONITORING WELL CASINGS ARE 2-INCH P.V.C. PERFORATED PIPE.

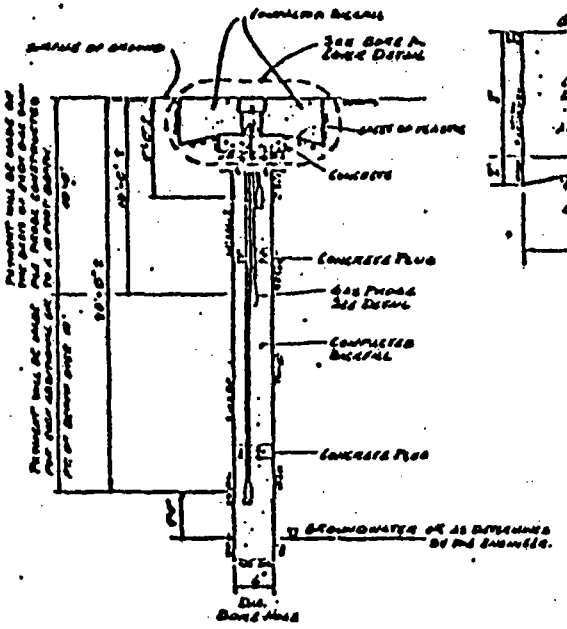
EXHIBIT 5



TYPICAL
GAS EXTRACTION WELL
NO SCALE



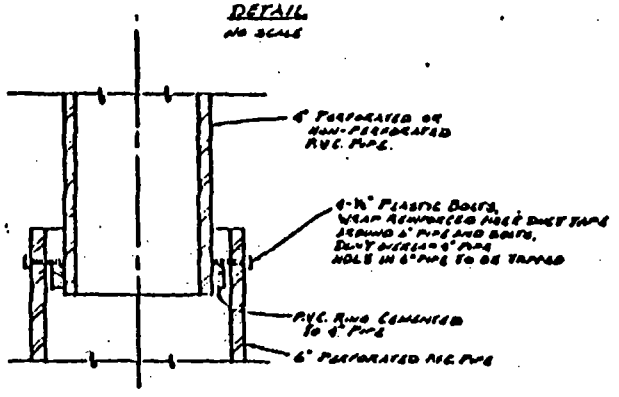
TYPICAL
PERFORATION
DETAIL
NO SCALE



TYPICAL
GAS SAMPLE PROBE
INSTALLATION
No Scale
NOT INCLUDED IN CONTRACT

WELL SCHEDULE	
A DEPTH OF	B PERFORATION, FT*
10	3.5
15	4.5
20	6
25	7
30	9
35	12
40	15
45	15
50	15

* See Typical Gas Extraction Well Above



COUPLER DETAIL
No Scale

CHAPTER 5

PLANNING OBJECTIVES & GUIDANCE

5.0 Planning Objectives and Guidance
5.1 Planning for the Future
5.2 Environmental Assessment
5.3 Legal Questions Summary
5.4 Responsibility in Government
5.5 Public Involvement
5.6 Plan for New Landfill Sites
5.7 Hazardous Waste Overlay

Preliminary Draft 173

5.0 Methane Management Planning Perspectives

Sanitary landfilling has been, and continues to be, the primary method for disposing of solid wastes in this country. Once landfills have been utilized for their primary purpose of concealing discarded materials, it is common to reapply the land to a variety of uses such as recreation sites, gardens, green belts, and farming; or for warrehouses, truck storage locations, and trailer parks. Oftentimes the reuse of such land parcels has been incidental, haphazard, and sometimes the land has actually been misused. Recently, however, the dilemma faced by public officials and professionals associated with landfills relative to the planning for, and reuse of, former landfills has been compounded by imminent environmental hazards caused by the production of flammable gas, primarily methane. This is particularly the case in light of the recently-enacted Resource Conservation and Recovery Act of 1976. The purpose of this presentation is to capsulize problems associated with flammable gas generation from former landfills, summarize potential landuse planning and implementation strategies, and present recommendations.

5.1 Problems Associated with Flammable Gas Generation From Former Landfills

Since 1966 no less than 20 cases have been documented involving precautionary actions, adverse environmental impacts, injuries, or death resulting from flammable gases that were emitted from solid waste disposal sites in the United States and Canada. Deaths associated with concentrations and explosions of landfill-related flammable gas were recorded in North Carrolina, Colorado, Missouri, and British Columbia; while effected prophylactic

measures, injuries, and property damages occurred in such places as Illinois, Michigan, Virginia, Minnesota, California, Colorado, and Montreal. An increased number of landfills, additional developmental pressures, and the general lack of understanding about landfill-related flammable gas contribute to a geographically widespread problem that should be dealt with from a planning perspective, as well as, from many other viewpoints.

As result of the inherent dangers associated with flammable gas production from former landfills, efficient and safe uses of any such sites have been negatively undermined. Many past reuses of former landfill sites have been experiencing gas migration and land settlement problems associated with flammable gas generation, while future reuses of such pacels have not occurred. In many cases, development of such land has remained dormant as a result of self-imposed owner moratoria due to potential legal liabilities for instances of calamity. To avoid future situations of this sort, a program of intensive investigation for future solutions to solid waste disposal and successive land use can be initiated and implemented.

Land Use Planning Implementation Strategies

Energy efficient commercial/industrial sites with associated public services are at a premium. In the past, due to imperceptibilities of the constraints necessarily placed on developmental reuse of former landfill sites that generate flammable gas and a lack of adequate planning, insufficient forethought was given to the end use of landfill sites. With the advent of flammable gases from many former landfills and a greater realization of the possible impacts associated with the production of potentially dangerous gas, greater concern for those problems can be manifested by responsible

governmental personnel.

Although planning for landfills frequently is done on an as-needed basis by various staff members, the situation can evolve into a prescriptive rather than reactive process. For example, shortly after a June 1977 explosion near a former landfill, Adams County, Colorado developed strategies to possibly avoid any similar occurrences in the future. At about the same time, an Intergovernmental Methane Task Force (IMTF) was formed by a group of interested individuals from local, state, federal agencies, and others that had become concerned with the problems of landfill-associated methane gas, migration, and the resulting health hazards. The IMTF has successfully served as a forum for methane and flammable gases-related data exchange on the local, state, national, and international levels.

Strategy for dealing with land use planning for former, present, and future landfill sites can focus on the following two primary aspects: 1) Research to effectively deal with the excisting problem of flammable gas generation from former landfill sites, and 2) Advance planning for future solid wast disposal facilities and land reuse.

Reserch relative to former landfill sites that are generating flammable gas should include, in chronological order; 1) inventory and survey of sites that are generating gas, 2) prioritization of any discovered sites for possible future in-depth analysis, and 3) completion of studies for high priority sites. Once individual landfills are examined, recommendations can be made regarding fesible control alternatives. Some possible controls include, liner placement to serrve as a gas migrtion barrier, off-site granular placement for venting, vacuum extraction systems designed to vent potentially harmful gases, and resource recovery alternatives.

Advance planning for future solid waste disposal facilities and successive

land uses is a cardinal point. Developing a plan for a landfill and its end use is a complicated process. Environmental engineers, hydrologists, hydrogeologists, planners, and ecologists all play prominent roles in the preliminary base studies that are needed before site selection can be made. Before any excavation or construction should being, questions involving zoning, land use restrictions, anticipated waste disposal volumes, economics of operations, geology, soils, groundwater hydrogeology and facility design capability should be resolved.

To estimate the capacity and life span of the landfill, specific essential studies should be performed. Waste generation rates, both for the residential and commercial districts, should be calculated. The area to be serviced should be defined. Finally, a breakdown of the solid waste components and/or the type of wastes generated should be identified. If resource recovery, shredders, or balers are to be utilized to any extent, this will have a positive effect on the capacity and lifespan of the landfill. An in-depth market analysis of recycled goods should be performed in order to determine projected fill capacity and lifespan.

Once environmentally sound sites are identified the next step is to proceed to determine the most economically and politically acceptable and feasible solid waste option. The Environmental Protection Agency Office of Solid Waste suggests that factors such as public opposition, proximity to major haul routes, assessment of highway load limitations, haul distancs, and potential acts of God also be strongly considered.

Once a plan for a landfill is completed and the implementation process commences, two other adjunct elements should be considered and possibly implemented. Each one relates to the planning process for control of development and exclusion of incompatible land uses on former landfills.

First, building codes to insure that building on any designated former landfill site will include considerations and designs that are structured to alleviate the problems of migrating flammable gas, should be adopted. Second, to assure "the protection of life and property from such related hazards as flammable gas, gas migration, asphyxiation, settlement, and explosion," the establishment of a zone overlay district should strongly be considered. Each of these tactics can greatly assist in mitigating potentially dangerous land use and building-related problems in the future.

Recommendations and Summary

As available land parcels for development grow scarcer, planning for end uses of landfills becomes increasingly important. The time to begin such investigations is well before the landfill is completed. Former landfill sites should be inventoried, and once that task is accomplished, technical assistance should be acquired from local health departments or other qualified individuals for the purpose of inspecting each site for possible flammable gas generation. Whenever potentially hazadous situations are discovered, adequate safeguards, such as a zoning overlay, should be prepared to insure that any such use of the land in question is both safe and calculated to protectt against adverse environmental impacts. As an added measure of protection to the health and general welfare of the public, sufficient building codes should be implemented for construction on former landfill sites.

Although flammable gas generation from former landfill sites is a problem that evidently is in its embryonic stages, it is one that coincidentally exists almost everywhere landfills are found. Identification of any such hazardous sites should be done by individuals from responsible agencies. Appropriate safeguards should be implemented in order to avoid adverse environmental and health situations. Advance planning for landfills and their end land uses

should be accomplished to maximize potential land use alternatives. Landfill sites are an excellent example of successive land uses, and coupled with the recent "in vogue" aspect of methane recovery, perhaps sanitary landfills will become the gas wells of the future - relinquishing valuable commercial gases while serving as examples of multiple land uses.

11.400 Flammable Gas (G) Overlay Zone District

11.410 Purpose

It is the purpose of this Overlay District to establish reasonable and uniform limitations, safeguards, and controls over uses of land designated as and/or adjacent to, an operating or former solid waste disposal site. Any building, excavation, construction, or other use proposed in this zone district shall require flammable gas testing and approval as indicated in this section prior to commencing operations. The requirements of this section are intended to assure the protection of life, and property from such related hazards as flammable gas gas migration, asphyxiation, settlement, and explosion.

11.420 Permitted Use Requirements

11.421 Review of Proposed Construction on Landfill Site:

(1) For any parcel of land which is,or has been a solid waste disposal site; no construction of structures or other land uses shall be allowed until the proposed action is referred to the Planning Department, the local fire department, and Tri-County Health Department.

(2) Tri-County District Health Department and the local fire department will be primarily responsible for obtaining flammable gas readings from the site and supply safety information related to construction on a landfill.

(3) The Planning Department's primary responsibility shall be to deal with the proposed land use and the engineering design.

(4) All comments and recommendations shall be presented to the Chief Building Inspector for his revie and decision as per Section 11.422 and 11.423.

11.422 Building Permits and Construction on a Former Landfill Site:

The Chief Building Inspector shall issue a permit on any such proposed development only after determining that the following criteria has been met based on the 20% lower explosive limit standard formulated by the National Institute of Occupational Safety and Health of the Bureau of Mines of the U.S. Department of the Interior:

(1) Flammable gas testing shall be conducted at the proposed site in order to determine if flammable gas is present in concentrations of 5.0% or more by volu (5.0% flammable gas is the lower explosive limit -LEL)

(2) All new construction shall be designed by a registered professional engineer to exclude and protect against build up of over 1.0% of flammable gas in the building.

(3) For construction on a known landfill area, the following steps shall be taken during the construction activity:

a. A flammable gas indicator shall be utilized at all times during trenching, excavating, drilling, or when working within ten feet of an open excavation.

b. When trenching, excavating, or drilling deep than 2 feet into the fill, or in the presence

of detectable concentrations of 1.0% flammable gas; the soils shall be wetted and the operating equipment shall be provided with spark proof exhausts.

c. A dry chemical fire extinguisher, ABC rated, shall be provided on all equipment used in the landfill.

d. Personnel within or near an open trench or drill hole shall, be fully clothed, wear shoes with non-metallic soles, wear a hard hat and wear safety goggles or glasses.

e. Exhaust blowers shall be used in instances where trenches may show a build up of flammable gas of 1.0% or less than 18.0% oxygen.

f. Smoking shall not be permitted in any area within 100 feet of the excavation.

g. Personnel shall be kept upwind of any open trench unless the trench is continuously monitored.

h. Before personnel are permitted to enter an open trench, the trench shall be monitored for flammable gas and at least an 18.0% oxygen sufficiency. When in the excavation, each work party shall be working no more than five feet from a continuous flammable gas and oxygen monitor.

(4) The applicant shall have a registered professional engineer submit an affidavit to the Chief Building Official stating as follows:

a. That all new construction is in compliance with these regulations, that all testing and monitoring has been done and is being done pursuant to these regulations; and the result of such testing and monitoring be submitted to the Chief Building Official.

(5) All construction or excavation sites shall be subject to inspection by the local fire department.

11.423 Building Permits and Construction within 1000 Feet of a Known Landfill Area.

The Chief Building Inspector shall issue a permit on any proposed development only after determining that the following safety precautions have been taken:

(1) The area under construction shall be checked with a flammable gas indicator before excavation in order to determine if flammable gas is in the area.

(2) Any excavation shall be monitored for the presence of flammable gas reading of a maximum of 1% and oxygen deficiency reading of a minimum 18%. This shall be carried out continuously unless there is no presence of flammable gas in the area.

(3) Should flammable gas of 1.0% or oxygen of less than 18% occur, those precautions applicable to excavating the landfill as outlined in Section 11.221 and 11.222 also apply to this situation.

(4) The applicant shall submit an affidavit by a registered professional engineer stating that all testing and monitoring as required by these regulations has been conducted and stating the result of the testing and monitoring.

(5) Any construction or excavation sites shall be subject to inspection by the local fire department.

11.424 In cases where a building permit has been granted the uses, restrictions, and standards of the underlying zone district shall apply.

11.430 Flammable Gas Hazard Areas:

1. Those areas identified in the report dated April 19, 1978 titled LANDFILLS IN WHICH METHANE GENERATION HAS BEEN DOCUMENTED, prepared by Tri-County District Health Department, as well as the surrounding property to within 1000 feet shall receive the Flammable Gas Hazard (G) areas these areas are defined as:

(a) Berkeley Village:

The hazardous area is bounded by the Adams County line on the south and west, Clear Creek on the north, and the north-south line 500' east of the centerline of Tennyson Street. This area corresponds to number 1 on the Zoning Restriction Map: Overlay Restriction - Flammable Gas hereinafter called Zoning Restriction Map.

(b) Adams County Landfill:

The hazardous area is bounded beginning at the intersection of Federal Blvd. and the Denver Salt Lake Railroad Crossing Tracks thence 6375' East along the Denver Salt Lake Railroad Tracks, thence North 1800' thence West 2250' thence South 1000' thence W 3350' thence North 200' to Clear Creek thence West along Clear Creek to the centerline of Federal Blvd. thence South to the point of beginning. This area corresponds to number 2 on the Zoning Restriction Map.

(c) Adams County Landfill:

The hazardous area is bounded beginning at Clear Creek 900' from the centerline of Federal Blvd. thence East along Clear Creek 3500', thence East 300', thence South 1700', thence West 3350', thence North 200' to the point of beginning. This area corresponds to number 3 on the Zoning Restriction Map.

(d) Property Improvements Inc.:

The hazardous area is bounded by the area beginning at the point of intersection of West 62nd Avenue and Huron Street thence North along Huron 2300', thence East 3300', thence South 3300', thence West 2600' along West 60th Avenue, thence North 1000', thence West 700' to the point of beginning. This area corresponds to #4 on the Zoning Restriction Map.

(e) Property Improvements Inc.:

The hazardous area is bounded beginning at a point 900' East from the centerline of Pecos Street at Clear Creek thence South 2300', thence East 250', thence South 650', thence East 1500', thence North 3350' along Huron Street, thence West 500' to Clear Creek, thence West 1400' along Clear Creek to the point of beginning. This area corresponds to number 5 on the Zoning Restriction Map.

(f) Landfill Inc.:

The hazardous area is bounded beginning at a point at Clear Creek 150' West from the centerline of

I-25 thence West along Clear Creek 4100' thence South 150' thence East 3300' thence South 650' thence East 300' thence North 2500' to the point of beginning. This area corresponds to number 6 on the Zoning Restriction Map.

(g) Western Paving:

The hazardous area is bounded beginning at a point 900' East from the centerline of Pecos Street at Clear Creek thence West 2100' along Clear Creek thence South 1100' thence East 1750' thence North 2300' to the point of beginning. This area corresponds to number 7 on the Zoning Restriction Map.

(h) Fiore & Sons:

The hazardous area is bounded by the area beginning at a point at the intersection of West 62nd Avenue and Huron, thence 700' East, thence 950' South, thence 1000' East on 60th thence 1050' South, thence 2700' West, thence 1000' North, thence 1000' East thence 950' North to the point of beginning. This area corresponds to number 8 on the Zoning Restriction Map.

(i) Property Improvements Inc.:

The hazardous area is bounded by the area beginning at the intersection of the Brantner Ditch and East 144th Avenue, thence North 2300' along the Brantner Ditch, thence West 3000', thence South 2350', thence 1700' East to the Brantner Ditch, thence North 500' to the point of beginning. This area corresponds to number 13 on the Zoning Restriction Map.

2. Boundaries of the Flammable Gas Hazard Overlay Area may be appealed to the Board of Adjustment based on technical information. The Planning Department shall designate flammable gas overlay areas as per Section 3.110 and 3.120 on the official zoning maps..

3. Appeals of the Chief Building Official's decisions as per Section 11.420 may be made to the Board of Adjustment as per Section 7.540.

4. The above restrictions shall also apply to any site discovered to have been a solid waste disposal area.

CHAPTER 6

DECISION PROCESS (CONCLUSIONS / RECOMMENDATIONS)

6.0 Decision Process (Conclusions/Recommendations)
6.1 Alternatives

6.1.1 Where Do You Stand?
6.1.2 But First - How Do You Find It?

6.1.2.1 Inventory
6.1.2.2 Consultant Services
6.3.2.3 Data Acquisition

6.1.3 Cost of Services

6.2 Selecting a Consultant

6.2.1 Responsibilities of a Consultant
6.2.2 Project Manager Responsibility

6.3 End Uses
6.4 Financing Alternatives
6.5 Prevention and Control

6.0 Decision Process (Conclusions/Recommendations)

"The ultimate disposal of solid waste on the land in an environmentally sound manner is a rapidly increasing problem. The environmental and economic impact of improperly located, designed, operated, monitored and controlled disposal sites is certain to increase on a national level and to be quite severe on local and regional levels."

"There is a general lack of control of solid waste facilities in the United States, especially for gas migration and water protection. There is very little monitoring of solid waste disposal sites."

Since methanogens can produce high gas pressures by the generation of methane, it is not feasible to solve the problem by constructing a gas-tight landfill. Although no research has been done to determine the maximum pressures exerted, it is not unlikely that pressures sufficient to lift the soil overburden might be produced. Thus the logical cure for the problem of methane migration from landfills is to supply the landfill with a number of vents or gas wells to prevent pressure build up. Furthermore, as shown by the successful gas recovey projects at Palos Verdes and at Mountain View, in California, the landfill gas may contain up to 60% methane, which may readily be cleaned to produce pipeline quality natural gas. The issue becomes a choice between control vs. recovery, because the liabiity question must be answered. The choice even among control alternatives is complex due to the site history and locality.

6.1 Alternatives

Which alternative or alternatives should the local or regional agency select to accomplish the objectives that it has set forth for solving its methane gas from solid waste problems?

The agency's decision-making is subject to many influences that must be considered when developing the local or regional gas management plan. Such influences may be both constraints and resources and include political, legal, social and financial factors, and available technology. Basic among these are technical and political influences. Because of the technical nature of the decisions, a specialized interdisciplinary staff--the one which has been developing the methane plan to this point--should continue to play a role in supplying information and evaluating alternative solutions and in implementing the plan. Evaluating existing state, regional, or local regulation is a particularly important part of this step.

Those alternative solutions that appear feasible on the basis of political exigencies, specialized technical analysis and existing laws, should be submitted to the appointed and elected public officials and to the public itself for review and possible adoption, but not without adequate preparation. This means a

program of education for both officials and the public--a vital and integral part of the entire process. The planning agency or task force should have initiated such an information and education program in the early stages of the plan formulation, and the public information progrm should continue throughout implementation of the entire landfill methane plan. News releases, films, articles, and speakers, for example, can help promote puiblic awareness and aid in approval of gas management plans and programs.

6.1.1 Where do you Start?

The methane problem exists with landfills, including sanitary landfills, open dumps, burning dumps, construction and demolition debris dumps and sanitary sludge burials. Subsequent to 1967, open burning of trash in dumps has ceased due to environmental efforts, however, this allowed a greater inventory of organic materials in the landfills. Additioally, procedures for compaction also used water spraying which increases bacteria action resulting in increased gas generation.

Several areas of interest were identified in this text as needing further investigation for determining the extent of gas migration.

I. Inventory

There is a need to identify and evaluate all of the potential gas problems from abandoned, operating and future waste disposal sites.

II. Land Use

There is a need to identify the potential land uses of abandoned and current landfill sites. Utility transmission line systems should also be reviewed for intrusions into the landfill impact areas.

III. Measurement

Models for gas generation in landfills should be reviewed for applicability. Measurements should be made of volatiles under static condition, i.e., as the landfill currrently exists, and under dynamic construction related situations.

IV. Prevention and Control

Current and Future Site Designations should be done with the greatest of care with particular attention to reclamation practices and gas elimination procedurees. The generated gas must either be vented to the surface and properly disposed of or collected and used for an energy source. For those locations having existing structures and utilities associated within the impact area, those entities shojld be appropriately ventilated.

6.1.2 But First - How do you find it?

As in any project of a large scope an aggressive management team is needed to inventigate the gas problem because it involves the integration of various disciplines. It is imperative that thorough project management techniques be applied throughout the course of the effort. The key to effective project management is centralized management resposnibility and authority--the project manager approach--which provides a single point of contact and liaison between a consultant team and the client. The government agency responsible should develop an in-house list of resources and an overall schedule prior to selecting a consultant. What are the components of such an undertaking? The investigation can be identified into five parts.

Part 1 - Field Reconnaissance and Review of Available Reports and Data

Part 2 - Analysis of Data and Evaluation of Alternative Control Technologies by Site

Part 3 - Recommendation of the Most Effective Gas Control Strategy by Site

Part 4 - Development of Methane Gas Monitoring Program

Part 5 - Summary of Findings and Recommendations

a) Feasibility for Gas Control

b) Criteria for Gas Control

Part 6 - Preparation of Engineering Details and Drawings

Part 7 - Supervision of Construction Facilities

The following is a discussion of those parts of a survey and their specific activities:

Minimum Tasking List for Gas Survey

In-House Tasking Effort

1. Compile List of Site with Known Problems
2. Assemble and Organize Data on Sites
3. Compile List of Sites with Known and Probable Problems Due to Gas Movement

4. Analyze All Data and Develop Urgency Ranked High Priority List of Sites

5. Finalyze and Approve List of High Priority Sites

6. Perform Data Acquisition on Selected Sites

7. Identify Significant Data Deficiencies for Each Site

Part 1 - Site Reconnaissance and Review of Available Reports and Data (In-house and Consultant)

1.1 Collect and review available published and unpublished background reports on the subject site and its immediate environs.

1.2 Interview persons knowledgeable about the site.

1.3 Obtain available air photos and maps of the site and its vicinity.

1.4 Conduct a site reconnaissance, including gas monitoring of selected locations to determine present levels of methane gas concentration.

1.5 Establish additional investigation, as required.

Review existing test boring information and recommend specific sites for futher borings.

Review all available geological informatin including geology reports for nearby buildings.

Review rain and snowfall records

Review Soil Conservation Service Soils Maps

Review State Department of Water Resources report on groundwater movement

Review existing information on gas movement

Part 2 - Analysis of Data and Evaluation of Alternative Control Technologies (Consultant)

2.1 Identify Significant Data Deficiencies and Develop Field Investigation program

2.2 Perform Field Investigations or Reconnaissance; Recommend type and location of gas sample lines within test boring holes for further data collection

2.3 Analyze and correlate all data obtained from field and laboratory test programs.

Evaluation of field data

A. Gas production
B. Migration
C. Hazard
D. Special conditions

2.4 Prepare a Site Specific Reconnaissance Report

A. Amounts of methane generated
B. General threat to the public safety
C. Conceptualize Site Specific Mitigation Programs
D. Prepare Cost Estimates for Conceptualized Mitigation Programs

Part 3 - Recommendation of the Most Effective Gas Control Strategy (Consultant)

3.1 Evaluate the technical and economic aspects of the alternatie control technologies.

3.2 Recommend the best control technology to ensure public safety and protection of the site environment.

A. Control of gas
B. Structure protection (on and off site)
C. Alarm system(s)

Part 4 - Development of Methane Gas Monitoring Program

4.1 Develop a gas monitoring system to verify the effectiveness of the recommended gas containment system.

Part 5 - Summary of Findings and Recommendations

5.1 Prpare a report summarizing findings and recommendations for an effective gas control system for all sites.

6.1.2.1 Inventory - In-house Effort

The inventory should have a specific plan and can be accompolished partially by the government agency in charge. The components of such a study would be:

A. Objective of investigation
B. Scope of investigation
C. Selection of sites for priority list

The agency may want to use the following list of items to establish a priority list.

In addition to the prioritizing of the sites, the responsible agency should prepare for each site

Typical of All Sites

I. Description of site

A. Location, city, township/range
B. Physiography
C. Operation and history

1. Period of operation
2. Owner
3. Type landfill (size, depth, type of material deposited)
4. Present use

II. Geological and hydrological data

A. Regional geology
B. Site geology
C. Soil condition
D. Groundwater conditions

The first task will identify the high priority sites and a background for the follow on investigatin by a consultant. The initial data search should also include a seach for old aerial photographs or topograph maps for each site within their jurisdiction. Coordinate contacting adjacent property owners, building occupants, and utility companies that are affected by the landfill site.

6.1.2.2 Consultant Services

The primary function of a consultant would be to perform a data analysis and develop recommendation for control based on end use of the landfill and/or surrounding structures.

Data analysis will determine the extent of gas production and migration in the landfill and its immediately surrounding area.s The analysis should indicate if there is a correlation between rainfall and/or snowfall and gas production. It should also indicate the predominant subsurface gas movement pattern. Follwoing this data review, a field investigation program would be developed for each site to include preliminary locatins for test borings, bar punch holes, foundatin surveys, samplin points, and combustible gas surveys.

Table ____
Factors for Prioritizing Landfill Sites
(methane gas hazards)

A. Generation Factors

1. Organic material (do not continue rating if site is only used as a Rubble dump)
2. Sewage sludge or septic pumpings received at site
3. Burning
4. Final cover (tightness, depth, etc.); no cover
5. Size (A)
6. Moisture (depth to groundwater, sprinkling, liquid wastes, surface ponding) if saturated fill (worst case) below water table is presumptive evidence of saturation, dry fill

B. Migration Factors

1. Liners or barriers

   effective liner
   no liner

2. Soil type or geology on a surrounding fill

   for pure clay (best case)
   sand and gravel (worst case)

3. Distance to utility lines (B)

C. Physiocultural Factors

1. Predominant land use (present)

   heavy residential or commercial
   agricultural

2. Planned Future land use (site and surrounding) 15 yr.

   residential or commercial
   agricultural or recreational (parks, etc.)

3. Existing structures near or on site

4. Other items of special importance

6.1.2.3 Data Acquisition

The government agency in an effort to reduce cost should prepare a site data package for each suspected site which establishes the relevant site characteristics, including site area, refuse depth, refuse characteristics, local geology and hydrogeology, history of site operations, location of adjacent building, and records of man-made installations and activities within 1000 feet of the landfill perimeter.

In any landfill gas generation occurrence, two elements are involved: organics and moisture. Background information on both of these materials needs to be gathered.

First, the exact location of the landfill, boundaries and its contents should be obtained. This can be done in several ways. Historical information can be gathered from individuals who have lived in this area for some time, from the fill site land ownere or fill operator, and from other individuals who are knowledgeable about the area. The precise boundary locations can be verified by drilling bore holes at or near the suspeted boundaries.

The nature of the material deposited in the fill and its location can also be obtained from the above cited individuals or drilling. j Once this preliminary information is known the theoretical biodegradeability of the organics can be estimated and the amount of potential methane generation can be calculated.

Second, the extent and rate of biodegradation is controlled by the moisture content. Therefore, further information needs to be gathered on the water influence of the area. Water may enter the area either by vertical movement through the surface or by horizontal movement of groundwater beneath the surface. Rain and snowfall records need to be investigated to determine the extent of direct vertical moisture penetration. the groundwater level fluctuation and dirction of flow should be determined in order to characterize its influence on gas generation as well as directional movement.

In addition to the nature and extent of gas generated in the landfill, information on subsurface gas movement needs to be gathered. This data can be obtained in two ways: 1) the geological formation of the area should be investigated to determine the lay

down pattern of various soils; and 2) gas sample lines should be installed in a number of bore holes throughout the landfill site, primarily along and outside the fill periphery.

Baseline for climatology, hydrology, geology, soils, type of wastes, and the presence or absence of methane gas conditins would be required for every site. If existing data is unavailable (and it is anticipated that this will be the case for the majority of sites), this phase of the work would include the collection of additional information.

Additional subsurface investigatin by the consultant and/or gas monitoring may be necessary to devlop adequate knowledge of the landfill (gas generator) and its environs. The extent of this investigative effort will be partially dictated by the end use of the landfill or if the report of survey is to be used in a court of law. Monitoring holes would be permanently installed for the purpose of collecting methane gas samples. A brief description of each hole type is as follows:

1. Monitoring Holes. These holes will be drillec using a 4 inch continuous flight auger or 7 1/2 O.D. hollow flight auger powered by a CME 45 or 55 drilling rig. j The holes will be advanced to the sampling depth and a relatively undisturbed sample will be taken. Typically, samples will be taken at 5 foot intervals unless closer sampling will be needed due to the type of materials encountered. The hole will penetrate to at least the bottom of the fill.

   After bottoming the hole, 2 inch diameter P.V.C. pipe hand slotted will be installed full depth. The pipe will be cut off at ground surface, capped, and the top 2 feet of the pipe sealed with soil or concrete. The pipes will be covered with soil for vandalism protection. In populated areas, steel vandal proof caps will be provided.

2. Profile Holes. These will be advanced using a 4 inch diameter continuous flight auger powered by a CME 45 or 55 drilling rig. Visual classification of the soil cuttings will be made and general log of the soils encountered will be recorded. No plastic pipe will be installed.

   A small portable vacuum pump with flow meter would be utilized to collect gas samples from the monitoring holes. Gas would be pumped through small charcoal absorption tubes and sent to the

lab for analysis. An alternative method would be to utilize a portable gas chromatograph unit for on-site analyses. It is anticipated that either or both methods could be rquired for specific sites on a case-by-case basis. A mass spectrophotometer would be utilized to calibrate the gas chromatograph. "Bomb" or vacuum bottle samples would be utilized in a few cases to collect samples. they have the disadvantage of being such a small quantity that they would only be utilized to detect the presence or absence of methane but not for quantitative purposes. We would outline for the state health laboratory the preparation of absorption tubes and would utilize to the maximum extent possible the portable gas chromatograph that the department has on order. It is anticipated that the services and equipment of the Air Quality Control Division could be utilized to some degree for gas collection and monitoring.

6.1.3 Cost for Such Services by a Consultant are: (See Table)

Possible Hourly Rate

Personnel	Per Hour
Principal Engineer	40.00 - 50.00
Principal Engineer	33.00 - 40.00
Senior Engineer (Civil, Sanitary, Hydraulic)	25.00 - 30.00
Engineer (Civil, Sanitary, Hydraulic)	21.00 - 25.00
Senior Engineering Designer	21.00 - 25.00
Water Resources Analyst	20.00 - 25.00
Senior Draftsman	15.00 - 20.00
Resident Engineer	15.00 - 20.00
Engineering Draftsman	12.50 - 18.00
Senior Resident Inspector	12.50 - 18.00
Resident Inspector	8.50 - 13.50
Engineering Technician	7.00 - 12.50
Technician/Secretarial	7.00 - 10.00

Automobile at 16-20¢ per mile
Four-wheel Drive Vehicle at 25-30¢ per mile

Monitoring Holes. We estimate about 1.5 hours of drilling time will be required for a 30 foot deep hole. The drill rig cost for hollow augers is $50.00-65.00 per hour. An engineer should be used to log the hole, obtain samples, install the pipe and generally assist with the work. We estimate two hours of engineer's time will be needed to accomplish the work at each site. There will also be the cost for plastic pipe and a vandal proof cap. Including some cost for typing up the data we believe a cost of $200-300 per hole can be expected.

Profile Holes. The profile holes will be relatively inexpensive. We estimate at least two an hour could be drilled. The drilling cost for these holes is $45-65 per hour with the engineer's cost, the data; for a total per hole cost of $55-80 can be expected.

3. Analyze Data

This phase of the work would be on-going from the time a site is identified for investigation. It would include the review of existing data complied by the loca health departments and the compilatin and analysis of the data from laboratory findings and field investigations.

Field investigation would consist of a comprehensive detection survey of the landfill perimeters to identify the presence of combustible gases, migration patterns and pathways, and the hazards to public health and safety.

This survey would be conducted by taking explosivity readings with combustible gas indicators in test borings, punch holes, perimeter utility trenches, and foundations of adjacent structures. We

anticipate that one field engineer or geologist would supervise one or more field crews consisting of two field technicians each. Every effort would be made to cover as many sites as possible with the available budget. This task assignment wouldl also include collection and analysis of samples of combustible gas and of selected soil samples to determine pertinent combustible concentrations and engineering properties.

Data collected during the field investigatin and laboratory testing program would be evaluated and a report prepared indicating, wherever possible, the existence of combustible methane gas, its pathway of migration, and an assessment of the associated hazards to public health and safety. Based upon our findings, a hazard priority would be assigned to those sites covered, and ecommendations would be developed pertaining to appropriate remedial actions necessary to abate the hazard. If sufficient data on landfill wast volumes are available, additional recommendations would be made pertaining to the potential for methane gas recovery. Whenever possible, within the available budget, conceptual designs for containment facilities would be prepared.

4. Prepare Engineering Report. The data and analysis for each site would be compiled and presented in an engineering report. The report will include a summary of baseline conditions, at least one map of each site indicting hold locations, topography and other data, at least one representative cross section, logs of the holes and a discussion of the types of materials enountered. The laboratory results will be included. We would present alternatives, including preliminary cost estimates for the initiation of remedial action at each site. This would include a final recommendation for a prevention or correction plan. We propose to discuss recovery and utilization of the methane gas at sites where conditions are favorable.

5. Determine Responsible Parties. At each site the legally responsible party or parties for corrective measures will be determined. In cooperation with the State Health Department, we would agree to meet with the responsible party to review the results of our investigation in order to pursue implementation of the remedial action.

6. Implement Corrective Measures. It is understood that the State Health Department, as a part of this contract, wishes to follow through with the initiation of remedial action required at each site. We would agree to commit time for an initial meeting with the responsible party designing or constructing the corrective measures. Field supervision or on-site inspection of the measures would not be part of this contract.

6.2 Selecting a Consultant

6.2.1 Responsibilities of Consultant

6.2.2 Project Manager Responsibilities

The project manager consultant is responsible for planning, implementing, and directing all aspects of the total project. The project manager:

- Translates all requirements into an effective and efficient work program, establishes concrete objectives in quantitative, qualitative, and schedule terms, and handles changes in the same manner.

- Interacts with client representatives to see that all requirements and guidelines are set forth to all technical groups and are complied with fully.

- Delineates all technical and administrative respoonsiblities within each technical group working on the project to provide full coordination and integration of all activities.

- Establishes operating procedures and sees that they are properly and fully applied.

- Coordinates and integrates all project personnel and work tasks, including those of subcontractors and consultants, so that inter-disciplinary interactions, data and information exchange, and feedback of iterative results take place appropriately.

- Conducts continuous progress review of all work results and outputs. Procedures provide for maintaining continuity of work, integration, and cross-fertilizatin among individual professionals and technical groups, and for internal technical and client review. They also provide for adequate flexibility among major tasks and subtasks to avoid serious delays and inefficiencies, as well as overexpenditures.

6.3 End Uses

Closing a landfill does not make it go away. This point seems obvious, but it is seldom treated that way. Recent years saw increased interest in what to do with landfills before they open; how to design and engineer them. Currently, industry interest focuses on what to do with landfills while they operate; how to prevent or contain pollutants, whether to monitor, and so on. The next trend should be concern with what happens after the landfill closes it gates and covers its faces.

Past landfilling practices have caused many problems which are not revealed until years after the landfill closes. Sites located above sand and gravel aquifers, for instance, have gradually polluted groundwater until it became unusable for long periods. Poorly planned or operated landfills have caused methane gas

generation. Fires, explosions, property damage, even deaths have resulted from this environmental hazad. Yet when the landfills closed and those financially responsible for them departed, the potential for such problems was not addressed.

Landfills present a special problem because they are in a class of business or municipal activities which never "go away." When the owner of a building decides to close out, he either sells the structure and thus attaches responsbility to a new owner, or the building is torn down and disappears. When a landfill closes, the buried wastes remain and the new site owner, if there is one, considers himself responsible only for what is above the cover material.

Most state agencies have little history on the past uses of closed landfills because its present identificatin does not carry with it any scar of a ravaged and destroyed land and certainly no legal identification in the way of restriction. Most agencies would also report that the "planned" end use would be "open space" or "recreation." This end use planning should be an essential part of the science of waste control design.

Some preliminary conclusions on end uses can be made:

1. Public landfill operators tend to use the completed fill for public purposes, at the very least the land is claimed as recreation or openspace.
2. Private landfill operators tend to convert completed fills to profit-oriented uses or intend to do so at some future date.
3. End uses of land disposal sites are as varied as are the uses of almost any other land. The exception is a completed landfill which surely rules out using the site as a landfill.

There are many innovative end uses that show design is limited only by the designer's imaginatin. There is a windmill atop a landfill in Holland, Michigan, a heliport and pistol range in Huntington Beach, California, a marina in Beaumont, Texas, and a cemetery in Fulton County, Georgia.

Certain municipalities have had significant success with specific end use types. New York City hs numerous parks and golf courses on completed fills, as well as the World's Fair site (1939 and 1964)

The municipality, however, must be aware of those problems which have resulted from building on landfills such as differential settlement, gas entrapment, utility continuity (pipelines, cables, and drainage surfaces) and landscaping.

Landfill Gas Utilization Modes

The final end use may choose to incorporate the gas being generated on site. There are several categories of use for methane from landfills.

-Injection into an existing transmission line (upgrade to pipeline standards)

-Direct sale to an interruptible customer (Low BTU heating value)

-On-site conversion to LNG (liquified natural gas (methane))

-On-site conversion to methanol (methyl alcohol)

-On-site steam generation as a source of heat or for electrical generation

-Conversion of landfill gas to ammonia ad ammonia products

-Direct combustion for space heating

-Compression

In addition, three different levels of gas clean-up are possible: dehydration; dehydratin and CO_2 removal; H_2O, CO_2, and N_2 removal.

Another idea proposed by John Pacey of EMCON Associates is a self-sufficient greenhouse on a landfill.

A greenhouse environment is most enhanced when moderated controlled heat, combineed with artifical light, and low cost land is available. Landfills can supply all of these ingredients at very low cost (although the landfill owner would conceivably charge a royalty). The compatability of greenhouse/landfill appears idela as the greenhouse structure is simple, flexible, low cost, temporary, and well adapted to the large settlements. Additionally, the heat and fuel value of the landfill are available for heat and electricity for greenhouse needs. Greenhouse use can be practical during and after landfill construction, one of the few benefical early uses of landfills.

Of important concern here is the decreasing availabilty of low cost greenhouse land in proximity to urban areas and the increasing interruptability of energy supply to this industry.

6.4 Financing Alternatives

Numerous financing options available for proposed gas recovery facility, including contractor financing, either complete or partial, revenue bonds, general obligation bonds, and various hybrid arrangements involving several sources of funds.

TABLE ONE GOES IN HERE (FINANCING OPTIONS)

Prevention and Control

The following provides a synopsis of the activities needed by your local agencies:

a) A Department of Health under the general public health laws and the solid wste regulations could preclude new sites from causing the problem, and cause action could be taken to remedy existing known hazard situations.

b) County Commissioners could restrict land use within the impact zone of such disposal sites and select more appropriate sites for landfills.

c) Zoning and building departments could restrict construction and require preventive measures at new facilities.

d) COSH and the Fire Marshalls could regulate the workplace when it is in the impact zone of such sites.

e) Public Service Company may wish to use this source of energy if economically feasible.

f) Construction industry and the landfill operator representatives could make the agencies' concerns known along with the identification of known completed site locations. Landfill operators might take a moe positive approach to proper operation if legal suits are anticipated.

g) A Task Force could function as an interagency committee to address the problem with the anticipation of positive action by those with authority.

h) Local District Health Department and appropriate fire officials inventory buildings around existing landfills for methane. If methane is found, then appropriate monitoring, control, or evacuation procedures will be implemented at the direction of these agencies.

In an effort to advise Building and Planning Departments of the hazards from landfills in any land use or building decision local health departments will:

1. Propose to the planning departments that they designate the affected sites on their master plan as hazardous areas.

2. Inform all building department of the areas involved and the hazardous conditions associated with methane in relation to building structures and their placement.

In order to prevent future hazards from landfill associated methane we suggest the following:

a) That the state health department promulgate more specific and enforceable rules, regulations and guidelines on the operation of landfills requiring the following:

1. The installation of barriers, vents, or other devices designed by a professional engineer to eliminate the migration of methane or other gases off the landfill property in amounts greater than fifty (50) percent of L.E.L.

2. Development of a comprehensive monitoring system designed to give warning of gases penetrating the barriers and leaving the landfill area.

3. Delineation of specific responsibilities and actions to be taken by the operator if the gas barriers are breached, including financial responsibility assured by escrow.

4. A plan for the development of the landfill after filling with considerations of safety and the needs of the community.

b) That local county district health department conduct frequent inspections of operational landfills in order to insure that:

1. The rules and regulations of state health department are being complied with.

2. The monitoring system provided by the operator is functioning properly and the results are being reported.

c) That city and county building departments place stringent standards on the issuance of building permits on or within one-thousand (1000) feet of landfills. At a minimum these standards should include:

1. Plans submitted by a professional engineer designed to protect the building from the entrance of methane.

2. A monitoring system that samples continuously and sounds an alarm if eighty percent (80) of the L.E.L. is reached in any room of the building.

d) That city and county zoning departments designate landfill sites as hazardous areas which require added safeguards against methane accidents, leachate runoff or othr potentially hazadous conditions.

SUMMARY OF THE PROCEEDINGS OF THE SAFETY DISCUSSION GROUP

1. There are many problems associated with methane from landfills.

a. The methane produced in landfills may be unpredictable in its movement and present explosion hazards in several areas.
b. Many of our completed landfills do have methane problems, yet they are up for sale and ready to be utilized.

c. Many of our newer fills may present methane problems due to a lack of regulation and improper construction, allowing methane migration.
d. There may be a time interval between the completion of the landfill and the generation of methane. The methane may also persist for 100 years or more.
e. There is a lack of agencies with specific responsibility and control over future or completed landfills.
f. Most of our landfills are privately owned and operated and in many cases the owner of the land and the operator of the landfill are separate.
g. Information on the potential dangers of methane from landfills has not been adequately provided to those contractors or agencies faced with these dangers.

2. The responsibility for future landfills must rest with several agencies.

a. The guidelines for the operation of landfills should be developed by the state health department enabling uniformity throughout the state.
b. The major inspectional and enforcement effort should be wit local governmental bodies since more frequent inspections can be made and the power of the law can be utilized faster.
c. The routine inspections should be the responsibility of the local health department, as well as, monitoring checks to assure the methane is not moving off of the fill area.
d. The city or county should require that before issuance of a landfill permit, a plan for utilization of the site after filling is safe and compatible with their future plans.
e. The landfill operator should be responsible for the installation of barriers or other devices to prevent methane from leaving the site. The landfill operator should also be required to conduct a monitoring program that is site-specific and was capable of detection of the lateral travel of methane. This system would depend on the geologic, topographic, and demographic conditions surrounding the fill area.
f. Due to the fact that the system may take several years to fail, the operator may be required to establish a trust fund, based on surtaxes or other charges, that could be utilized for methane or leachate control. This trust fund may run from $100,000 to $1,000,000.

3. Those landfills that have already been filled must be equipped with devices to protect the surrounding structures.

a. If the property owners are held responsible for these remedial measures there will undoubtedly be lengthy lawsuits and court battles.
b. Although the governmental agencies involved may not be legally responsible, they may be morally responsible. If these agencies or governments are sued, the cost of the defense may be more costly than the remedial measures necessary.

c. A governmental entity may be able to act faster. They may be able to condemn the land or file suit in order to regain some of the money spent on control measures. The gas present may also be able to be utilized and thereby offset the costs.
d. The cost of remedial measures could be fairly large and therefore only within the fiscal reach of the larger governmental entities such as the state or federal government.

4. New buildings that are to be built on or near existing landfill areas must be closely scrutinized.

a. These buildings may be able to be controlled by the local governmental agencies through the use of building permits. This may be effected by the building departments through the denial of these permits or through the fire marshals.
b. Before building in these areas an engineering plan for methane control should be submitted by the developer. This plan should include methods for keeping methane out of the building, as well as, a monitoring system to warn them if methane does enter the building. Adequate ventilation must also be provided.
c. The city itself must closely review any plans for buildings on landfills since even if a professional engineer states that the system will work, it may not. If someone is hurt due to a system failure, the city may still be held responsible if they had approved the plans.
d. In some cases it may be better for the land to be acquired by the government and utilized for open space rather than being built on. These open space areas may become even more important as the area becomes more urbanized. In some cases, however, present landfills are in industrial areas not conductive to parks, etc.

5. Buildings that are presently on or near landfill areas must also be considered.

a. The owners of buildings that may be in danger must be notified of the seriousness of the problem. This notification should be made in writing whether or not methane has been found in the building. It is felt that any building within 1000 feet of a landfill that is producing methane may be in danger.
b. In those buildings where a methane hazard may exist, monitoring and ventilation systems must be proficed. The monitoring system must be of a continuous type to the variability of methane gas migration.
c. These controls may be forced on the building owners by either condemnation of the building by the fire marshal or by removal of Public Service Company utilities. This could not normally be accomplished unless methane was detected within the building.

6. There are several types of control systems available for both new and old landfill areas..

a. The passive vent system is the least expensive system, although it may lack the reliability of the other systems since it relys on the pressure of methane within the fill which is fairly low. They may also be ineffective if they do not extend down to the water table or bedrock.
b. Barrier systems may be fairly effective if they are extended down to the water table or bedrock. The barrier, however, must be installed properly and for a vapor barrier. This type of system may also be relatively short-lived as the barrier may deteriorate within several years.
c. A combination of a passive vent and barrier may be utilized and be more effective than either one used alone.
d. The power vent system is probably the most effective system when properly designed. This type of system also allows the possibility of gas utilization for other persons. This system is also the most expensive system.

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APPENDIX

CONSULTANTS HAVING EXPERIENCE IN LANDFILL-GENERATED METHANE PROBLEMS*

EMCON Associates
326 Commercial Street
San Jose, California 95112

Engineering - Science, Co.
7903 Westpark Drive
McLean, Virginia 22101

Heath Consultants, Inc.
100 Tosca Drive
Stoughton, Massachusetts 02072

Lockman and Associates
249 East Pomona Blvd.
Monterey Park, California

Mandeville and Associates
26981 Escondido Lane
Mission Viejo, California 92675

Montgomery Engineers of Virginia, Inc.
Reston International Center
11800 Sunrise Valley Drive
Reston, Virginia 22091

SCS Engineers
11800 Sunrise Valley Drive
Reston, Virginia 22091

Ralph Stone and Company, Inc.
10954 Santa Monica Blvd.
Los Angeles, California 90025

Leonard S. Wegman and Associates
New York City Area
Address not known

*This list consists of consultants known to the City of Richmond to have methane gas experience and is not intended to be otherwise complete.

DRAFT
5 MAR. 79

Flux Box Measurement of Methane Emanation from Landfills

C. Kunz and A.H. Lu

Division of Laboratories and Research
New York State Department of Health
Empire State Plaza
Albany, New York 12201

A simple, inexpensive technique has been developed to measure the rate of methane emanation from the surface of landfills. These measurements were made at the Fresh Kills Landfill test site on Staten Island. A methane recovery and utilization study at this site is being funded by the New York State Energy Research and Development Authority. The Brooklyn Union Gas Company, the New York City Resource Recovery Task Force, the Leonard S. Wegman Company, Inc., and the New York State Department of Health are taking part in this study. Four production wells and a number of pressure probes have been installed and gas production studies are under way.(1)

The methane emanation measurements were made using flux "boxes", consisting of halves of 55-gallon metal drums. The function of the drum is to trap gases leaving the landfill surface during the period of measurement (normally about 20 minutes). To prevent mixing with outside air, the open end of the drum was imbedded about ½" into the surface of the landfill. Care was taken to be sure there were no gaps between the surface and the edge of the imbedded drum. The closed end of the drum was fitted with two ports of ¼" o.d. metal tubing. During measurements, one port was left open so that the gas pressure in the drum was always in equilibrium with that of the

(1) A.J. Guiliani, Methane Recovery From a Shallow Landfill, Experien... at the Fresh Kills, Staten Island, N.Y., Intergovernmental Methane Task Force Symposium, Denver, CO, 21-23 March 1979.

atmosphere. The other port was used to extract samples for measurement of CH_4 concentration, using a portable methanometer of the type used extensively in mines. These hand held methanometers are battery operated and contain a pump for drawing samples from the flux box. Methane concentrations in the range of 0.1% to 5% in air can be measured, and about 300 measurements can be made with a fully charged battery. Mass spectrometer analyses performed on several samples collected separately agreed to within ±5% of the methanometer readings.

Once the drum was in place, measurements of the CH_4 concentration were made every two minutes for twenty minutes. Knowing the enclosed landfill surface area and the volume of the flux box, the rate of CH_4 emanation was calculated.

Flux box measurements were made at 21 different locations in the vicinity of the wells during 5 days in September and October 1978 (Fig. 1). The methane emanation rate varied considerably from location to location. The gases being generated throughout the landfill will vent through the most porous, fractured areas. The measured emanation rates show a number of locations with little or no methane being released, whereas a few locations were found to be venting methane at more than three times the average rate.

Variations will also occur with changing atmospheric pressure. Decreasing atmospheric pressure will cause landfill gas to vent at a faster rate, while increasing atmospheric pressure will slow the rate of emanation. To obtain a reasonably accurate measure of the methane emanation rate, measurements must be made at a number of locations

during periods of relatively constant atmospheric pressure, or the study should be conducted over the course of several days to average out the effects of atmospheric pressure changes.

The average rate of methane emanation determined for the Fresh Kills site was 26 ft^3/min/acre. We assume the average value determined for the rate of emanation is a good approximation for the production rate. Mass spectrometric analysis of flux-box gas samples showed that the average concentration of CO_2 was the same as CH_4. Therefore, the CO_2 emanation and production rates are similar to that for CH_4 resulting in a total gas production of 52 ft^3/min/acre. The total gas production rate estimated from pressure measurements[2] and gas flow modeling was 45 ft^3/min/acre.

Figure 2 shows the effect of pumping on the methane emanation rate. One drum was placed 30.7 ft from one of the wells and another 64.3 ft from the same well. Both locations showed a relatively high rate of methane emanation when gas was not being pumped from the well. When gas was pumped at 170 cfm, the rate of emanation observed for the flux box at 64.3 ft from the well decreased from 3.3 ft^3/ft^2-day to 0.9 while for the flux box closer to the well the emanation rate went from 2.2 ft^3/ft^2-day to -0.3. The negative result shows that the pumping causes air to be drawn into the landfill in the area near the pump.

In conclusion, the flux box measurements can be used to give a good approximation of the rate for methane production and can be used to evaluate the extent to which air intrudes into the landfill during pumping.

(2) A.H. Lu and C.O. Kunz, "Transducer Measurement of Landfill Gas Pressure", Intergovernmental Methane Task Force Symposium, Denver, CO, 21-23 March 1979.

FLUX BOX MEASUREMENTS OF METHANE EMANATION (ft^3/ft^2-day)

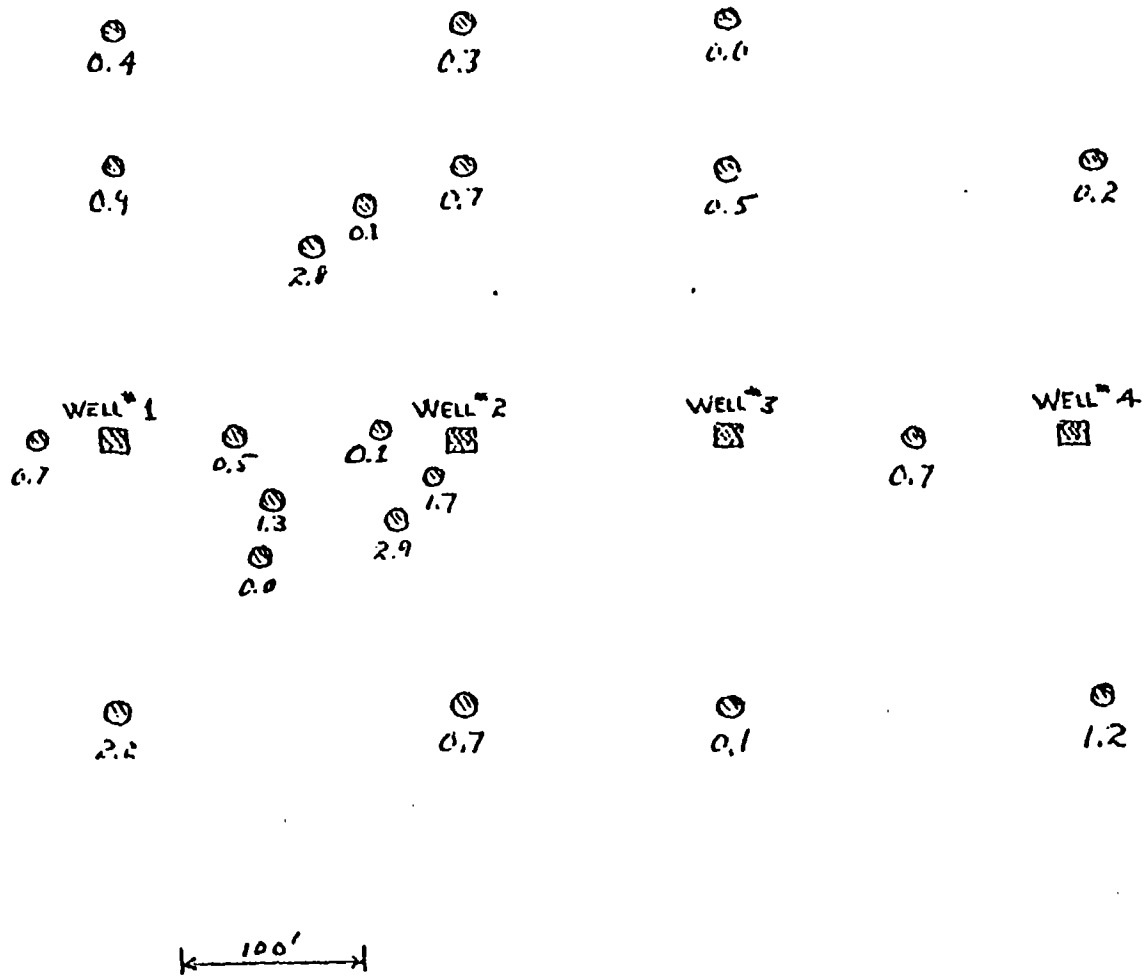
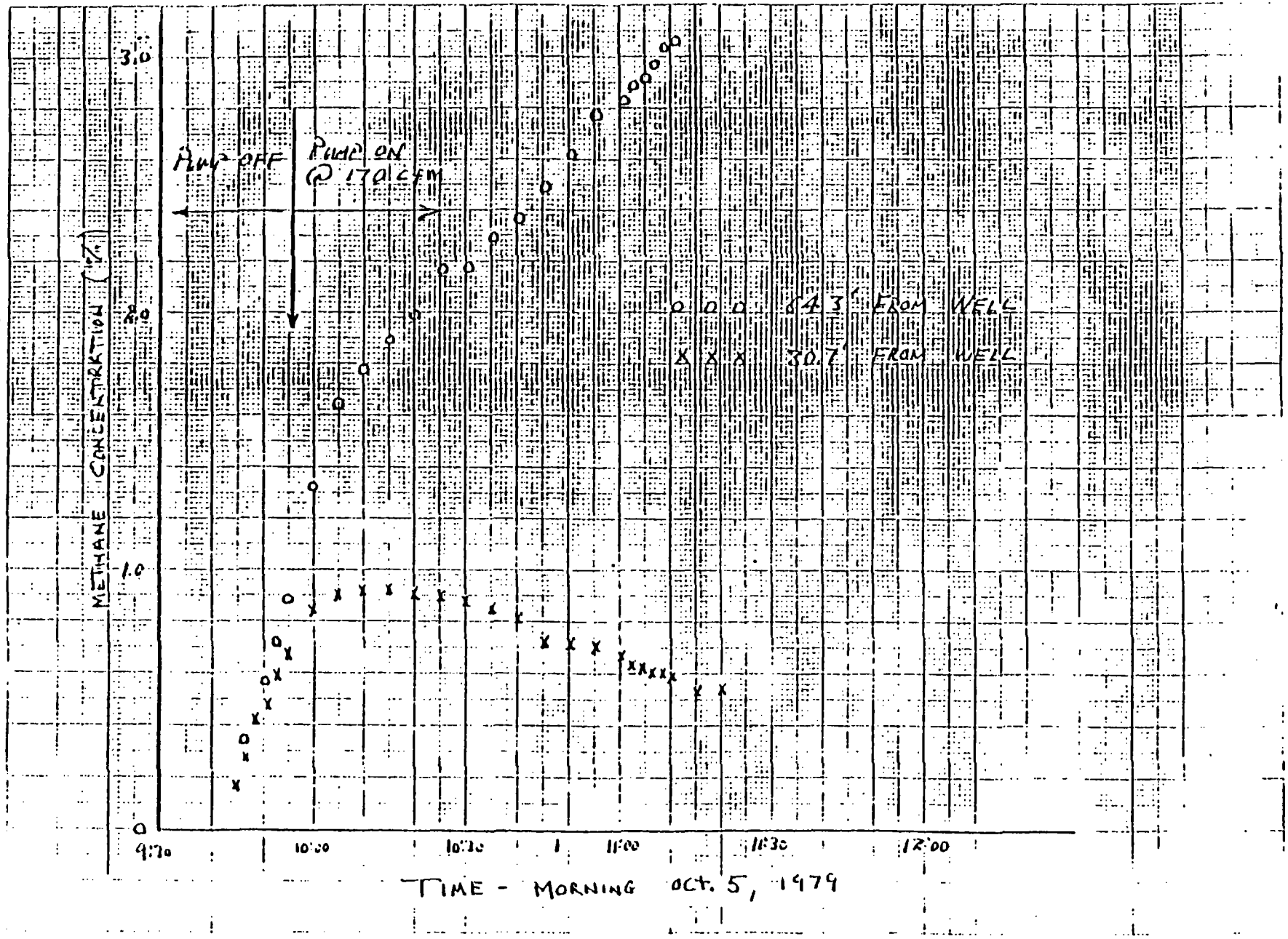


FIG 1

FIG 2


3.0
2.0
1.0
0
METHANE CONCENTRATION (%)
PUMP OFF
PUMP ON @ 170 CFM
643' FROM WELL
30.7' FROM WELL
9:30
10:00
10:30
11:00
11:30
12:00
TIME - MORNING OCT. 5, 1979

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Transducer Measurement of Landfill Gas Pressure

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The New York State Department of Health is participating in a methane recovery project at the Fresh Kills Landfill on Staten Island (1). Our primary objectives are to (1) estimate the current rate of production of methane for the entire site; (2) determine the permeability of the fill for gas movement; (3) estimate the volume of the gas reservoir in the landfill; and (4) to project an optimum pumping rate and well configuration. The Brooklyn Union Gas Company, the New York City Resource Recovery Task Force, and the Leonard S. Wegman Co., Inc. are also participating in this study, funded by the New York State Energy Research and Development Authority.

The gas production rate can be computed by studying pressure changes of gas in the landfill. The gas pressure in the landfill will be influenced by changes in atmospheric pressure, the rate at which gas is generated in the landfill, and the rate at which gas is pumped out of the landfill. This dynamic study requires accurate measurement of small pressure differentials. Six electrically-operated pressure-differential transducers are installed in well-points driven into the wastes at various locations from the production wells in order to measure the small pressure differentials between atmospheric pressure and landfill gas pressure. The atmospheric pressure at the site is also recorded with an "absolute-pressure" transducer. The differential transducers have a pressure range of three inches of water with

an accuracy of ±0.25% and a repeatability of ±0.02% of the range. The effect of temperature is less than 0.009% per degree centigrade. The associated equipment includes a constant voltage transformer and a d-c. power supply. Insulated wires up to 200 feet long are used to connect all the transducers to a data logger. The output from all transducers is recorded every one to ten minutes depending on the dynamics of the particular experiment.

Figure 1 shows a plot of atmospheric pressure measured with the absolute transducer and a plot of landfill gas pressure measured with a differential transducer. Pressure values were recorded every ten minutes. The changes in atmospheric pressure were closely followed by the landfill gas pressure, demonstrating the highly permeable nature of the landfill. During the morning of October 27, atmospheric pressure increased rapidly and the positive pressure differential existing between landfill gas and the atmosphere decreased from approximately 0.4 inches of water to 0.1 inches of water. During periods of rapidly increasing atmospheric pressure most of the gas being generated in the landfill merely increases the pressure of the void volume of the landfill. This has the effect of decreasing the loss of landfill gas to the atmosphere via pressure-induced venting through the covering soil.

Figure 2 shows a plot of atmospheric pressure and landfill gas pressure measured with three pressure probes at various distances from one of the production wells. With the pump off the three pressure probes show a positive pressure of between 0.3 inches and 0.4 inches of water. Pumping at 165 cfm caused the pressure in the landfill at 25'5" from the well to decrease to about -0.25 inches of water. Negative pressure will cause air to be drawn into the landfill

At 70'5" and 111' from the well the landfill pressure decreased but remained positive at about 0.1 inches and 0.2 inches of water, respectively.

Measurements such as those illustrated in Figures 1 and 2 are being used to develop a model which will describe the flow of landfill gas, allowing estimation of the gas production rate, void volume, and landfill permeability. A paper describing the model and results is being prepared for publication.

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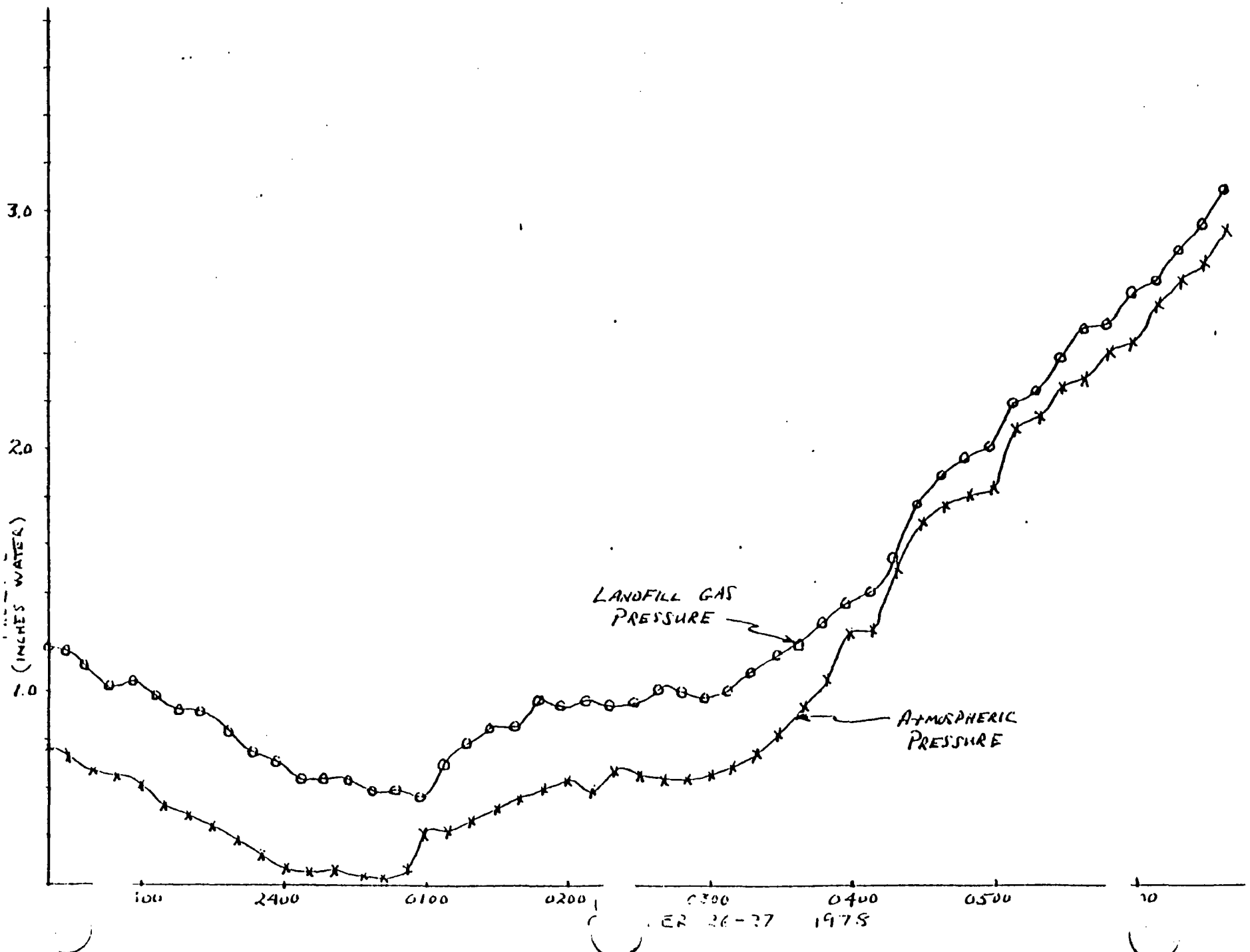
(1) A. J. Guiliani, "Methane Recovery from a Shallow Landfill, Experience at the Fresh Kills, Staten Island, N. Y.", Intergovernmental Task Force Symposium, Denver CO., 21-23 March 1979.


3.0
2.0
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LANDFILL GAS PRESSURE
ATMOSPHERIC PRESSURE
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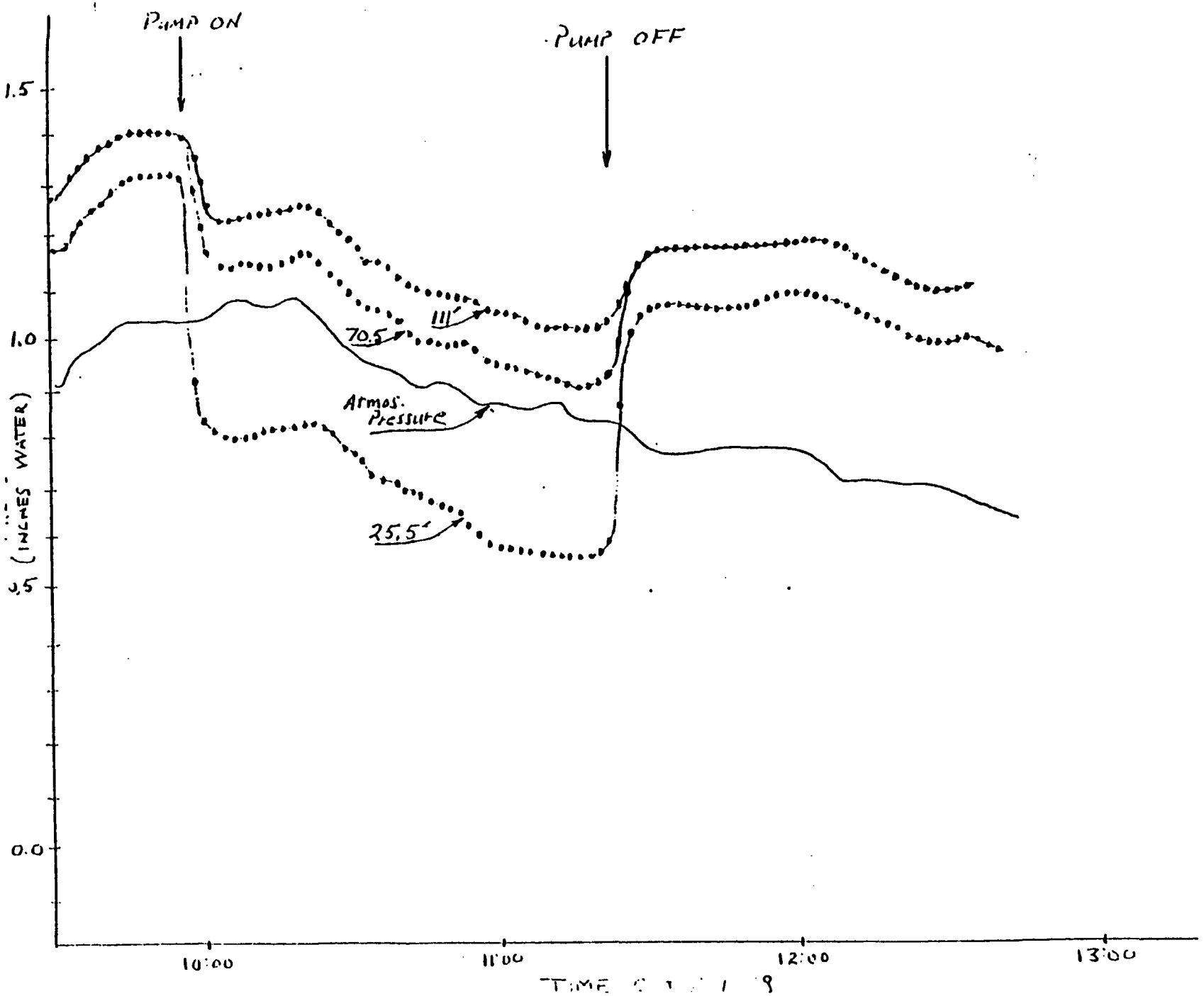
0200
0400
0500
10
1975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0.0
(INCHES WATER)
111'
70.5'
Atmos. Pressure
25.5'
10:00
11:00
12:00
13:00
TIME

Appendix

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4) "Treatment and Utilization of Landfill Gas - Mountain View Feasibility Study" (SW-583) prepared by PGandE for EPA, 1977.

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ABSTRACT

CONDUCTING A LANDFILL

GAS INVESTIGATION

by

J. A. Oliger, Senior Project Engineer,
Engineering-Science, Inc.

This paper discusses the elements of conducting an investigation of landfill produced gases in and around a sanitary landfill. These elements described include preliminary investigative work, preparation for field work, field sampling and monitoring in and adjacent to the landfill, and analyses of data developed during the preliminary office and field work.

ABSTRACT

STATE OF THE ART OF THE
DESIGN OF SYSTEMS TO CONTROL
LANDFILL PRODUCED GASES

by
Terence E. Franklin, Project Engineer
Engineering-Science, Inc.

This paper discusses the state-of-the-art of the design of systems to eliminate or mitigate the potential hazards associated with landfill produced gases. The major topics to be discussed include the predominant methods of gas transport, and the relationship to gas control, active gas control systems and passive gas control barriers.

ABSTRACT

SANITARY LANDFILL METHANE

RECOVERY PIPING DESIGN

by
Frank E. Teeple, Sr. Mechanical Engineer
Engineering-Science, Inc.

Methane gas contained in sanitary landfills is a large and valuable source of gaseous fuel. The recovery of this resource by methane mining is technically practical and where a market for the gas exists can be profitable. Systems for mining sanitary landfills consist of gas recovery wells drilled into the landfill, collector piping, flow controls, pumping subsystem and gas treatment as required by the subsequent use of the gas. This paper discusses some elements of methane mining system design including well spacing and depth, collector piping, and materials of construction.

ABSTRACT

HOW TO SELECT A
CONSULTING ENGINEER TO PERFORM
GAS CONTROL ENGINEERING SERVICES

by
Myron Ellis Nosanov, Associate,
Engineering-Science, Inc.

This paper discusses elements of the objectives and responsibilities of the client, the elements of a potentially successful gas control program, the responsibilities of the engineering consultant, impediments to success of a gas control program, and the potentially litigious nature of the use of works influenced by the presence of landfill gases.

HOW TO SELECT A CONSULTING ENGINEER TO PERFORM GAS CONTROL ENGINEERING SERVICES

by

Myron Ellis Nosanov, Associate
and
Gordon S. Magnuson, Vice President
Engineering-Science, Inc.

ABSTRACT

This paper discusses elements of the objectives and responsibilities of the client, the elements of a potentially successful gas control program, the responsibilities of the engineering consultant, impediments to a success of a gas control program, and the potentially litigious nature of the use of works influenced by the presence of landfill gases.

INTRODUCTION

The selection of the consulting engineering firm to provide landfill gas control related services can be a function of that scope perceived by the client and will be a function of the extent of the clients precognition of the extent of services to be provided.

A contractual agreement between an entity requiring services, for gas control, and a consulting engineer is most likely to satisfy all project objectives when both the client and the engineer are qualified. Not all such entities which seek gas control engineering services are, in fact, qualified, and it has been demonstrated that not all engineers and geologists which offer the said services are likewise qualified. There are only a limited number of objectives for entities which would retain an engineer to provide gas control consulting engineering services. They include identification of existing hazards, elimination or mitigation of existing hazards, and either avoidance, elimination or mitigation of the possibilities of future hazards. These objectives become the client's responsibilities when that entity elects to assume the risks implied in the above described factors. When cognizance of these factors is manifested by the entity requiring service, that entity is a qualified client.

A qualified client has a greater probability (than one who is not) of retaining an engineering consultant most qualified to address the project objectives. This article is intended to

(1) Assist the reader to become a qualified client, and

(2) Assist the qualified client to determine which prospective engineering consultant, among those available and qualified to satisfy the required objectives, should be retained.

In the opinion of the authors, the selection of a consultant should be based on evaluation of the sum total of each candidates experience in gas control, subsidence and settlement analysis, process engineering, and odor control, in each of the potential disciplines. The potential range of engineering services includes civil, structural, geologic, sanitary, mechanical, electrical, combustion, and control systems. Further, infra-red optical and heat scanning services may be required in rare instances when landfill fires occur.

THE ELEMENTS OF A SUCCESSFUL LANDFILL GAS CONTROL PROGRAM

A successful landfill gas control program can be defined as one which defines and either corrects, eliminates, or mitigates existing, potential, and future landfill gas related hazards or nuisances. The gas control hardware should be compatible with elements of construction of the development which the gas control system is to help to protect. In many cases where an existing hazard has been identified others may not yet have been detected. Additionally, a carelessly conceived control system may introduce new or secondary hazards. Therefore, careful examination of the proposed system hardware and its operating characteristics is appropriate. Naturally, existing or proposed elements of construction should be reviewed as secondary sources of potential leakage, migration, or hazard. Further, because the soils or substrate beneath which development is or is proposed and in which substructures or utilities may repose, could contain combustible gases, the terminology, "hazardous below grade" is a significant designation within the National Electrical Code.

After designs have been translated to drawings and specifications, frequency of field observation by the engineer should be established

and the nature of reporting established. Construction procedures required to prevent explosions, toxic reactions, nausea and accidents should be thoroughly discussed with the client and any contractors, subcontractors, and field superintendents prior to ordering material or equipment and again prior to breaking ground. At the latter meeting the contractor's proposed construction techniques, monitoring, and safety equipment should be discussed. During construction, all significant activity should be logged. All passive subsystem installations should be observed for conformity with the drawings and specifications by the design engineer and so certified. After construction, a report of construction should be issued and dynamic systems activated, performance tested, and balanced.

A monitoring and maintenance program should be prepared in conjunction with design, construction, and post-construction system operations. The monitoring program should contain a scenario which would occur at the time of potential failure of discrete elements of the gas control system and describe recommended corrective or precautionary action. This program should be fully reviewed, understood and approved by the client and all agencies possessed with governmental jurisdiction.

Monitoring should be performed, extending over a predetermined period of time, with a predetermined frequency. Copies of all monitoring data sheets, together with engineering analyses should be submitted to an appropriate agency.

The maintenance program should be funded and contracted for annually. Possible damage or impairment of system elements, caused by differential settlement, should be considered. The entity responsible therefore should be clearly identified. That entity should not be the engineering consultant.

THE RESPONSIBILITIES OF THE GAS CONTROL ENGINEERING CONSULTANT

The responsibilities of the gas control engineering consultant include continuous manifestation of cognizance of the objectives and responsibilities of the client and elements of a potentially successful

gas control system. Gas control engineering can be described as the application of, by the preparation of calculations, drawings, and specifications, the results of scientific research, analysis and experience involving the disciplines of geology, civil engineering, mechanical engineering, electrical engineering, combustion engineering, and process and control systems applications. The gas control engineer should be responsible for only those system components for which the engineer would be contractually oblicated, bearing consideration of the fact that the engineer did not cause the gas and therefore, (1) unless exacerbating the situation, is not responsible for its existence, and (2) unless authorized to perform construction or charged with operations, maintenance, and security of the system, cannot accept responsibility for those matters. Not addressed hereinabove, are the services of contract administration and technical observation. The former service may not be essential but may be of significant value to the client; the technical observation is, in almost all cases, an imperative service, if construction is to take place in the presence of either potentially combustible, toxic, or noxious gases. Note that the term used is technical observation, not inspection. When and because the contract for construction is between the client and the contractor, the engineer has no authority and can provide, or be, only an observer. An observer reports, without authority and therefore sans responsibility, on only those matters which the observer is privileged to view.

THE POTENTIALLY LITIGIOUS NATURE OF THE USE OF WORKS AS INFLUENCED BY THE PRESENCE OF LANDFILL GASES

There probably is no risk-free gas control project, only those which represent a risk acceptable to the client and local agencies of jurisdiction. When the risks have been deemed acceptable, and when, each party to a contract becomes involved in a gas control program, then a new potential liability of both parties begins.

Previous liabilities for potential hazards from landfill gases may extend back to the original landfill operator or landowner and may be a function of, or depend on, the state of the art and contracts, previous or extant. Many determinations of liability undoubtedly have yet to be made in the civil courts.

The primary causes for action could include: (1) diminishment of property value; (2) accident because of ignition of combustible gas; (3) toxicological or biological effects produced by odorous components of landfill gas, including nausea, illness, or fatality. Generally, these incidents could occur prior to the institution of mitigating measures or, with possibly scarcer frequency in spite of mitigating measures or, because of the lack of security for mitigating measures.

Once an active system is installed it may not function during all planned periods of operation. Further, the design and construction of passive systems, in conjunction with developer's schedules and practical construction limitations is not 100 percent efficient. Additionally, the existence of hardware systems is often a special enticement or attractive nuisance to a variety of individuals, varying from the child-like inquisitor to the malicious vandal.

Well, you the reader or listener might ask, "what has all this to do with me?" And you might say, "All I plan to do is hire an engineer and pay him to solve the problem". There are several responses to this. First, its your problem and it will probably succeed you and the engineer and his assignees or heirs. Second, there is a growing tendency to initiate legal action against all visible entities when damages are brought so the "buck" cannot be passed that readily and if it could be, third, errors and omissions insurance, for those engineers who carry it, is extremely costly so that many engineers no longer thereby indemnify themselves. Among those who do, the threat of withdrawing of coverage for this type of activity is significantly present.

SUMMARY

The client who is most likely to be assured of a successful gas control program is one who understands the total scope of the work and the nature of the services which should be expected from the gas control engineer. In the presence of a significant hazard, proposed protection or mitigation systems should include active and passive systems where and when possible; their design should be based on a comprehensive landfill gas investigation. Construction of all facilities hardware, subject to and impacted by gas hazard should be subject to either periodic

or continuous technical observation and a report and as-built drawings should be prepared. Excavation and development components constructed below grade, where methane has been detected, should comply with applicable codes and procedures for areas that are "hazardous below grade." A monitoring program should be prepared and implemented, compatible with the project objectives gas control hardware.

Maintenance should be scheduled, funded and performed. Security of facility components should be provided against accidents or intentional interference with active or passive system hardware. Responsibility for maintenance and operations should not be delegated to the consulting engineer.

CONCLUSIONS

Gas control engineering projects of significant scope and therefore, significant risks are, in fact, total concept engineering projects in that a wide variety of construction is being proposed on, in, or adjacent to properties wherein one may encounter free toxic or combustible gases. Undesirable foundation characteristics abound. The development of these projects in a manner which optimally mitigates the ever present risks involved requires engineering services which include civil, structural, geologic, mechanical, combustion, electrical, and sanitary engineering. Infra-red scanning services may also be required. The firm which is selected should be one with a history of successful experience in these disciplines.

It would benefit both the client and the consultant if each would communicate with each other, (1) regarding the client's basic objective; (2) that program which if ideally performed would provide the "safest possible situation", and (3) potentially circumstances which could limit, hamper, or impair achievement of the mutual objective of the client and consultant.

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3) "Methane Recovery Demonstration Project - Engine Generator Set Operation Report" by the L.A. Department of Water and Power, October 1975.

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