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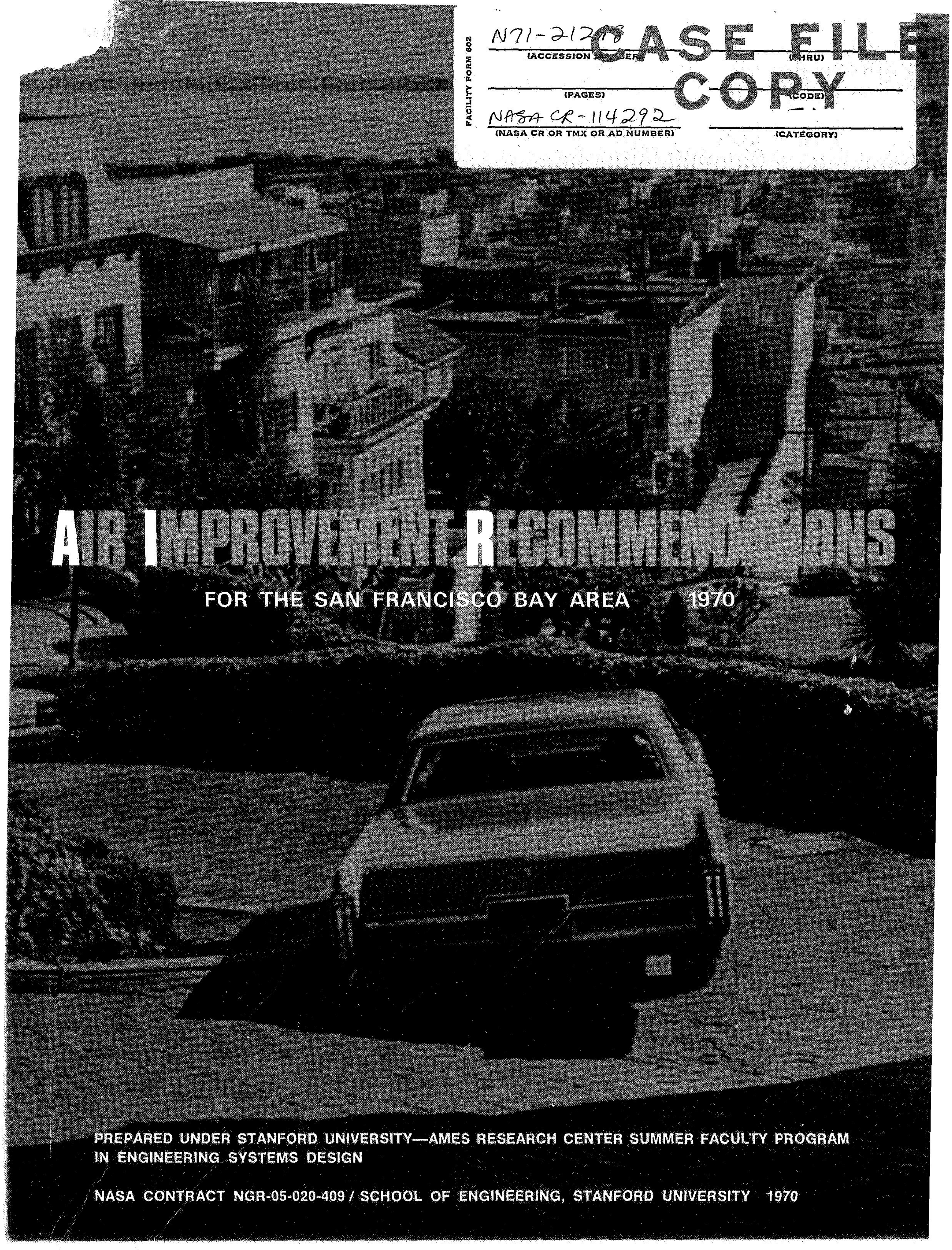

AIR IMPROVEMENT RECOMMENDATIONS

FOR THE SAN FRANCISCO BAY AREA 1970

PREPARED UNDER STANFORD UNIVERSITY—AMES RESEARCH CENTER SUMMER FACULTY PROGRAM IN ENGINEERING SYSTEMS DESIGN

NASA CONTRACT NGR-05-020-409 / SCHOOL OF ENGINEERING, STANFORD UNIVERSITY 1970

The Stanford-Ames NASA/ASEE Summer
Faculty Systems Design Workshop
FINAL REPORT

AIR IMPROVEMENT RECOMMENDATIONS
FOR THE
SAN FRANCISCO BAY AREA

October 1970

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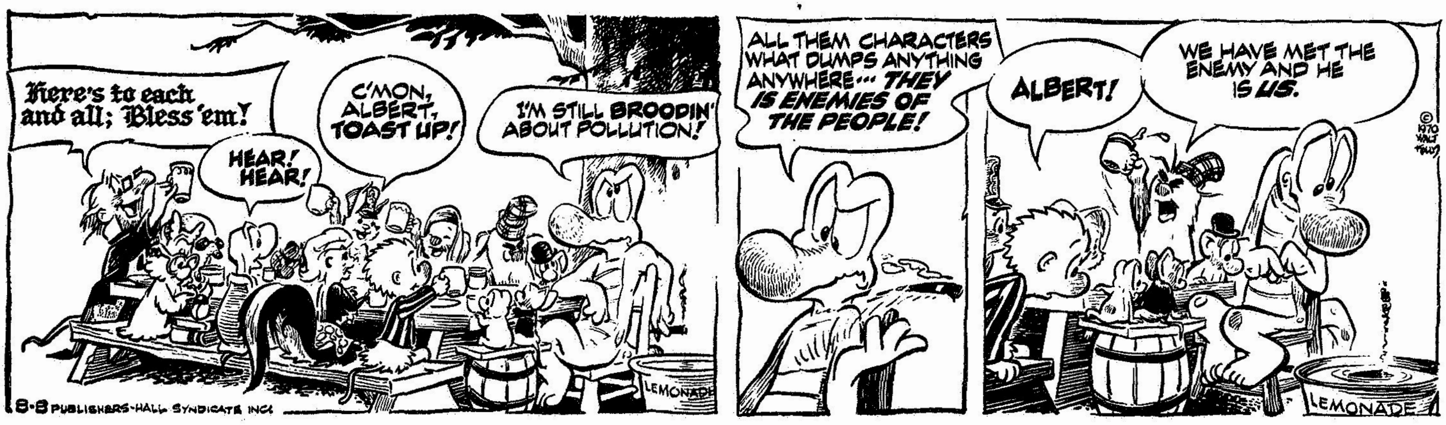

Here's to each and all; Bless 'em!
HEAR! HEAR!
C'MON, ALBERT, TOAST UP!
I'M STILL BROODIN' ABOUT POLLUTION!
LEMONADE
8-8 PUBLISHERS-HALL SYNDICATE INC
ALL THEM CHARACTERS WHAT DUMPS ANYTHING ANYWHERE... THEY IS ENEMIES OF THE PEOPLE!
ALBERT!
WE HAVE MET THE ENEMY AND HE IS US.
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LEMONADE

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INTRODUCTION

This report is the result of an eleven-week systems design project, sponsored jointly by the National Aeronautics and Space Administration and the American Society of Engineering Education. The initially stated objective of this study was to design an effective air quality monitoring system for the San Francisco Bay Area. The participants in the project, which was held at Stanford University during the summer of 1970, were twenty faculty members, from various schools and universities across the country, most of whom had not been previously involved in any air pollution studies.

After a week and a half of introduction to the air pollution problem, highlighted by lectures by various experts in the business--members of national, State, and local control agencies and some researchers in the field--the group spent three weeks in gathering information and developing interesting topics without attempting to consolidate the results into a cohesive whole. Some of the areas studied in this phase were:

(a) the Bay Area Air Pollution Control District (BAAPCD), its administration, and its operations.

(b) the current status of the ambient air quality monitoring system and the air pollutant source surveillance system in the Bay Area.

(c) the role of modeling in the air pollution problem.

(d) a survey of currently existing models, their usefulness and limitations, and areas where they might be further developed.

(e) the role of the automobile as a pollutant emitter, now and in coming years.

(f) potential sources of funding for more comprehensive monitoring and control programs.

The next three weeks were devoted to converging upon solutions. The outline of the final report was developed early in this phase and responsibility for developing various sections of the report was assigned to the individual members of the project. The presentation of an interim project report to a meeting of the Board of Directors of the BAAPCD proved to be a stimulating and beneficial feature of this phase, since it served to point out some of the weaknesses in the study. The final three weeks of the project were spent in further development of the subjects covered in the report, in providing the necessary cohesiveness, and in producing a summary report for BAAPCD. The heart of this summary report was a series of specific recommendations, all also contained in this final project report, of means by which the air pollution control program could be made more effective.

In developing an outline for the final report, the project participants decided that the report should attempt to answer the following questions.

1. What is the air pollution problem in the Bay Area? What are the important pollutants and their sources? Is the concept of "air quality" well defined? Are sufficient data available to definitively show that air quality is getting better or worse in the Bay Area?

2. What data should a good ambient air monitoring and source surveillance system provide. Is the current Bay Area system providing this information? What improvements should be made to the present system?

3. What specific changes and/or additions could be made to the BAAPCD program and the programs of other local, State, and Federal agencies in the immediate and near future to make them more effective in alleviating the air pollution problem in the Bay Area? What other alternate and/or additional strategies should be considered in developing a long-range air pollution control program?

The first two chapters in this report could serve as a primer on the air pollution problem in the San Francisco Bay Area. Chapter 1 addresses the questions in group 1 above. In addition, the roles of the various Federal, State, and local control agencies are discussed. The control programs currently in effect in the Bay Area are briefly described in Chapter 2, along with projections of how the pollution problem may develop in the future in the light of these programs.

Chapters 3, 4, and 5, which answer the questions of group 2 above, should be of particular interest to those readers who are concerned with the problems of air quality monitoring and pollution source surveillance. Chapter 3 outlines the project participants' view of what data a good monitoring and surveillance system would produce and how the data could be used for such purposes as the prediction and control of air pollution episodes, more effective enforcement of pollutant emission regulations, and the testing of the validity of various models which relate air quality to pollutant emissions. In Chapter 4 the presently existing monitoring and surveillance system in the Bay Area is described and its shortcomings are pointed out. This leads to Chapter 5, which describes both improved monitoring systems for air quality and source emissions and the data handling and storing methods that should be used with them. The predictive capability of models, which can use these new data, and the status of their development are outlined in Chapter 6.

The questions of group 3 above are the subjects of Chapters 7 and 8. Recommendations of specific steps which could be taken in the immediate and near future to improve the presently existing control programs are the subject of Chapter 7. Most of these recommendations are directed toward the BAAPCD, but other local and state agencies are also considered.

Examples of the areas covered by these short-term recommendations are increased public awareness and support of the control agencies, more efficient regulation enforcement, and internal administrative changes. Chapter 8 is concerned with the long-range solution of the air pollution problem. Suggestions are made for control strategies which are not concerned solely with emission restrictions on pollutant sources. Among other ideas, these strategies involve alternate means for providing necessary goods and services the production of which is now accompanied by excessive pollution emissions, reduction in demand for such goods and services, and the inclusion of pollution considerations in regional planning and development.

The more detailed technical aspects of the study, such as tests of new monitoring and surveillance instruments, discussions of the computer programs used during the project, and details of sample calculations, are included in the appendices.

Although this report is focused on the air pollution problem in the San Francisco Bay Area and most of the suggestions and recommendations are pointed toward that problem, many of the ideas contained herein should be readily extendable to the air pollution problems in other areas. Thus it is expected that this report will be of interest to a wider spectrum of readers than those in the Bay Area.

Chapter 1

THE PRESENT BAY AREA AIR POLLUTION SITUATION

1.1 Introduction

What is the situation in the Bay Area? Is the air bad? When and where is air pollution the worst? Is the air becoming more polluted or less polluted? Who are the major polluters? Are the control agencies doing their jobs? These are questions which should be occuring to concerned citizens in the Bay Area. Available data seem to indicate that the level of pollutants in the air could be hazardous to the health of certain segments of the population; pollution is worse in some areas than others, and there are strong seasonal variations; the diversity of industry and the geographic scale of the Bay Area makes it difficult to isolate major sources of pollution other than the automobile. The exact nature of the present threat to health has not been established. Past activities of control agencies have prevented much pollution from entering the air, but continued growth of the area has offset this to the point that only a holding action, or at best a slight improvement has resulted. In order to appreciably reduce air pollution it will be necessary for attitudinal changes (explicit goal-setting) to take place throughout the control agencies. The contents of this chapter will elaborate on these statements.

When, at the request of the study group, a private citizen telephoned the Bay Area Air Pollution Control District (BAAPCD or "The District") and asked "What can I do about local air pollution?", it was suggested that he become educated in the intricacies of the pollution problem, that he communicate his concern to legislators and other pertinent public officials, and that he report any violations of District regulations--usually smoke or odor. The caller was also mailed a copy of the District's public information primer,[1] which introduces some of the technical aspects of the problem and includes a selected set of statistics. The hard information contained in this booklet is meager, however, and in some respects misleading.* It does not provide the citizen with a clear statement regarding the implications of the present pollution levels in the Bay Area, nor does it attempt to explain why pollution still seems to be a problem even though the local District has been in operation since 1955.

It is not surprising that public information released by the local District has been somewhat simplistic in nature since it is a control agency, concerned primarily with the legal and technical aspects of air pollution. District people have felt, and probably rightly so in the past, that the average citizen would not understand the technical details which would be required to support a more comprehensive treatment of the subject. However, education of the public is proceeding at a rapid rate, and air pollution is not strictly a technical problem. Many students of the phenomenon are coming to believe that control will ultimately be

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*Note added in final editing: a new, expanded edition of this booklet is in preparation.

achieved only through drastic changes in attitudes and life styles. If this is true, then the technical components of the problem may be by far the easiest to solve. As the number and severity of air pollution incidents increase around the world, the average citizen is being introduced by newspaper and television to some of the technical intricacies of the pollution problem. Those living in major urban areas, particularly in the Eastern United States, are being made painfully aware of the fact that the existing legal and political apparatus for pollution control is inadequate for dealing with the accelerating degradation of air quality. The social and political problems encountered in attempting to reach a concensus on what to do are monumental.

It was a general feeling of the participants in this study group that a concerned and knowledgeable public is a powerful resource which the local District could use to help control air pollution. The discussions contained in this chapter and the following one are addressed to such concerned individuals who wish to learn more about the air pollution problem in the Bay Area, its past, present, and future. It is assumed that the reader is somewhat familiar with the basic physics of air pollution;[1] although a brief review is undertaken for the purposes of establishing definitions and setting perspective. The primary objective of this introductory chapter, however, is to present an integrated picture of the social, political, and technical aspects of pollution control, including the structure and local implications of the Federal and State activities, and to relate the present Bay Area situation to this picture. In this way it is hoped to establish not only what is wrong, but also who should be responsible for corrective action.

1.2 Air Pollution: Contaminants, Effects, and Sources

In considering the air pollution problem, it is useful to distinguish between two aspects, the "emissions" of pollutants at their sources (usually measured as a weight per unit time: pounds per day, grams per second, tons per day) and the "concentrations" of pollutants in the atmosphere (usually measured in parts per million, ppm, or micrograms per cubic meter, $\mu g/m^3$). The situation is complicated by the fact that many pollutants, once emitted, undergo chemical changes in the atmosphere and are transformed into new substances, or "secondary" pollutants. "Primary" pollutants, on the other hand, may remain in the atmosphere, exactly as emitted, for long periods. The effects of pollution are related to the concentration of contaminants in the air, but control measures must be applied to the sources.

The effects of pollution can be measured in terms of health (both physical and mental), aesthetics, and economics (including damage to structures, plants, and animals). Different pollutants produce different effects, and accurate quantitative determination of these effects is generally lacking. The state of knowledge regarding effects of different concentrations of pollutants can be assessed by examining summary charts, prepared by health agencies, of available experimental results, such as included in Appendix 1-1. Such data are sketchy at best, are occasionally contradictory, and show primarily that different groups of people are affected differently. Nevertheless some qualitative observations enjoy fairly general acceptance and are useful for illustrating the nature of the threat.

The major pollutants can be classified as follows:

Particulate Matter. This includes carbonaceous particles, tars, oils, insoluble metal fumes, dust, amorphous lead, and organic debris. Large particles (over 10 microns) produce dust fall and soiling, resulting primarily in economic damage. Smaller particles (0.1 - 1.0 micron) scatter light, causing aesthetically unpleasant haze. They may penetrate and lodge in respiratory passages producing a serious health hazard, particularly for children and persons with respiratory illnesses.[2]

Irritants and Oxidants. Irritants include soluble dusts, volatile hydrocarbons, acidic mists, aldehydes, olefins, vapors, and gases such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2); oxidants include ozone, peroxyacetyl nitrate (PAN), and its homologs PBN, PPN, etc. Depending on their relative concentrations, these pollutants cause eye, nasal, and pulmonary irritation, as well as aggravating any chronic respiratory illness. In addition, oxidants are known to produce plant damage.

Systemic Poisons. These include carbon monoxide (CO), hydrogen sulfide (H_2S), cyanides, nicotine, pesticides, nitrogen dioxide and lead compounds. Carbon monoxide has been linked to a spectrum of adverse health effects ranging from dizziness and headaches to heart attacks, brain damage, and disorders of the nervous system; it is absorbed exclusively via the lungs, and its primary effect is due to its reaction with hemoglobin, resulting in less oxygen being carried to body tissues. Some of these poisons have a tendency to accumulate in the body over long periods of time, and some have been linked to cancer.

Air pollution sources may be divided into two categories: stationary (i.e., powerplants, industrial processes, incinerators, residential units, etc.) and mobile (i.e., automobiles, trucks, buses, trains, ships, and airplanes). Stationary sources are the major emitters of particulates and sulfur oxides; mobile sources emit the bulk of the carbon monoxide and lead. Both contribute organic materials (hydrocarbons, or HC) and nitric oxide (NO) which chemically react with one another in the presence of sunlight to form eye irritating oxidants and the whiskey-brown color of smog.

In determining which pollutants are the most immediate problems, which sources should be controlled, and what level of control should be imposed, consideration must be given to concentration and distribution of pollutants in the air, relative toxicity, and rates of emission. A local problem caused by a single source is relatively straight forward to correct. The tough control problems are presented by the distributed sources, both stationary and mobile, and by the economically and politically powerful stationary sources.

The pollutants presently recognized as having the highest priority for control (i.e., those for which standards have been set) are particulates, CO, H_2S, SO_2, NO_2, and oxidants. Of these, the first four are primary pollutants, and the major components of the last are secondary pollutants. NO_2 appears both as a primary pollutant (from power plants) and as a secondary pollutant (from automobile exhaust). Emission control for oxidants must be imposed on sources of NO_x (i.e., all of the oxides of nitrogen) and hydrocarbons. It is popular to talk about air pollution in terms of the total emission of all contaminants in tons per day, the total reported for the Bay Area in 1969 being 9179 tons per day.[3] Such numbers make it appear simply that the total quantity of pollutants emitted is important, and that a ton of one pollutant is as serious as a ton of another. In fact, the measurement of particulates in tons per day is completely meaningless for determining health implications unless the measurement is broken down according to particle size and composition: a cloud of 0.5 micron particles which obstructs visibility and is ingested and retained in the lungs contains a thousand times as many particles as an equal weight cloud of 5 micron particles (of the same composition) which do not obstruct visibility and are not retained in the lung.

The extent to which such emission tonnage numbers can be used to generate confusion is further illustrated by their use in the automobile controversy: is the automobile the primary source of pollution or not? Depending upon how the numbers are manipulated either answer can be obtained. Consider, for example, the data contained in Table 1.1. On the basis of tons per day of emissions, the automobile accounts for 72% of the total, but the percentage figure rises to 84% if the tonnage figures are compared for only CO, and drops to 52% if the tonnage figures are compared for the sum of organics and NO_x (the precursors of photochemical smog). To present a valid overall comparison for the two source categories, it seems appropriate to correct for relative toxicity, as implied in the concentrations allowed by the State air quality standards (see Table 1.2); this is the basis for the concept of "normalized emission units" shown in the right hand columns of Table 1.1. Viewed this way, the figures show the automobile accounting for 56% of the problem.

The sum up: It is clear that we have neither a good yardstick for comparing various air pollutants nor can we say what is the major contributor to air pollution. Although various interests have blamed either the automobile or industry as the major polluter, both sources contribute heavily, and major air quality improvements are not likely to come about until both are controlled effectively.

1.3 What is "Air Quality"?

The term "air quality" as generally used refers to the "goodness" or "badness" of the air. Evidently this should be determined by measuring what is actually in the air. Although the previous section indicated the potential for confusion when treating combined emission figures, there are nevertheless good reasons for seeking combined indicators for what the state of the air is in terms of its contents. The primary uses of such indicators are for public information and for use in planning control or emergency strategies.

The control of air pollution cannot wait until research can establish precise relationships between concentration levels and degree of damage to

Table 1.1

COMPARISON OF BAAPCD-CONTROLLED EMISSIONS AND AUTO EMISSIONS IN TONS/DAY AND IN NORMALIZED EMISSION UNITS

	Emissions, Tons/day (1)		Normalized Emissions, Units (2)	
	District	Auto	District	Auto
ORGANICS	941	958	0.49 (3, 4)	0.50 (3, 4)
NO_x	194	370	0.31	0.59
SO_x	330	21	0.18 (5)	0.01 (5)
CO	956	5208	0.03 (6)	0.16 (6)
Particulates	160	41	- (7)	- (7)
TOTAL	2581	6598	1.01	1.26
%	28%	72%	44%	56%

(1) Data from 1969 BAAPCD Emission Inventory.[3]

(2) Units defined as concentration in homogeneous 1000 ft. ceiling box divided by ARB standard.

(3) Based on average molecular weight equal to hexane.

(4) Based on 0.4 ppm standard set by NAPCA: "Air Quality Criteria for Hydrocarbons".

(5) Based on 0.5 ppm standard for low particulate concentrations.

(6) Based on 20 ppm standard.

(7) No basis for establishment of units.

Table 1.2

AMBIENT AIR QUALITY STANDARDS

Pollutant	Standard	Objective
Oxidant (Corrected for Nitrogen Dioxide)	0.1 ppm for 1 hour.[1]	To prevent eye irritation and possible impairment of lung function in persons with chronic pulmonary disease, and to prevent damage to vegetation.
Carbon Monoxide	20 ppm for 8 hours.	To prevent interference with the capacity to transport oxygen of the blood.
Hydrogen Sulfide	0.03 ppm for 1 hour.	To prevent odor.
Nitrogen Dioxide	0.25 ppm for 1 hour.	To prevent possible risk to public health and atmospheric discoloration.
Sulfur Dioxide	0.04 ppm for 24 hrs.[2] 0.5 ppm for 1 hour.	To prevent pulmonary irritation To prevent odor.
Visibility Reducing Particles	In sufficient concentration to reduce visibility to 10 miles at relative humidity of less than 70%.[1]	To prevent visibility reduction.
Particulate[3] Matter	60 ug/m^3, annual geometric mean, 100 ug/m^3, 24 hour sample.	To prevent health effects attributable to long continued exposures.

[1] Not to be equaled or exceeded 3 days consecutively or 7 days in any 90-day period.

[2] Applicable in areas where the particulate matter standard is exceeded.

[3] Applicable in the S. F. Bay Area Air Basin and South Coast Basin only.

health or property for each pollutant. Consequently, what information is available has been used to establish "air quality standards" (discussed further in the next section), which are pollutant concentrations that should not be exceeded in the atmosphere. This is not to say that air containing pollution to just below these levels will be "good" air. Essentially, these standards provide one definition of "bad" air, in terms of single pollutants, but leave open the question of what "good" air is.

The BAAPCD combined pollutant index, or CPI[4] is a first attempt to combine measured pollutant concentrations into a single number which can be used as a scalar indicator of air quality. The CPI is formed by combining measured concentrations of oxidant, carbon monoxide, nitrogen dioxide, and particulates with rather arbitrary weighting factors in such a way that the value ranges roughly from zero to one hundred for the Bay Area. The value is computed and released to the news media on a daily basis. For purposes of interpretation, the scale of possible values is again rather arbitrarily broken down into regions denoted as "clean air", and "light", "moderate", "heavy", and "severe air pollution". These descriptions are not entirely adequate, however, since an unmistakable whiskeybrown haze is sometimes clearly visible on days when the CPI shows "clean air".

Depsite the last statement, the Bay Area's CPI is heavily weighted toward visible pollution and does not explicitly consider the established air quality standards for the pollutants included. A next generation combined index, based primarily on these standards, is proposed and described in Chapter 3.

1.4 Who is Responsible for the Control of Air Pollution?

The present programs for the control of air pollution in the San Francisco Bay Area are the culmination of the actions of a number of organizations and individuals, ranging from the U. S. Congress to local citizens and interest groups. The resulting "chain of command" is shown in Figure 1.1. The roles of the various elements in this chain are discussed in the following paragraphs.

In response to growing public concern over health and ecological hazards, the U. S. Congress began legislative action concerning air pollution which culminated in the Air Quality Act of 1967 and several subsequent amendments. The intent of Congress in passing this act can be seen in these quotes from the report of the Committee on Public Works:

> "The committee feels that under any circumstances protection of health should be considered a minimum requirement, and whenever possible, standards should be established which enhance the quality of the environment.
>
> "Considerations of technology and economic feasibility, while important in helping to develop alternate plans and schedules for achieving goals in air quality, should not be used to mitigate against protection of the public health and welfare."

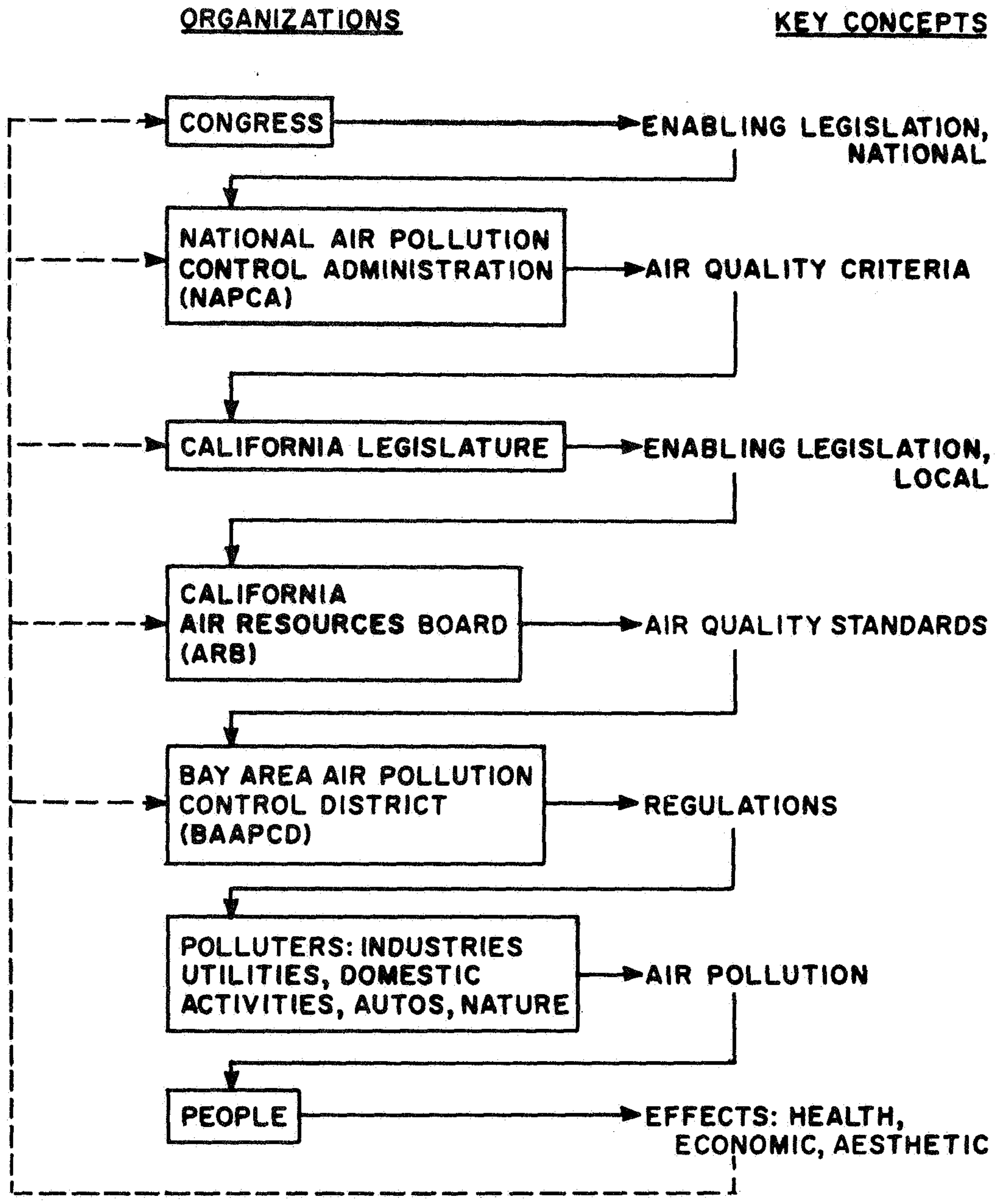

Figure 1.1. ORGANIZATIONS AND KEY CONCEPTS INVOLVED IN AIR POLLUTION GENERATION AND CONTROL IN THE BAY AREA.

It is important to note that the Congressional intent was not to compromise air quality for economic or technical reasons.

The National Air Pollution Control Administration (NAPCA) is the agency presently responsible for the Federal program. NAPCA is now within the Department of Health, Education, and Welfare, although it may soon be moved to the newly created Environmental Protection Agency. NAPCA has created various Air Quality Control Regions, one of which encompasses the San Francisco Bay Area. NAPCA is also charged with establishing "Air Quality Criteria", which link pollution levels with health and economic effects. Such criteria have been established for several pollutants.[5]

Federal law requires the states to establish "Air Quality Standards", acceptable to NAPCA, based on the Air Quality Criteria. These standards represent air quality goals in terms of desired limits on pollution concentrations actually in the air. In California, the legislature has established the Air Resources Board (ARB). The ARB has formulated Air Quality Standards,[6] summarized briefly in Table 1.2, which apply to the Bay Area as well as to the rest of California. These standards are now under review by NAPCA.

Within the Bay Area the responsibility for regulating the sources of pollutants, so that the State air quality standards are met, rests with the Bay Area Air Pollution Control District. Actually, the District has been involved in air pollution control since 1955, so that the Air Quality Act of 1967 amounted to the injection of an external review agency (the ARB) into already-established District programs and activities. To date, the District has adopted three regulations to limit pollution emissions:

Regulation 1 (effective October 1, 1957) - prohibits open burning.

Regulation 2 (effective January 1, 1961) - limits emission of particulates, hydrocarbons, and sulfur dioxide from industrial, commercial, and industrial sources.

Regulation 3 (effective January 4, 1968) - controls emissions of reactive hydrocarbons.

In addition, residential incineration has been banned since January 1, 1970. The District maintains a staff of inspectors to cite violators of these regulations. In addition to controlling pollutant emissions, the District is also required to monitor air quality (contaminant concentrations) in the Bay Area and provide the data to the ARB for evaluation.

The final and most important group in the chain is the people: through their consumption of products and services, they are the root cause of the air pollution problem; it is their health and comfort which poor air quality jeopardizes; it is presumably on their behalf that the legislative and control bodies act. Just as the people are influenced by the other elements in the chain, so can they influence those elements, either individually or collectively through interest groups such as the Sierra Club, Citizens Against Air Pollution, and the Bay Area League of Industrial Associations. This influence is indicated by the dotted lines on Figure 1.1.

The chain of command described above is very nice in theory; how does it work in practice? Unfortunately, like many other such chains, this one does not work as well as it might. There are at least two major reasons. First, the desire for continued economic growth and the desire to preserve the environment are often in conflict. Our national policy has long been committed to stimulation of continued economic growth. The concept that "growth is progress" is perhaps too well engrained in both national and local policy, in both organizational and individual thinking. Existing economic and political pressures are such that, despite the neat phraseology of the Committee on Public Works quoted earlier, any member of a legislative or regulatory agency would think long and hard before attempting to enact or enforce regulations which might stifle regional growth, say by driving out an industrial installation and thus eliminating some jobs and reducing the tax base.

Secondly, the changing number and identity of elements in the chain of command tends to obscure and confuse the authorities and responsibilities of the individual elements. Long-range objectives have been established by the Federal Government in vague and somewhat ambiguous terms, such as "protection of health" and "enhancement of the environment". These have been translated by the State into short-term goals; i.e., air quality standards which should not be exceeded. The final responsibility for regulating sources so that the standards are met is divided between the District (for fixed sources) and the State and Federal Governments (for automotive sources). This span of bureaucratic control, coupled with the instability of bureaucratic structure, leads to "passing the buck" and gaps in the overall control program. Historically, air pollution control was carried out within the Department of Public Health. When extensive pollution became noticeable in the San Francisco Bay Area, the local District was formed. The history of national Congressional action since 1959, State action creating the ARB in 1968, and the recent creation of the National Environmental Protection Administration, as well as pending bills in State and Federal legislatures have produced kaleidoscopic changes in the legal operating environment of the District. Considerable energy must be diverted from the primary task of controlling air pollution to the jobs of interpreting and meeting new requirements as well as to conducting legislative advocacy in cases affecting the District's operations.

There are two prime examples of how the District has been caught in a legislative squeeze. Napa, Solano, and Sonoma Counties, although within the air basin that encompasses the Bay Area, have chosen not to join the Bay Area Air Pollution Control District. This was permitted by the State legislation which established the District. Thus, although the pollutant emissions from these three counties affect the air quality in the area for which it is responsible, the District at present has no authority to regulate those emissions. In spite of requests by the

District to the State Legislature, the membership of Napa, Solano, and Sonoma Counties in the BAAPCD has not yet been made mandatory.*

More important is the automobile problem. As pointed out in Section 1.2, the automobile is a major source of air pollutants in the Bay Area, yet the District has no authority to set emission limitations for individual cars; this has been preempted by the Federal and State programs. The only recourse left to the District is to enforce the vehicle emission standards currently established by the State (see Section 2.3 of Chapter 2) or to encourage regulation of automobile traffic as it deems necessary. Such actions by the District are recommended in Chapters 7 and 8 of this report. To date, the District has maintained a "hands off" policy toward the automobile; although it is a major contributor to a local problem, there is no local regulation.

The task of communicating and competing with other agencies is a further complicating factor. Planning agencies concerned with transportation, housing, utility services, and industrial development, as well as agencies concerned with water pollution and waste management, should be continuously exchanging information with the District in order to ensure consistent, orderly, and desirable development of the entire Bay Area. Support of such planning and communication activities is an investment in the future, and resources spent in this way are not available to enforce existing regulations or to develop new regulations for producing some immediate reduction in pollution levels. As far as the District is concerned the need to produce immediate results is far more pressing than the need for a sound long-range plan. It is immediate results which establish credibility and a good image, providing ammunition for entering the annual skirmish for funds; adequate funding is essential if the battle against air pollution is to progress. Here, again, the appearance of economic pressures tends to force the system into a hold-the-line posture, devaluing the "expensive" search for an effective, more permanent solution.

Although the District is the control agency most visible to local interest groups, it is important to keep sight of the legitimate distribution of responsibility throughout the bureaucratic hierarchy. One cannot be too critical of existing public agencies for their past actions, considering the dynamic nature of the associated bureaucracy. However, any such agency should be expected to maintain an up-to-date statement of its interpretation of the nature of its authority and responsibility. Table 1.3 presents an interpretation of such responsibilities based on study of published literature. In addition to those responsibilities listed, each governmental agency should disseminate information which will facilitate independent evaluation of its effectiveness by outside interest groups. Ultimately, the responsibility for air pollution control rests with the people, who must continually reassure themselves that the governmental machinery they have set up for protecting their interests is functioning effectively.

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* As of this writing, such legislation is under consideration.

Table 1.3

AN INTERPRETATION OF THE DISTRIBUTION OF RESPONSIBILITIES PERTINENT TO AIR POLLUTION CONTROL IN THE BAY AREA

Organization	Responsibility
People	Gather into interest groups which formulate and articulate objectives and goals and convey them to legislative and regulatory agencies.
U.S. Congress	Transform objectives and goals of certain interest groups into national objectives and goals. Provide organizational structure and funding for implementation of national goals. Establish legal structure consistent with these goals.
NAPCA	Provide technical support for, and review effectiveness of, state control activities. Direct and support research into the effects of air pollution, development of more meaningful measures of air quality, and development of analysis and prediction tools.
California Legislature	Provide legal structure for establishment of strong air pollution control organizations on a regional basis.
ARB	Set air quality standards and time-table for compliance. Evaluate effectiveness of local districts and provide backup where local districts are legally hampered.
BAAPCD	Pass and enforce emission regulations. Collect and interpret air quality data. Inform local population of extent and cause of local threat.
Polluters	Obey the law. Form into interest groups to advocate changing unfavorable laws.

1.5 The Bay Area Situation: Past and Present

Is the Air Bad?

The State Air Resources Board has set air quality standards, Table 1.2, which it feels should not be exceeded anywhere in the State at any time. According to these standards the air in the Bay Area is in fact "bad", in that the standards for nearly all of the principal pollutants are exceeded frequently. Table 1.4 is a compilation of these occurrences for 1969.

When and Where is Pollution the Worst?

Air pollution is definitely seasonal. The "smog season" is said to be from April to November, although meteorological conditions conducive to pollution episodes also occur in the winter. Air pollution is worse in the neighborhood of significant sources and where meteorological conditions tend to cause high concentrations. Low altitude temperature inversions* (300-500 feet) lasting for several days are occasional occurrences in the Bay Area, and what winds there are during these periods are light and variable and tend to blow in a southerly direction, causing pollution buildups in the South Bay and Livermore Valley areas. This geographic variability of air quality is indicated in the data of Table 1.4.

Is Air Quality in the Bay Area Improving or Degrading?

Long-time Bay Area residents are in disagreement when asked to make a subjective response to this question. Available data are not much more enlightening. As Chapter 4 will point out, pollutant emission data published by the BAAPCD are largely based on estimates, many of dubious value, while it is uncertain how accurately the measurements of pollutant concentrations by the BAAPCD at its present air monitoring stations reflect actual air quality throughout the Bay Area. Based on these data, however, some tentative conclusions can be drawn.

Table 1.5 shows the BAAPCD's estimates of pollutant emissions over the past fifteen years. The entries for "Total" emissions should be considered meaningless, as discussed earlier. It should be remembered that the numbers in Table 1.5 are only estimates; the District has stated that they are perhaps valid to ten percent.

Particulate emissions under the District's jurisdiction (stationary sources) show the effects of the early regulations against open burning (1957) and emissions of HC, SO_2, and particulates from industrial and commercial sources (1961). Particulates are a major

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*A "temperature inversion" is a meteorological condition under which the temperature of the air increases with altitude, rather than decreasing, for some range of altitudes. This situation inhibits the tendency of warm gases (polluted air) to rise, thus putting an effective "lid" on an area, under which contaminants tend to accumulate (see Appendix 6-1).

Table 1.4

AIR POLLUTION IN THE BAY AREA--1969--BY STATION (Source: BAAPCD)

STATIONS	Oxidant		Carbon Monoxide		Nitrogen Dioxide		Sulfur Dioxide		Suspended Particulates	
	Max	*	Max	*	Max	*	Max	**	Mean	***
San Francisco	.09	0	24	0	.34	2	.054	8	51	5
San Rafael	.14	16	20	0	.18	0	.037	0	-	-
Richmond	.14	13	19	0	.29	1	.037	0	57	15
Pittsburg	.17	28	12	0	.10	0	.043	2	67	24
Walnut Creek	.23	54	-	-	-	-	-	-	-	-
Oakland	.18	11	24	0	.25	1	-	-	-	-
San Leandro	.23	36	-	-	-	-	-	-	-	-
Fremont	.27	74	16	0	-	-	.006	0	73	26
Livermore	.37	128	-	-	.29	1	-	-	-	-
San Jose	.26	71	26	0	.21	0	.010	0	60	19
Redwood City	.25	39	19	0	.28	2	.008	0	53	16
Burlingame	.15	14	20	0	-	-	-	-	-	-

[*] Number of Days Ambient Air Quality Standard was Exceeded

[**] Percent of Observed Days when Ambient Air Quality Standard was Exceeded

[***] Percent of Observed Days when Ambient Air Quality Standard for 24 hours (100 $\mu g/m^3$) was Exceeded

Notes:

1. For oxidant, carbon monoxide and nitrogen dioxide, "max" is highest hourly value expressed in parts per million.
2. For sulfur dioxide, "max" is highest 24-hour value expressed in micrograms per cubic meter.
3. For suspended particulates, "mean" is the annual geometric mean in micrograms per cubic meter.
4. Sulfur dioxide data are for only 3 months: 10/69 to 1/70.

Table 1.5

BAY AREA EMISSIONS[3]--1955 - 1969--TONS/DAY

	1955	1957	1959	1961	1963	1964	1965	1966	1967	1968	1969
Organics											
Dist. Jur.	1133	1179	849	871	863	873	871	902	939	960	941
Motor V.	736	820	909	973	1062	1088	1130	1072	1027	1028	958
	1869	1999	1758	1844	1925	1961	2001	1974	1966	1988	1899
NOx											
Dist. Jur.	170	168	187	226	220	204	222	255	240	219	194
Motor V.	155	172	190	208	236	249	265	282	299	335	370
	325	340	377	434	456	453	487	537	539	554	564
CO											
Dist. Jur.	2142	2245	1398	1399	1344	1329	1296	1332	1386	951	956
Motor V.	3204	3564	3966	4318	4892	5171	5510	5338	5220	5323	5208
	5346	5809	5364	5717	6236	6500	6806	6670	6606	6274	6164
SOx											
Dist. Jur.	404	383	412	463	374	357	354	372	409	375	330
Motor V.	11	12	13	14	16	17	18	19	20	21	21
	415	395	425	477	390	374	372	391	429	396	351
Particulates											
Dist. Jur.	285	300	256	250	203	154	149	154	160	161	160
	20	23	25	28	31	33	35	36	38	40	41
	305	323	281	278	234	187	184	190	198	201	201
TOTAL											
Dist. Jur.	4134	4275	3102	3209	3004	2917	2892	3015	3134	2666	2581
Motor V.	4126	4591	5103	5541	6237	6558	6958	6747	6604	6747	6598
	8260	8866	8205	8750	9241	9475	9850	9762	9738	9413	9179

contributor to visibility reduction; the table (and the regulations) reflect the District's early emphasis on this aspect of the air pollution problem. Particulate emissions from automobiles, though relatively small, are increasing as the number of cars in the Bay Area increases. Overall, the amount of particulate emissions seems to be fairly constant over the past five years. Figure 1.2 shows the history of annual mean particulate concentrations measured in various Bay Area locations. The overall trend seems similar to that of particulate emissions, but the trends at individual locations vary widely. Air quality, in regard to particulate concentrations, appears to be remaining roughly constant on a Bay-Area-wide basis but is still slightly above State standards.

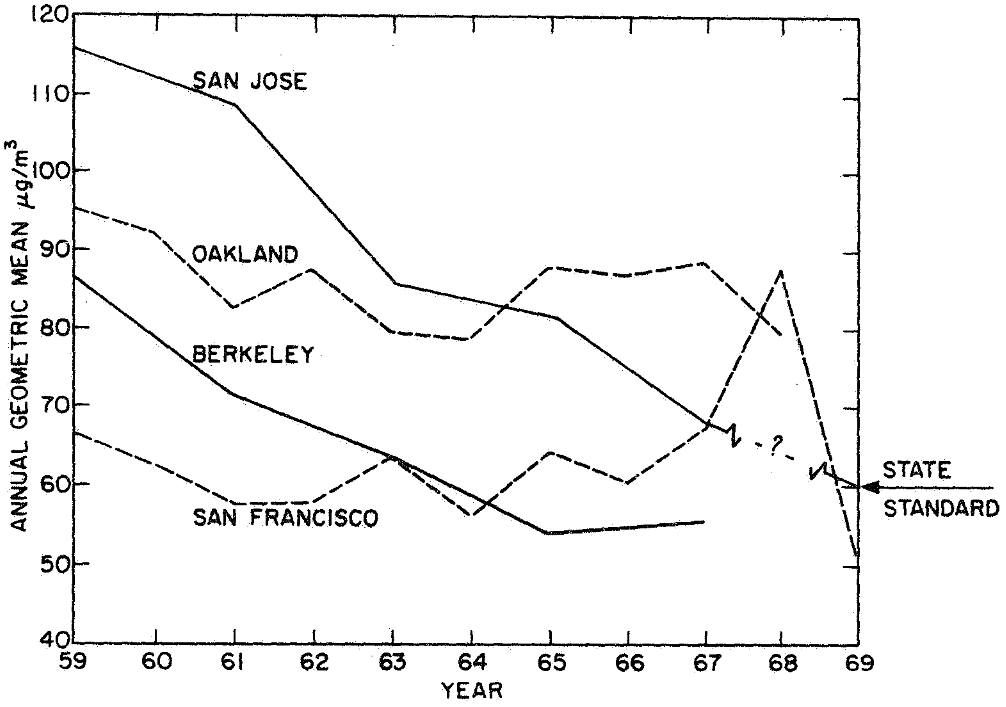

Figure 1.2. PARTICULATE CONCENTRATIONS 10-YEAR TRENDS.[6,8]

Reactive hydrocarbons and nitrogen oxides are the precursers of oxidants. Overall emissions NO_x from all sources appear to be rising, due to the increasing contribution from automobiles. Total hydrocarbon (organic) emissions are remaining roughly constant. Although year-by-year breakdowns into reactive and non-reactive components are not available, such a breakdown for the year 1968 has been published by the ARB, which estimated that 706 tons per day of reactive organics were emitted by motor vehicles, 167 tons per day by stationary sources. Figure 1.3 shows the trend of peak oxidant concentrations measured at the various BAAPCD monitoring stations. Again the trends at some individual locations are quite different from the area-wide average.

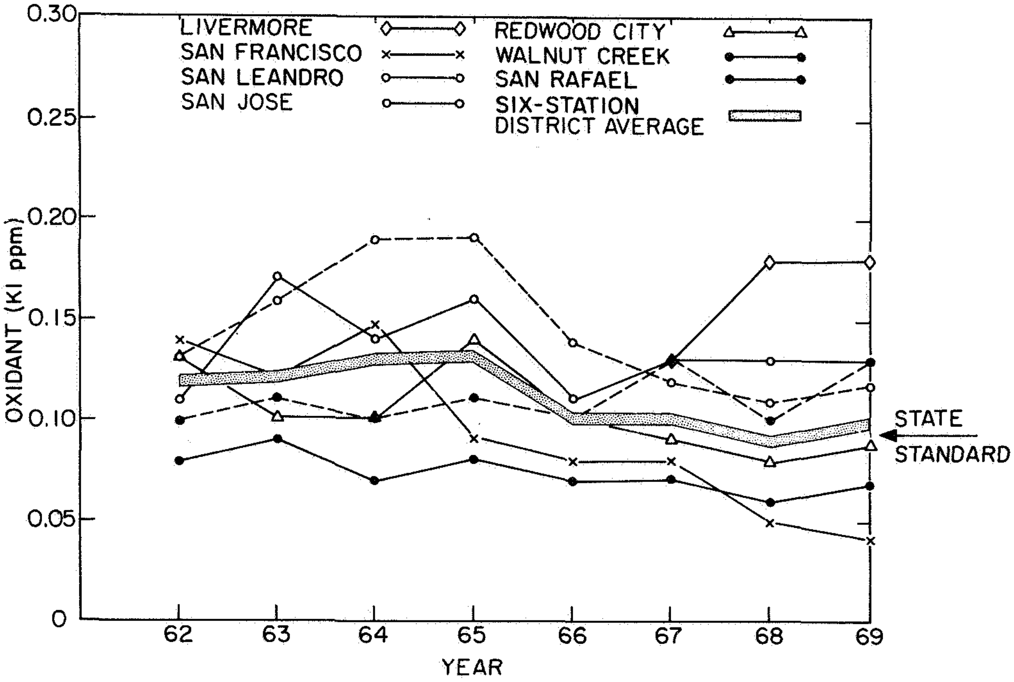

Figure 1.3. TREND OF AVERAGE HIGH-HOUR OXIDANT CONCENTRATIONS FOR DAYS WITH COMPARABLE TEMPERATURE AND INVERSION CONDITIONS (APRIL THROUGH OCTOBER PHOTOCHEMICAL OXIDANT SEASONS, 1962-1969).[9]

The BAAPCD combined pollutant index (CPI) represents an attempt to combine the measured ambient concentrations of the major pollutants into a single index. This operation tends to smooth, or "average out", the uncertainties associated with single measurements. The CPI is perhaps the best available number for indicating a trend for air pollution in general, but has only been compiled since January of 1969. Comparisons for the first seven months of 1969 and 1970 are shown in Figure 1.4 and indicate a uniform increase in pollution level throughout the Bay Area. However, the complete picture is not contained in these numbers alone. Climatic conditions vary from year to year, and the early months of 1970 were characterized by conditions conducive to pollution buildup. The inadequacy of a year and a half worth of data for predicting trends is particularly evident in the face of observed weather cycles in excess of ten years.

To summarize, the uncertainty in emission data, the question as to how well a measurement of pollutant concentration at a single point represents air quality in the surrounding neighborhood, and the lack of any observed trend in either direction make it impossible to definitively answer the question, "Is air quality in the San Francisco Bay Area improving or degrading?"

The figures below represent the average combined pollutant index reading for each of the first seven months in 1969 and 1970.

The north area covers Richmond to San Rafael, the central area is San Francisco and Oakland, and the south area represents the Midpeninsula from Redwood City to San Jose.

1969

	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg.
North	23	25	26	26	24	20	27	24
Central ...	26	27	30	23	22	23	27	25
South	26	23	30	26	30	22	34	27

1970

	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg.
North	24	31	27	22	30	23	27	26
Central ...	27	32	30	26	34	22	27	28
South	33	37	29	27	32	32	39	33

Figure 1.4. COMPARISON OF THE COMBINED POLLUTANT INDEX FOR 1969 AND 1970.[10]

How Well Are the Control Agencies Doing Their Jobs?

The August 1970 issue of Sunset Magazine lists 44 national, state, and local citizens groups which are actively challenging environmental threats in the Bay Area. Four of these are specifically aimed at air pollution; one has even seen fit to sue the BAAPCD in an attempt to get information on emissions of major area polluters. The BAAPCD gets an average of forty telephoned complaints per week regarding local situations. The local newspapers give considerable attention to air pollution news. It would appear, then, that the public is trying to get through to their legislative representatives.

The initial version of the Clean Air Act emphasized local control of regulation activity. The continued worsening of the national pollution scene and the inability of many local dstricts to form or function effectively has led Congress to consider setting national emission standards. NAPCA performed a study and submitted a draft bill on the subject in February of 1970. However, opponents of the bill have reduced its thrust from an initial intent to establish emission standards on a national basis, reserving for the states the right to adopt more stringent standards, to control only of new, high-toxicity sources. One possible byproduct of the adoption of such national emission standards is that pressures which can now be brought to bear on State and local legislative and regulatory agencies would be sidestepped.

Concern about the role of the automobile in air pollution is manifested in proposed action before the Congress ranging from stricter emission regulations imposed on manufacturers to the complete banning of the internal combustion engine. The debate on this subject is currently intense, and the outcome is uncertain. It does seem likely, however, that strong Congressional action on the automobile might stimulate similar strong action in State legislatures regarding local problems.

The California legislature has tended to mimic Congress in preserving the concept of local control of air pollution. Recent legislation (AB83) has passed the requirement for establishing timetables for compliance with state air quality standards on to "coordinating councils" of all county pollution control districts within an air basin. Such timetables are to be submitted by 1972. However, the San Francisco Bay Area and Los Angeles districts were specifically excluded from the provisions of this bill since they are presently being dealt with by NAPCA as Federal Air Quality Control Regions. It is uncertain as of this writing whether NAPCA or the State will be more effective in forcing districts to establish timetables for compliance. Recommendations for further state action are contained in the Progress Report of the Environmental Quality Study Council; the response of the legislature to these recommendations remains to be seen.

Although the ARB is charged by the State law with the task of evaluating the performance of the local districts, no such evaluation has been made to date; in fact, the current data-processing activities of the ARB appear to be aimed at the past, rather than the present and immediate future. An evaluation can be inferred, however, from a recent ARB statement of policy that the established standards are not to be exceeded anywhere, anytime, in California. These standards are now often being exceeded, in some cases dramatically, in both the Los Angeles and San Francisco Districts. The ARB should be pushing both Districts to tighten their emission regulations.

It would be unfair to judge the past activities of the Bay Area Air Pollution Control District on the basis of newly emerging goals. There is no arguing the fact that the District has been effective in causing many emittors to emit less. Considering past legislative and budgetary limits and lack of strong public support, the District has done well. However, the ball-game is changing and it is of interest to assess the manner in which the District has adjusted its goals and operating policies in response to the changing character of the pollution problem. The history of development and enforcement of regulations by the BAAPCD shows emphasis on "technical feasibility" within existing operating regimes for establishing emission limitations, extensive use of "administrative variances" allowing special timetables for compliance for individual cases, loopholes in the regulations which permit continued operation with faulty or inoperative control equipment as long as the breakdown has been reported to the District, and a very low ratio of fines to violation notices. The District has in the past valued its good relations with industry: "The name of the game is compliance with the regulations" is a statement made by the Pollution Control Officer in a recent meeting of the Board of Directors of the District; the philosophy in the past has apparently been that the carrot is more effective than the stick at encouraging compliance.

However, the policy of the District is set by the Board of Directors, and there is evidence that this body is sensing a shift in the mood of the people toward a sense of urgency; policy may be shifting to "the name of the game is protection of the health of the people!" Provision of such protection is going to require some tough decisions. The growing impact of the automobile has caused the pollution problem to worsen, bringing more attention on the industrial fixed sources, which are the bailiwick of the local District. In fact, the people may be deciding that they would rather have their automobiles than some local industries; and they need to be made aware of the consequences of such a choice.

The problem of information release has long been a sore point in relations between the District and the community. Past reluctance on the part of the District to release figures on tonnage of emissions for all local industries was based on the possibility of compromising some trade secrets or of casting unfavorable light on a company which was, in fact, in strict compliance with the law. The credibility of the District has been hurt also by the occasional release of conflicting or misleading information; its publicity strongly emphasizes how much it is reducing emission and says little or nothing about the magnitude of the remaining problem or the weaknesses in the District's control program.

The District would benefit by a refurbishment of its image. This could be accomplished by a more open and honest public information program, the establishment of well defined goals regarding the improvement of air quality, and the announcement of a timetable for achieving these goals. Some specific recommendations in these areas are made in Chapter 7.

1.6 Conclusions

Is the air bad? Yes, according to the policy and air quality standards established by the ARB.

Is it getting better? Not noticeably so. The exact nature of the present hazard to health is not known because data gathering and interpretation are hampered by the complexity of the physical, chemical, and meteorological processes involved.

Who is responsible? Ultimately, the people, whose activities and consumption patterns are the primary causes of air pollution, and whose representatives are responsible for the legal and regulatory structure under which sources of air pollution are allowed to operate.

The fragmentation of authority and responsibility has probably slowed the progress of effective control measures. The important decisions are being pushed down to the level of highest competence and knowledge, but unfortunately this is also the level most susceptible to economic and political pressures from the regulated groups.

What is needed is strong higher level action to establish policy and goals explicitly, with the local agency carrying out the details of enforcement.

Chapter 2

PRESENT CONTROL PROGRAMS AND RESULTING POLLUTION TRENDS

2.1 Introduction

Any analysis of the air pollution problem in the San Francisco Bay Area should include a projection of what the air pollution problem will be in the future if presently legislated pollutant emission control programs are carried out. Only by studying such projections is it possible to have a firm basis for developing effective additional control programs which will keep air quality within acceptable bounds in the years to come and yet be consistent, to the greatest possible extent, with the increased demands for goods and services that must inevitably accompany a growing population. Such control programs may incorporate one or more of the following five elements:

(1) Emission control--Restrictions on the emissions of air pollutants which are by-products of the production of the goods and services sought by the public.

(2) Alternate production processes--Development of alternate methods for providing those goods and services which have lower levels of by-product pollutants than present production techniques (e.g., the use of electric rather than combustion furnaces to produce fiberglass).

(3) Alternate products-- Development of alternatives, acceptable to the public, for those goods and services which cannot be produced without unacceptable levels of pollutant by-products (e.g., the use of mass public transit rather than conventional automobiles).

(4) Voluntary changes in demand--Voluntary reduction or elimination of the demand for those goods and services the production of which is accompanied by unacceptable levels of pollution and for which no acceptable substitutes or alternate production methods are available. Such reduction of demand could only be accomplished by making the necessary changes in life style acceptable to the public. An example would be the large-scale reduction in individual use of electric power.

(5) Compulsory changes in demand--Compulsory reduction or elimination of the demands for any goods and/or services for which the associated pollutant emissions cannot be effectively controlled by any of the other methods. This is obviously a "last resort" technique which should only be applied when the public gain from better air quality outweighs the loss of the goods and/or services eliminated. Examples would be banning automobiles in densely populated urban areas and mandatory birth control programs.

Present control programs are primarily concerned with the first of the above elements. Only token efforts are being made in the areas suggested by the second and third elements, which are potentially very fruitful. With respect to the air pollution problem, nothing is being done concerning the fourth control element, although such a program is being carried out in the case of cigarette smoking by means of an effective public education and awareness program.

In the remainder of this chapter, the pollutant emission control programs that are currently in effect in the San Francisco Bay will be considered in the light of how they are likely to control future emissions of air pollutants. Specific recommendations for alternate or additional control programs will be made in Chapters 7 and 8.

2.2 Population Growth

It is axiomatic that people, through their demands for goods and services, are the primary source of the air pollution problem, not only in the San Francisco Bay Area, but wherever the problem exists throughout the world. Without people there would be no demand for, or production of, any goods and services the inevitable by-product of which is some degree of air pollution. The present magnitude of the air pollution problem is directly related to the present population, and it follows that as the population grows, the air quality will worsen unless ever more stringent control programs are initiated and carried out.

Figure 2.1 shows the population histories of both California and the Bay Area,* as contained in the data from the U. S. Census Bureau, and estimates of how those populations may grow in the immediate future. The most striking feature of Figure 2.1 is that the populations of both California and the Bay Area have been growing exponentially over the past seventy years. Although the population of the Bay Area appears to be growing less rapidly than that of California, over the past seventy years it has doubled every twenty-five years. It is therefore not unreasonable to assume that the Bay Area population will double again by the year 2000, reaching a total of some ten million persons.

There is, of couse, some question as to whether the Bay Area population will continue to grow in an exponential fashion in the years to come. Indeed the Census Bureau has predicted that the population of California will not continue to grow exponentially but will increase less rapidly. That may happen, but the history of such population projections has quite often been one of underestimation. In any event, when developing pollution control programs for the future, it would seem to be prudent not to be too optimistic about population growth. Pollution control programs based on a continued exponential population growth would result in cleaner air than expected if the population growth in fact were less than predicted. Such a result could only be viewed as beneficial.

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*For purposes of the data and projections shown in this chapter, the Bay Area means the following counties: Alameda, Contra Costa, Marin, San Francisco, San Mateo, and Santa Clara.

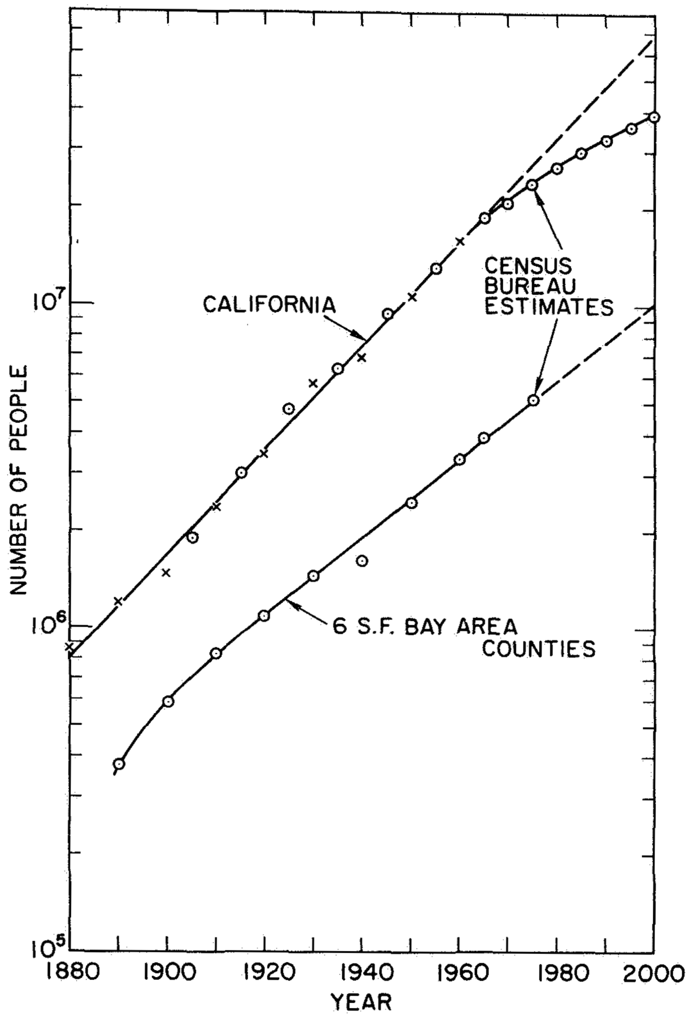

Figure 2.1. POPULATION GROWTH IN CALIFORNIA AND SAN FRANCISCO BAY AREA.

2.3 Automobiles as a Source of Air Pollution

There is no doubt that the automobile is presently a major source of air pollutants in the Bay Area. Pollutant emissions from internal combustion engine automobiles could be controlled by a program involving one or more of the following techniques:

(a) control of the pollutant emissions from each car.

(b) limitation of the number of cars in a given local or regional area.

(c) restriction of the amount of driving in various local areas.

To date in the Bay Area, only the first of these techniques is being used, and that to a limited extent.

Programs of emission limitations for carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x) for all new cars sold have been established by the Federal Government and by the State of California.* The emission limitation program established for all new cars sold in California is summarized in Table 2.1.

Table 2.1

A SUMMARY OF THE STATE OF CALIFORNIA CONTROL PROGRAM FOR POLLUTANT EMISSIONS FROM AUTOMOBILES

Year	CO (gm/mile)	NO_x (gm/mile)	HC(1) (gm/mile)	
			exhaust	total
Uncontrolled(2)	87.2	5.7	5.7	8.5
1966	34	(8.8)(3)		
1970	23		2.2	5.0
1971		4.0		2.7
1972		3.0	1.5	2.0
1974	12	1.0	0.5	0.5

(1) The difference between the total emission of HC and that from the exhaust only is primarily from fuel evaporation, which estimated at 2.8 grams per mile. This is to be reduced to 0.5 grams per mile in 1971 and eliminated by 1965. Prior to 1963 there was an additional emission, estimated at 3.1 grams per mile, from the crankcase. This has presumably been eliminated by crankcase control devices required on all cars sold since 1963.

(2) The uncontrolled emission figures are estimated average emissions for urban driving. They are probably no more accurate than 10-15%.

(3) The initial control for CO apparently caused an increase of about 50% in NO_x emissions.

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* The Federal control program for automobiles was preceded, spurred, and guided by California's efforts. By Federal law, California is the only state permitted to set more restrictive emission standards than those of the Federal program. The major difference between the two programs, from 1970 onward, is that California has established more stringent control of NO_x emissions.

Both the federal and State of California programs to control pollutant emissions from automobiles is severely weakened by five factors:

(a) The confirmation of these emission limitations is restricted to testing only a few prototypes of the various new car models. No random testing of new cars as they come off the assembly line is currently being done. Indeed, John T. Middleton of the National Air Pollution Control Administration (NAPCA) has recently announced[1] that, because of uncertainties in test procedures, even those prototypes certified as having met the 1970 standards (23 grams per mile of CO, 2.2 grams per mile of hydrocarbons) are actually emitting twice those amounts.

(b) The emission control devices become less effective with age. Control devices for CO appear to lose their effectiveness quite rapidly over the first 50,000 miles, leveling out at about 30% loss of effectiveness above 80,000 miles.[2] Similarly HC control devices level out at about 20% loss of effectiveness after 50,000 miles.[2] Apparently no data exist for deterioration of NO_x control devices. In addition, there is no inspection program to insure that automobile owners are maintaining the control devices that have been installed on many cars.

(c) Many of the cars registered in California were purchased before any emission limitations came into effect, and as more stringent emission limitations are put into effect, they apply only to new cars sold from that model year on. Half of the cars in use now (1970) were sold prior to 1966* and thus are in the "uncontrolled emissions" category.

(d) The present control program includes no limitations on emissions from trucks or buses. These emissions will become relatively more important as emissions from automobiles are reduced. In addition, the public would probably be more responsive to their individual responsibilities in controlling air pollution if the all too common occurrences of smoky, smelly diesel trucks and buses were eliminated from the roads.

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*This 50% figure was obtained from a survey of automobile registrations by model year published by the Automobile Manufacturers Association. The age distribution of registered automobiles does not vary appreciably from year to year.

(e) Unless some limit is imposed on the number of automobiles in the Bay Area, the effectiveness of the present control program in reducing total emissions from automobiles will eventually be negated by the increasing number of cars on the road.

Figure 2.2 shows how the number of cars registered in California and in the San Francisco Bay Area has been increasing year by year. The

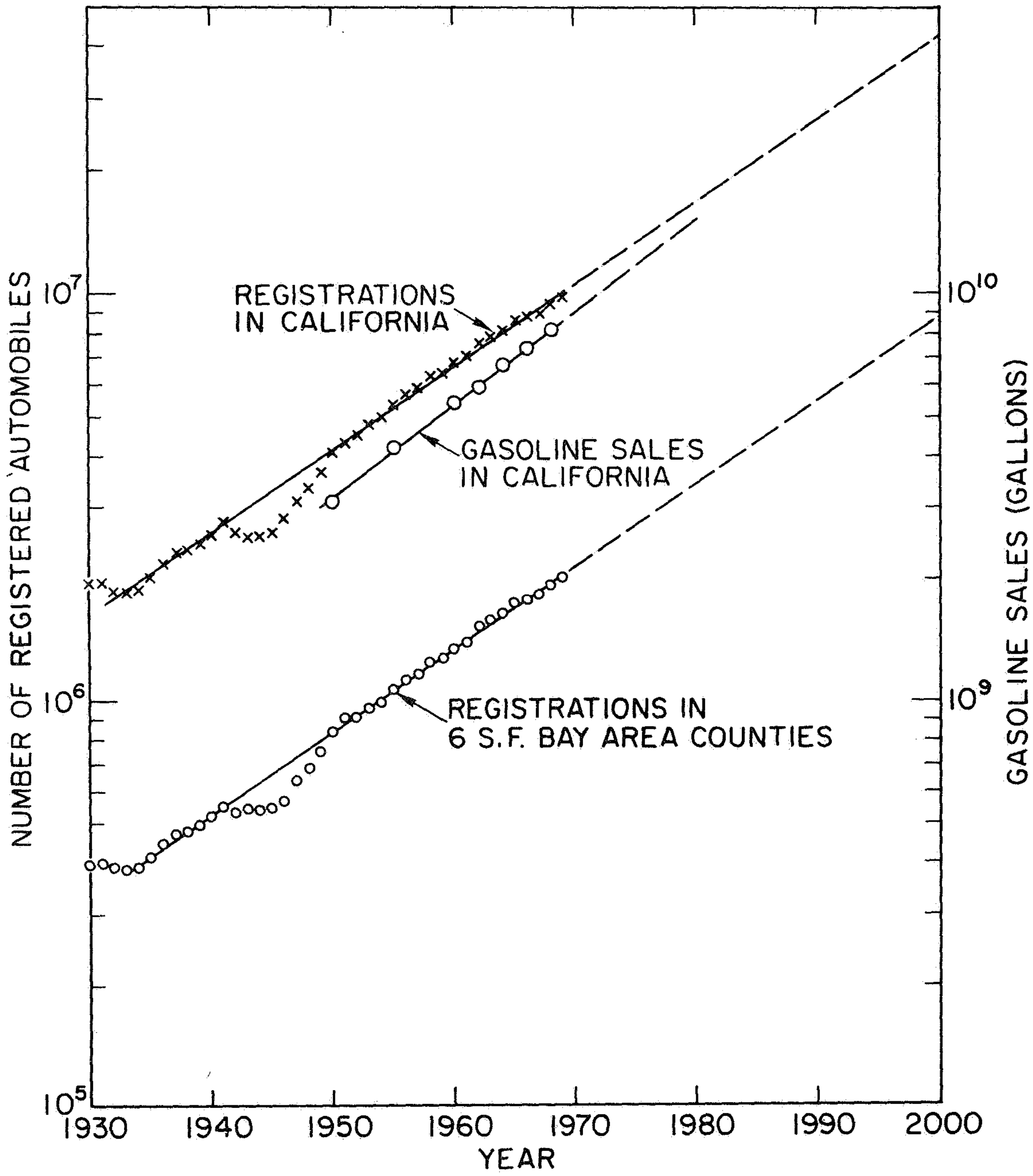

Figure 2.2. AUTOMOBILE REGISTRATIONS IN CALIFORNIA AND SAN FRANCISCO BAY AREA AND GASOLINE SALES IN CALIFORNIA.

data were taken from California Department of Motor Vehicle records. In both California and the Bay Area, the number of registered automobiles has been growing exponentially since the depression with a doubling time of 15 years, with the exception of the World War II years when no cars were produced (a very effective pollution control technique). There is no evidence of any slowing down in this automobile population growth rate. The exponential growth of registrations is a reflection of the exponential growth of population although, interestingly enough, a comparison of Figures 2.1 and 2.2 shows that the automobile population is growing more rapidly than the human one. As further evidence of the growing problem of air pollution from automobiles, Figure 2.2 also shows the exponential growth of gasoline usage, as indicated by State of California sales reports.

Using the automobile population data from past and projected registrations and assuming the emission control program outlined in Table 2.1 will be implemented, it is a relatively straightforward job to calculate the amounts of pollutant emissions from automobiles that can be anticipated in the coming years. A program has been developed to carry out such calculations on a high speed digital computer. The program, which is described in some detail in Appendix 2-1, allows any year by year variation of automobile population, any desired emission control program, any deterioration of the control device with age, and any age distribution for the automobiles.

Figures 2.3a, 2.3b, and 2.3c show how the amount of CO, HC, and NO_x emitted by automobiles in the Bay Area can be expected to vary from year to year until 2000. The results are based on the following assumptions:

(a) The car population continues to grow at the exponential rate shown in Fig. 2.2.

(b) The uncontrolled emission factors and the emission control program shown in the Table 2.1 are valid. For HC, the calculations are based on total emissions, rather than exhaust emissions alone.

(c) The age distribution of automobiles, the deterioration of the control device, and the average annual miles driven are as shown in the historical data shown in Appendix 2-1.

The projected emissions of CO and HC are undoubtedly too low in the years between 1966 and 1985 because, as previously mentioned, the control levels assumed for 1966 and 1970 were not actually attained. Because of this and the uncertainties in the uncontrolled emission rates, the projected emissions shown in Figures 2.3a, 2.3b, and 2.3c should not be considered for the exact numerical values they show, but rather for the trends they predict.

An <u>independent</u> estimate of the emissions of pollutants from automobiles in the San Francisco Bay Area has been made for the years 1965 and 1980. The estimates, which are made for the individual subregions

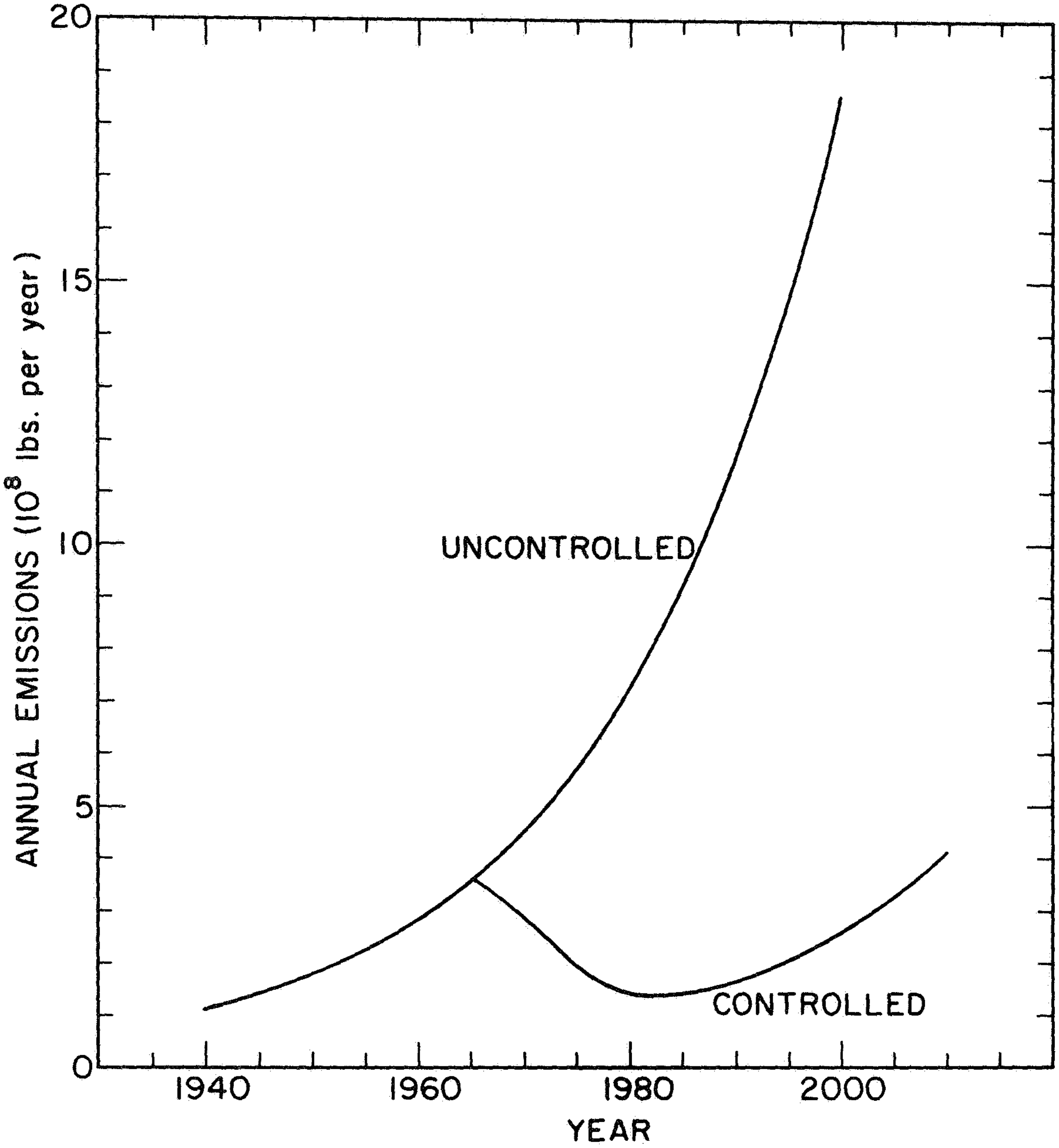

Figure 2.3a. PROJECTED EMISSIONS OF CO FROM AUTOMOBILES IN THE SAN FRANCISCO BAY AREA.

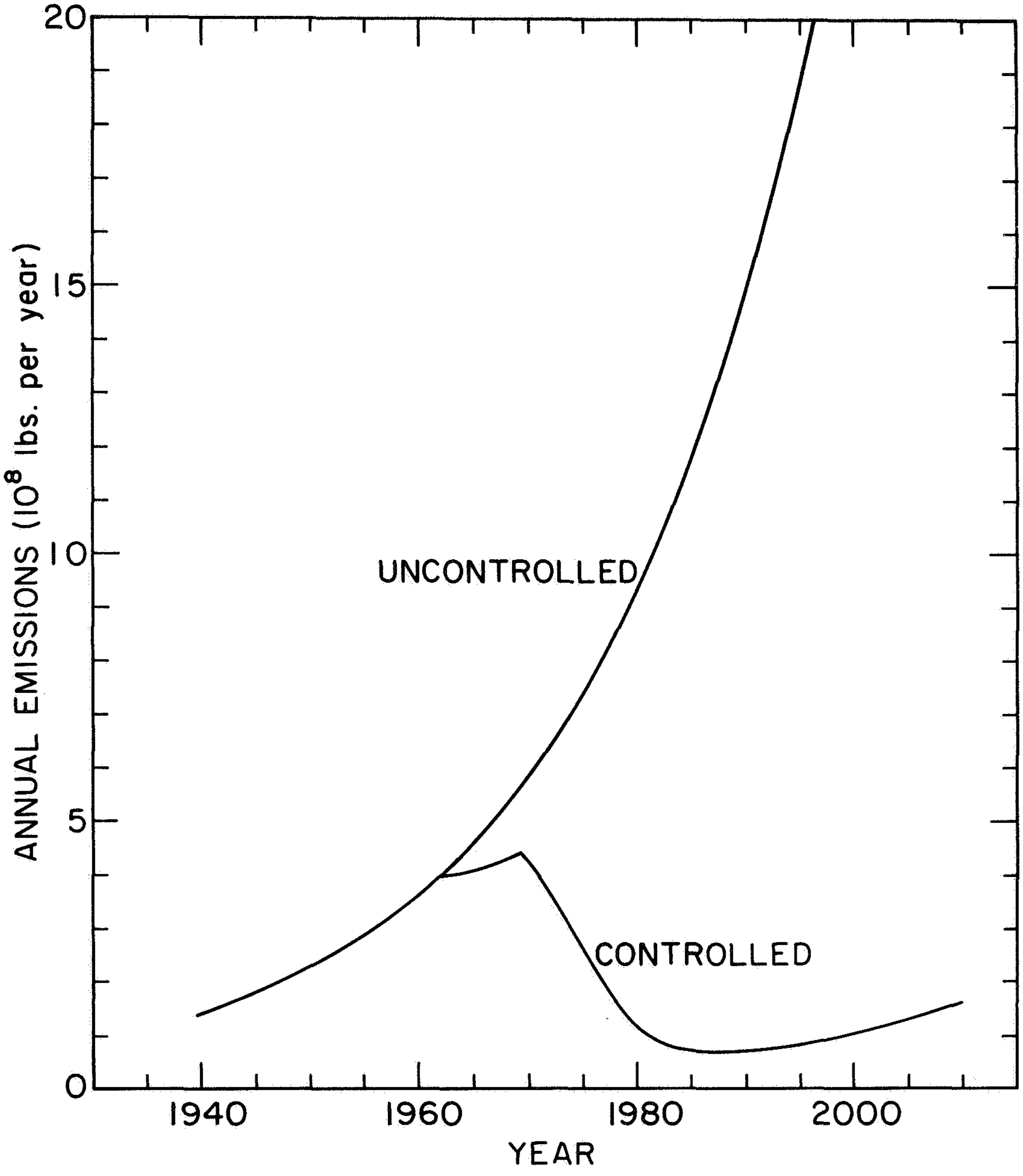

Figure 2.3b. PROJECTED EMISSIONS OF HC FROM AUTOMOBILES IN THE SAN FRANCISCO BAY AREA.

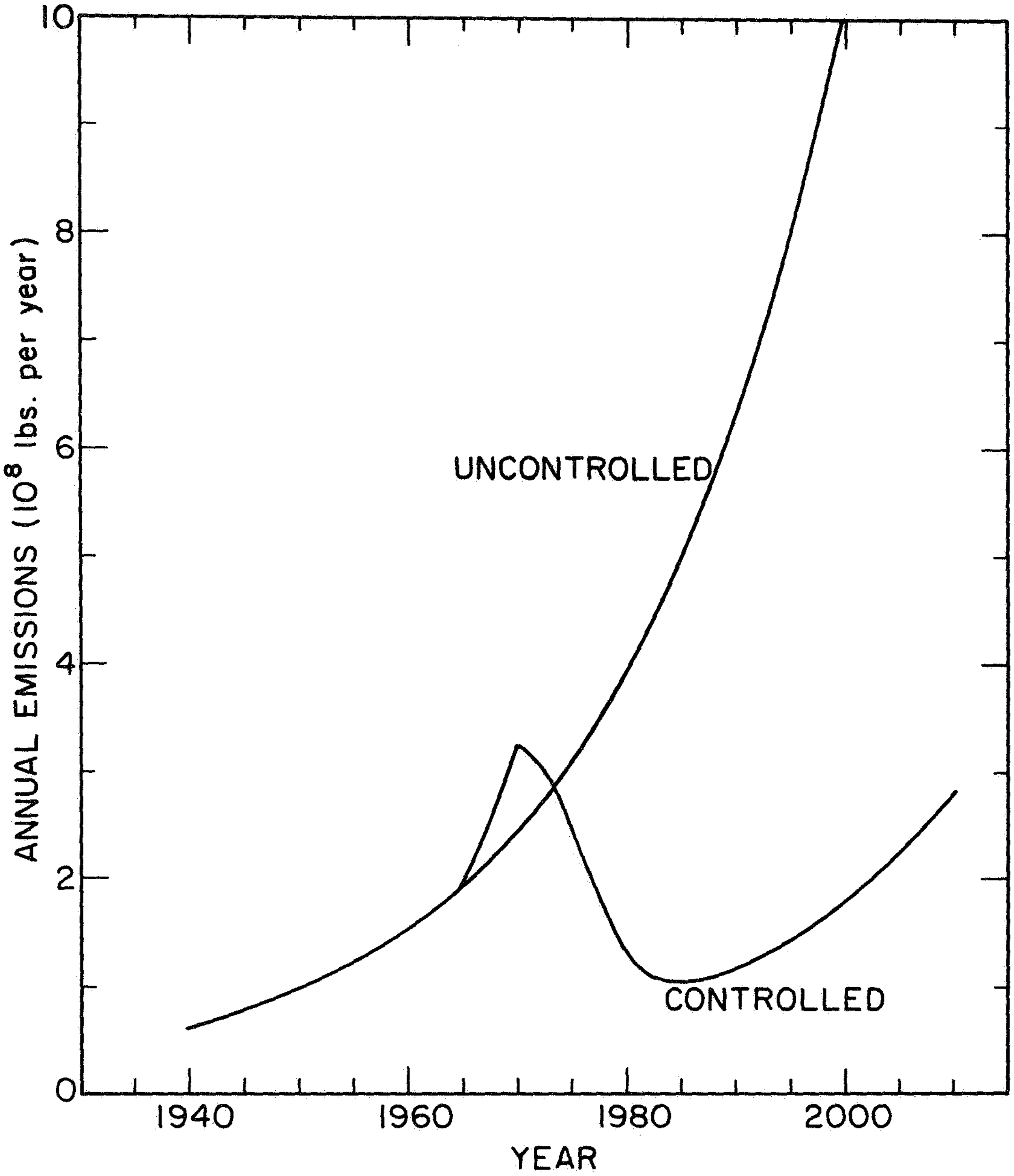

Figure 2.3c. PROJECTED EMISSIONS OF NO_x FROM AUTOMOBILES IN THE SAN FRANCISCO BAY AREA.

of the Bay Area, are based on estimates of traffic in each subregion made by the Regional Transportation Planning Commission (RTPC). The details and assumptions involved in the calculations are shown in Appendix 2-2. The calculations are summarized in Table 2.2. Considering the uncertainties involved in each, the two independent calculations for total emission of the various pollutants agree quite well (see Table 2.2).

Table 2.2

COMPARISON OF TWO INDEPENDENT ESTIMATES OF POLLUTANT EMISSIONS FROM AUTOMOBILES IN THE BAY AREA

Basis of Estimate	Pollutant emissions (tons per day)					
	1965			1980		
	CO	HC	NO_x	CO	HC	NO_x
Car sales (Appendix 2-1)	4930	561	268	1980	162	180
Traffic in districts (Appendix 2-2)	4172	765	235	1953	215	238

Several conclusions about the present automobile emission control program are apparent from Figures 2.3a, 2.3b and 2.3c. First, the program will be effective in reducing emissions to levels well below the uncontrolled levels. Second, because the controls are applied only to new cars, it takes a rather long time for total effects to be realized. For example, although the last and most stringent emissions limitations in the current program are to be applied in 1975, the maximum reduction in pollutant emissions will not occur until some 10 to 15 years later. Third, very shortly after the minimum emission levels are obtained, pollutant emissions will once again grow exponentially at the same rate at which the automobile population is growing.

Thus the current emission control program for automobiles is at best a program to buy time, time to develop more pollution-free internal combustion engines or to make available alternate means of transportation. The amount of time depends on the acceptable amount of automobile emissions. For example, if CO emissions from automobiles are to be reduced to 1950 levels or less, the present program will be effective until perhaps 1990. If it is deemed advisable to reduce NO_x emissions from automobiles to 1950 levels, the present program is probably already too late.

2.4 Stationary Sources of Air Pollution

The current and projected emission control programs for stationary sources in the San Francisco Bay Area, which are the responsibility of the BAAPCD, are much less definite than those for control of automobile emissions. The present control program for stationary sources is based on three regulations:

(a) Regulation 1, which became effective in October 1957, bans open burning. Exceptions to this regulation are allowed for agricultural burning, fire hazard control, fire fighting training, and fires for recreational purposes such as barbecues.

(b) Regulation 2, which became effective in January 1961, controls the emission of particulates, hydrocarbons, and sulphur dioxide from commercial and institutional sources. The emission limitations imposed are expressed in terms of maximum concentrations, emission rates, and opacities of the pollutants in the effluent from the source.

(c) Regulation 3, which became effective in January 1968, limits the emission of reactive hydrocarbons into the atmosphere. Again the limitation is expressed in terms of maximum effluent concentrations.

The first two regulations are primarily directed at visible emissions, to which the general public is undoubtedly most sensitive.

The general philosophy and goal of the BAAPCD is to reduce stationary source emissions to the extent necessary to satisfy the ambient air quality standards. The emission regulations are applied on an "across the board" basis, with little consideration being given as to how a particular source, as a result of its location and the prevailing winds, affects the overall air quality of the area. At the present time, this may well be a suitable approach, but as (hopefully) a better understanding of the relationship between source location and ambient air quality is developed, new regulations should be established which are directed more heavily toward those sources which have the most harmful effect on air quality. In its program for enforcement of the existing regulations, the BAAPCD is presently severely limited by its rather meager manpower and resources.

As more and more people settle in the Bay Area, with an accompanying increase in the demand for goods and services, the overall potential emission of pollutants from stationary sources will also increase. Figure 2.4 shows the recent history of the usage of electrical energy and natural gas in California* as well as projections of the usage rates

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*The data from which these curves were drawn were taken from the California Statistical Abstract - 1969.

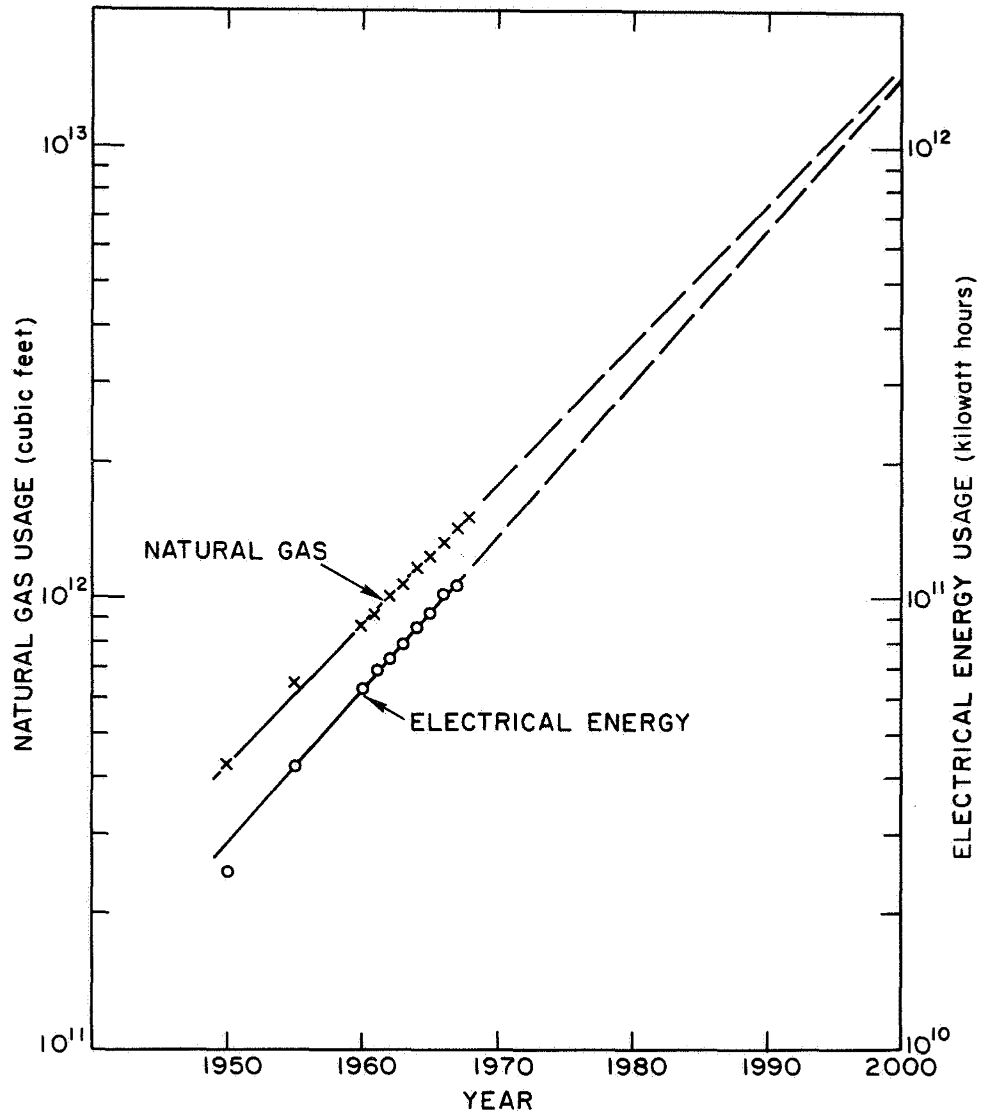

Figure 2.4. ELECTRICAL ENERGY AND NATURAL GAS USAGE IN CALIFORNIA.

into the near future. Over the past twenty years both usage rates have increased exponentially. A comparison with Figure 2.1 shows that the increase in the usage rate for both electrical energy and natural gas is larger than the corresponding rate of population growth, so that per capita usage is also increasing.

As a lower limit, it seems reasonable to assume that the total potential emission from stationary sources will increase at a rate proportional to the rate of population growth. Since the BAAPCD has no time-phased program for more stringent emission control regulations, a meaningful projection of future emissions would be very difficult, if not impossible, to calculate. It would be safe to conclude, however, that if emission control regulations will continue to be based on pollution concentrations in effluents, they will have to become more and more limiting as time goes by if ambient air quality is to be kept within acceptable limits.

Figure 2.5 outlines the future emission control program for stationary sources that the BAAPCD must maintain to hold the total emissions from these sources at 1969 levels if the population of the Bay Area continues to rise at the exponential rate shown in Figure 2.1. For example, if the population continues to grow exponentially, the BAAPCD will have to reduce 1990 per capita emissions to 55% of the 1969 levels. If the population in 1990 is 10% less than the value predicted by Figure 2.1, the reduction in 1990 per capita emissions from stationary sources could be 10% less than shown in Figure 2.5 (i.e., a reduction to 61% of the 1969 level would maintain total emissions at the 1969 value).

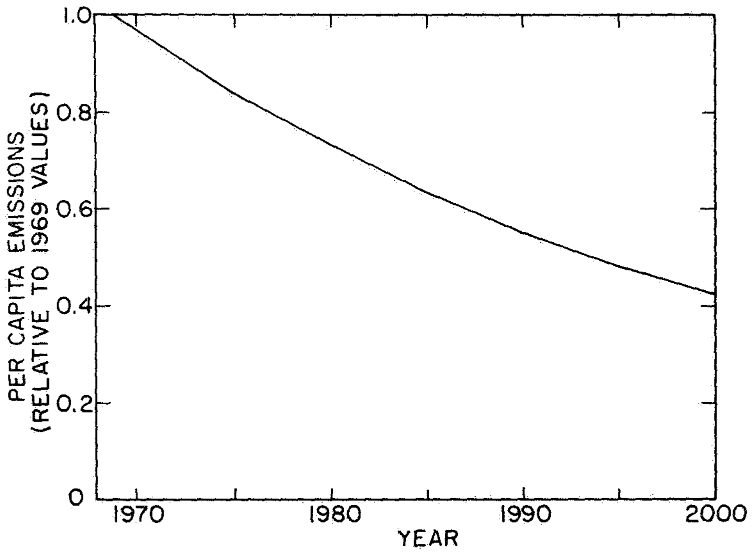

Figure 2.5. THE PER CAPITA EMISSIONS FROM STATIONARY SOURCES IN THE BAY AREA WHICH MUST BE OBTAINED IF 1969 EMISSION LEVELS FROM THESE SOURCES ARE TO BE MAINTAINED FOR AN EXPONENTIALLY INCREASING BAY AREA POPULATION.

How long such a program can be successfully maintained is debatable. According to the 1969 BAAPCD Source Inventory Report, estimated total emissions from stationary sources have remained relatively constant in the past few years as shown in Table 2.3. Within the limits of the present three regulations, and the BAAPCD's ability to enforce them, it appears quite likely that total emissions will begin to rise in the near future.

Table 2.3

EMISSIONS FROM STATIONARY SOURCES UNDER BAAPCD JURISDICTION - TONS/DAY

Year / Pollutant	1963	1964	1965	1966	1967	1968	1969
HC	863	873	871	902	939	960	941
NO_x	220	204	222	255	240	219	194
CO	1344	1329	1296	1332	1386	951	956
SO_x	374	357	354	372	409	375	330
Particulates	203	154	149	154	160	161	160

To keep the average ambient air quality within the San Francisco Bay Area at acceptable levels, it will be necessary to limit the total emissions from stationary sources and to study the best locations for any new sources constructed within the Bay Area. The present regulations cannot effect an upper limit on stationary source emissions since, although for a plant of fixed capacity the presently existing regulations will limit total pollutant emission from that plant, there is no regulation limiting the number or capacity of plants.

2.5 Conclusions

Although at the present time the exact relationship between the location and magnitude of a pollutant source and its effect on the local and area-averaged ambient air quality is not known, it is very reasonable to assume that there is an upper limit on the total amount of a pollutant that can be emitted into the atmosphere if the air quality standard for that pollutant is to be maintained. Chapter 6 describes a simple Box Model which relates pollution emission rate to air quality. Based on this model and 1968 estimates[3] of total pollutant emissions, the calculations in Chapter 6 indicate that if a 300 foot inversion height and a five mile per hour wind persist throughout the Bay Area for more than one day, the average NO_x concentration would be that prescribed by the air quality criterion; if there were no wind, the average NO_x concentration would be nearly four times the air quality criterion.

The model of Chapter 6 is an oversimplified one and its numerical results may perhaps only be valid to within a factor of two, but the conclusion is clear. To maintain the present air quality standards, total pollutant emissions should be kept at (better yet below) current levels. The current program for control of emissions from automobiles should result in decreasing emissions of CO, HC, and NO_x until the mid-1980's. If no further emission restrictions are imposed, emissions of these pollutants can then be expected to increase in proportion to the number of automobiles. The emissions from fixed sources in future years, assuming a continuation of the present BAAPCD program, is less easy to predict, but it is likely that such emissions will begin to increase unless more stringent effluent regulations are enacted and enforced. It appears advisable for the BAAPCD to switch from regulations based on pollutant concentrations in effluents to regulations based on limiting total pollutant emissions in their stationary source control program.

In the long run, any emission control program based on the reduction in emissions from individual sources, be they automobiles, power plants, petroleum refineries or whatever, seems doomed to failure if no limit is placed on the number of such sources. Thus the eventual successful solution of the air pollution problem, in the San Francisco Bay Area or elsewhere, will require a leveling off of the area's population, or failing that, a continuing reduction in per capita emission of pollutants.

Chapter 3

AN IDEAL AIR POLLUTION SURVEILLANCE SYSTEM

3.1 Introduction

In order to quantitatively understand the air pollution problem in any locality, it is necessary to have meaningful data; that is, there must be enough information of sufficient accuracy to adequately determine such quantities as pollutant emission rates, local and averaged pollutant concentrations, and meteorological conditions. As was pointed out in Chapter 1, the current lack of such meaningful data in the Bay Area makes it impossible to definitively show whether the air pollution problem is getting better or worse.

Further, in order to fully understand the problem it is not sufficient to know what the emission rates and air quality are; one would also like to know the cause-effect relationship between the two. This relationship is now understood in only a rudimentary way, but models to describe it more accurately are being developed (see Chapter 6). Once developed, each of these models must be verified by comparison of their predictions with measured data. This verification, and the resultant credibility of the model, will only be as good as the data available.

As a first step in determining what information is necessary, it is useful to consider a schematic description of the air pollution problem, such as shown in Figure 3.1. The central block in the diagram, labeled pollution dynamics, represents the complex interactions between the inputs* (meteorology, topography, and pollutant emissions) which result in the output state of the atmosphere (temperature, humidity, pollutant concentrations, wind velocity, and the like). All of the inputs as well as the components of the output will generally vary with both position and time. One of the purposes of the models mentioned above is to simulate the pollution dynamics block.

External control of the system is available only through regulating pollutant emissions. This is accomplished through the Controller, which represents the Pollution Control District (PCD), its staff, and the body of laws and regulations under which it operates. In order to effect any degree of control, the controller organization must have a set of objectives or indices of performance which constitute the framework within which it makes its control decisions. It must also have information or data on the state of the pollution system and on the emission and meteorological forcing functions. Additional inputs to the controller are the public through its actions and opinions, State and Federal laws and standards, and a collection of economic, political, and constitutional constraints within which the controller must function.

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*One might also consider the reactions among the various constituents of the air (for example, the photochemical reactions) as one of the inputs. Since the mechanisms of these reactions presumably do not vary, they are considered here as an integral component of pollution dynamics. If the study of air pollution is restricted to a particular area, topography could be considered in the same manner.

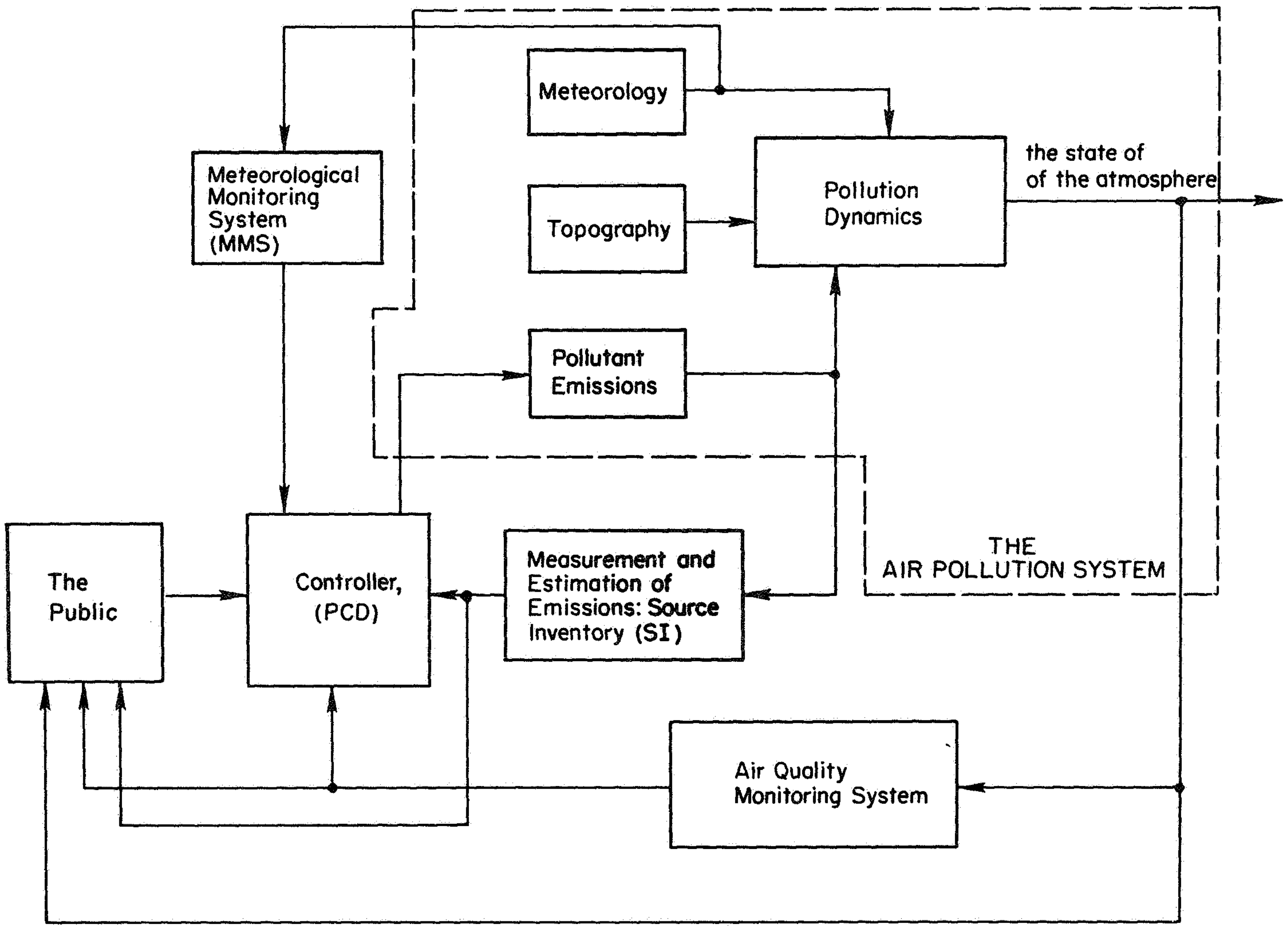

Figure 3.1. A SCHEMATIC REPRESENTATION OF THE AIR POLLUTION PROBLEM.

This chapter will focus on the three blocks in which measurement or estimation are carried out, namely the air quality monitoring system (AQMS), the source inventory (SI), and the meteorological monitoring system (MMS). This focus will not be on the hardware aspects of these measurement systems; these will be treated in Chapters 4 and 5. The measurement requirements are dictated by the control objectives and indices of performance adopted by a PCD. Such a set of indices will be suggested and the necessary data specified. In addition, some of the ways in which this information will be useful will be outlined.

Before proceeding, it would be helpful to specify what is meant by "air pollution surveillance". Generally speaking, surveillance is the gathering of specific data for a purpose. In the present context, air pollution surveillance means the gathering of air quality, pollutant emission, and meteorological data for the purposes of the control objectives and performance indices.

3.2 Air Quality

The terms "air quality" and "ambient air quality" appear prominently in air pollution literature, but they are rarely defined. Very often they refer to the concentrations of pollutants in the air. Two specific measures of air quality, a local daily air quality index (LDAQ) and a monthly ambient air quality index (AAQ), both of which are directly related to established air quality standards, are defined in detail in Appendix 3-1. The term "air quality" as used here means the broad category of measurements of pollutant concentrations. These measurements should be made near ground level (where the people are), and the air cells for which the concentration measurements are made should be of such an area that the monthly AAQ are truly representative. One measurement per hundred square feet of land area would be unnecessary; one measurement covering several hundred square miles would be grossly inadequate in any urban area. Consider the graphical representation of air quality at a given instant of time by an isopleth plot, a contour map of pollutant concentration over a district. Such a plot for highly space-variable carbon monoxide could not possibly account for the distinct effect of every automobile exhaust pipe, while at the other extreme, one reading per several hundred square miles would make such a plot meaningless. Time averaging of pollutant concentrations at fixed stations is common practice and serves to produce a figure which is more representative than a single instantaneous value. Ideal air quality measurements should include local space averaging as well as time averaging, and should reflect the medium scale geographical distribution of pollutants.

Figure 3.2 illustrates the space averaging and distribution aspects of air quality measurement as discussed above. The graph shows a hypothetical continuous curve of a pollutant concentration at ground level, along a line drawn on the surface of the earth, at a given instant of time. It should be obvious that neither concentration, C_a or C_b, is representative of the entire distance spanned in the graph, and that measurements in the vicinity of at least both points, a and b, are

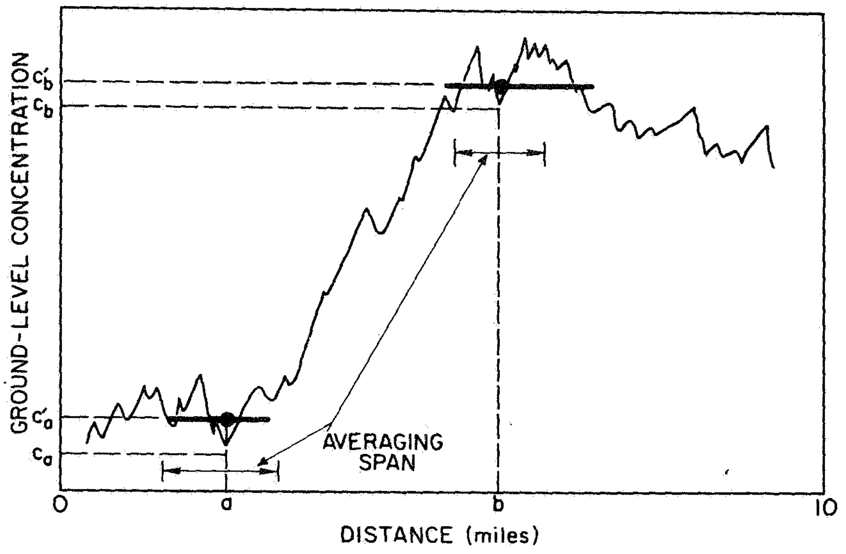

Figure 3.2. A HYPOTHETICAL GROUND-LEVEL POLLUTANT CONCENTRATION SECTION FOR A GIVEN INSTANT OF TIME.

necessary for proper characterization of air quality in that span. Note also that C_a could be labeled a poor reading insofar as characterization of air quality in the vicinity of point a is concerned. Local space averaging would be done over an averaging span such as that indicated in Figure 3.2, with the resulting averaged concentration values indicated as C'_a and C'_b.

Evidence which confirms the existence of local and medium-scale concentration variability is presented in Chapter 4.

3.3 Control Objectives and Indices of Performance

Surveillance should be carried out not for its own sake, but to meet the requirements established by the objectives and indices of performance adopted by the controller. Should a PCD adopt as its sole objective the 100% elimination of all man-caused emissions, then the air quality and meteorological inputs to the controller are unnecessary, and the overall system of Figure 3.1 would be operating virtually open loop, with the only feedback occurring in the controller-emissions-source inventory loop. Such an objective is, however, clearly unrealistic; it is mentioned only to emphasize that data requirements are dictated by objectives. The inverse is to be avoided; i.e., the availability of data should not dictate the objectives.

The overall objective of a PCD should be the maintenance of the ambient air quality indices throughout its air basin at or below the value of unity, with no single normalized concentration exceeding 1.0. Further, this level of ambient air quality should be maintained even under the highly unfavorable meteorological conditions typified by a three-day, 300-foot inversion without wind.

The indices of performance listed below are suggested as useful and meaningful adjuncts in describing how successful the control strategy is in meeting the overall objective, and in pointing to possible improvements in that strategy. All are on a monthly basis except 11. Categories 6 and 7 use BAAPCD counties for illustration. The indices are first listed, then followed by the format of tables by which they are to be presented monthly to the directors of the PCD. The local newspapers should be encouraged to publish these monthly summary reports.

1. Emissions
2. Upsets and breakdowns called in, not cited
3. Violation notices
4. Automotive vehicle inspection data
5. Citizen interaction
6. Peak residential area values for the month
7. Average values for the month
8. Largest emitters and their average outputs
9. Compliance data
10. Ambient air quality index
11. Daily local air quality index

1. EMISSIONS (Tons per day)	Part.	HC	NO_x	SO_2	CO	H_2S
a. Net eliminated last Quarter						
target						
actual						
b. Net eliminated same Quarter prior year						
c. Total Eliminated during the Quarter						
d. Total Added/Discovered in Month						
2. UPSET/BREAKDOWNS CALLED IN (not cited) a. Tons extra effluent due to breakdown						

b. Total breakdowns during month ______

c. Max. breakdowns per company: Past month ______ Past year ______

d. Company with Max.: Past month ______________ Past year ______

3. VIOLATION NOTICES	Current mo.	Mo. last yr.	Yr. to date
a. Number issued (month)			
b. Number noticed but uncited			
c. Dollars of fine collected/citation			
d. Average fine potential per notice			
e. Average excessive effluent/citation			
f. Most repeated offender			
g. Second most repeated offender			
h. #Night or weekend Insp./Day insp.			
i. #Citations/night or weekend insp.			
j. #Citations/day insp.			

4. AUTOMOTIVE VEHICLES	Current mo.	Mo. last yr.	Yr. to date
a. Number inspected during month			
b. Citations/Inspection			
c. Number of "smokers" reported			

5. CITIZEN INTERACTION	Current mo.	Mo. last yr.	Yr. to date
a. #Visitors to District office			
b. #Complaint notices received			
c. Citations/complaint			
d. #Citizens groups working with Dist.			
e. #Students working on Dist. projects			
f. #Talks by District personnel			

6. PEAK RESIDENTIAL AREA VALUE (pollutant concentrations normalized by air quality standards)	Part.	OX	NO_x	SO_2	CO	H_2S
a. Contra Costa County						
b. Alameda						
c. Santa Clara						
d. San Mateo						
e. San Francisco						
f. Marin						

7. AVERAGE VALUE FOR MONTH (pollutant concentrations normalized by air quality standards)

	Part.	OX	NO_x	SO_2	CO	H_2S
a. Contra Costa this year/last year						
b. Alameda						
c. Santa Clara						
d. San Mateo						
e. San Francisco						
f. Marin						

8. LARGEST EMITTERS AND THEIR AVERAGE OUTPUTS (Tons of that emission/day)

	Particulates	Hydrocarbons	NO_x	SO_x	CO	H_2S
1st						
2nd						
3rd						
4th						
5th						
6th						
7th						
8th						
9th						
10th						
Stationary Total						
Bay Total						

9. COMPLIANCE

	This Mo.	Last Mo.	Yr. to date
a. #Variances Issued			
b. Avg. Variance Length (days)			
c. Longest Variance (days)			
d. Avg. compliance schedule length (days)			
e. Longest compliance schedule			

10. AMBIENT AIR QUALITY INDEX

The AAQ is defined in Appendix 3-1. Equally as important are the normalized concentrations C_i^*/C_{is}, which are satisfactory when they are less than or equal to unity. The AAQ and these normalized concentrations should be published monthly for each air cell.

11. DAILY LOCAL AIR QUALITY INDEX

The DLAQ is also defined in Appendix 3-1. The DLAQ and the accompanying table (Table 3-1.1) for each air cell should be made available for publication daily.

3.4 What Data Should the Surveillance System Produce?

Air Quality Monitoring System

The overall objective and indices in categories 5, 6, 7, 10, and 11 shown in the preceding section establish the need for air quality monitoring. Some additional comments are in order relative to the nature and value of such monitoring.

Typically, an air basin will have among its industries such concentrated point sources of pollutants as power plants, cement mills, or oil refineries, to name a few, as well as significant line sources such as heavily traveled freeways and airport arrival and departure lanes. Many thousands of people may live and work within the direct zones of influence of these sources. These people breathe air which may, on one or more counts, be chronically sub-standard relative to a state's air quality standards. Recalling the overall control objective from Section 3.3 and our understanding of ambient air quality, one may conclude that the ideal air quality monitoring system will reveal the existence of any such sub-standard areas.

To meet this ideal, ground-level concentrations of all recognized primary and secondary pollutants should be measured with sufficient time and spatial frequencies and accuracies to allow the construction of monthly concentration-frequency plots. Such a system need not be a "real-time" system in the sense of having the capability to produce a plot of pollutant isopleths for a given time instant or for a given day. It should, however, be capable of producing measurements or reliable estimates of peak daily concentrations within all aircells. It must be re-emphasized that the integrity of the monitoring system, vis-a-vis the medium-scale variations associated with point sources, must be unimpeachable if the objective of uniformly standard-or-better air quality is to be achieved.

Air pollution episodes are periods when pollutant concentrations build up to high levels as a result of protracted low temperature inversion height and lack of ventilation. The concentrations can reach levels well above the air quality standards in a day or so and remain there for several days. Under these conditions, the air quality monitoring system may be required to make measurements with both good spatial resolution and relatively high time frequency. Data is also of course needed to predict such episodes in advance in order to take emergency prevention measures if necessary.

Source Inventory

An emission measurement and estimation system, or source inventory, operates in another feedback path to the controller, as shown in Figure 3.1. Indices of performance in categories 1, 2, 3, 4, 5, and 8 establish the need for such an inventory.

A source inventory is basically a list which catalogs the geographical location and pollutant makeup of specified classes of fixed and mobile sources. Point, line, and area location in a three-dimensional coordinate system is relatively straightforward. In districts where a permit system is employed, one class of fixed sources to be included is very neatly and logically defined by the class of operations for which permits to construct and operate are required. Under the permit system, only those operations are exempt which are either not significant sources or else are practically and realistically incapable of being cataloged, such as the family frying pan or the backyard barbecue. The permit system also requires that the applicant make known the makeup of his emissions, thereby meeting that requirement of the inventory. Among additional information of potential value to a district would be the time schedule of emission. Some operations, by the nature of their processes, function around-the-clock every day, while others may operate on a one shift, five day week basis. Districts without a permit system are faced with a considerable one-time effort to establish this part of their inventory; in either case, maintaining the currency of such an inventory requires modest resources.

Another class of stationary sources not covered by permits but nonetheless significant is domestic space and water heating. The pollutants involved would be oxides of nitrogen in districts where natural gas is the principal fuel, and sulfur dioxide in regions where coal and fuel oil are used. Daily amounts would have to be estimated on the basis of population density and standard emission factors for space and water heaters. This is obviously an area source, and could be described in units of tons per day per square mile on a one-mile grid.

Another major source to be cataloged is the automobile. Because of its mobility, it has to be treated either as a line or area source. Actual measurement and precise location of daily auto tonnages is an obvious impossibility. At the other extreme, gross estimation of total airbasin auto emissions on the basis of gasoline sales, without regard to geographical distribution and traffic density, will contribute little to the value and utility of a source inventory. The auto segment of the inventory should be a compromise between these two extremes: one in which the fine structure of urban traffic is treated as an area source, with estimates of tons per day per square mile (1-mile grid) made on the basis of traffic surveys. More distinct auto sources such as major freeways in suburban areas would be described as linear sources in units of tons per day per mile.

Such a complex inventory would have to be stored in a computer-compatible mode. Although the inventory is not a real-time record or representation of pollutant production, it must nonetheless be so designed as to allow easy and rapid access for such purposes as updating and extraction of required summaries. Computerization would allow such functions as entry sorting and compilation by grids of selected size and for all pollutants.

One further aspect of source surveillance should be noted: that of actual source measurement. In the inventory discussion above, it is implied or stated that few if any measurements of emissions are involved in inventory construction. The bulk of the catalog would be arrived at by enlightened estimation, with expected accuracies ranging from perhaps 5-10% for fixed stacks to 20-25% for automobiles. This is not to say, however, that source monitoring should be ignored. A district should possess, and have the authority to use or require the use of accurate in-stack monitoring devices and sensitive "sniffing" devices to detect leakage in valves and other plumbing. These instruments would be most valuable in the District's enforcement program. Another very desirable enforcement measure involving source monitoring would employ either random or periodic testing of automobile exhaust emissions, with power to issue citations for those cases in which an auto exceeds emission standards for its particular age and configuration of required control devices. The desired effect of such a program would be a more conscious effort on the part of automobile owners to maintain their vehicles in a highly-tuned, minimum-pollution condition.

One important use of the source inventory is to enable correlation of trends in air quality to growth or shrinkage in emissions, both on a total air basin scale and on a local scale. A district should be able to inspect, analyze, and interpret such trends in a way that leads to such conclusions as: "Emissions of SO_2 in area A must be reduced by 30% over the next three years so that air quality standards can be met in downwind area B".

Meteorological Monitoring System

Meteorology is an extremely important element in the complex transformations of pollution dynamics. Even the most primitive attempts to gain and employ an operationally useful understanding of these dynamics would require meteorological monitoring. The potential for more sophisticated and enlightening interpretive analysis of pollution processes is very much a function of the level of understanding of the airbasin's meteorology. The direction in which airborne pollutants are carried is a function of wind direction. The manner in which they diffuse is a function of turbulence, vertical wind velocity, and other meteorological factors which affect mixing. These aspects of atmospheric transport directly affect the physical distribution of air quality measurements by which ambient air quality would most efficiently be determined on a local level. Measurements upwind of a stack on a windy day, for example, will not yield much information once a background level is established.

The ideal meteorological monitoring system would provide data on inversion height, vertical and horizontal wind velocity profiles, and vertical temperature profile. They would be obtained by the release and tracking of radiosonde devices with such time and spatial frequencies as to allow, in the judgement of a district's meteorological staff, the extraction of significant geographic and diurnal variations in that particular district's basic meteorological patterns. Inversion height, for example, might be known from experience to most likely be at its minimum and maximum at 0600 and 1500 hours, respectively; these are thus logical times for the release of the radiosondes.

Additional capability for local-scale meteorological measurements must be available for purposes of properly conducting ground-level air quality measurements, and especially for standardizing methods and means of sampling at fixed stations. These data include wind velocity, temperature, humidity, and solar radiation.

3.5 Additional Uses of Data

Figure 1.1 shows a block entitled "The Public", into which are fed inputs from the state of the atmosphere, the AQMS, the SI, and the PCD. The first of these inputs is unavoidable; the public depends for its life upon the atmosphere. The second and third inputs in raw form would probably be quite confusing and useless to the average citizen. What is implied by the path from the PCD to the public, therefore, is a channel that will transmit data and information in a form both meaningful and appropriate to the public's concern about the consequences of air pollution. Indices of performance 1 through 10 given in Section 3.2 should be published monthly and index 11 daily in all newspapers in a district for purposes of public information. The ideal surveillance system once fully operational could and should provide to the public the following additional items:

1. Ground level peak values for any square mile of Bay Area for each of the primary and secondary pollutants. (Computer accessible--if there is much demand for this information, it may be offered at an appropriate price to cover costs of outputting it to the specification of any citizens.)

2. Ordered list of most significant contributors to pollution concentration maxima of any given square mile. The computer output will specify who the main contributing polluters are and what would happen to the pollution maxima of each pollutant in that square mile if any of those polluters were shut down.

3. Alternate combined pollutant indices for use by newspapers and by interest groups such as TB Societies and Cancer Society. These will include single numbers which can be compared with historical trends and comparative numbers such as average shortening of life span and increase in the probabilities of contracting various diseases.

4. Forecasts of any of the above numbers.

Some of the above will require complete monitoring and computer modeling (discussed below) to fill in the details. During the interim, estimates of advancing refinement will be made available.

As a means of testing its effectiveness in transmitting information, a District should determine the ability of citizens, polled at random, to describe the importance of air quality, its causes, and actions they can take to affect it. These polls should be designed and performed by professionals with the aim of evaluating how well the district is performing its education function. Part of the procedure should be to grade the district on this performance in such a way that evaluations can be made of its progress in this activity over time. The grades should then be made available to anyone, but particularly they should become part of the report to the Board each year.

The preceding sections in this chapter suggest that pollutant source surveillance and air quality monitoring can have definite values in themselves. Such surveillance, if properly done, can answer the questions

a. Where are the sources located?
b. How much of what are the sources emitting?

c. What is ambient air quality, as measured throughout the District?
d. Is the present control program effective?

Providing answers to these four questions might be the full and only purpose of surveillance, especially if the answer to (d) is positive. If, however, that answer is negative, or if there are serious questions as to the meaning of "effective" or the adequacy and relevance of the abatement program goals, then some additional questions might and should be asked. Among them are:

e. How are cause and effect related in the air pollution problem?

f. What would be the effect upon air quality of a given basic change in the nature of emission regulations?

g. What would be the effect upon air quality of given basic changes in land use and zoning policy?

h. How would changes in regulation and land use policy affect the economics of the community and of individual industrial polluters?

i. Is it possible to determine, much more conclusively and reliably than is now the case, that localized variations in air quality are traceable to distinct emission sources?

j. Is it possible to reliably predict conditions favorable to the generation of extraordinary air pollution levels, and so enable the formulation of regulatory steps whereby the severity of the episode may be decreased?

Underlying any attempt to answer questions (e) through (j) would be the concept of systems modeling. The application of this powerful concept to the air pollution problem is discussed in considerable detail in Chapter 6. It is sufficient here to note that a source inventory and an air quality monitoring system are very much a part of model building and subsequent model usage. Source information constitutes the input data to the model. In like manner, air quality measurements are necessary either to the construction of the model or its validation, and in some cases both.

3.6 Summary

A well-designed surveillance program, augmented by interpretive analysis of the data produced, would contribute significantly to several aspects of the pollution control problem. It would allow the integration of geography, topography, and meteorology into the formulation of emission regulations. It might thereby be possible, for example, to be relatively permissive in a geographic area known to be consistently well-ventilated, while a virtual prohibition of industrial operations might be indicated in an area known to be poorly ventilated or subject to repeated episodes of low inversion. Additionally, it would allow a more accurate and legally sound way in which to correlate localized reductions in air quality with existing individual sources. This would allow the district to adequately adjust emission regulations so as to maintain air quality in localized regions known to be under the strong influence of nearby point sources. All too often, when such local degradations are observed, the neighborhood industry says, in essence, "But how do you know we're to blame?" What about the hundreds of other sources emitting that pollutant?" The means of indirectly demonstrating responsibility can be devised. They would yield a more systematic basis upon which to identify those sources to be controlled and the extent of control necessary to achieve the desired air quality.

Chapter 4

EXISTING DATA COLLECTION SYSTEMS

4.1 Introduction

The present status of air pollution measurement and surveillance in the San Francisco Bay Area is described in this chapter. It is divided into three sections.

- Air Quality Measurement
- Meteorological Data
- Sources of Pollution

In each of these three sections we shall discuss the system as it exists today, its capabilities and short-comings, and what a better system should accomplish.

4.2 Air Quality Measurement

Location of Existing Stations

Ambient air quality, i.e., the concentration of pollutants in the air, is now measured at twelve locations in the six counties in which the BAAPCD operates. A map, Figure 4.1, shows the location of these stations. Table 4.1 indicates which pollutant is measured at each station.

The District has attempted to locate stations at sites representative of air quality throughout a large area. This is difficult to do with ten effective stations in an area of about 3400 square miles and without knowledge on how air pollution concentrations vary from place to place.

The vertical locations of the air sample tube also varies from station to station. At some stations it is on the roof of a one-story building, in Livermore it is but a few feet above the ground, in San Francisco it is on the roof of a seven-story office building (see Figures 4.2 - 4.5).

The difficulty of obtaining meaningful average readings on air quality from these fixed stations is illustrated by the following comparisons.

(1) One of the authors made a trip around the streets of San Francisco in the District's mobile vans to measure carbon monoxide (CO). At the same time the District took its standard measurement at its fixed station on top of District headquarters in downtown San Francisco. The records from both instruments are superimposed on one another in Figure 4.6. The enormous difference between the readings

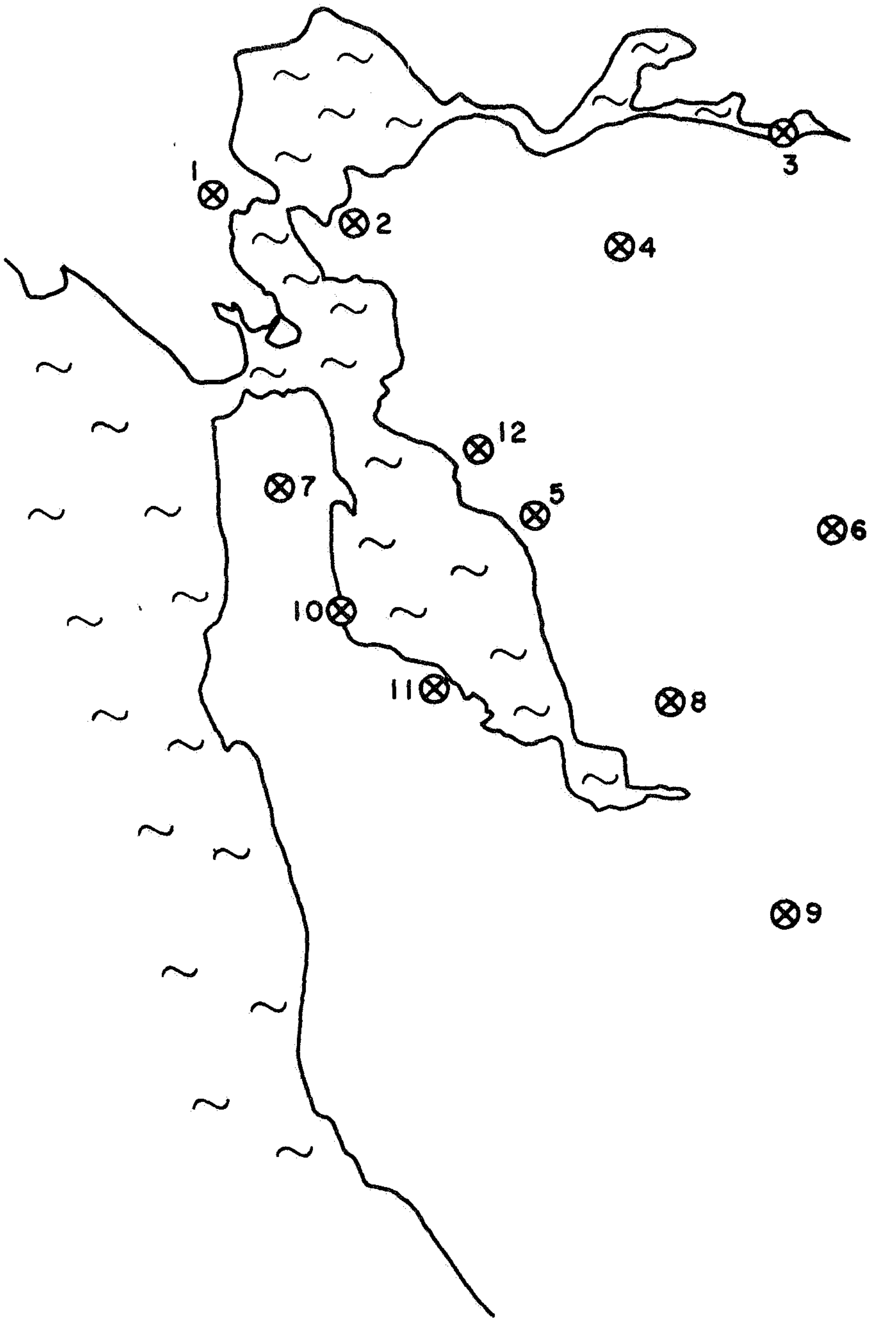

Figure 4.1. MAP OF THE BAY REGION SHOWING THE LOCATION OF THE MONITORING STATIONS. The numbers refer to the number of the station as given in Table 4.1 following.

Table 4.1

Number on Map	Location	OX	COH	CO	HC	NO_2	NO	SO_2^*	Hi. Vol.	
1	San Raphael	x	x	x	x	x	x	x	x	
2	Richmond	x	x	x	x	x	x	x	x	
3	Pittsburg	x	x	x	x	x	x	x	x	
4	Pleasant Hill	x								
5	San Leandro	x								
6	Livermore	**2	x	x	x			x	x	
7	San Francisco	x	x	x	x	x	x	x	x	
8	Fremont	x	x	x	x			x	x	
9	San Jose	x	x	x	x	x	x	x	x	
10	Burlingame	x	x	x	x			x	x	
11	Redwood City	x	x	x	x	x	x	x	x	
12	Oakland									NOT BAAPCD, ARB.
	†									

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[*] SO_2 where made only twice a week.

[**] Made at two locations.

[†] One traveling van, presently SO_2 only.

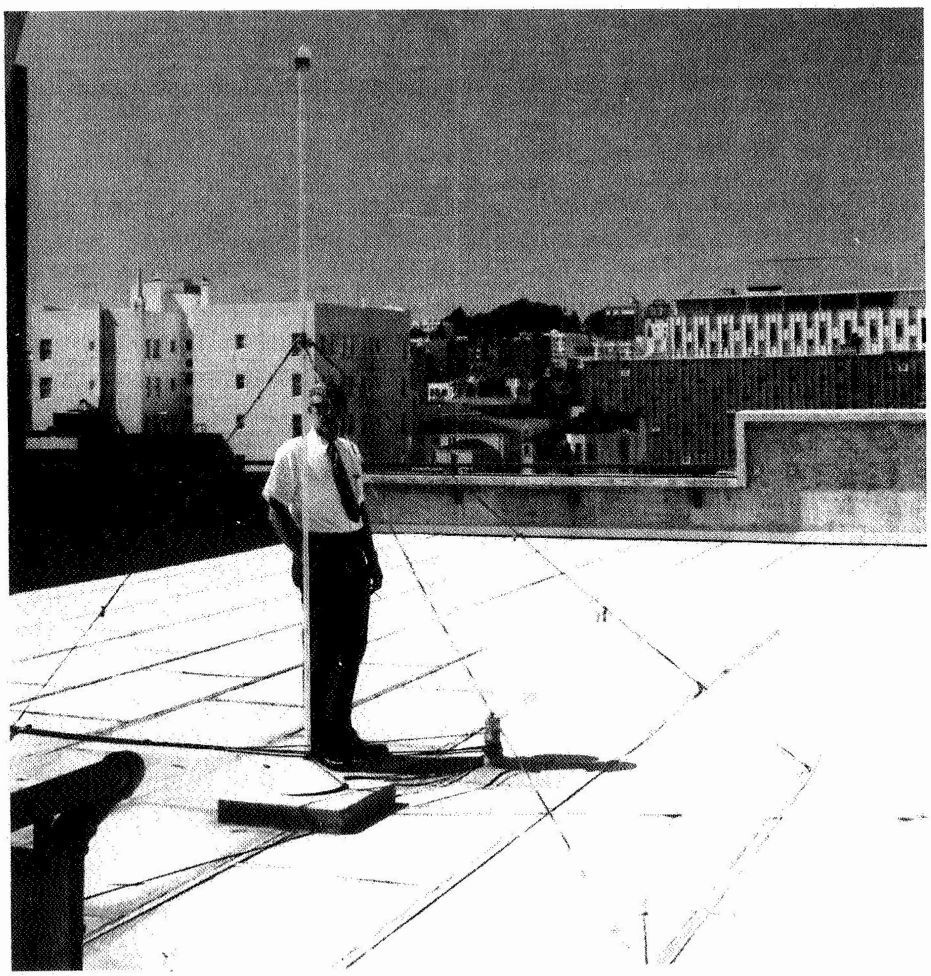

Figure 4.2. SAN FRANCISCO HEADQUARTERS BAAPCD AND MEASURING STATION INTAKE.

Figure 4.3. SAN FRANCISCO HEADQUARTERS BAAPCD.

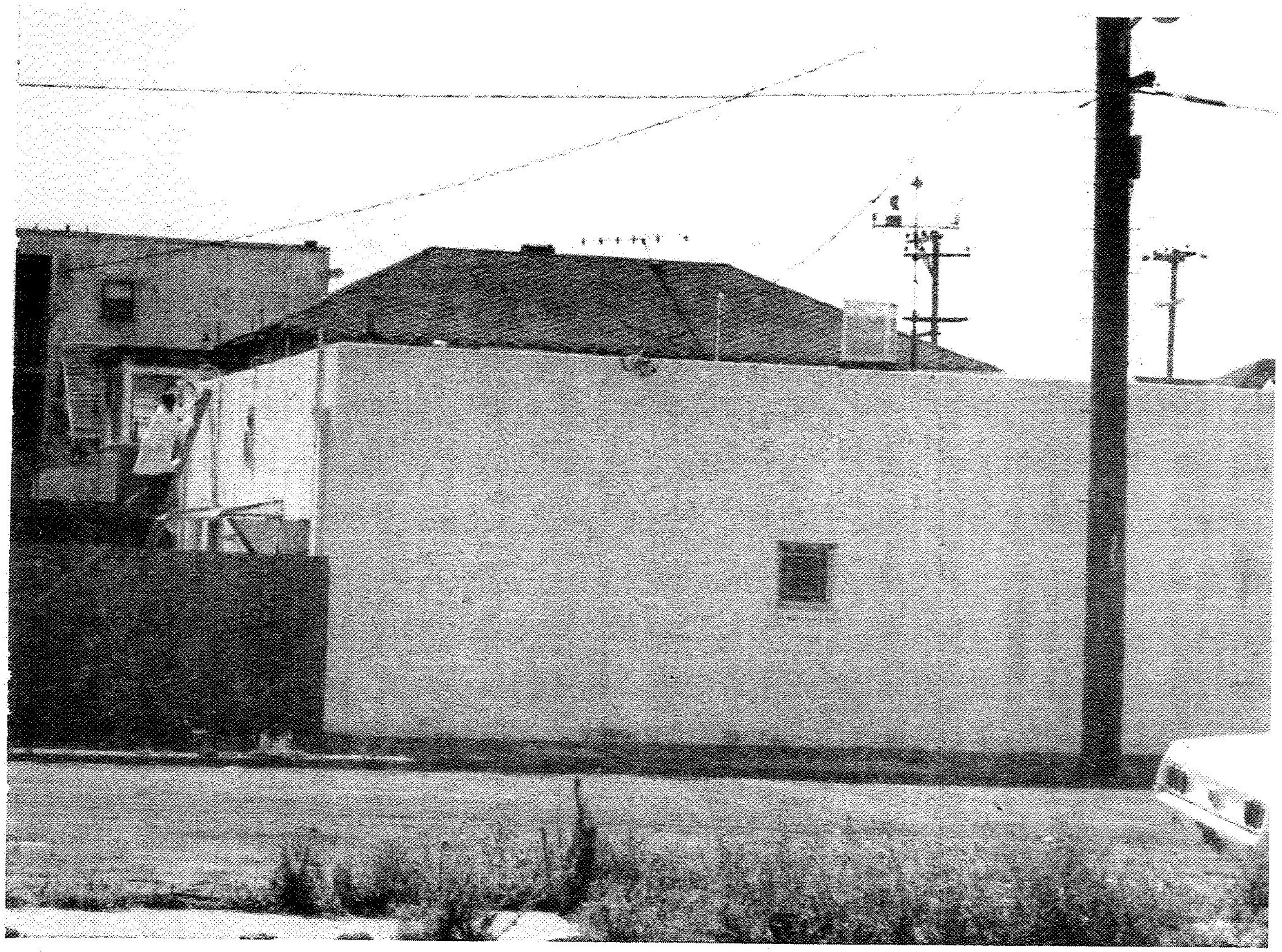

Figure 4.4. RICHMOND MONITORING STATION.

Figure 4.5. LIVERMORE MONITORING STATION.

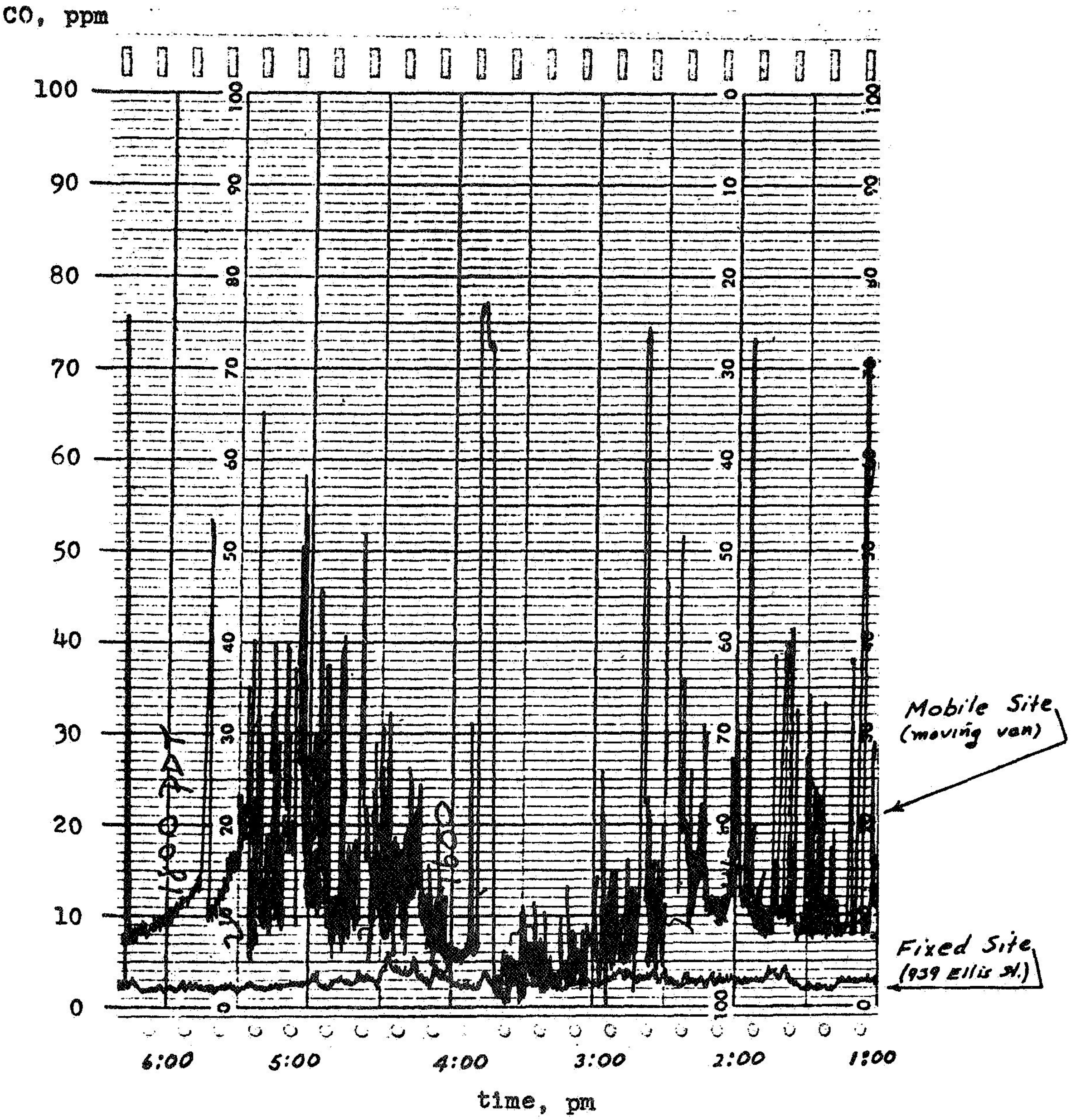

Figure 4.6. COMPARISON OF CO CONCENTRATIONS MEASURED BY FIXED AND MOBILE SITES ON AUGUST 11, 1970, IN SAN FRANCISCO.

Note: Time Scale goes from right to left. The five extreme tall peaks of the mobile data (70 to 80 ppm) are responses to the calibration or "span" gas.

is obvious. While the fixed station was reading CO concentrations of 2-5 ppm, the moving recorder was measuring peaks as high as 65 ppm at the level where people work and breathe.

(2) An example showing the variation in CO readings between two stations not too far apart comes from the san Joaquin County Health Department which operates two stations only 2-1/4 miles apart, one station located at the Stockton Hotel in an urban environment and the other at the Health Department at Hazleton Street in a suburban environment. On November 25, 1969, the suburban station reported a high for the day of 5 ppm for one hour. The urban station had a high hour of 32 ppm and even registered a peak of 70 ppm CO. However, on November 1, 1969, both stations registered a high hour of 20 ppm CO. On September 15, 1969, the urban station had a high hour of 10 ppm and the suburban only 1 ppm.

(3) Similar examples are shown in Table 4.2 for both CO and oxidant levels.

Table 4.2

HOURLY HIGH READINGS OF CO AND OXIDANTS

Fresno/CO, Oxidant, 1969

Date of Hourly High	9/1	9/5	9/6	9/29	10/31	11/23	11/27	8/22
Fresno Cedar Street Oxidant	.16	.14	.14	.08	.16	.10	.02	.31
Fresno Court House Oxidant	.16	.11	.19	.21	.37	.09	.11	.22
CO Cedar Street	5	4	1	7	13	10	10	3
CO Court House	2	8	5	10	7	7	11	2

Sacramento/Oxidant 1969

Date	9/4	9/5	9/10	10/7	10/21	11/3
13th & J Street	.19	.09	.10	.07	.07	.10
Creekside School	.17	.21	.22	.07	.15	.17

Livermore/Oxidant 1969

Date	10/7	10/22
Railroad Avenue	.14	.14
Rincon & Pine	.17	.07

All data are in ppm.

The two stations in Fresno are 2.1 miles apart, the two in Sacramento are 5.4 miles apart, and the distance between the Livermore stations is just 1.0 miles. It is evident that local variations may be quite large.

Measurement Techniques

The pollutants generally measured (see Table 4.1) are oxidants, nitrogen dioxide (NO_2), nitric oxide (NO), hydrocarbons, sulphur dioxide (SO_2) and particulates. In addition most stations record a coefficient of haze (CoH).

Oxidants are measured by a coulometric technique using the oxidation of potassium iodide solution. The instrument is sensitive primarily to ozone (O_3) which comprises 90% or more of the oxidants, but it also responds to NO_2. Its useful range is 0 to 0.5 ppm with scale divisions of 0.02 and an estimated accuracy of no better than one scale division. Instrument response is faster than that of the strip chart recorder used with it. Its total cost is about $1700 including recorder.

Nitrogen dioxide (NO_2) is measured by a wet chemical reaction. The change in color of the reagent is a measure of the quantity of NO_2 in the air sample and is compared optically against the clean reagent. The sensitivity of the instrument is about 10% and it records on a logarithmic scale from 0.02 to 2 ppm. Because of the need for careful mixing of sample and reagent the response time of the instrument is about 15 minutes.

Nitric oxide (NO) is not measured but calculated from a difference between total oxides of nitrogen and NO_2. A two channel instrument is used. One channel measures NO_2 by the above described technique. The other channel passes the air through an oxidizing environment which oxidizes all oxides of nitrogen to NO_2 and proceeds to test for NO_2 once again. The technique suffers from slow response and the possibility of other chemicals confusing the measurement. Since NO is obtained as the difference between these fairly large readings, errors in measurement may be very large. In fact, it is not unusual to read negative NO values. The combined NO, NO_2 instrument costs about $9,000.

Hydrocarbons are measured by flame ionization. The instrument measures on any of four ranges--0 to 10, 20, 50, 1000 ppm (methane equivalent) each scale is accurate to ±5% full scale. The cost of the instrument is $5000.00. Its major drawback is that it does not distinguish between reactive and non-reactive hydrocarbons. Non-reactive hydrocarbons, primarily methane, make up a large part of most air samples but contribute little to smog. Reactive hydrocarbons are the really important ingredients since they are involved in the photochemical reactions that produce eye irritants.

Sulphur dioxide (SO_2) is measured by bubbling air at a metered rate through a West-Gaeke reagent for twenty-four hours at a station and returning the liquid to San Francisco for analysis, the measure is in the 0 to 10 pp billion ±10%. Presently the sulphur dioxide burden is so low in general that it is not an ambient problem. It may, however, be a serious local problem in the vicinity of sources.

Particulate and haze measurements are very difficult, and each measurement technique is complicated by special faults. Two measurements techniques are popular in the Bay Area: the small filter unit called CoH (coefficient of haze) which draws air through a filter tape for a specified time and measures the comparative optical density of the tape, and the high volume sampler, which draws a large volume, of air through a paper or glass filter and obtains the weight increase. The hi-vol may also be used to analyze the composition of the filtrate. Of these two techniques, the second is more basic but it suffers from three faults. The first of these is the loss of high volatility aerosols which evaporate before they are weighed; the second, the undue influence of very large particulates; and the third, the possibility of chemical reaction between corrosive aerosols and material of the filter. The first technique suffers all these faults, plus the additional problem that different absorbed aerosols affect the optical transmission differently. In fact, the correlation between the two measurements is poor, and even the vague correlation that may exist at one station is not repeated at another.* (See Figure 4.7.)

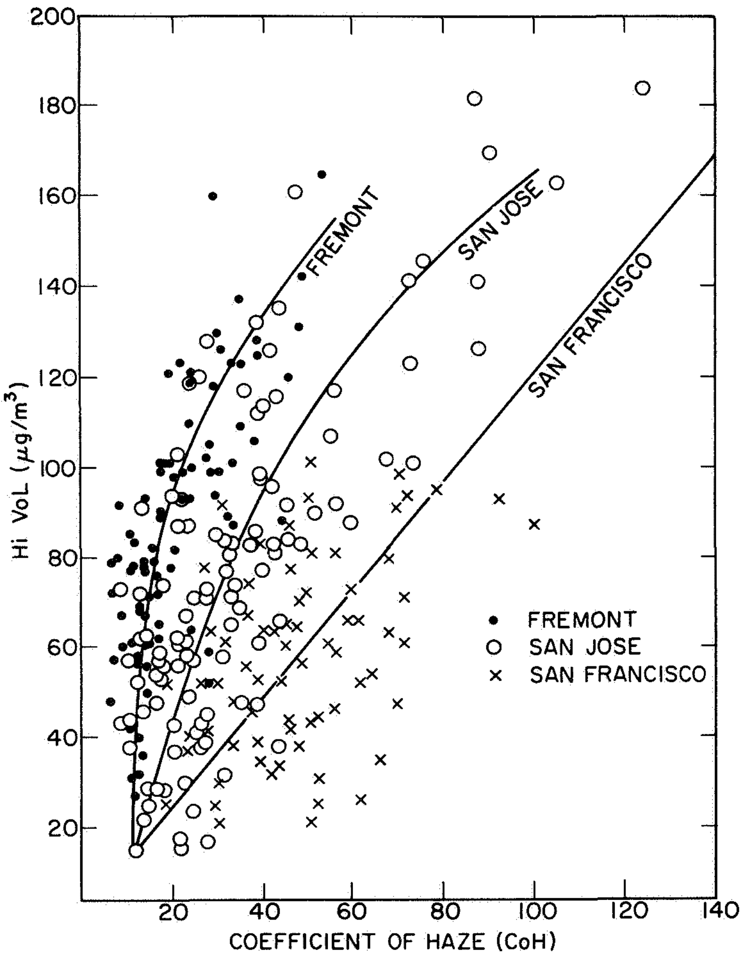

Figure 4.7. COMPARISON OF HI-VOL AND COEFFICIENT OF HAZE, JULY 1969 - SEPTEMBER 1969.

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*Private communication from Rich Thuillier, BAAPCD.

4.3 Meteorological Data

The meteorological variables most important for air pollution problems are wind velocity and direction, temperature, vertical mixing (turbulence), and the height, thickness, and type of inversion layers.

Ten of the District's stations measure wind velocity and direction, and local temperature. The location of the instruments is not always optimum, as illustrated by the Livermore station (Figure 4.5) which shows the proximity of several obstructions likely to influence the wind velocity measurement.

Winds aloft and inversion height are obtained twice a day (0400 and 1600) from the U. S. Weather Bureau's radiosonde readings at Oakland. No measurements are made elsewhere in the District.

4.4 Sources of Pollution

Air pollution sources are measured for two reasons:

(1) to establish a source inventory, and

(2) to catch violators of District emissions regulations.

The techniques used for these two functions are very different and will be discussed separately.

Source Inventory

Air pollutants come from a tremendous variety of sources, including boilers, incinerators, fresh paint, steamboats, frying pans, airplanes, burning houses, foundries, gas pumps and garbage pails, as well as more notorious sources such as oil refineries, cement plants and automobiles. To prepare a catalog or inventory of emission sources for use in air pollution control it is necessary to narrow the millions of sources down to a manageable number of most significant individual sources and categories of lesser sources. Then numbers describing emissions for each of these major sources and categories of minor sources must be obtained.

The Bay Area Air Pollution Control District has begun this inventory preparation but has not yet progressed to where the inventory fulfills data needs described earlier in this report. An IBM card file has been begun on approximately 16,000 sources of emissions, but it is not complete and not adequate for calculating area emission totals. For some of the major emitting companies estimates of the amounts of emissions have been prepared, but the list is not nearly as extensive as it should be.

Moreover, a geographical map of emission sources, describing how much of what pollutants come from each segment of the Bay Area is not available. Such a map is essential for the application of analytical prediction models. Appendix 4-1 illustrates the nature of such a map as it was developed from the Puget Sound District's emission inventory.

It is convenient to distinguish between stationary sources, such as cement plants, paint spray booths, and oil refineries, and moving sources, such as automobiles and airplanes.

Inventory of Stationary Sources

It is not economically feasible to measure each source directly. The District must rely on measurements made on prototype, typical, or average units, be they boilers, catalytic crackers, storage tanks or train engines. These measurements lead to "emission factors" which specify the emission from each unit in terms of its size, thru-put, load factor, or other important operation parameters. By determining or estimating the number of units of each type in an area and their operation parameters, and applying the appropriate emission factor, an estimate of emissions in that area is obtained. Emission factors or total emissions from some of the larger sources are occasionally checked by direct measurement.

It is important to realize that the source inventory is fundamentally an estimate and not a compilation of measured emissions. As a result it is subject to a number of errors:

(1) Errors in the emission factor. For example in 1969 new measurements on NO_x emissions from the ten power plants in the District led to a revised 1968 source estimate. Where previously 105 tons/day had been attributed to utilities, the revised figure was 63 tons/day. The magnitude of this adjustment is indicated when it is realized that the resulting estimate of total NO_x emissions from non-automotive sources was 219 tons/day. Therefore the change reduced the estimated total by nearly 25%.

(2) Errors in source parameters. As thruput and other operational parameters change the District is not always notified. Breakdowns, mis-operation, and upsets can seriously affect the emission from many units.

(3) Fluctuations in effective emission factors. In many installations the emission deteriorates slowly between overhauls. This is not reflected in the emission factors. For example, District data show that the appropriate emission factor for a fluid catalytic cracker can change by a factor of 2 to 3 between overhauls. Degradation of seals on floating roof tanks can result in a similar two- to three-fold increase in emission factor.

At present the source inventory is obtained by combining equipment registration and emission factor on a county-wide basis. It is not the District's practice to break out these figures in terms of emissions from specific industries or companies. For a variety of reasons, including public pressure, the District has begun the practice of accounting for the effluent for certain companies--81 at the most recent count. These 81 blessed ones are chosen at the discretion of the District management.

If a company is on the list of 81 companies and if it is issued a violation notice, its emission estimates are made public in the District's monthly Enforcement Report. In the four monthly reports since this practice was instituted, 32 of these 81 companies have been issued such notices. From this information and data on categories available from the 1969 District Source Inventory (summarized in Appendix 4-2) a number of meaningful conclusions can be drawn:

(1) The top 30 emitters comprise over 90% of the total SO_2 emissions in the District. In other words, the preponderance of such emissions issues from a relatively small number of rather large companies concentrated in the petroleum, chemical, metallurgical, and utilities categories.

(2) Four companies and the ten utility plants account for slightly less than 50% of the NO_x attributed to non-automotive sources.

(3) With the cessation of residential incineration and excepting a minor contribution from agricultural burning, CO emissions from stationary sources are negligible compared with the automobile's contribution.

(4) Jet aircraft contribute 3.5% of particulates.

(5) Utility companies contribute 3.5% of particulates. No particulate control equipment is installed on these plants. Since 90% effective equipment is available, these ten utility companies deserve some attention.

(6) Emission of hydrocarbons are widely dispersed. The 32 cited emitters account for only 2.5% of the total. Painting, dry cleaning, fuel storage, etc., make up a large portion of the remainder. No reports are issued on the reactivity of these various sources.

Automobile Emission Inventory

Automobiles are acknowledged to be a major source of emissions. They are the largest source in terms of absolute total tonnage. In terms of normalized* tonnage they are roughly equal in magnitude to all other sources combined.

The District estimates effluents from automobiles on the basis of total gallons of gasoline sold in each county. Other estimates (see

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*Normalized means weighted according to air quality standards. Although cars emit more carbon monoxide than all other pollutants combined, CO is tolerable in much higher concentrations than some of the other pollutants, and hence is weighted less heavily.

Appendix 2-2) can be based on transportation studies and arrive at different conclusions. No agency is presently estimating auto emissions on the basis of direct sampling of vehicles on the road.

Violations

One of the important aspects of District operation is its enforcement procedures. At present it employs twenty-four inspectors and four supervisors. A typical day of operation of one of the inspectors is described in Appendix 4-3.

Particulate Emission Measurement

The violation most frequently observed is smoke, and the measure of smoke violation is the Ringelmann scale. This scale was developed in the 19th century to judge the blackness of smoke from coal burning fires. The plume from a stack is viewed against the sun and an estimate is made of the percentage obscuration of light by the plume. The Ringelmann scale extends from 0 (for no obscuration) to 5 (for total darkness), so that a Ringelmann 2, for example, indicates 40% obscuration.

Inspectors are trained to estimate plume obscuration by eye, and are required to observe the same plume many times during a one to two hour period before deciding on the proper or average Ringelmann number for that plume.

Besides the obvious subjectivity of this evaluation, its other disadvantages are as follows:

(1) The reading is strongly dependent on the type and size of particulates (see Figure 4.8).

(2) It can only be read if

  (a) the sun is in the proper position relative to the plume
  (b) the humidity is less than 60%
  (c) there is little or no water vapor in the plume
  (d) plumes from other stacks do not combine with the observed plume.

(3) It cannot be read at night.*

(4) It is unsuitable for automation.

Some of the larger industries have installed continuously reading particulate monitors in their stacks. The records from these stack-meters are occasionally made available to the inspectors.

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*It is possible therefore to "blow" stacks, burn smoky fuel, or otherwise emit large quantities of smoke at night without danger of a violation.

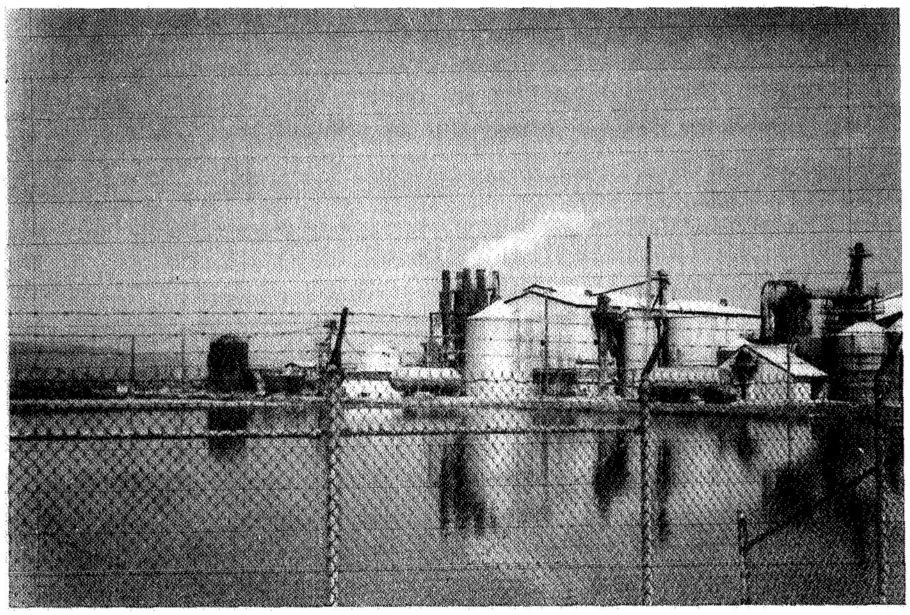

Figure 4.8. FERTILIZER PLANT. Note battery of stacks in center of picture. (1) This is a combined plume. (2) The stacks on the left end are putting out the same stuff as those on the right of the battery. The difference is that afterburners have just been installed on them making the plumes invisible. The inspector thinks this is because they somehow keep the steam from condensing. This stops citizen complaints but not pollution.

However, there is no requirement to install these instruments, to have them properly calibrated, or to make the records available to the District.

Sulfur Dioxide Measurement

The regulations covering SO_2 emission specify ground level concentrations which, basically, may not exceed 1.5 ppm for three consecutive minutes. Large emitters are required to install "at least three recording sulfur dioxide monitoring stations located in the area surrounding the source".* The regulation says nothing about the distance of these stations from the stack or their relation to stack height. Plumes may well pass over these stations and cause heavy ground level concentrations further downwind. A typical installation is shown in Figures 4.9 to 4.11.

Present instruments have large time lags and slow response which produces peak readings lower than they actually are. For example,

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*BAAPCD Regulation 2, Section 3123.3.

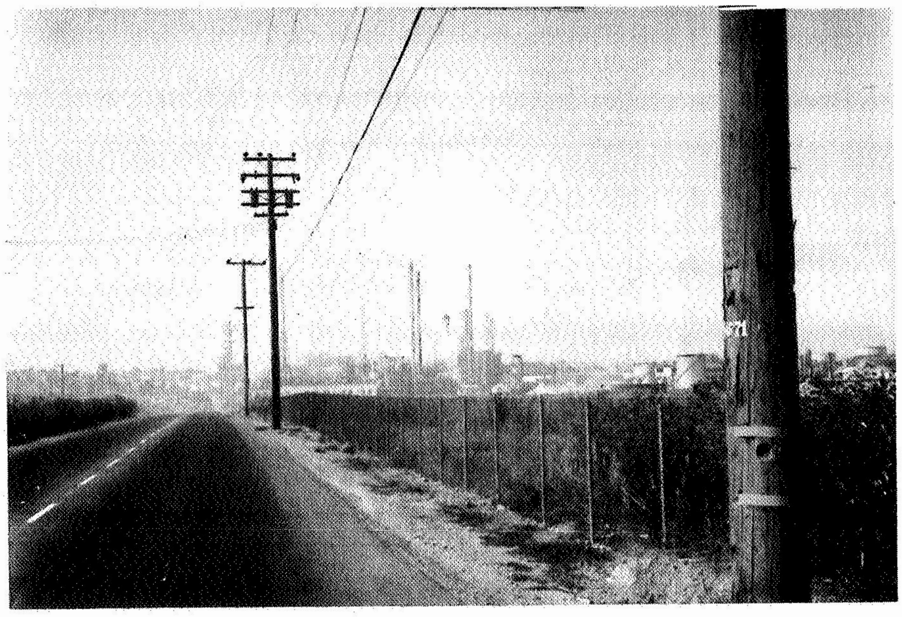

Figure 4.9. SULPHURIC ACID SCAVENGER PLANT.

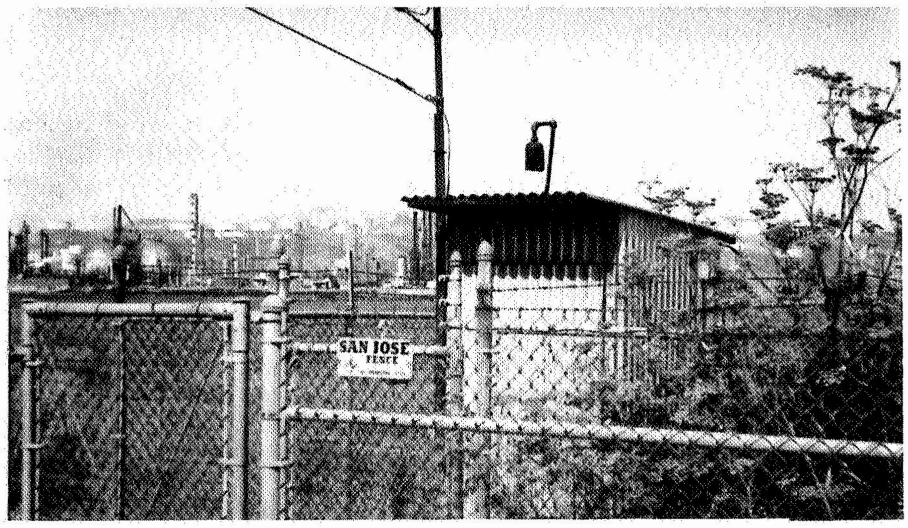

Figure 4.10. SO_2 MONITOR MAINTAINED BY PLANT (DISTRICT INSPECTOR HAS A KEY).

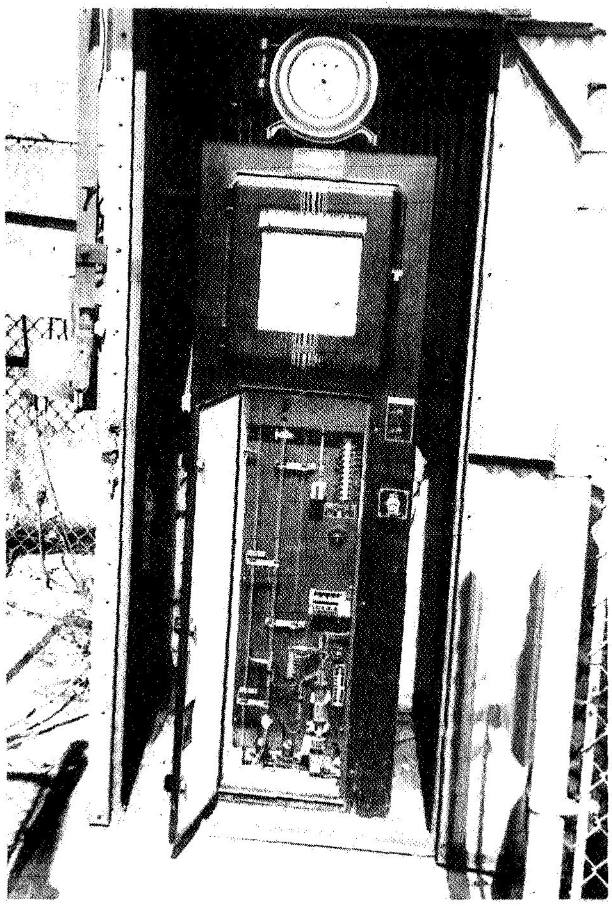

Figure 4.11. INTERIOR OF SO_2 MONITOR (OPERATES 24 HOURS PER DAY).

the Westhoff U3S analyzer, one of the fastest and best instruments used in the District, has a dead time of 0.6 minutes, and takes 1.6 minutes to reach 90% of a true reading after a step change input. A puff of air containing 1.6 ppm SO_2, and passing the station for one minute would not allow the recorder to reach more than 75% of the correct reading. Therefore, the highest recorded reading would be 1.2 ppm. It is estimated that because of this effort, only 50% of all time violations are being recorded.

Hydrocarbon Measurements

Inspectors use hydrocarbon "sniffers" to observe emissions from hydrocarbon sources. These sniffers are not specific for hydrocarbon type, nor can they measure total emissions from a source.

Loopholes

There are many loopholes in the regulations: for instance, a company is allowed 3 minutes per hour of excessive emissions, airplanes emitting excessively can be cited only in single county districts, autos in Contra Costa County are exempt from control device requirements, combined plumes cannot be judged on Ringelmann.

We did not have time to explore how many such loopholes there are, why each of them exists, whether they all should exist or what would be the consequence of eliminating any or all of them. We think such a review should be made by someone not connected with the District.

Chapter 5

IMPROVED DATA COLLECTION SYSTEM

5.1 Introduction

Chapter 4 has illustrated existing methods for measuring and monitoring air quality and emission sources and discussed deficiencies in the presently existing systems. In this section, changes in both the source and ambient monitoring systems in the Bay Area are discussed and suggestions are made for implementing an automobile inspection program. The suggestions made here follow an intensive investigation of alternate methods of collecting and disseminating air pollution data. Our recommendations are technically quite modest, but adequate to add significantly to the value of the Bay Area air pollution monitoring system. Our intent was to outline a system which would be able to monitor both ambient air and sources in sufficient detail so that it is possible to determine the contribution of particular sources to the measured air quality. Such a system is needed to provide a more rational basis for placing controls on emitters which can be directly related to local violations of air quality standards.

5.2 Fixed Source Measurements

The conclusion of this study is that major industrial emitters (a major emitter is one which contributes 0.1% or more of a contaminant to the total in the Bay Area) should be required to continuously monitor and record their emissions and periodically report them to the BAAPCD. The BAAPCD should not attempt to specify the particular instruments used by the industry, but should rather devote their effort to ensuring that the instruments meet specifications, are properly calibrated, and are correctly installed and operated.

Typical concentrations for gaseous pollutants in stacks is shown below.

Table 5.1

Pollutant	Typical Range
CO	0-1000 ppm
NO	0-5000 ppm
SO_2	0-2000 ppm

Because of the rather large concentrations involved and because of a larger current market, source contaminant monitoring instruments are more readily available than ambient air monitoring instruments. There are no technical reasons why it is not feasible for major emitters to monitor their effluents.

The following brief discussion outlines some techniques suitable for source monitoring.

Gas chromatography is a specific analysis tool especially useful for separating and identifying hydrocarbon emissions. Typically the chromatograph will be used in combination with a flame ionization detector. Since the response time may be 20 or 30 minutes it is best used to analyze a "bag" sample taken at the source. Since hydrocarbons are not often emitted from stacks, these bag samples would necessarily be taken near potential emission points such as leaking tanks and process equipment. Calculating emission rates from analysis of such samples is obviously difficult. Thus, chromatography does not seem to be a prime candidate for further development.

Mass spectrometry is currently finding use in measuring contaminants at levels (greater than 1 ppm) found near sources. Unlike chromatography the response is rapid. However, analysis is still made at specific points. Emission rates other than in stacks require integration of the various point measurements with wind data. For in-stack measurement of many contaminants the technique has promise. Current high cost of instrumentation and somewhat sensitive compound identification procedures are barriers which must be overcome before mass spectrometry can be used on a widespread basis.

Microwave spectroscopy is also currently being developed as a rapidly responding point monitoring technique. It is useful for compounds which have absorption spectra in the lower frequencies. However, line broadening at atmospheric pressure necessitates operation at pressures less than 1.0 mm Hg. This requires a reduction operation, presently done across a membrane. More effort is needed to pursue the feasibility of this method.

Correlation spectroscopy has been used as a source integrating technique for SO_2 and NO_2 by using the sun as the light source. Further study can provide several other compounds or groups of compounds analyzable in this way. For non-stack source monitoring the technique simplifies determination of emission rates since the reading is of total pollutant mass in the light path to the instrument.

Electro chemistry. Certain specific pollutants may be preferentially transferred across a liquid membrane. Electric current generated during this transfer can be monitored to yield concentration, following suitable calibration. Because this is a secondary technique it is dependent on finding appropriate membranes for each pollutant. It seems less likely for broad application than correlation spectroscopy.

Protable measuring instruments have three uses in the air pollution field: making perimeter inventories of geographical areas, locating unknown sources of pollution, and measuring industrial sources too small to require continuous monitoring. There are several colorimetric detectors for CO which weigh 2 lbs or less and can detect CO levels of 10 ppm. Portable hydrocarbon "sniffers" can detect HC concentrations as low as 0.2%.

Particulates and aerosols can be monitored in the stack by densitometers which measure the optical transmittance of the smoke inside the stack in the infrared region (primarily from 1 to 2 microns). They do not give information concerning the size distribution of the particulates. By measuring the transmittance of the stack gas at several different wavelengths, an estimate may be obtained of the size distribution as well as the number of particles being emitted. Appendix 5-4 contains a description of a multiple frequency densitometer which can produce data on particle size distribution as well as quantity emitted. Such an instrument could be used to replace the Ringelmann approach to monitoring stack effluent.

5.3 Auto Surveillance System

A major polluter in the Bay Area is the automobile. It produces most of the carbon monoxide, and a large portion of the hydrocarbons and oxides of nitrogen present in the air. Yet the BAAPCD exercises no control over these emissions. As a first step in an automobile emission control system, it is recommended that the District initiate an automobile surveillance system. The purpose of this system will be to determine just how bad the emissions from particular automobiles can get and how much improvement can be effected through a control system. Within the near future, every new automobile will have to pass an assembly line emissions test before it can be registered or sold in the State of California. This will provide excellent information on the pollution contribution from new automobiles. An inspection system would ensure that automotive emission control systems are maintained after sale of the automobile.

It is recommended that this surveillance system consist initially of a single van instrumented to read concentrations of carbon monoxide, hydrocarbons, and oxides of nitrogen. Attached to the van should be a trailer, mounted with a chassis dynamometer, and large enough to accomodate an automobile. The vehicle to be tested can be driven onto the dynamometer and have its exhaust emission tested. At present the automobile manufacturers are developing an assembly line exhaust emissions test satisfactory to the State of California. It is recommended that this same test that will be used for new automobiles also be used in this surveillance system. If this is not feasible, then a test such as described by Cline[1] should be used.

It is estimated that the cost of the van and trailer would be approximately twenty-seven thousand dollars.* Random vehicles can be stopped for checking just as the Highway Patrol presently stops vehicles for safety checks. Based on one van with one team working forty hours per week, approximately ten thousand vehicles could be checked per year. This assumes that the van is running tests only twenty hours per week, the other twenty hours being consumed by driving, maintenance, etc.

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*	
Emissions Instrumentation	$12,000
Van	7,000
Trailer-mounted Dynamometer	8,000
	27,000

The test program would require three people. One, a police officer, would direct vehicles to the van. Another would supervise the vehicles on the trailer, and record the year, model, and make of the car, as well as type of control systems, while a third would operate the instrumentation in the van.

This initial single-van program is expected to give the district data necessary to more rigorously define its program with respect to automobiles. The automobile issue is discussed more fully in Chapter 7.

5.4 Air Quality Measurement System

One of the primary purposes of the monitoring system is to identify the most heavily polluted areas in the region. These areas are the governing factors in the determination of whether air quality standards are being met. In conjunction with the source measurements, data in such areas will make it possible to determine the specific causes of these high pollution levels.

In designing a monitoring system one must make sure that there is not some unmonitored source area in the basin which has air of consistently poor quality (below ARB standards), or that episodes (of dangerously high pollutant levels) occur in regions where there are no monitoring stations. Pockets of high pollution are more likely the lower the wind velocity. High winds cause atmospheric turbulence and good mixing of pollutants, but, without wind, pollutants move primarily by molecular diffusion, a slow process. Yet it is precisely during low subsidence inversions, when wind velocities are very low, that smog is most severe, and the greatest variations in air pollution concentrations can be expected. Consequently, any effective air quality monitoring system must be able to function in a situation of zero wind and representatively sample and measure air quality in the entire basin.

As discussed in Chapter 4, significant variations in pollution levels have been measured within distances of a few miles. The present network of stations based approximately 20 miles apart is clearly inadequate on those days where the wind is weak and pollution is heavy under a subsidance inversion. The present air quality measurement system can be improved by any of three general alternatives.

(1) Adding additional fixed stations;

(2) Replacing fixed stations by a larger number of mobile stations;

(3) Adding a series of mobile stations.

Fixed Monitoring Stations Only

A recent directive by George Morgan, Director, Air Quality and Emission Data Division, NAPCA, discusses guidelines for distribution of monitoring stations. His estimate arrives at 15-25 stations to furnish "an adequate amount of air quality data", distributed as follows:

1 - Heavily polluted or dirty areas	3-5 stations
2 - Non-urban areas	2-4 stations
3 - Population oriented	3-7 stations
4 - Source oriented	3-5 stations
5 - Comparison (Center City)	1 station
6 - Other (modeling or gradient analysis)	3 stations

Assuming that 20 complete stations would be satisfactory for the Bay Area--an unlikely situation considering that even then each station would cover on the average an area of 170 square miles--ten new stations would have to be added to those presently in existence. Mr. John Kinosian, Chief Supervising Engineer, ARB, has estimated the annual cost of equipping and operating a fixed station at $40,000. This figure is based on a seven year depreciation of station equipment, personnel cost, supervision, and services such as calibration. The annual cost of 10 additional stations would then be $400,000.

The new stations should be located primarily in areas of high air pollution potential, for it is best to have them measure unrepresentatively high pollution values and thus be on the safe side. Unfortunately, we do not know today where these high pollution areas are, nor are they likely to remain in the same location year after year as industry and population change. The only way to find and follow these locations is to utilize mobile monitoring stations.

Mobile Stations Only

Although it is possible to conceive of a monitoring network consisting only of mobile stations, the existing of fixed stations and the experience gained with them makes it desireable to keep them operating, at least until enough experience with a mixed system has shown conclusively that they can be replaced. Historical data from the fixed stations is valuable in determining trends. In addition, fixed station data provides a continuous reference to which mobile unit data can be prepared.

Mobile and Fixed Stations Combined

The main purpose of mobile stations should be to obtain meaningful data on air pollutions over the entire area. This data can be correlated with fixed station readings to obtain air quality maps which include "pollution hot-spots". The vans can also be used specifically to find and monitor such hot-spots. Mobile stations should be able to cover 150-250 road miles a day and an area of 200-500 square miles, depending on population density. When not operating in the mobile mode, the stations can be parked with instruments operating in spots which require more intensive data.

Assuming that mobile units would drive 50,000 miles a year at a cost of 10¢ per mile and would be replaced every two years at a cost of $4000, each vehicle alone would require $7000. Instruments, operator (driver) salary, supervision and overhead would bring the total cost to about $50,000 per year per van. More details on van cost are contained in Appendix 5-2.

It is estimated that, in the six counties presently controlled by the District, 6 mobile stations, in addition to the existing 10 stations with upgraded instrumentation, would adequately cover the area. The cost of adding these 6 mobile stations is estimated to be $300,000 per year. This is the system which we recommend. We further recommend that as an initial step, a single van be used for one year to gain experience in operating such a mobile system and in setting up data retrieval and evaluation techniques.

Mobile Sampling Operation

The mobile unit is the most practical method of monitoring ambient air quality under those conditions which normally produce episodes (low winds, subsidence inversion, pollution travel by diffusion with resulting high concentration gradients). In addition, the mobile unit has the advantage of reaching every inhabited region of the basin so that the probability of undetected dangerous local pollution areas can be reduced drastically. The mobile unit can be used to take data either while moving or while stationary.

Data taken with a mobile unit in motion are averaged over distance because of the velocity of the vehicle and because of the time response of instruments. For an instrument which requires 30 seconds to reach 90% of an equilibrium value, a vehicle moving at 30 mph (44 fps) will cover 1320 feet. The instrument reading will be smoothed by the integration over this distance. The interpretation of mobile data will thus require knowledge of vehicle speed and position of a function of time so that the data can be related to a specific location at a given time. Because of other unknowns (the effect, for instance, of the vehicle's own exhaust in traffic) data taken in motion is of a more qualitative nature than data taken while halted.

By stopping the mobile station for a 10 to 15 minute interval, stable readings can be obtained which can be related to a specific point at a specific time. Unknowns can be reduced (for instance, the vehicle can be shut down and the station run by local power) and temporal mapping of the air quality can be done. It is therefore possible to use the mobile unit data for either spatial mapping of air quality at a given time, or for temporal mapping of air quality at any point.

Spatial Mapping with Mobile Units

It is frequently useful to plot contours of constant concentration (isopleths) on a map of an air basin. These curves are presently developed by assuming a linear interpolation model such as those discussed in Chapter 6. This assumption corresponds to the solution of the steady state diffusion equation and assumes the absence of wind and neither sources nor sinks between adjacent stations. This is obviously a poor assumption. In the event that sources do exist between adjacent stations and that the winds are blowing, it becomes impossible to accurately predict intermediate pollution levels from only the data at the presently existing fixed stations.

Monitoring between adjacent fixed stations with mobile units allows comparison of the measured value at an intermediate point with the value predicted by interpolation between adjacent stations. The difference between the measured and interpolated values is a function of local sources and air movement. Consideration of these differences will result in an increased understanding of these sources and the air movement. This is precisely the understanding needed to more logically control emissions.

5.5 Temporal Mapping with Mobile Units

Larsen at NAPCA has shown that the distribution of a pollutant at a fixed site can be graphically represented by log-normal plot of the frequency with which certain concentration levels are exceeded (see Figure 5.1).

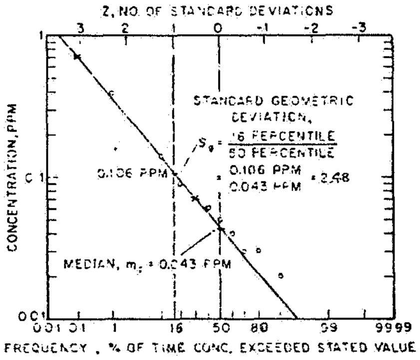

Figure 5.1. FREQUENCY THAT VARIOUS 1-HR-AVERAGING-TIME NITROGEN OXIDES CONCENTRATIONS EXCEEDED VARIOUS VALUES IN WASHINGTON, D.C. FROM 12/1/61 TO 12/1/64.

When a mobile unit has been to a site in a community for a sufficiently large number of measurements a plot such as Figure 5.1 can be constructed.

By comparison of such plots for various sites in the air basin the control district and the local residents can identify those areas which have the highest potential for severe air pollution. By comparison of these plots on a yearly basis the control district can determine the effectiveness of control procedures in any particular region.

5.6 Fixed Station Design and Equipment

The ideal fixed station should measure two classes of variables: pollutant concentrations and meteorological parameters. The table below lists the variables of interest.

Table 5.2

Meteorological Parameters

1 - Wind Direction
2 - Horizontal Components of Wind Velocity
3 - Vertical Component of Wind Velocity
4 - Temperature--Dry Bulb
5 - Temperature--Wet Bulb
6 - Height to Base of Inversion
7 - Height to Top of Inversion
8 - Incident Radiation
9 - Precipitation

Pollutant Concentrations at Nose Level

1 - Carbon Monoxide (CO)
2 - NO
3 - NO_2
4 - O_3
5 - Total Oxidant
6 - Total HC
7 - Reactive HC
8 - PAN, or other specific hydrocarbons
9 - SO_2
10 - Lead
11 - Total Particulate as $\mu g/m^3$
12 - Particulate in Submicron Range

The air sample for measurement of pollutants should be taken at a level about five feet above the ground, the level at which most people breathe. The sampling line and pumping rate should be sufficiently large so that the diffusion of reactive particles or gases to the wall will be minimized.

Pollution Instrumentation

Ambient instruments must be capable of measuring concentration levels orders of magnitude lower than the concentrations in stacks. Table 5.3 lists some typical ambient concentrations of pollutants.

Table 5.3

TYPICAL CONCENTRATION OF POLLUTANTS IN URBAN AREAS

Pollutant	Mean Range ppm	Peak Values ppm
SO_2	0.05 - 0.10	1.5
NO	0.03 - 0.10	1.4
NO_2	0.03 - 0.06	0.8
CO	5 - 10	70
Oxidants	0.05 - 0.30	1.0
Hydrocarbons	2 - 3	20

Operational requirements of ambient instruments should be such that a highly trained operator is not needed. Because such instruments should be portable in the sense that they may be carried in a van or airplane, their weight should be less than one hundred pounds.

Many of the principles listed in Section 5.2 should be adaptable to ambient air monitoring. However, current technology provides only one type of instrument which meets the above requirements for gaseous ambient air monitoring--the absorption spectrometer. Several other types of instruments, such as the Faraday cell and the enzyme fluorescence detector, may become suitable in the future.

Absorption Spectrometry

The absorption spectrometer may operate either in the infrared region or the ultra-violet region of the spectrum. It can be used to make quantitative measurements, and can be operated either with an artificial light source or with direct or reflected sunlight.

All pollutants have infrared absorption bands, so that an infrared spectrometer can be adapted to measure the concentrations of all of the pollutants of interest, although presently existing instruments can measure only one pollutant at a time. Table 5.4 shows the performance specifications of a typical Luft-type infrared spectrometer* which has been designed so that it may be changed from one pollutant to another in the field.

Table 5.4

TYPICAL SPECIFICATIONS OF INFRARED SPECTROMETER

Speed of response	90% of final reading in 5 seconds
Noise level	Less than 1% of full scale
Accuracy	1% of full scale
Sensitivity (example)	0-10 ppm CO_2 with 40" cell
Selectivity	Background affects analysis less than 1%
Power requirements	200 watts
Dimensions (40" cell)	67" × 13" × 10"
Weight	85 lbs.

There are several ultra-violet spectrometers designed specifically for air pollution measurements. One of these uses a correlation detection scheme and is designed to make volumetric measurements using

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*Mine Safety Appliance Co. Infra-red analyzer.

either the sun or a lamp as light source so that the total number of molecules of the pollutant between the light source and instrument will be measured.* (Appendix 5-1). Table 5.5 indicates the performance specifications of the correlation spectrometer. At the present time, only one pollutant at a time can be measured but work is in progress to measure two pollutants with one instrument simultaneously.

Table 5.5

SPECIFICATIONS OF CORRELATION SPECTROMETER

Present Application	SO_2, NO_2, (I_2)
Threshold sensitivity	2 ppmm†
Power requirements	5 watts
Dimensions	
Viewing unit	11" × 26" × 10"
Electronics unit	15" × 18" × 7"
Weight	72 lbs.

Another UV spectrometer designed for air pollution measurements uses a derivative detection scheme. It is at an early stage of development although some prototype testing has been done.** Like the infrared spectrometer it makes point measurements by drawing an air sample through a cell. Typical specifications for this type of derivative spectrometer are given in Table 5.6. The number of contaminants analyzed by this instrument is apparently limited by data handling capabilities.

Table 5.6

SPECIFICATIONS OF DERIVATIVE SPECTROMETER

Measureable pollutants	SO_2, NO, NO_2, O_3, NH_3	
Threshold sensitivity	O_3	2.5 pphm‡
	NO_2	5.0 pphm
	NO	0.6 pphm
	SO_2	0.05 pphm
	NH_3	0.1 pphm
Weight	80 lbs.	

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[*] Barringer Research Inc. Correlation spectrometer.

[†] ppmm--part per million over entire view length in meters.

[**] Spectrometrics Derivative Spectrometer.

[‡] pphm--parts per 100 million.

Future Possibilities for Gaseous Ambient Air Monitoring

Faraday cell devices - Simple devices based upon the fuel cell principle for measuring SO_2, NO_2, NO, or H_2S are now becoming available. These devices have a dynamic range of 0.1 to 5000 ppm. The primary advantage of these instruments is low cost--the cells cost about $225 with a life expectancy of 6 months and the electronics cost about $2000 additional.

Enzyme detectors* - Work has just started on the response of certain biologically important enzymes to nitrogen dioxide. The enzymes normally react with a substrate to produce fluorescence. The reaction rate--and the fluorescence--is reduced in the presence of NO_2. At present 1-10 ppm of NO_2 can be detected although increased sensitivity is hoped for in the future. Research in this area has just started, and results should not be expected soon.

Particulate Monitoring

The most important parameters for particulate analysis are the numbers of particles of each size and their composition. The measurement system should determine the particle size distribution by a densitometer such as that described in Appendix 5-4. The chemical analysis of the sample collected by a Hi-Vol sampler can give the overall composition of the mass collected. Cascade impacters which can collect particles of the respirable sizes are also available.

Meteorological Monitoring

Sampling for meteorological data is quite different from sampling for pollution concentration. The meteorological standard for reporting wind data is ten (10) meters above the ground over open terrain. If open terrain is not available the standards recommend the instruments be placed at such an elevation that the measured value is equivalent to the 10 meter value over open terrain. Needless to say this is difficult in practice. A local survey, taking into account neighboring buildings and trees should be made at the station prior to placement of the wind instruments.

Figure 5.2 shows the effect of a cubical building upon wind flow patterns. The BAAPCD usually maintains meteorological instruments on the roof of their monitoring stations. It is readily obvious from this figure that the wind velocity measured and even the direction are changed significantly by the drag effect of the monitoring station.

The ideal monitoring station would be designed to minimize its own disturbance of the wind field. The ideal station would therefore be hemispherical in shape, and the geodesic dome design of the CAMP stations is a practical solution. The meteorological measurements should be at a height sufficient to be above the displacement flow over

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*Ames Research Laboratories, National Aeronautics and Space Administration.

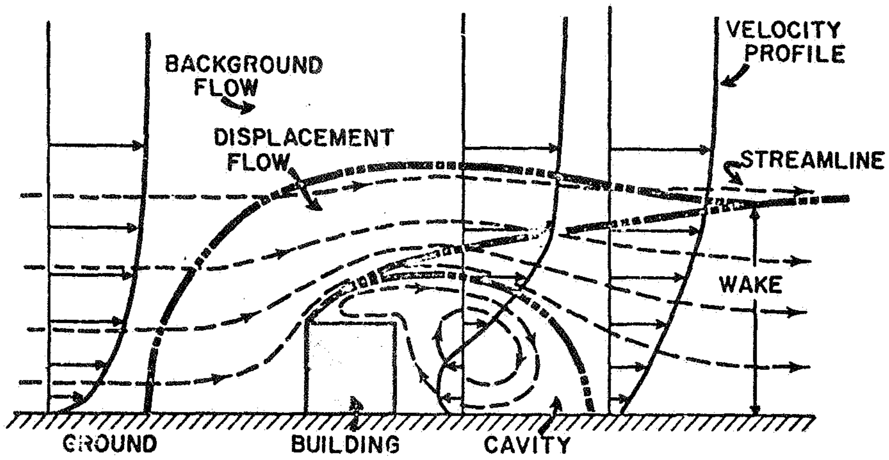

Figure 5.2. MEAN FLOW AROUND A CUBICAL BUILDING. The presence of a bluff structure in otherwise open terrain will produce aberrations in the wind flow generally similar to those shown.

the building. It is therefore recommended that the BAAPCD install towers above their present stations and that all wind velocities be taken at a uniform height above ground level. A tower will also allow the measurement of temperature at two or more levels which is invaluable in determining the local atmospheric stability. For a more complete discussion of data taking aloft see Chapter 6.

Specific Fixed Station Recommendations

The philosophy recommended in this study utilizes fixed stations to provide data on average ambient air contaminant levels, data as reference to that taken by mobile stations, and data for historical trend analysis. Preliminary analyses were done ignoring the present network. This resulted in a system requiring only six fixed stations, located at the entrances (and exits) to the air basin and in a few locations far removed from sources. Mobile units were then proposed to provide data on deviations from the average contaminant levels.

Realizing the impractibility of constructing an entirely new network, the final conclusions of the study are that the present fixed stations should be retained and updated. All air sampling intakes and meteorological instruments should be relocated to be consistent between stations and free of unwanted flow effects from the stations themselves and from other objects nearby. If this is not possible for particular stations, they should be relocated and housed in dome structures, if possible.

Station instrumentation should be updated as rapidly as possible to minimize the wet-chemistry required in taking data. Our specific recommendations for gaseous monitoring instruments for fixed stations are the same as those for mobile stations (see next section). We also suggest that high priority be placed upon securing particulate measuring instruments which can monitor particle size as well as total content.

5.7 Mobile Station Design and Equipment

Mobile units need not measure as many variables as the fixed stations. They need to measure wind and temperature only in the stationary mode.

The variables to be measured by mobile stations are:

Table 5.7

Meteorological Parameters (when stopped)	Pollutant Concentrations at Nose Level
1 - Wind direction	1 - CO
2 - Horizontal component of wind velocity	2 - NO
3 - Vertical component of wind velocity	3 - NO_2
4 - Temperature Dry Bulb	4 - Total Oxidant
5 - Temperature Wet Bulb	5 - Reactive HC
	6 - SO_2

As far as possible, the pollution measuring instruments should be spectrometric or dry chemistry with maximum response times of a few seconds. Our specific recommendations at present are:

CO:	Use non-dispersive infrared (NDIR) analyzer(1) or HgO reduction.(2)
NO:	NO measurements should await the availability of a suitable derivative spectrometer.(3)
NO_2:	Correlation spectrometer(4) with folded light path.
Oxidant:	The potassium iodide oxidation technique is recommended until a derivative spectrometer specific for O_3 has been developed.(3)
Reactive HC:	Reactive HC are presently unmeasurable in a mobile unit. A total HC analyzer is a second choice and should be installed pending development of the specific device for reactivity.
SO_2:	A correlation spectrometer(4) should be used, with folded light path.

(1) Such as made by Mine Safety Appliance Co. or Beckman Instruments, Co.

(2) Johnson-Williams, Co.

(3) Spectrometrics, Inc.

(4) Barringer Research Inc. (see Appendix 5-1).

The meteorological instrumentation should be placed on a retractable tower which will be raised into place when parked. The ideal mobile unit would be an electric vehicle capable of attaining 60 mph with a range of 200 miles over an 8 hour period. The obvious drawback of the IC engine is that there is always the possibility of the vehicle exhaust reaching the probe and distorting the reading. At the present time electrical propulsion cannot meet the specifications. The second alternative is to convert the IC engine and AC generator from gasoline to LPG for low emissions. It is recommended that the BAAPCD take this step immediately for their existing mobile unit. Total cost is about $500.

The mobile unit while in motion will require AC electrical power for the instrumentation. There is a definite effect of unregulated voltage on the span of some of the instruments. For consistency, voltage regulation is a must.

Mobile Unit-Driving Patterns

During the first year a single mobile unit should operate throughout the entire air basin obtaining sufficient data to further refine the exact number of mobile units (6) recommended in this study. It is anticipated that eventually one mobile unit will be assigned to each county. Within each county, such as Santa Clara, there are many identifiable regions which can be monitored (Coyote, Gilroy, Los Gatos, Saratoga, South San Jose, East San Jose, Downtown San Jose, Santa Clara, Sunnyvale, Palo Alto, Milpitas, etc.). The mobile unit should be assigned a circuit within the county bringing it to each of these locations on a regular basis. At each location the BAAPCD should assign a specific place for the van to park at which electrical power will be available. The van should drive ten minutes and stop ten minutes as it goes from location to location. The 10 minute sampling time at a given location will allow the instruments to reach equilibrium values. Between stops pollutants can be monitored as described previously. The mobile unit should be able to reach each specified location twice in an ordinary working day.

In the event that atmospheric conditions are conducive to prolonged periods of high air pollution levels, the mobile units should be kept operating into the evening and around the clock if necessary. The scheduling of additional monitoring under these conditions should be part of an episode warning and control procedure which is discussed in detail in a following section.

It is therefore recommended that the BAAPCD immediately complete the instrumentation of their mobile unit and begin a program of monitoring throughout the entire air basin. In the first year the BAAPCD should develop the information necessary to refine the exact design of the mobile unit network necessary for the entire Bay Area. Estimated first year expenditures are discussed in Appendix 5-2.

5.8 Additional Recommendations

Measurement of Vertical Pollutant Distribution

The vertical distribution of pollutants is an important parameter in determining the mechanism of dispersion of pollutants. The upper atmosphere may act as a capacitor, storing pollutants and later releasing them back to the ground as high level air is mixed with the ambient air.

There are three methods available for measuring vertical pollution distribution:

1. Ventilation sampling from a probe placed at the top of a tower.
2. Air sampling by flying over the region. Instruments can be mounted in the plane or samples can be taken for later analysis.
3. Long path sampling using correlation spectrometer or other techniques. This measurement corresponds to the total amount in ppm-meters above the ground.

The data obtained from these 3 techniques have different utility. The ventilation sample taken at the top of a tower can provide very useful information when compared with the ground level concentration with knowledge of the vertical wind velocity.

The airborne sampling is limited to heights above about 1000 feet. Although it is possible to take vertical soundings by touching down at airports in the basin, the movement of the plane provides an integrating effect. The total burden at various levels can be measured quite accurately by circling above a given area of the basin.

The correlation spectrometer is described in Appendix 5-1. Its main utility is in determining atmospheric burden for inventory purposes. If downwind from a source, these data in conjunction with wind velocities can be used to compute the source emissions.

It is recommended that the District sponsor, or urge NAPCA to support, research on the vertical mixing parameters and effects in the Bay Area.

5.9 The Application of Air Quality Measurements

A monitoring system for air quality can only be justified by demonstrating how the data can be used to promote the reduction of air pollution levels. If the data are not analyzed and used as a basis for action, the money is wasted and would be better spent in hiring additional inspectors.

Before the data can be analyzed, they must be presented in a form which can be understood. It is almost impossible to comprehend the meaning of data when presented in the form of a table of numerical values. Graphical presentation of the data should be used to further understanding and to promote the acceptance of control action based on the data themselves.

Data Analysis

If data are gathered from fixed stations only, reduction to graphical form depends on the use of an analytical model of the variation of air quality from point to point in the area. Such models are discussed in Chapter 6. One function of the mobile units in the network is to provide the additional data necessary for evaluation of these models and to decide how best to apply them to determine source contributions to pollution. The District will also use this data in conjunction with source maps, described in Chapter 4. By placing contour maps of lines of constant concentration (isopleths) over the source maps it will be possible to visually detect which sources are most likely the major cause of local pollution. This information can then be utilized for justification of special control measures for those emitters found to be causing high levels of pollution in local regions.

The data can also be plotted on probability paper as shown in Figure 5.1. As previously discussed these plots can be used to compare air pollution levels between regions as well as to provide a comparison by year for the purpose of evaluation of control measures. The question as to whether air pollution is increasing or decreasing in a given area is a particularly difficult one to answer, but comparison of such charts for the same region, over several years would indicate the trends.

To use raw data effectively in a computer without tedious and costly card punching or other manual data conversion, the measurements at all stations should automatically be converted from analog to digital form and punched on paper tape or punched cards for direct input to the computer. Instruments to perform this function are readily available at nominal cost.

It is recommended that the raw data be converted by the computer into a format compatible with SAROAD,* so that these data can become a useable part of the national air quality data bank.

Episode Control

One of the most important functions of an air quality monitoring system is the prediction of episodes of dangerously high pollution in time for public action.

The present alert warning system by the BAAPCD is highly inadequate for the following reasons.

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*SAROAD: Storage And Retrieval of Air Quality Data--a special computerized data bank maintained by the Federal government.

(1) The State health limit for oxidants is 0.1 ppm (for one hour). The District does not consider an alert warning until an average level of 0.40 ppm has been exceeded for one hour. Even then the warning cannot be issued without the approval of the Chief Administrative Officer.

(2) The BAAPCD monitoring stations are manned only 8 hours per day, Monday through Friday. If dangerous levels occur at night or over the weekend, no warning can be given because the system does not transmit data to Headquarters. A peak of 0.48 ppm and an hourly level of 0.42 ppm oxidant was reached on a Sunday in October 1968 in San Jose. No alert was given.

(3) The present system has no predictive capability. That is, episode warnings come too late for any corrective or preventive action. At best, people can be urged to stay indoors and not drive.

Most episodes occur during periods of prolonged subsidence inversions. The state of the art of meteorology today is such that a subsidence inversion can be predicted 12 to 24 hours in advance. If a prediction of continued low inversion coincides with a rapid rise in pollutant level, one should anticipate an episode and issue warnings to minimize automobile travel and close down other sources of pollutants.

If the atmospheric conditions are right for an episode to occur, the warning should be given before the danger levels are reached. Under these conditions overtime should be authorized to man the monitoring stations evenings or weekends, and to make observations until the danger is passed. A detailed procedure is outlined in Appendix 5-3.

5.10 Recommended Instrumentation Research

NAPCA should intensify its support of research and development of source emission instrumentation and ambient air quality instrumentation. Specific recommendations in each of these two categories follow.

Ambient Air Quality Measurement

Mobile vans are almost certainly the ambient monitoring stations of the future. The reasons for this have been discussed. In order that data taken in a moving van be truly assigned to a given location, the response time of the instruments must be of the order of 1-5 seconds. This criterion eliminates from consideration for development most instruments which require gas dissolution and subsequent wet chemical analysis.

Two techniques, very similar in principle, have been utilized already in making working instruments able to detect ambient levels of several pollutants. Since every gas has an emission and an absorption spectrum, each is theoretically analyzable by spectroscopy. However, it must be determined exactly which part of the spectrum is most feasible for analysis. This choice is determined by the strength of the absorption or emission at any given frequency, the relative strength of common background at that frequency, and the availability of techniques (emission sources and detectors) at that frequency.

Given sufficient effort, it is probable that only 1 or 2 instruments need be used to analyze for every known gaseous pollutant. Further, these instruments could be modified to handle other pollutants as they are identified.

Recommendation

Spectroscopic techniques should be further developed to allow measurement of all known gaseous pollutants.

The estimated time for this development is about 6 man-months per pollutant. At $20/hour, this amounts to $200,000 for 10 pollutants. Tests of the techniques themselves will require about 1 man-year, or $40,000. Integration of the multi-pollutant analysis in a single instrument will probably require an additional 2 man-year effort or about $80,000. Thus, the total R & D budget for the initial exploitation of a spectrometric ambient analysis system would be about $320,000.

A spectroscopy team at NASA-Ames Research Center has been investigating long-path high resolution spectroscopy to resolve constituents of planetary atmospheres.

Recommendation

It is recommended that this technique be combined with techniques of reaction rate chemistry to provide information on the precise chemical reaction kinetics of the air pollution process. As previously mentioned, the particle size distribution is extremely important in monitoring particulates.

Recommendation

Instruments should be developed which are capable of monitoring particle size and composition as well as total particulate contamination in ambient air.

Source Measurements

Interferometric spectrometers are capable of measuring the infrared (IR) emission spectra of emissions from calibrated smoke stacks and plumes.* The use of this technique is limited only by the limited state of knowledge of pollutant IR spectra and the IR radiation of interfering chemicals.

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*This has been done by Digilab Corporation of Block Engineering.

Recommendation

Basic research should be directed towards obtaining IR emission and absorption spectra of pollutants for use in interferometric spectroscopy.

The Ringelmann Measurement is one of the most justly criticized tools used in Air Pollution Control. However, it is still used.

Recommendation

An instrument for use in source monitoring which can account for both particle size distribution and total emission (such as that in Appendix 5-4) should be developed as soon as possible.

Chapter 6

MODELING AIR POLLUTION

6.1 Introduction

An air pollution model is an abstraction designed to predict the effects on the outputs of a real system of the controllable inputs to the system. The purpose of the abstraction is to further the understanding of the real system and to allow decision makers to assess the effects of various control strategies that may be employed. Because of the complexity of the air pollution problem, it is most important to be able to know in advance the consequences of a particular control action. If a tightening of emission regulations for a certain process is proposed, one must ask the questions:

1. How much does the reduction in emissions improve the air quality?
2. What is the cost of the tighter emission requirement?
3. Are there other control strategies which might be more effective at the same or lower costs?

As a specific example, in 1967 elimination of agricultural burning in the Bay Area was proposed by the BAAPCD. While estimates of the reduced tonnages of resulting pollutants could be made, these figures could not be translated into the resulting improvement in air quality at any point in the Bay Area. Furthermore, one likely effect of this proposed control program was that the amount of land devoted to farming would have been reduced, with a percentage of the land made available being occupied by industry. Thus, the overall effect might well have been a net increase in pollution levels in the Bay Area. Fortunately, meteorologists at San Jose State College pointed out that by requiring agricultural burning to be done only at meteorologically favorable times, the resulting pollutant emissions could be effectively controlled. As a result the ban on agricultural burning was not imposed.

The point of the example is that the decisions to be made often involve technical questions of a complicated nature. The straightforward philosophy of simply squeezing all sources may not result in substantially better air quality, in fact, unforeseen side effects may even lead to a degradation in air quality. In addition, effective control programs can be carried out most effectively when the pollutant emitters find it in their best interest to cooperate; such cooperation is more easily obtained when emission regulations are based on demonstrable technical considerations rather than on arbitrary decisions.

The purpose of air pollution models is to provide a link between source emissions and air quality. More specifically, these models could be used to:

1. Provide a basis for locating air quality monitoring instruments to guide in source emission regulation. From specified source emission data, points of maximum concentration can be estimated and pollutant concentrations measured at these points.

2. Be used as a guide in source emission regulation enforcement and monitoring of ambient air quality. A high reading of a particular pollutant at a monitoring station can be attributed to the emissions from a specific source.

3. Enable one to make rational planning decisions by assessing the effects of adding or altering sources (the pollutant concentrations in Santa Clara caused by a new freeway or housing development near Gilroy can be determined).

4. Help to systematize the collection of source emission data (the operation of models requires a complete source inventory).

5. Provide a means of predicting the occurance of air pollution episodes and developing abatement strategies (a model could indicate whether the refineries in the North should be shut down, or traffic banned from downtown San Francisco, if an alert occurs).

6. Provide information to the public about which sources contribute most to degradation of air quality in various residential areas.

A validated model does provide important information on which rational technically-oriented decisions can be based; however, current practice indicates that the development and use of models is just beginning. In the remainder of this chapter, the status of model building is indicated by a review of several existing models, and examples of applications of these models to the San Francisco Bay Area are presented. The conclusion of the chapter gives a set of specific proposals, including estimated costs and manpower requirements, for an initial entry of the BAAPCD into the use and development of models.

6.2 A Review of Several Existing Models

In an attempt to determine the state of the art of air pollution modeling, a survey of existing models was undertaken by this study group. To provide a complete survey would have required a far greater time than was available, so the enumeration given below is presented as being representative, not as a complete list.

1. "Development of a Practical, Multipurpose Urban Diffusion Model for Carbon Monoxide", W. B. Johnson, F. L. Ludwig, and A. E. Moon. Presented at the Symposium on Multiple-Source Urban Diffusion Models, Chapel Hill, N.C., Oct 1969.

This is a thoroughly computerized diffusion model which computes hourly local concentration of a primary pollutant throughout a city. It is primarily designed for automotive sources but can also accommodate stationary sources.

The program utilizes traffic surveys, and, on the basis of traffic density and estimated average speed of cars, calculates total hourly emission of carbon monoxide along every major street in a city. These streets are then taken as line sources of pollution. The pollutants are assumed to diffuse according to an equation which takes into account wind velocity and direction, and certain statistical distribution coefficients which govern vertical and horizontal spreading.

Assuming that the terrain is flat and that meteorological data taken at one point (usually the local airport) are valid everywhere, the program calculates and combines the pollutant concentrations from all these street sources and produces a map of the city overlaid with lines of constant pollutant concentration (isopleths).

The model has been applied to CO in St. Louis, and a comparison of calculated and measured data is presented. Although the calculated values differ from the measured values, the authors contend that proposed refinements will make the model more accurate.

2. "A Diffusion Model for Air Pollution Over Connecticut, A Summary", N. E. Browne, Journal of Air Pollution Control Association, Vol. 19, No.8, 1969.

A geographical area is subdivided into a rectangular array of grid points. Each grid square is assigned a value that specifies its source strength in a particular instance and a wind field value that determines the advection of material. The wind field is represented by a stream function ψ and the rectangular components of the wind velocity are given by the gradient of ψ. This is the mechanism by which the large scale motion (or transport) of the pollutants is modeled. The small scale motions, or diffusion, are handled by using the Gaussian plume equation. Empirical data is used to determine the pollutant variances in the lateral and vertical directions.

Pollution from a point or from a small area is traced along a trajectory following the mean wind; it spreads by diffusion as it travels. At any receptor point the total pollution is found by summing the contributions at that point from all of the sources. To make the computational procedure more efficient, backward pollutant trajectories are computed.

Five pollutants are considered and predicted patterns for CO and SO_2 in Connecticut are presented.

3. Regional Air Pollution Analysis (RAPA), Phase I, TRW Systems Group, U.S. Dept. HEW PHS NAPCA, Wash. D.C., Contract No. PH 22-68-60.

The RAPA model contains four integrated submodels: an atmospheric diffusion model, a control-cost effectiveness model, an abatement strategy model, and a regional econometric model (for the St. Louis area). The cornerstone of the integrated model is the atmospheric diffusion model which is based on the Gaussian plume equation described by Martin and Tickvart and a statistical model proposed by Larsen. The control-cost effectiveness model provides cost and cost effectiveness values for air pollution control measures applicable to each of the sources in the regions' emission inventory. The abatement strategy model provides control strategies to prevent or control air pollution source emissions within a specified timetable. The econometric model assesses the economic impacts on a region of the possible control strategies.

4. "Numerical Investigation on the Atmospheric Dispersion of Stack Effluents", C. C. Shir, IBM Research Laboratory.

   This is a diffusion model which must be regarded as a second-generation attempt at determining the dispersion of an effluent from a stack. Instead of using the Gaussian approximating solution of the nonlinear partial differential equations, a finite difference approach is used to solve the equations governing the behavior of the physical process. Surface roughness is incorporated in the model, and close correlation with observed plume data is reported. The primary limitation of the approach is the enormous computing facilities required; however, this elaborate model may be instrumental in indicating the important parameters, thereby leading to simpler and more feasible models.

5. Chicago Air Pollution Systems Analysis Program APICS, Argonne National Laboratory Report No. ANL/ES-CC-006.

   Argonne National Laboratory has developed this model for the Chicago area. There are actually two distinct models: a regression model for predicting the occurrence of episodal pollution situations and a Gaussian plume model for predicting longer-term pollutant concentrations.

6. Seinfeld and Friedlander (Meteorological Research/Cal. Tech.) "A Dynamic Model of Photochemical Smog", Environmental Science and Technology, Vol. E, Nov. '69, p. 1175.

   Seinfeld states that smog formation over urban areas is controlled by (1) reactant emission rates, (2) wind velocity vector, (3) mixing, (4) temperature, and (5) solar radiation. In principle, complete space and time histories could be developed for each constituent by solving the appropriate conservation equations. Even presuming accurate meteorological inputs, two drawbacks are the number of chemical species involved and the computational task in solving sets of non-linear partial differential equations. Assumptions lead to the compromise of this case with the perfectly mixed element model. The number of species, it is noted, also is compounded by the formation of free radicals for which some gross reactions must be assumed to reduce the model to manageable proportions.

Seinfeld's model uses an expanding volume. The model has two time periods: (1) the time in which volume of reactants expands to inversion height and (2) the subsequent time in which the reactants are well-mixed under the inversion layer, whose height can also change. This approach was explained in a research proposal which included a preliminary result in the form of a graph similar to the plot of average pollutant concentrations in L.A. No further data is yet available.

7. Eschenroeder and Martinez (General Research Corp., Santa Barbara, Calif.), "Mathematical modeling of photochemical smog", AIAA 8th Aerospace Sciences Meeting, Jan 1970.

   The model of Eschenroeder and Martinez is perhaps the first publication of results on a well-developed simulation of a photochemical reaction process. Especially gratifying is the well-documented validation. While the model does employ some assumptions and is not portrayed as a rigorous mechanistic model, it makes a strong case for the feasibility of photochemical smog models of this type. The efforts indicate a depth of knowledge of the chemistry, meteorology, and computational aspects of the problem. Several features worthy of note are: (1) inclusion of experimentally-determined diffusion coefficients, (2) range of reactivities of hydrocarbons, (3) capability of ranging from homogeneous mixing through a 5 point vertical diffusion model both with and without advection (wind) effects, and (4) the volume element basis of a flow channel through the inversion layer. The authors suggest further attention to recent information about hydrocarbon reactions and also the need to study the formation of aerosols and the extinction of ultraviolet radiation, the latter an affect which would have direct bearing on the initiation of the photoclytic reactions.

Each of the above models, and others not included in the summary, have required the expenditure of large amounts of manpower, yet a telephone survey of several pollution control districts revealed limited usage of these models. There are several factors which may account for this relative inattention of control districts to existing models:

1. The models themselves are still in an embryonic stage of development; most have not been validated using measured data, and none are at the stage where they can be considered off-the-shelf items.

2. In most cases, neither the source emission data nor the meteorological data required as input to the models exist.

3. Very few of the pollution control districts surveyed have personnel who have been active in the area of modeling. Without exception this was attributed to insufficient manpower to meet other than day-to-day control and enforcement requirements.

In an effort to learn more about the data requirements and potentialities of various models, the study group carried out several feasibility studies. The results of these investigations are discussed in the following section.

6.3 Examples of Air Pollution Models

Three models were investigated by the group: a Box Model, the Gaussian Plume Model, and a Photochemical Reaction Model. The first two will be discussed briefly here; a more lengthy discussion of the Photochemical Reaction Model appears in Appendix 6-2.

A Box Model for Airshed Capacity Estimations

The physical laws that govern the distribution of pollutants in the atmosphere lead to nonlinear partial differential equations that are very difficult to solve, even using modern digital computers. For certain purposes, however, solution of the partial differential equations is not necessary; for example, airshed capacity of the San Francisco Bay Area under certain meteorological conditions can be estimated using a geometric approach. The following paragraphs describe the assumptions and reasoning used to derive an airshed capacity Box Model for the Bay Area.

The airshed is pictured as a box of volume V and (inversion) height h as shown in Figure 6.1. The box is oriented so that one face is perpendicular to the prevailing wind, which is assumed to be of constant speed v and direction. This face of the box has a length L. The following conditions are also assumed.

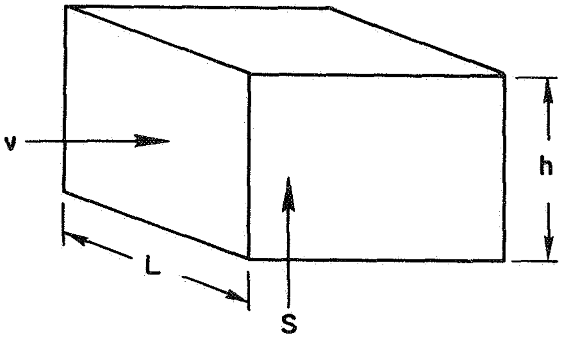

Figure 6.1. A BOX MODEL.

(a) The source emission rate S (mass per unit time) of any pollutant of interest into the box is constant with time.

(b) There is instantaneous perfect mixing within the box, so that the concentration C (mass per unit volume) of any pollutant is uniform throughout the box at any time.

(c) The air pressure and temperature are uniform and constant throughout the box.

(d) Any reactions involving the pollutants are ignored.

(e) The wind blows only clean air into the box at the volumetric rate $Q = hLv$. Dirty air, of pollutant concentration C, leaves the box at the same rate Q.

Let $C(t)$ represent the concentration of a pollutant in the box at some time t. Then a mass balance for the pollutant in the box yields the differential equation

$$V \frac{dC}{dt} = S - QC$$

or

$$\frac{dC}{dt} = \frac{S}{V} - \frac{C}{T} ,$$

where $T \equiv V/Q$ is the average residence time of a unit mass of the pollutant in the box. If C_0 is the pollutant concentration at time $t = 0$, the differential equation for $C(t)$ has the solution

$$C(t) = \frac{S}{Q} (1 - e^{-t/T}) + C_0 e^{-t/T}$$

Thus, after a sufficiently long time $(t \gg T)$, the pollutant concentration will approach a steady-state concentration $C(\infty) = S/Q$. The variation of pollutant concentration with time, for the case $C_0 = 0$, is sketched in Figure 6.2.

As a simple numerical example, assume an inversion height of 300 feet and a box volume of 9.3×10^{12} cubic feet* with a wind velocity of 5 mph, and let $L = (V/h)^{1/2} = 1.76 \times 10^5$ feet.

Then

$$Q = 1.39 \times 10^{12} \text{ ft}^3/\text{hr} ,$$

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*Based on a planimeter measurement of the size of the Bay Area at two elevations, sea level and 300 feet.

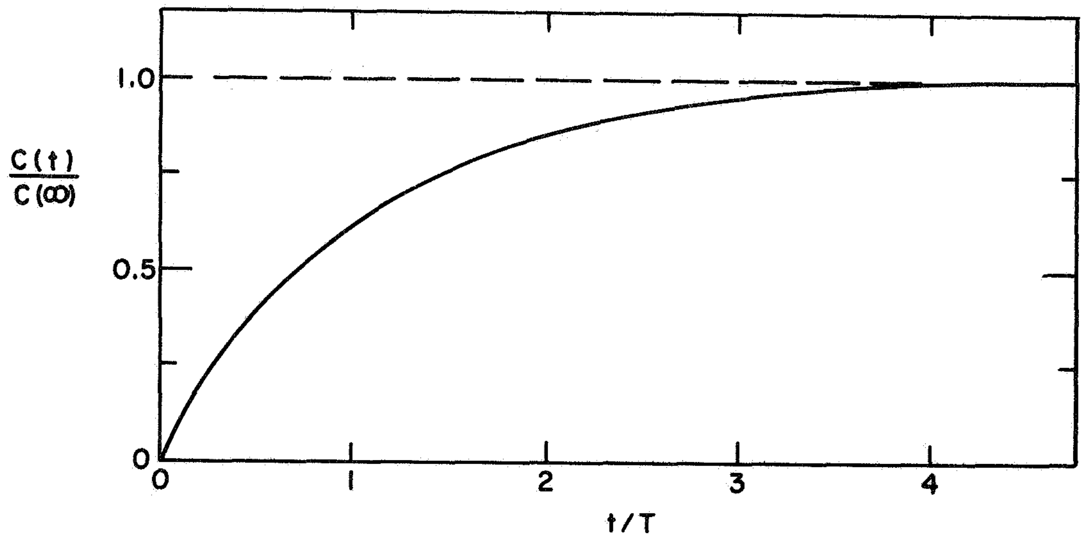

Figure 6.2. THE GROWTH OF POLLUTANT CONCENTRATION WITH TIME PREDICTED BY THE BOX MODEL.

and

$$T = 6.7 \text{ hrs.}$$

In about one day $(t \approx 4T)$ the pollutant concentration will reach its steady-state value. To estimate that value, assume S is the value quoted by the BAAPCD for 1968.[3] For SO_2 the source rate quoted is 396 tons/day or 3.84×10^4 lbs/hour. Hence

$$C(\infty) = S/Q = 2.76 \times 10^{-8} \text{ lbs/ft}^3 \quad \text{or} \quad 4.45 \times 10^{-4} \text{ gm/meter}^3$$

This number can be compared with the air quality standard for SO_2, which is 0.5 ppm if the particulate level is not exceeded. Letting this be C_R, and assuming the SO_2 is at standard conditions,

$$C_R = 0.5 \text{ ppm by volume} \quad \text{or} \quad 1.43 \times 10^{-3} \text{ gram/meter}^3$$

Thus, under the conditions assumed, the concentration of SO_2 would, in about one day, approach a steady-state value that is about one-fourth as large as the more relaxed of the two air quality standards.

The situation for SO_2 is not unique. Table 6.1 summarizes similar calculations, under the same assumptions, for the pollutants for which air quality criteria have been established and source data are available. The results for particulates are of dubious value, since most are relatively heavy and do not remain suspended in the air indefinitely.

Table 6.1

STEADY-STATE POLLUTANT CONCENTRATIONS PREDICTED BY THE BOX MODEL FOR A 5 mph VENTILATING WIND

Pollutant	S	$C(\infty)$	C_R		$\frac{C(\infty)}{C_R}$
	(tons/day)	(gm/m^3)	(ppm)	(gm/m^3)	
CO	6275	6.05×10^{-3}	20	2.5×10^{-2}	.24
NO_x	555	5.35×10^{-4}	0.25	5.13×10^{-4}	1.05
SO_2	395	3.80×10^{-4}	0.05	1.43×10^{-3}	.27
			.04	1.15×10^{-4}	3.3
Particulates	200	1.95×10^{-4}		6.0×10^{-5}	3.2

The crucial question is, of course, how valid are the results of these calculations based on the simple box model. Instantaneous mixing does not occur, so the pollutant concentrations will not be uniform. There will be some "hot spots" and corresponding regions of lower concentrations. In that sense, the calculated concentrations represent Bay Area-wide averages. Also, the effects of photochemical reactions, particularly for NO_x, have not been considered. The choice of the average wind velocity is also critical, inasmuch as the steady-state concentration $C(\infty)$ is inversely proportional to the wind velocity. The situation of low inversion height is indicative of low wind velocity, since the only significant "escape route" is through the Carquinez Straits. The assumed wind velocity of 5 mph may be too high a value for a 300 foot inversion height. In the limit of zero wind velocity, the solution for $C(t)$ becomes, with $C_0 = 0$,

$$C(t) = \frac{S}{V} t$$

For such a case, the well-mixed concentrations that would obtain at the end of a two day, 300 foot inversion with the sources used previously are shown in Table 6.2. A final assumption to be considered is the occurrence of a 300 foot (or lower) inversion which persists for two or more days. Such situations have occurred several times a year.* Appendix 6-1 discusses the meteorology of the Bay Area.

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*Data on inversion heights measured at the Oakland Airport show 5 such cases in 1962, 3 in 1963.

Table 6.2

POLLUTANT CONCENTRATIONS PREDICTED BY THE BOX MODEL AFTER TWO DAYS OF NO WIND

Pollutant	C(48 hrs) gm/m^3	C_R gm/m^3	$C(48)/C_R$
CO	4.35×10^{-2}	2.5×10^{-2}	1.7
NO_x	3.85×10^{-3}	5.13×10^{-4}	7.5
SO_2	1.40×10^{-3}	1.43×10^{-3}	1.9
		1.15×10^{-4}	24
Particulates	1.40×10^{-3}	6.0×10^{-5}	23

These calculations based on a simple box model of the San Francisco Bay Area indicate the potential for serious pollution episodes with the present sources of pollutants. Further development of the model would be valuable, particularly the relaxing of the restrictive assumptions of perfect mixing and no photochemical reactions.

The use of the box model for long-term forecasts of Bay Area pollution conditions should be quite dependable. At 300 feet above mean sea level, the area to the east and south is well enclosed by the mountains. With light, variable winds, very little ventilation of the box can take place. This model provides a reasonable basis for control of the total emission of pollutant allowed in the Bay Area. If design conditions are acceptable for this "episode condition" to occur three or four times per year, conditions during most of the year will be rather pleasant. Episode prediction is comparatively easy with the box model as a base. With a knowledge of the height and duration of the inversions and the total emission rate, the intensity and duration of a pollution episode is readily predicted. No serious episode can occur with a high inversion level and good ventilation.

When more complete meteorological data becomes available this model can be refined to include any ventilation that occurs. The model becomes more inaccurate as the inversion height is increased and for non-stagnant wind speeds in the mixing layer. Even under adverse conditions, some ventilation may occur through the inversion layer over high ground to the east and south of the Bay. Where high surface temperatures occur, especially in summmer, ventilation through holes in the inversion is anticipated. The use of a correlation spectrometer should indicate such areas of ventilation.

The Gaussian Plume Dispersion Model

An approximate solution to the nonlinear partial differential equations which govern the transport of the effluent from a stack is the Gaussian plume equation for a continuously emitting point source. The Gaussian plume equation is an integral part of several of the diffusion models described in the previous section. The form of the Gaussian equation used here is

$$C(x,y,z) = \frac{Q}{\pi u \sigma_z \sigma_y} \exp\left\{- \frac{1}{2} \frac{(h - z)^2}{\sigma_z^2} + \frac{y^2}{\sigma_y^2}\right\} \tag{1}$$

where

C is the calculated concentration at the point x,y,z (g/m^3)

Q is the point source emission rate (g/sec)

u is the wind speed (m/sec)

σ_z, σ_y are the vertical and horizontal diffusion parameters (m)

x is the distance from the source in the downwind direction (m)

y is crosswind distance from average plume centerline (m)

z is the height of the receptor above ground (m)

h is the effective source height above ground (m)

The coordinate system is shown in Figure 6.3.

By calculating the concentration of several points, concentration isopleths can be drawn. In addition, the simulation can be used to illustrate the utility of the model in decision making.

If the area surrounding the source is divided into sixteen sectors (corresponding to the points on a compass) with the sector centerline one of the sixteen standard wind directions, and if it is assumed that every wind direction within a sector occurs with equal probability, then Eq. (1) becomes

$$C(x,y,o) = \frac{2Q}{u\sigma_z \sqrt{2\pi} \left(\frac{2\pi x}{16}\right)} \exp\left\{ - \frac{1}{2} \left(\frac{h}{\sigma_z}\right)^2 \right\} \tag{2}$$

where it has also been assumed that the concentration is to be calculated at ground level $(z = o)$. Evaluating the constants in Eq. (2) gives

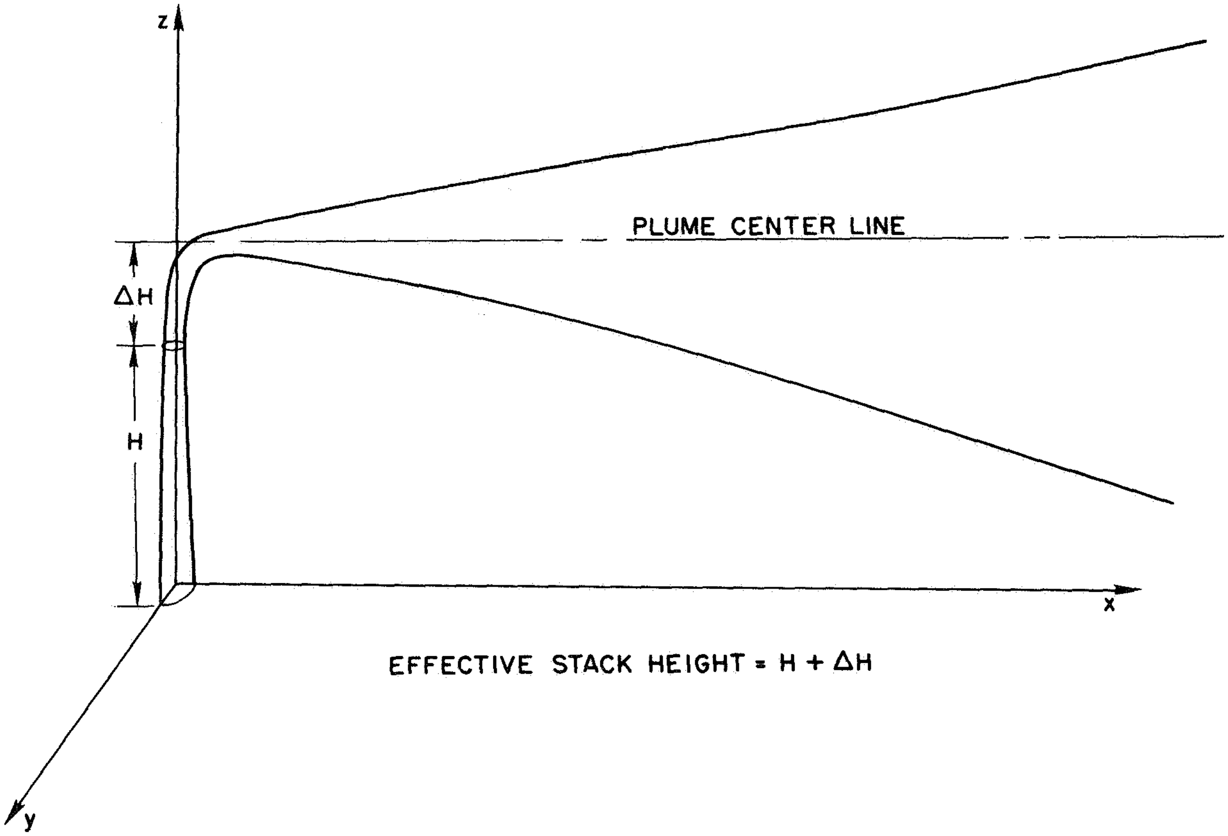

Figure 6.3. COORDINATE SYSTEM FOR GAUSSIAN PLUME EQUATION.

$$C(x,y,o) = \frac{2.03Q}{u\sigma_z x} \exp\left\{-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right\} \tag{3}$$

This equation is considered to be valid when $x < x_L$, where x_L is the distance at which

$$\sigma_z = 0.47\ D_m ; \tag{4}$$

D_m is the mixing depth (assumed to be equal to the height of the base of the inversion above ground), an input parameter. For $x > 2x_L$, the mixing is assumed to be uniform and the relationship

$$C(x,y,o) = \frac{2.55Q}{uxD_m} \tag{5}$$

applies. For $x_L \leq x \leq 2x_L$ the concentration is determined by linearly interpolating between the values given by Eq. (3) with $x = x_L$ and by Eq. (5) with $x = 2x_L$.

The above equations apply for one wind velocity; to account for the different relative frequencies of the various wind speeds Eqs. (3) and (5) are multiplied by the factor

$$\frac{f_k}{u_k} ,$$

where f_k is the relative frequency (obtained from windrose data) of the k^{th} wind speed in the direction of interest. To obtain the total concentration at a point then,

$$C(x,y,o) = \sum_{k=1}^{n} \frac{2.03\ f_k Q}{u_k \sigma_z x} \exp\left\{-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right\} \tag{6}$$

is used for $x < x_L$, and

$$C(x,y,o) = \sum_{k=1}^{n} \frac{2.55\ f_k Q}{u_k x D_m} \tag{7}$$

applies for $x > 2x_L$; n is the number of wind speeds in the direction of interest. The parameter h is the effective stack height; it is determined empirically. To account for the stability condition of the atmosphere, h is multiplied by the factor $(1.4 - 0.1S)$; $S = 1.0$ corresponds to the most unstable class, and $S = 5.0$ corresponds to the most stable class. For a first approximation, $S = 4.0$ (which corresponds to neutral stability) may be used.

The Permanente Cement operation, near Los Altos, California, was selected as an example application of the program. Realistic emission data was available, and the BAAPCD provided monthly averages of measured particulate concentrations obtained by high volume samplers in the vicinity of Permanente.

A comparison of the measured and calculated concentrations was inconclusive. There are several reasons which may account for this:

1. The windrose data used was from Moffett Field which is approximately 10 miles from Permanente and in very different terrain.

2. The mixing depth was estimated from data taken at Oakland Airport.

3. The terrain around Permanente is very undulating, hence the value used for height above ground level is open to question. This is likely to be a large possible source of error because of the exponential involving h^2.

4. The directions given for the measurements taken by the BAAPCD near Permanente were East-Southeast and Northwest, and any slight deviations from these directions, or equivalently a difference in wind frequency data, could cause difference in calculated concentration of a factor of five to eight.

5. No attempt was made to incorporate terrain information into the program--this could be done at the expense of further complexity.

6. Ground roughness, a significant factor according to the work of C. C. Shir of IBM Research Laboratory, was also not included.

7. The effects of particulate background level, accumulation effects, and particulate fallout were not included.

8. An average wind speed was used in the effective stack height equation (8) rather than calculating h for each wind speed.

Although meaningful data comparisons were not achieved, the utility of the model and the importance of accurate input data were illustrated. By reviewing the equations used, it is seen that the effects of such factors as emission rate, process changes (such as exhaust gas temperature and stack gas exit velocity), and stack height on pollutant concentrations can be obtained. Furthermore, the model can be used to predict points of maximum concentration where samples should perhaps be taken.

6.4 Research and Development Proposals

Although air pollution models have not yet received widespread application in decision making, it appears inevitable that within the next five to ten years this situation will change. There are several factors which indicate that this is the case:

1. Existing models will improve in accuracy as the pollution modeling process becomes better understood.

2. Optimal and realistic long-range planning of transportation and area development will be increasingly reliant on model estimates of pollutant effects.

3. Pollution control districts will be forced to become more model-oriented as the industries to be controlled develop pollution models to support contentions about their own

emissions. In the Bay Area, for example, the Shell Development Company is in the process of developing one model to relate process emissions to Ringelmann number and another model for estimating the visibility effect in the Bay Area of the Shell process emissions. If these models can be shown to have a reasonable degree of accuracy, Shell will be able to present concrete technical evidence at hearings of the Technical Advisory Board of the BAAPCD or when confronted by court action. The impact of such a sophisticated technical presentation will be difficult to counteract unless the validity of the model can be refuted, or more accurate models can be presented by the BAAPCD.

4. As source emissions increase in an airshed, it will become more and more important to apportion emissions in an optimal manner. To accomplish this, a more complete understanding of the effect of emissions on air quality, as can be obtained from validated models, will be required.

It is the recommendation of this group that expanded modeling efforts be initiated by NAPCA and that the BAAPCD should establish a program designed to acquire the expertise required to contribute to the eventual development and operation of models of air pollution dispersion in the Bay Area. This should not be construed as a recommendation that the BAAPCD immediately embark on an expensive development program of diffusion models, rather that the in-house capability be developed to adapt general modeling principles and future models to the Bay Area situation. Since a unique feature of the Bay Area is its meteorology, it is important that meteorological expertise be the foundation on which the modeling efforts are built. It is also important that an engineer with experience in computer operation and pollution measurement technology be included in this initial effort. These considerations lead to the following proposals.

1. NAPCA should make a major commitment to an extensive modeling effort in at least one Western urban area. The purpose of this study would be to develop general modeling principles which will be applicable to models for individual pollution control districts.

2. NAPCA should provide funding and technical assistance for adapting models to meet the control, enforcement, and planning needs of individual districts.

3. The BAAPCD should establish a division, initially consisting of at least two technically qualified people, responsible for research and development, data analysis, and modeling. The charter of this division would be to initiate long-range technical programs to assist the District in formulating optimal control and enforcement policies, and to make the responsible agencies aware of the air pollution implications of land use, planning, zoning, and transportation decisions. Specific tasks for this division could be:

a. A two-year study of existing models in cooperation with Stanford Research Institute, or a similar firm, leading to a proposal for NAPCA support to adapt existing models to the control, enforcement, and planning needs of the BAAPCD.

b. Collaboration with the Enforcement Division of the District in establishing an up-to-date computerized source inventory.

c. Initiation of a statistical study of the air quality data that have been obtained at existing measurement stations to determine techniques for re-locating these stations, and to provide routing information for mobile vans.

One of the goals of this new division should be the identification of, and specifications for, necessary data that is not provided by the existing surveillance system or by the improved system outlined in Chapter 5. The division should actively encourage air pollution research in universities, particularly those in the Bay Area.

6.5 Summary

Modeling holds the promise not only of being a powerful tool for assisting in current control programs but also for reliably predicting the consequences of today's decisions. The present efforts of the BAAPCD toward achievement of better air quality are laudable and must continue. The District should establish a vigorous parallel effort in interpretive and predictive analysis based upon a growing expertise in mathematical modeling.

The recommendations made in this chapter would require the expenditure of a significant amount of money. Current funding at Federal, state, and local levels are not adequate to effectively protect and improve air quality. Air pollution is a complex and serious problem; its solution requires a stronger degree of financial commitment.

Chapter 7

RECOMMENDATIONS FOR THE BAY AREA AIR POLLUTION CONTROL DISTRICT

7.1 Introduction

The previous chapters have dealt primarily with the technical considerations of air quality monitoring, measurement of source emissions, instrumentation, airshed modeling, and data analysis. The purpose of Chapter 7 is to recommend and discuss various approaches that will help the BAAPCD reduce air contaminants.

There are two classes of recommendations in this chapter. Class one, are those that could be effected by the District immediately. That is, the existing laws, funds, and manpower are available. A class two recommendation requires a combination of additional legislation funding and manpower and could be implemented within 3 years. Some of the class one recommendations lead into class two recommendations with little or no break. When this is the case, attention will be specifically directed to each class.

7.2 Goals

Literature published by air pollution districts usually fails to mention a specific timetable for achieving particular air quality levels or particular emission levels. This omission exists because the districts do not have specific programs defined for the future.

The State law establishing the BAAPCD charged the District with "the reduction of air contaminants".[1] Implicit in this is continual improvement of air quality. This was interpreted into the rather loose goal of attaining air quality of 1950 levels (sometimes 1940 levels). Sometimes the District talks of meeting the State's air quality standards, but there is no indication as to how much worse present conditions are or when and how these standards are to be met.

Problem 1: The BAAPCD needs well-defined written goals.

Recommendation: Two sets of goals appear to be necessary, one to deal with air quality and the other to handle emission regulations.

A. Air Quality -- the air quality at <u>all</u> places within the District shall <u>never</u> exceed the California State Air Quality Standards.

B. Emission Regulations -- the emission of each pollutant must be reduced by the shown percentage of total emissions of that pollutant within the District each year in order to meet the Air Quality Goal.

Table 7.1

EMISSION REDUCTION GOALS
For All Sources in the Bay Area Combined

Pollutants	Particulates	SO_2	NO_x	CO	HC
1969 emissions (tons/day)	201	351	504	7164	1899
Goals (tons/day)*	86	210	(74.5)**	3620	(586)**
Annual reduction required to achieve goal in 5 years (%)	15.6	9.8	(31.8)	12.8	(21)
in 10 years (%)	8.1	5	(17.4)	6.6	(11.1)

[*] Pollutant levels required so that the average air quality could not exceed State standards even during a 300 ft. subsidence inversion lasting two days or more with little or no wind.

[**] These numbers assume that these pollutants remain unchanged in the atmosphere. In reality they react chemically and form other products, some of them harmful. A realistic reduction program awaits a better knowledge of the chemistry of the atmosphere. This assumes that 90% of the particulates settle out in two days.

Discussion

To calculate reasonable emission goals it is necessary to relate emissions to the quality of air in the airshed. This relationship has been made here through the use of the "Box Model". The Box Model considers the Bay Area airshed as a box of air that is ventilated due to winds and the "box top" is the bottom of a subsidence inversion layer. For purposes of goal-setting, the box top has been assumed at 300 feet, a condition which occurs 4 to 8 times a year in the Bay Area. Secondary pollutant reactions were not considered by this approach.

A goal which seems reasonable is to reduce emissions so that, for a 2 day subsidence inversion at 300 feet, with the various wind conditions shown, the average ambient air quality at least meets the state standards. Shown in Table 7.2 below are the maximum rates of emissions in tons/day that the airshed can accommodate without exceeding the State Air Quality Standards, on the average. The "Box Model" is used to calculate these rates. This does not mean that air quality standards are not exceeded locally!

Table 7.2

TOTAL ALLOWABLE EMISSION RATES IN TONS/DAY

Effective Wind Speed	Particulates	SO_x	NO_x	CO	Organics[*]
0 mph	8.6 T/day	210 T/day	74.5 T/day	3320 T/day	586 T/day
2 mph	25.2 T/day	593 T/day	212 T/day	10500 T/day	1680 T/day
5 mph	63.2 T/day	1480 T/day	530 T/day	26200 T/day	4200 T/day
1969 Total Emission Rates	201 T/day[**]	351 T/day	564 T/day	6164 T/day	1899 T/day
Automotive	41 T/day	21 T/day	370 T/day	5208 T/day	958 T/day
Stationary	160 T/day	330 T/day	194 T/day	956 T/day	941 T/day

[*] Calculated using 0.4 ppm as a state standard and hexane as the average organic.

[**] For comparing with airshed capacity 10% of the total emissions will be assumed to stay suspended in the air. This is quite conservative since in a memo from M. Feldstein to D. J. Callaghan on June 1, 1970, 50% was assumed.

It is seen that for a 0 mph wind all contaminants exceed the allowable emission rate. Therefore, emission rates must be reduced or state standards will probably be exceeded when a zero wind condition with a 300 foot subsidence inversion occur. In order to reduce the 1969 emissions to the total allowable emissions within 5 years, or as an alternative 10 years, the emissions of each pollutant must be reduced by the percentages indicated in Table 7.1 every year. Since these are based on the simple box model, these percentage goals should be revised when better models become available.

Some of these percentages may be difficult to attain in practice. Therefore, Table 7.3 shows the number of years required to reduce 1969 emission rates to the allowable emission.

This indicates that for a 2 mph effective wind all but the NO_x standards are going to be met according to the "Box Model". (A 2 mph effective wind corresponds to a wind of approximately 40 mph through the Golden Gate.

If the automobile contributions are neglected, that is, only district jurisdiction contributions to emissions are considered, then the table looks as shown in Table 7.4. However, it must be realized that this does not assure that the air quality standards will be met. In fact, the NO_x, particulates, organics, and CO from autos alone will cause the state standards to be exceeded when a 300 foot subsidence inversion holds for 2 days according to the Box Model. This is seen by comparing the automotive emissions with the allowable emission rates.

Table 7.3

RATES FOR VARIOUS PERCENTAGE PER YEAR REDUCTION

YEARS REQUIRED TO ATTAIN ALLOWABLE EMISSION RATES					
Effective Wind	0 MPH			2 MPH	
	% Decrease in Emissions Per Year				
	5%	10%	15%	5%	10%
Particulates	17	8	5	0	0
SO_x	10	5	3	0	0
Organics	23	11	7	2½	1
NO_x	39	19	12½	19	10
CO	12	6	4	0	0

Table 7.4

YEARS REQUIRED TO REDUCE STATIONARY SOURCE (DISTRICT JURISDICTION) EMISSIONS TO ALLOWABLE LEVELS*						
Effective Wind						
	% Decrease in Emissions Per Year					
	5%	10%	15%	5%	10%	15%
Particulates	13	6	4	0	0	0
SO_x	14	7	4½	0	0	0
Organics	11	5½	3½	0	0	0
NO_x	25	12	8	4½	2	1½
CO	0	0	0	0	0	0

*Based on 1968 data.

7.3 Approaches and Tools Available to Help Meet the Goals

Basically the aids for achieving these goals can be divided into two broad categories: Operating Procedure and Education. Briefly, Operating Procedures include the establishment of a source inventory and enforcement policies of the District. Education of the public includes the availability of information and an involvement of the public in the improvement of air quality.

A. Operating Procedures

Problem 2: Effective regulation of emissions is difficult if the identity of the emitters and the mass of pollutants emitted is unknown or not conveniently accessible.

Recommendation A: The BAAPCD should issue a Request for Proposal to data processing firms for the development of a comprehensive source inventory system.

Discussion: A comprehensive source inventory system will allow the BAAPCD easy and quick access to information as to who is responsible for particular emissions, the mass of pollutants each source is emitting, and who has effective control equipment. Also the RFP presents the District with diverse expert opinions as to how to organize and operate a source inventory.

The system discussed in Appendix 7-1 would cost approximately $40,000 per year when contracted outside. This includes programming and masterfile building and the salary for full time people at the District to coordinate with the contractor. Also included in the above costs are monthly reports described in detail in the appendix. Weekly reports would be available upon request for approximately $50 per report.

The District would supply forms to the service bureau which then keypunches, programs, and processes the information.

It is estimated that the proposed source inventory system would require 6 months to 1 year to become operational after signing a contract. Two alternatives to contract batch processing were investigated. Both are more expensive. The cost for time sharing, $41,000/year is sufficiently close to that of the contract estimate that it may be preferable if the additional computer capability provided by time-share terminals is an advantage to the District.

The cost to the District of attempting to do their own source inventory and operating their own computer would range from $80000 to $150,000 per year depending upon the size of the computer rented and the support it requires.

Issuing the RFP is a class 1 recommendation. Actually deciding upon a system and implementation of it is a class 2 recommendation.

Problem 3: Difficulty in obtaining and determining accurately the emissions from various large sources.

Recommendation: The BAAPCD should exercise its authority under paragraphs 3210 and 3211 of Regulation 2 to require the large emitters, those who emit over 0.1% of the total of any one pollutant to purchase and properly install and operate emission measuring equipment for that pollutant. They should measure continuously and report daily emission averages and peak emission rates to the District on a monthly basis, except during upsets or other unusual operating periods, when they should report every hour. The District should offer calibration service for the instruments at a fee. It should check their proper installation and operation at unannounced and irregular intervals.

Discussion: One important reason for instituting a reporting system is that it establishes the intent of the District to exert effective control upon pollutant emitters. This right, established by law, will only become a reality when demands, such as reporting, are imposed on emitters. Instruments for stack installation should require approval by the District. The District should have the right to require an emitter to purchase new and better equipment if it becomes available.

This reporting of effluents would initially be compared with the calculations of the BAAPCD. After the source inventory was operational the reporting system would be integrated with the source inventory at minimal expense. It is recommended that these two recommendations be started simultaneously to reduce the overall time (2 to 3 years) required for complete integration.

The source inventory-reporting system will produce hard data on who is putting what into the people's air. This will allow fair and equitable determination as to who should reduce their emissions and by how much.

The preliminary reporting system is a class 1 recommendation and combining the reporting system with the source inventory is a class 2 recommendation.

Problem 4: Lack of communication channels between other planning and control agencies, colleges and universities and the BAAPCD.

Recommendation A: The District should actively influence the activities of zoning commissions, area planning commissions and agencies dealing with rapid transit, water pollution, waste disposal, etc. toward improving air quality and the quality of life in the Bay Area.

Discussion: This may be done by having regular meetings of directors, but informal discussions will also prove fruitful. The District must not be afraid to discuss the problems of air pollution that are caused by lack of zoning, lack of planning, and the automobile. The BAAPCD must introduce air pollution data into these activities because if they don't no one will.

This gives the BAAPCD an informal method to attempt to solve some of their problems by encouraging non-polluting alternatives and suggesting a unified approach to improve the quality of life in the Bay Area.

It should be noted here that a good way to determine helpful improvements in existing mass transit systems is to use them. It is felt that the employees of the District should be the leaders in using municipal and mass transportation systems to travel to and from work. This is a Class 2 recommendation since it will require manpower and money.

Recommendation B: A Research and Development liaison person should maintain open channels of communication with interested faculty and students in the local universities and colleges in an effort to present the R and D problems of the District.

Discussion: The District could obtain answers, free of charge, through graduate student theses, to some of the Districts problems. There is a sizable amount of research going on in the universities and colleges anyway so the District may as well try to direct some of the research toward the solution of the BAAPCD's pressing research problems. This is a Class 2 recommendation since additional manpower is required.

The proposed approval system gives the District a reasonable control over small emitters, provides guidelines for those small operations (dry cleaning establishments, auto part shops, etc.) who have no technical expertise, and yet avoids the complications of a percent system.

Recommendation C: The District should urge the ARB to publish standards for hydrocarbons as soon as possible.

Recommendation D: The District should review the upset and breakdown exception in Regulation 2.

Discussion: The upset and breakdown procedure now does not encourage industries to maintain their pollution control equipment. If a breakdown occurs, the plant needs only to notify the District to avoid a violation notice. This attitude encourages minimum maintenance and should be abolished by a change in the regulation.

B. Education

The Board must define its clientele as those who breathe bad air rather than as those who produce bad air. The BAAPCD sometimes seems to be acting like a buffer between the general public and industry instead of acting in the public interest. This attitude has produced a public feeling of frustration with the BAAPCD.

Public support and cooperation are very important aspects of air pollution control and should be encouraged. Increased public support could result in an increased budget and more effective pollution control. Public awareness of who is emitting what could produce economic pressure on the polluter.

Problem 5: Public support, cooperation and involvement in the fight for better air quality has not been adequately encouraged by the District.

Recommendation A: The Board should establish a policy of releasing all data collected by the District. This does not suggest compulsory publication, but the data should be made available on a cost basis to scientific, technical, industrial, and citizen groups.

Recommendation B: The District should establish and publish its exact performance goals. It should explain what these goals, if achieved, mean in terms of air quality, of health and visibility, and why these, rather than more stringent goals have been selected.

Recommendation C: The District should prepare a monthly progress report for the Board similar in form to that shown in Chapter 3. This report should be published regularly in "Air Currents", the District's monthly bulletin, and given wide circulation.

Recommendation D: The District should publish the complaints, suggestions, and problems identified by citizen's groups and hold special hearings where conflicts between such groups, and between a group and the staff can be heard.

Recommendation E: The District should relocate its headquarters in an area where air pollution concentrations are highest, such as Richmond, San Jose, or Livermore. Such a move would not only show the District's real concern with air quality but could also alleviate its parking problem.

Recommendation F: The District should attempt to enlist the aid of active citizens groups to help pass legislation that is felt by the District to be necessary to reduction of air contaminants. The District should also enlist the aid of the public to economically censure repeating violators.

Discussion: These recommendations make the District more "visible" to the public and make the information and activities of the BAAPCD more available to the public. They effectively change the stance of the District from a buffer between industry and the people to an agency of the general public in the fight for clean air. Another recommendation on how to deal with and utilize the good will of citizens' groups is shown in Appendix 7-2.

C. Approaches to Reduce Automobile Emissions

The following two quotes from the "Harvard Bulletin", 13 April 1970 should be considered before deciding whether emissions should be controlled or automobile usage should be actively discouraged.

"God help us if we invent the automobile that doesn't pollute the air. The automobile is a pollutant not only of our air, but of our physical environment. In urban situations, the physical pollution is worse than the air pollution."

"A city with any wisdom should shift the competitive balance between private and public transportation in favor of public transportation. Cities complain endlessly about the failure of their mass transit systems, when in fact in every action they have taken they have opposed them by favoring private transportation."

There are basically three approaches to the automobile:

(1) The active discouragement of automobile usage coupled with the active encouragement of alternative transportation modes without legal enforcement.

(2) Control, by legal enforcement of both automobile growth in population centers and auto emissions, thereby helping both "land" and "air" pollution.

(3) Control only of automobile emissions to help solve the air pollution problem.

Which of these approaches is followed must be decided on the basis of the automobile surveillance system recommended in Chapter 5. This information will provide a basis for deciding (a) whether all autos should meet the same emission standards or whether cars should only meet the standards in effect the year it was produced, (b) whether or not a statewide auto emission inspection combined with licensing should be advocated, or (c) whether controlling emissions only will be effective.

The three basic approaches are discussed below.

Approach A

This is a weak method of attack since it has no legal enforcement behind it. It consists mainly of working with other agencies as proposed in Recommendation A of Problem 4. However, it is also easy to implement and can be done by the District alone.

Approach B

This is a strong method of attack but will require much legislation and will upset people's love affairs with their cars.

Approach C

If the conclusion is to only control auto emissions then two paths lie ahead. One is to legislate that no cars with emissions above a certain level be licensed. The other is less publicized but may be effective. It basically consists of "flagging" cars according to their emission level. This is necessary to call attention to auto emissions since they are invisible.

Basically it tells the driver "Your 'smokestack' is 'smoking' badly" or to others "That guy's exhaust is terrible". With present public awareness and with a sound public education program this "flagging" procedure could be quite effective because "social pressure" would be exerted on individuals to reduce emissions.

Whichever approach is used, the automobiles' emissions must be analyzed by a short test which will compare favorably to the standards described in Chapter 4.

Problem 6: The automobile produces a large fraction of the objectionable pollutants emitted.

Recommendation A: Initiate an automobile emission testing program such that all cars registered in the Bay Area are tested once every two years. A practical test which takes about two minutes per car is available (see Chapter 5). It not only gives a measure of the exhaust emission performance but also a rough diagnosis of adjustments needed to improve performance. Require that these adjustments are made before the car is registered. We believe that the District has the legal right under its charter to initiate such a program.

Recommendation B: Provide economic incentives to minimize the use of cars in cities by promoting:

(a) the installation and use of urban mass transportation systems;

(b) the designation of express lanes on bridges and freeways for buses and for cars with four or more passengers;

(c) the imposition of regional gasoline or automobile use taxes;

(d) the use of graduated bridge tolls (and tolls on highways leading into the city), higher during rush hours, and lower when traffic is low, higher for single drivers and lower for ride-share groups.

Recommendation C: Take the lead in coordinating the efforts of city councils, county zoning boards, and local and regional planning and development agencies on plans that discourage the use of automobiles, such as:

(a) support of city-centered planning to reduce commute distances;

(b) prevention of construction of new access roads into the cities and of new parking lots;

(c) installation of bicycle paths and pedestrian malls.

Recommendation D: Have local inspectors report smoking autos observed in the normal course of their duties to the Highway Patrol for issuance of citation. Violators to be required to make corrections within 15 days and present their car for a smoke test or face a fine.

Discussion: It is clear that the law establishing the District does not give it the right to legislate or control automobile emissions. It is equally clear that, without effective control of auto emissions the District cannot do the job it is intended to do. Therefore it should actively promote by publicity, advocacy, recommendations, etc. the kind of laws and ordinances that will control the automobile. Only the District knows the full extent of the local problem. It could be a most effective advocate for the people in the area. The cost of inspection of the 2,500,000 automobiles in the Bay Area will be in the neighborhood of 4 million dollars. This could be regained by charging $2 per car for the inspection. Detailed cost figures are in Appendix 7-3.

The "flagging" system can be instituted by a District regulation. However, a system of inspecting emissions before licensing must be worked through the Department of Motor Vehicles.

Evaluation of the Performance of the BAAPCD Toward Meeting the Above Goals

After examining the data published by the BAAPCD it becomes clear that no good reliable method exists that can give one confidence that the District is effectively reducing pollution. BAAPCD has published ambient air quality levels for the various pollutants. These levels indicated that the concentrations of some of the pollutants have been decreasing. However, the data on which these trends are developed are considered unreliable for such conclusions because of the inadequacy of the present monitoring system. Until a meaningful measure for air quality has been found and a monitoring system has been set up that can give a reliable picture of air quality in the Bay Area, the District's performance must be based on source emission, on how well the District meets stated emission goals.

Problem 7: There is no effective performance measure for the District, nor a measure of effectiveness which is comprehensible to the public.

Recommendation A: The District's annual performance should be measured against clearly stated goals to be published at the beginning of the year. These goals should be expressed in terms of percent net reduction of total emissions until such time when a reliable and meaningful measure of air quality has been established, at which time air quality goals should be set.

Recommendation B: An outside agency such as the Air Resources Board should be responsible for an annual review of the District's performance. This review should receive wide publicity.

Recommendation C: A measure of effectiveness should be used which explains the District's performance to the public in clear and simple terms. Appendix 7-4 illustrates one such measure.

Discussion: At present the District measures its own performance by estimating the tonnage of pollutants it has prevented from being emitted. This can be compared to a man who convinces himself of a bigger income if, in fact, he has only spent less. What is needed is a net reduction of total emissions in the District. The District's own records over the last six years show very little change in the total emission of any one of the pollutants even in those emitters under the District's jurisdiction. The one exception, carbon monoxide, is vastly overshadowed by the CO emitted from automobiles.

It is not a good policy for any agency, public or private, to be asked to evaluate its own performance. Its creditibility can be increased immeasurably if independent auditors find that the agency's performance meets or exceeds its goals.

The proposed index of effectiveness--one of many possible measures--has as its primary purpose an indication of whether emissions are being reduced. It is based on historical emission data already generated, and more reliably available in the future if sources are going to be tested as is recommended in Chapter 5.

7.4 Finances

Problem 8: It is important to move toward an economic association between the sources of pollution and the abatement costs. The District now relies for revenue on the property tax, a revenue source already overburdened.* It is difficult to see how the higher cost for a more effective District can be derived without resorting to other sources. It is important to move towards an explicit economic association between the sources of pollution and the costs of abatement; the implicit public subsidy of private and corporate polluters is inequitable and indefensible.

Since new taxation is needed, one should ask: what is the least painful and fairest taxation, the most easily enforced, the one most suited to be self-liquidating once the air pollution problem is solved? If emission taxes were proposed, how should they be applied to industry and commerce, and how to the automobile?

Recommendation A: The District should sponsor and promote for stationary emitters effluent taxes which create economic incentives to reduce emissions, to install and maintain pollution control equipment and to improve its effectiveness. The following is a somewhat arbitrary tax schedule, based on the relative importance of each pollutant to air quality.

SO_2	5¢/lb.
CO	0.2¢/lb.
NO_x	10¢/lb.
Particulates	0.1¢/trillion (10^{12}) particles**

The tax schedule for organics is yet to be determined, but should be based on their reactivities. Of course such a schedule does not preclude limits on maximum emissions and such limits should be established.

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[*] For example, the property taxes in San Francisco now approach $13 per $100 valuation; and the state legislature has discussed (and barely defeated) a property tax relief bill.

[**] This is an unusual definition intended to penalize emitters of small particles. It can be enforced only when a reliable particle size distribution means is available. Until then a "per pound" tax may be the only possible alternative.

Recommendation B: For large emitters the tax should be computed from continuously recording monitors. For smaller emitters, the tax is based on emission estimates for the process. The burden of showing that his emission is smaller than estimated by the District rests with the emitter.

Discussion: Revenue from these taxes should be used to finance the activities of the District, and for research into anti-pollution devices. On the basis of the above tax schedule and 1969 emission data, the revenue would be $50,000 to $100,000 per day, or about $30,000,000 per year. Of course, as emissions are reduced the revenues will become lower.

Recommendation C: The District should propose to the State a pollution tax on gasoline to be redistributed to the Districts in the State according to the gasoline sold there. For example, a 1¢ per gallon tax on gasoline would produce an estimated 90 million dollars in the State of which $18,000,000 is generated in the Bay Area. Finances from taxes on automobiles are discussed in Section E.

Discussion: Other possibilities include a $1 "Air Pollution Tax" on automobile registrations which would yield $25 million annually, and a $1 addition to drivers license fees which would yield another $2-3 million annually.

Road and bridge tolls of 3¢ per vehicle mile on only 1% of Bay Area roads would yield $16 million per year.

If the Federal Highway Trust Fund can be tapped, the Bay Area's proportionate share of only a 10% diversion would amount to some $60 million annually.

This is to say that the money is available but the BAAPCD must travel new roads to obtain some of it.

Chapter 8

LONG-RANGE STRATEGIES FOR THE CONTROL OF AIR POLLUTION

8.1 Introduction

Previous chapters of this report have pointed out that presently existing data are not sufficient to adequately describe the extent of the air pollution problem in the San Francisco Bay Area; the question "Has the quality of air in the Bay Area improved or degraded in the recent past?" cannot be definitively answered. The design of a system for collecting the necessary data has been proposed. These data, when input to models that seem likely to be developed in the not-too-distant future, will also allow answers to such questions as "How would a new pollutant source at one point in the Bay Area affect air quality everywhere else in the region?", or "To what extent will decreasing the emission rate from an existing source improve overall air quality?" It must be remembered, however, that regardless of how extensive the data are or how exactly the models establish the cause-effect relation between pollutant sources and air quality, they are only more accurately defining the problem. Effective control programs for limiting pollutant emissions to the extent necessary to obtain and maintain the desired air quality will still have to be developed.

For a given set of air quality standards (which themselves are subject to revision), and with the possibility of a continually increasing population with its accompanying demands for goods and services whose byproducts are pollutant emissions, what constitutes a long-range "solution" to the air pollution problem? Such a solution might be defined as a system for providing in an optimum manner the goods and services desired by the consumers (people) of the area so that total pollutant emissions are consistent with the maintenance of air quality standards. The "optimum manner" should be determined by the consumers. They should determine, for example, whether additional transportation capability is more desirable than a higher per capita usage of electrical power, or how much they are willing to pay (both in money and reduced availability of other goods and services) for continued, unrestricted use of private automobiles so long as air quality standards can be maintained.

There are two interrelated steps in providing this solution. First, the total pollutant emissions consistent with the maintenance of air quality standards must be determined. Second, the optimum distribution of this total "pollution pie" must be arrived at. These two steps will be considered in detail in the following sections of this chapter. That these two steps are not independent is illustrated by the following hypothetical example. A new housing project in Palo Alto will require more cement than can be provided by existing sources, so that construction of a new cement plant is being considered at one of two locations. (For simplicity, assume any other material or plant location is not acceptable.) Location A is close to Palo Alto and the sources of supply of the necessary materials for making cement, so the cost of cement in Palo Alto would be low. Unfortunately, the meteorological conditions prevalent at location A are such that pollution emissions from a cement plant located there would have a large effect on air quality in neighboring areas. Building a cement plant there would necessitate a reduction in emissions from other sources in the neighborhood. Location B has favorable meteorological conditions, so that a large amount of cement could be produced there with very little effect on air quality. Negligible reductions in emissions from other sources would be necessary (the total "pollution pie" could be increased). Unfortunately, location B is far from Palo Alto and the sources of the necessary materials; the cost of cement in Palo Alto would be high if the cement plant were located at B. Thus a choice must be made between three options.

(a) Build the cement plant at A and reduce emissions from other sources accordingly.

(b) Build the cement plant at B and pay more for cement.

(c) Abandon the housing project, thereby limiting the growth of Palo Alto.

This hypothetical example serves to illustrate an important point about the long-range solution of the air pollution problem: Planning and development must be carried out on a regional basis, and consideration of pollution emissions must be a factor in the planning and development of the region. Only through such regional action, in which the BAAPCD should be an active and forceful participant, will it be possible to effectively and equitably resolve questions such as:

(a) Is it prudent to continue to build more parking facilities in downtown San Francisco, thereby encouraging further automobile traffic into San Francisco, accompanied by increasing business and air pollution, while at the same time pushing for an expanded Bay Area Rapid Transit (BART) capability and promoting its use?

(b) To what extent should South Bay residents be permitted to participate in the decision to build further refineries in the North Bay if it is determined that emissions from the new plants will further degrade South Bay air quality?

8.2 The Magnitude of the Pollution Pie

The first step in establishing a long-range control program is to determine what limitations on total pollutant emissions must be imposed in order to maintain air quality at levels equal to, or better than, the existing standard. One might rephrase this with the question "What is the maximum total rate, from all sources, at which a particular pollutant can be emitted in the Bay Area and still maintain the air quality standard for the pollutant?" However, this is not an adequate question, for as pointed out in the preceding section, the location of a source and the prevailing meteorological conditions at that location will also affect the degree to which the source contributes to the degradation of air quality. Thus the maximum size of the pollution pie can only be determined if the relationship between source (strength and location) and regional air quality is known.

At the present time, knowledge of the cause-effect relationship between source and air quality is quite scanty. Possibly the most reliable information available now would be a simple calculation based on the Box Model (see Chapter 6) tempered by the judgement and experience of the technical staff of the control district. As more comprehensive models, such as those discussed in Chapter 6, are developed and validated, more exact determinations of the cause-effect relationship will become available. Therefore, it is virtually mandatory for a control district to stay abreast of developments in air pollution modeling, and the adaptation of the best models to the district's particular needs, if it is to carry out an optimum air pollution control program.

Although the necessary comprehensive models for determining the exact source--air quality relationship are not yet available--work can be done now toward getting a better estimate of the magnitude of the pollution pie than can be made using the Box Model. Appendix 8-1 outlines a program for making such an estimate by dividing the total Bay Area airshed into air cells and then determining the maximum permissible pollutant emission rate in each such cell.

Appendix 8-1 also describes how the pollution pies for the individual air cells could be distributed. Caution must be taken, however, if these allocations are to be made independently of each other. In fact, this approach is very similar to the present situation, where each locality (towns, districts, perhaps even counties) acts as a cell and determines as best it can how much industry it should try to attract or what transportation system best suits its needs. What is good for a single cell may be harmful for the region as a whole. Referring to the hypothetical example of the previous section, it might be very beneficial for the economy of Location A to build a cement plant there but bad for the overall area. In any further development of the Bay Area, the effect on the overall air quality must be considered. In other words, the allocation of pollution limits for an individual air cell or locality must be consistent with the best interests of the entire Bay Area.

Once the maximum permissible amount of each pollutant is established, it is the function of the control program to see that actual emission rates are not larger. In Chapter 2, the following five control techniques have been identified.

(a) Emission control.

(b) Alternate, less polluting production processes.

(c) Alternates to products which result in excessive pollution.

(d) Voluntary reductions in demand for products which result in excessive pollution.

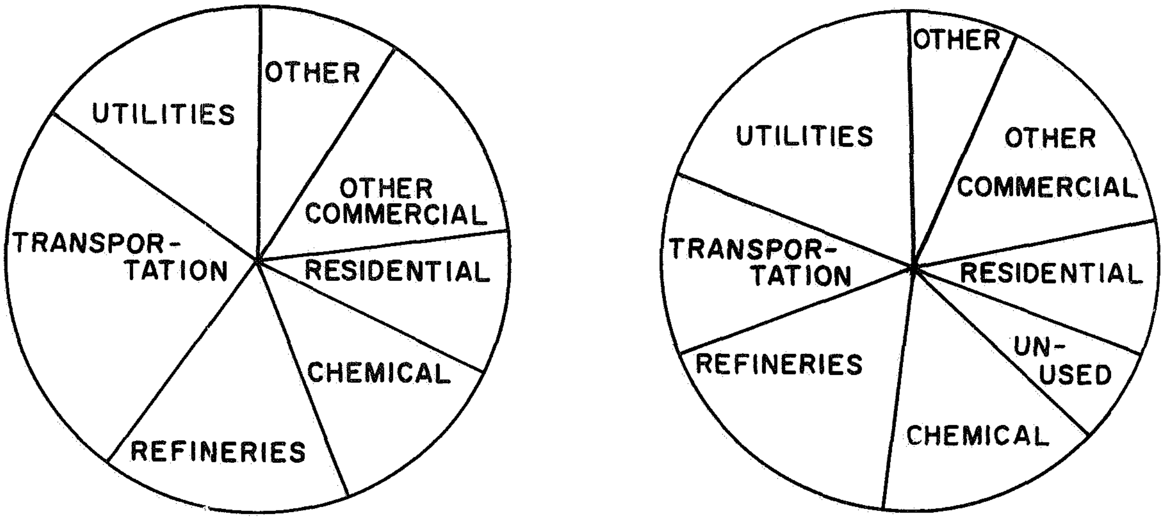
(e) Compulsory reductions in demand.

Present control programs, such as the State of California emission standards for new cars and the BAAPCD control of fixed sources, are based on only the first of these techniques. Chapter 1 points out that the air quality standards are being exceeded in the Bay Area, so the present emission rates are too large. In addition, the discussion in Chapter 2 indicates that, with a continued growth of the Bay Area population and a continuation of the present control programs, these emission rates are likely to increase.

To reduce and maintain total pollutant emission rates to acceptable levels, the other control techniques will have to be used if the Bay Area population continues to grow. The BAAPCD must take the lead in this regard. For example, the projections of emissions from automobiles (Figures 2.3a, 2.3b, 2.3c) indicate reductions until the mid-1980's and rather rapid increases thereafter. The BAAPCD should start now to exert whatever pressures it can for the development of alternatives to the internal combustion engine automobile: expanded BART capability and small, "around town" electric cars are possibilities. Before long, it will probably be necessary to reduce or eliminate automobile traffic in certain downtown areas; the BAAPCD should begin now, with the cooperation of the Regional Transportation Planning Commission (RTPC) and other local planning agencies, to acquaint the public with the likelihood of this action and the need for it. In short, the BAAPCD should start now to increase the scope of its activities in order to develop a comprehensive control program. In the long run, its most profitable activity may well be public education: thoroughly acquainting the public with the growing seriousness of the problem, honestly pointing out the limitations of the present control program, and doing everything possible to encourage active public involvement and support in the creation and carrying out of a comprehensive control program.

8.3 Distributing the Pollution Pie

Once the total permissible emission rate for each pollutant has been determined by the best available means, the next step is to establish the pollution quotas for the various categories (transportation, residential, refineries, electrical power generation, etc.) in such a manner as to best satisfy the wide spectrum of demands for goods and services, as illustrated by Figure 8.1a. Although the magnitude of the pollution pie will remain essentially constant (subject to small variations caused by such things as the siting of a new cement plant), its distribution is likely to vary with time. For example, as shown in Figures 2.3a, 2.3b, and 2.3c of Chapter 2, the emissions from automobiles can be expected to decrease until the mid-1980's. Thus the transportation slice of the pollution pie might be decreased accordingly and the other slices could be increased correspondingly, as shown in Figure 8.1b. In an ideal situation, the slice labeled Unused, which represents the extent to which actual total emission rates are less than the maximum allowable rates determined from air quality standards, would grow continuously with time, indicating that air quality in the region is getting better and better. Practically speaking, in the light of



a. A hypothetical distribution of quotas among various categories to maintain air quality at state standards.

b. A later distribution reflecting a reduction in emission from automobiles. The Unused slice indicates air quality with regard to this pollutant is better than the state standard.

Figure 8.1. DISTRIBUTION OF THE POLLUTION PIE FOR A SINGLE POLLUTANT.

ever-growing population and the resultant increase in total demand for goods and services, the Unused slice of the pie will only develop if the air pollution control program is a vigorous and effective one.

The mechanics of how the total pollution pie is actually divided are complex and, to some degree, unclear. The current mechanism begins with the summation of the individual desires of the consumers, often subtly influenced by various means of advertising, which are reflected in the amounts of the various goods and services produced. Their production is accompanied by pollutant emission rates, controlled by the BAAPCD and the automobile emissions standards, which constitute the pollution pie. As long as there is no real squeeze on the size of the pie, this mechanism is perhaps the most satisfactory one. However, when uncontrolled consumer demands result in a tendency for the pollution pie to grow too large, other pressures will have to be exerted by control agencies, planning and development commissions and citizens groups. These should be directed toward reducing consumer per-capita demand or shifting it to alternate products and services. Here the value of public education will become very apparent, since an informed public is more likely to cooperate with the demands of a restrictive control program.

Although control agencies like the BAAPCD will not, and should not, decide how the pollution pie is to be distributed, they should be participants in the process. They will be, if they have effectively enlisted the support of the public and if their voices are heard when decisions are made on such questions as "If and where should a new freeway be built?" or "Should there be any limit to the number of refineries located in the North Bay Area?"

8.4 Transportation--A Case Study

Once the pollution pie has been distributed among the major categories (such as transportation, residential, refineries, etc.), each of these will itself be subject to distribution. As an example, how should the transportation slice be apportioned between automobiles, buses, trains, etc. so as to provide the necessary passenger-mile capabilities within the Bay Area, keeping total pollutant emissions within the prescribed limits while at the same time meeting the desires of the commuters to the greatest possible extent? This is clearly a complex problem, but equally clearly one which must be solved on a regional basis. There will be many conflicting factors; for instance, commuters often favor the individual freedom and convenience of automobiles although automobiles emit a relatively large amount of pollutants. Thus there will undoubtedly be many acceptable solutions but no apparent "best" solution. It is not the purpose of this section to arrive at, or advocate, any particular transportation system; its purpose is to illustrate how one might go about providing commuter transportation within a prescribed pollution level constraint but with a given, increasing commuter transportation requirement.

The State of California is well recognized as the nation's leading innovator in control of automobile emissions. It is generally conceded that it is still quite possible to make sizable gains in controlling the emissions from gasoline piston driven engines. However, there will clearly come a point where it is simply not economical or technically feasible to reduce these emissions further. In order to prepare for this time it is useful to consider alternative automotive power plants which would permit the public to continue in its present transportation life style but with some pollution-level-from-automobile constraint. Table 8.1 presents a summary of the optimistic pollution estimates from alternative power as summarized by the Technical Advisory Committee of the California Air Resources Board. The electric car was not reported on at this time because of its serious range limitation. However, this vehicle may eventually have real value as a second car alternative.

It is apparent that there are gains to be made on alternative power plants, and it may well be that a very low emission passenger vehicle can be developed given sufficient money, time and interest. Depending upon the success of each of these alternatives power plant programs, the State through either incentives or regulating action, could control the mix to achieve the desired goal. However, the success of an alternative power plant development program is clearly in the hands of the Federal government. The enormous expense of such a program compared to the available resources in individual corporations or state agencies without substantial Federal subsidy will make this approach, however desirable, completely impractical.

Table 8.1

ESTIMATES OF POLLUTION EMISSIONS FROM ALTERNATIVE AUTOMOBILE POWER PLANTS[2]

	Pollutant Emissions (grams/mile)		
	HC	CO	NO_x
Gas Turbine(1)	.05	3.0	0.8
Wankel	1.8	23	2.2
Stirling(2)	.06	0.3	1.0
Natural Gas	1.5	6	1.5
Steam(3)	0.2	1.0	.15
Gasoline Internal Combustion(4) (for comparison)	8.5	87	5.7

(1) Appears to be a reasonable replacement to the gasoline internal combustion engine.

(2) Unlikely alternative because of size and weight.

(3) Appears impossible for steam engine to compete economically.

(4) For uncontrolled emissions (see Table 2.1).

What then can the state do to hedge against the uncertain emergence of a strong Federal research and development program in automotive transportation? Further, what can the State do to hedge against the almost certain delays and failures which such a Federal program would experience if, indeed, it were to evolve? Simply stated, the State and the Bay Area have to plan and be ready to implement alternative transportation systems and to insure that the public will alter its transportation life style to utilize these alternatives.

In considering the large variations in pollution per passenger-mile of various transportation modes, it is clear that an overall transportation plan can be developed which serves to minimize the air pollution resulting from passenger transportation. It is also noteworthy that with the exception of the helicopter, the cost per passenger-mile is comparable to the pollution per passenger-mile for the various modes of transportation. Consequently, it is reasonable to expect that efforts to minimize the overall pollution resulting from transportation will in fact tend to reduce the expense to the community of daily commuting.

For ease in visualization, Figure 8.2 presents a hypothetical conjecture of how the Bay Area community might utilize its future transportation resources. Transportation planners seek to meet these requirements and provide at the same time the most convenience and flexibility to the public. In so doing, it is not at all unreasonable to expect that transportation planners should press for additional freeways and parking facilities. On the other hand, the air pollution control planner, recognizing the overall transportation requirements

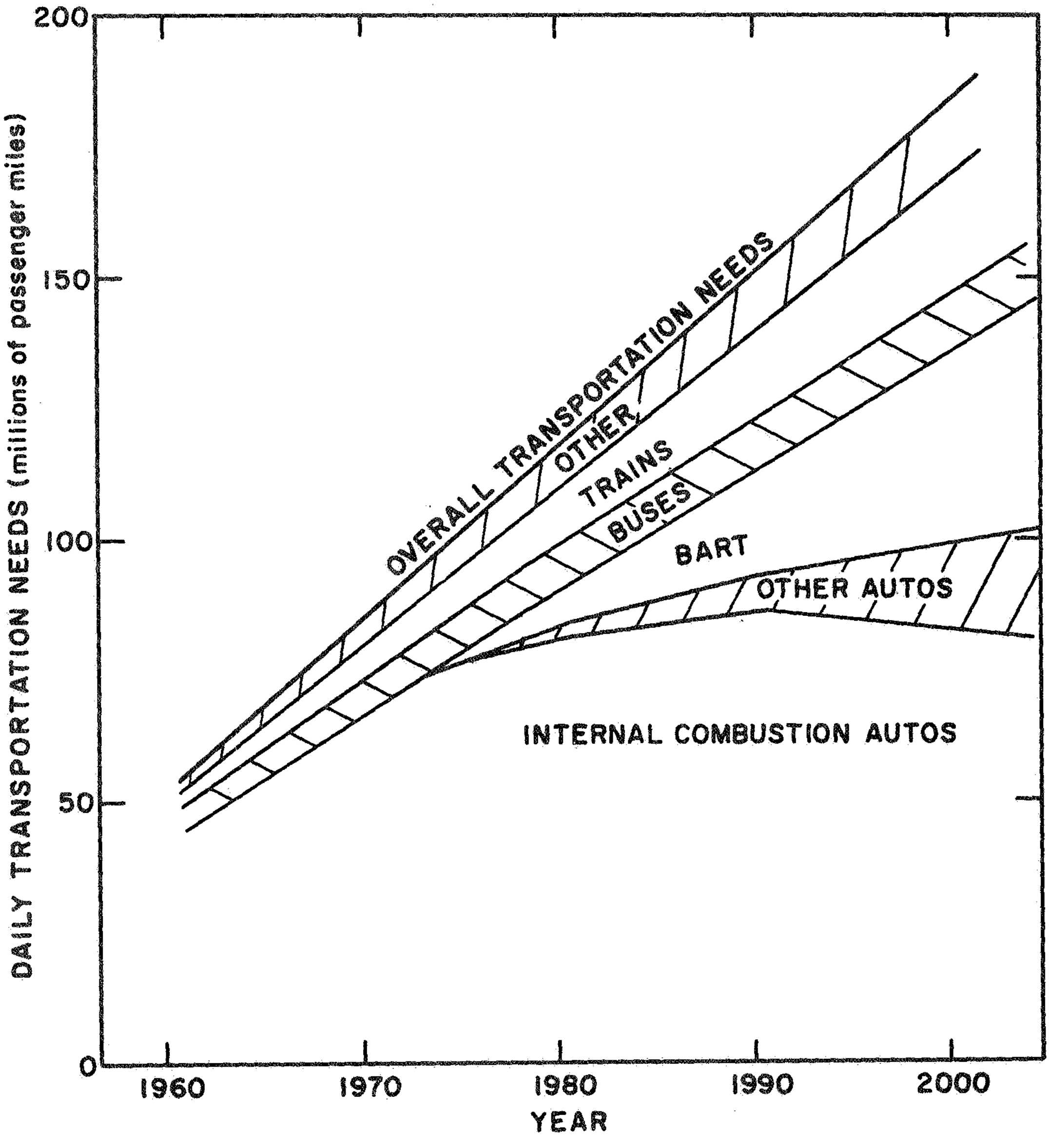


Figure 8.2. A HYPOTHETICAL MIX FOR MEETING THE GROWING TRANSPORTATION REQUIREMENTS OF THE BAY AREA.

forecast, must seek to help meet those requirements with all of the same objectives of the transportation planner, but with the additional and heavily weighted objective of accomplishing the task with minimum pollution. That is to say, he must generate, present, and argue for alternative transportation systems which meet the public's need but would not exceed the pollutant emission limitation.

The problem of distributing the transportation slice of the pollutant pie might be stated as follows: "Given a time-varying limitation $P_i(t)$ on the total emission (due to transportation) of each of the various pollutants, what mixes of transportation are feasible within a specified time frame if the overall transportation requirements are specified?" For simplicity, assume that the overall transportation requirement, in passenger-miles, as a function of time is given by $R(t)$, and is composed of the contributions from automobiles, buses, trains, and ferries [$A(t)$, $B(t)$, $T(t)$, and $F(t)$ respectively].

Thus,

$$R(t) = A(t) + B(t) + T(t) + F(t) \quad . \tag{1}$$

Although there are clearly other modes of travel, these four comprise a sufficiently large majority for this illustration. Ferries, which were once very popular in the Bay Area, are introduced not at all whimsically when one considers the flair of going to work across or up the Bay in a modern, high speed water surface craft.

With a given pollution per passenger-mile for the automobile, bus, commuter train and ferry (k_a, k_b, k_t, k_f), it is possible to write a pollution-level constraint equation for each pollutant.

$$k_aA(t) + k_bB(t) + k_tT(t) + k_fF(t) \leq P_i(t) \tag{2}$$

Similarly, with costs per passenger-mile known (say c_a, c_b, c_t, and c_f), the operating cost $C(t)$, or the system can be written as

$$C(t) = c_aA(t) + c_bB(t) + c_tT(t) + c_fF(t) \tag{3}$$

This approach to transportation and its resulting pollution can be used to present the consequences to a variety of "what if" questions or situations such as:

What if a new proposal to increase BART by 300% over the 1975-85 time period is accepted?

What transportation alternatives must be considered if automobile growth continues at its present exponential growth rate and P_i is specified for each of several pollutants?

To take a specific case, consider the evaluation of the effects of changing the transportation plan for buses from $B(t)$ to a new plan $B'(t)$. Using Eq. (1) and the known plans for $R(t)$, $T(t)$, and $F(t)$, the new automobile plan, $A'(t)$, can be determined.* If the transportation plans $A'(t)$, $B'(t)$, $T(t)$, and $F(t)$ satisfy the pollution restraint of Eq. (2), the transportation distribution they represent is satisfactory from the pollution standpoint. If not, either a new bus plan must be tried or the train and/or ferry plans adjusted.

As a hypothetical case, suppose that a 30% increase in busing capabilities is to take place over a three year period beginning in 1975. During that period, no additional train or ferry facilities are contemplated. Because the total transportation requirement will rise faster than busing capabilities between 1975 and 1966, additional automobile traffic will be necessary. As a result, the pollution restraint P_i for hydrocarbons will be exceeded, starting in June 1976, unless by that time the ratio of two-person to one-person automobile trips increases by 20%. A variety of options are thus available to transportation planning agencies, among which may be:

(a) Begin increasing busing capabilities earlier, say in 1974, and continue through 1978, so that a 50% increase is obtained.

(b) Plan for increased train capabilities, to begin no later than June 1976.

(c) Increase the ratio of two-person to one-person automobile traffic by graduated bridge tolls and other economic incentives.

(d) Increase the transportation slice of the total pollution pie for hydrocarbons and either reduce other slices accordingly or accept further degradation of air quality.

8.5 Conclusions and Recommendations

Air pollution in the San Francisco Bay Area comes about from a variety of urban systems, upon the creation or design of which the BAAPCD has little or no influence. As an example the choice between or ultimate mix of alternative transportation or power generation systems is determined by completely separate agencies even though the impact of such decisions may dramatically alter the quality of air. In such an arrangement the BAAPCD is forced into a defensive and

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* The automobile plan is chosen as the dependent variable since any failure of buses, trains, and ferries to supply their shares of the necessary overall transportation requirement will most likely result in the public's using automobiles to make up the deficit.

inappropriate posture of trying to control polluting systems which have been designed quite apart from the goal of clean air. Present control programs are, at best, just "holding the line"; in the face of increasing Bay Area population, it is a virtual certainty that air quality will get worse unless more effective control measures are carried out. As a primary step in establishing a comprehensive control program, *it is strongly recommended that any further planning and development of the Bay Area be done on a regional basis, with pollutant emissions and effects on local and regional air quality as important factors when consideration is given to locating any new freeways, industries, residential developments and the like*.

The BAAPCD must broaden the scope of its activities to develop a comprehensive program of air pollution control. In particular, in addition to the operation recommendations set forth in Chapter 6, the BAAPCD should:

(a) Adopt the philosophy that there is an upper limit on the total rate of emission of any pollutant from all sources in the Bay Area and reflect this philosophy in its regulations.

(b) Stay abreast of the latest models and techniques for determining the cause-effect relationship between pollutant sources and air quality.

(c) Make the best possible computation of the total pollution pie for each pollutant that is consistent with the maintenance of air quality standards and direct its source emission control program toward ensuring that actual total emission rates do not exceed these upper limits.

(d) Familiarize local and regional planning agencies with the air pollution problem and the role which such agencies can play in its solution; in particular, the BAAPCD should use whatever influence it can to insure that these agencies strongly consider effects on air quality in all of their actions.

Appendix 1-1

AIR QUALITY CRITERIA

The following tables were extracted from Reference 6 of Chapter 1. These tables are summaries of some of the experimental evidence which was studied by the technical advisory staff of the Air Resources Board in adopting the latest version of California's Air Quality Standards.

Table 1-1.1

AIR QUALITY CRITERIA FOR OZONE BASED ON HEALTH EFFECTS[1]

EFFECT	EXPOSURE (ppm)	DURATION	COMMENT	REFERENCE
Odor Detection	0.02	5 Minutes	Odor detected in 9/10 subjects within 5 minutes.	Henschler et al
Respiratory Irritation (Nose and Throat), Chest Constriction	0.3	Continuous During Working Hours (8 Hours)	Occupational exposure of welders (other pollutants probably also present).	Kleinfeld et al
Changes in Pulmonary Functions:				
a) Diminished FEV$_{1.0}$ after 8 weeks	0.5	3 Hours/Day 6 Days/Week for 12 Weeks	Experimental exposure. Change returns to normal 6 weeks after exposure. No changes observed at 0.2 ppm.	Bennett
b) Small decrements in VC, FRC and DL$_{CO}$ in respectively 3, 2 and 1 out of 7 subjects	0.2-0.3	Continuous During Working Hours	Occupational exposure. All 7 subjects smoked. Normal values for VC, FRC and DL$_{CO}$ based on predicted value.	Young et al
c) Impaired diffusion capacity (DL$_{CO}$)	0.6-0.8	2 Hours	Experimental exposure of 11 subjects.	Young et al
d) Increased airway resistance	0.1-1.0	1 Hour	Increase in 1/4 at 0.1 ppm and 4/4 at 1.0 ppm.	Goldsmith et al
e) Reduced VC, severe cough, inability to concentrate	2.0	2 Hours	High temperatures. One subject.	Griswold et al
Acute Pulmonary Edema	9.0	Unknown	Refers to peak concentration of occupational exposure. Most of exposure was to lower level.	Kleinfeld et al

[1] Compiled by the California State Department of Public Health.

Table 1-1.2

AIR QUALITY CRITERIA FOR OXIDANTS BASED ON HEALTH EFFECTS[1]

EFFECT	EXPOSURE (ppm)	DURATION	COMMENT	REFERENCE
Eye Irritation	0.1	5 Minutes	Result of panel response.	Renzetti and Gobran
Impairment of Pulmonary Function (Airway resistance)	Regression about 0.1	1 Week in Room Containing Ambient Air	Subjects were smokers and nonsmokers. Most subjects had emphysema.	Remmers and Balchum
Aggravation of Respiratory Disease: Asthma	0.13*	Continuous	Patients exposed to ambient air. Value refers to oxidant level at which number of attacks increased.	Schoettlin and Landau
Impaired Performance of Student Athletes	Regression about 0.1	1 Hour +	Exposure for one hour immediately prior to race.	Wayne et al

* Calculated from a measured value of 0.25 ppm (phenolphthalein method) which is equivalent to 0.13 (KI).

[1] Compiled by the California State Department of Public Health.

Table 1-1.3

ADDITIONAL SELECTED AIR QUALITY CRITERIA FOR OXIDANT*

Effects On	Contaminant	Concentrations and Duration	Comments	Reference
Animals	Oxidant	0.3 ppm for 3 hours	Exposure produced impaired breathing in laboratory animals	Swann, et al
	Oxidant	0.5 ppm daily peak	Exposure produced increased breathing resistance in older laboratory animals	Swann, et al
	Oxidant	0.15 ppm for 4 hours	Exposure to oxidant and then to infectious aerosol produced increased mortality among laboratory animals	Coffin and Blommer
Vegetation	Ozone	0.05-0.1 ppm for 2 hours	Caused irregular necrotic spots, with appearance of lesions or flecking on upper leaf surfaces on many species	Heggested, Menser, et al; Sechler and Davis; Berry and Ripperton
	PAN**	0.1 ppm for 5 hours	Caused "silver leaf" appearance on lower leaf surface	Stephens, et al
Visibility	Oxidant	0.07 ppm	Associated with photochemical haze found in Los Angeles	U.S. Department H.E.W.
Materials	Ozone	0.02 ppm for 1 hour	Laboratory exposure caused cracking of stressed rubber	Bradley, Haagen-Smit, Crabtree and Erickson
	Ozone	0.02-0.06 ppm for 50 days	Deterioration and loss of Tensile strength of exposed wet cotton textiles	Bogarty, et al

*Derived from HEW Air Criteria for Oxidant.

**Recent findings of O. C. Taylor indicate that injury can be produced on sensitive species with 20 ppb PAN in a 2 to 4 hour exposure (Paper #68-168, 61 Annual Meeting of the APCA, June 1968).

Table 1-1.4

BASES FOR AIR QUALITY CRITERIA FOR NITROGEN DIOXIDE*

EFFECTS	CONCENTRATION	DURATION	COMMENTS	REFERENCE
Atmospheric discoloration	0.25 ppm	na**	On days with otherwise good visibility (20 miles) the coloration effects will be objectionable for objects of 10 miles distance.	State of California Department of Public Health
Chronic respiratory effects in workmen	Short exposures to 25-200 ppm (estimated)		In silo-fillers, in miners exposed to dynamite fumes.	Lowry and Schuman Becklake et al
Damage to vegetation	0.5 ppm 2.5 ppm	12-19 days 7 hrs.	Prolonged exposure of sensitive plants (tomato). Exposure of bean, tomato and tobacco.	Taylor Middleton et al
Pulmonary edema in animals (rats)	Log ppm NO_2 = 2.38 - 0.525 (log exposure time in minutes) Valid range 2 min. - 2 hrs.		Based on lung-weight to body-weight ratios.	Gray Carson
Emphysematous changes in animals	25 ppm	2 hrs. (repeated)	Rabbits and Guinea Pigs.	Kleinerman and Wright
	Activated charcoal shaken with NO_2 (estimated 25 ppm)		Mice.	Boren
	25 ppm continuously		Rats.	Freeman and Hayden
	0.5 ppm continuously		Mice.	Blair, Henry and Ehrlich
Narrowing of terminal air passages	4 ppm continuously		Rats (and Monkeys).	Hayden, Freeman and Furiosi
Increased respiratory rate in rats	0.8 ppm continuously		Rats.	Freeman and Furiosi
Increased susceptibility to experimental infection	0.5 ppm continuously		Mice.	Ehrlich and Henry
Reversible lysis of rat lung mast cells Lipid peroxidation Structural protein alteration in lung	0.25 ppm to 1 ppm	1 hr. to 4 hrs.	Rats and Rabbits.	Thomas, Mueller and Wright Thomas, Mueller and Lyman Buell, Tokiwa and Mueller

* Compiled by California State Department of Public Health.

** Not appropriate.

Table 1-1.5

AIR QUALITY CRITERIA FOR CARBON MONOXIDE

CONCENTRATION AND METHOD	DURATION OF AVERAGING	EFFECT	COMMENTS	REFERENCE
More than 10-12 ppm NDIR	4-5 Hours	Increased COHb 0.5-2%	Traffic police in Paris and Detroit and students in Los Angeles. May be overwhelmed by smoking exposure.	Chovin et al Clayton et al.
About 10 ppm NDIR	24 Hours	Possibly increased risk of auto accidents.	Epidemiological association. Smoking or alcohol use might contribute or the association might be spurious. Being studied in Los Angeles 1963-1968.	Chovin et al Clayton et al.
More than 8 ppm NDIR	Weekly Average	Possibly increased case fatality rate in hospitalized myocardial infarction patients.	Higher case fatality in L.A. area with higher pollution during the quartile of weeks with highest CO levels. 1958 data needs to be confirmed with later data. Other factors may be involved.	Cohen et al.
Mean of 50 ppm MSA Colorimetric	8 Hours	Increased hematocrit. COHb mean of 3.8% in smokers and 3.4% in nonsmokers.	All occupational exposure data do not show an effect on hematocrit.	Hofreuter.
30 ppm NDIR	8-12 Hours	Equilibrium value of 5% COHb reached.	Experimental exposure of nonsmokers.	Smith State of California, Department of Public Health.
50 ppm NDI	90 Minutes	Threshold for the impairment in time discrimination. Unpublished data shows this effect with substantially shorter exposures.	COHb levels not available but expected values about 2%. Certain psychomotor test results were impaired at 2% COHb.	Beard et al. Schulte.
100-300 ml Injection of pure gas into air stream	10-15 Minutes	Impairment of visual function detectable at 4-5% COHb.	Data given for very small number of subjects.	Halperin et al.

Table 1-1.6

AIR QUALITY CRITERIA FOR SULFUR OXIDES

Effect	SO_2 Exposure (ppm)	Duration	Comment	Reference
Visibility Impairment			Theoretical work is suggestive but adequate measurements of sulfuric acid and sulfate particles have not been made.	
Corrosion	0.03 to 0.12	Annual average	Moist temperate climate with particulate pollution.	Upham (1967)
Vegetation damage (alfalfa mostly but many other species are similarly sensitive)	0.3	8 hours	Laboratory experiment; other environmental factors optimal. Field studies are consistent but dose is difficult to estimate.	Thomas (1937) Katz & MacCallum. (1952)
Odor Threshold	0.47 ppm. 50% of subjects detect	<1 hour	May be higher for many persons or when other methods are used.	Manufacturing Chem. Assn. (1968)
Respiratory symptoms	0.2	Daily average	Community exposure exceeding 0.2 ppm more than 3% of the time.	Bell (1962)
Respiratory symptoms	>0.05	Long-term average	With particulates >100 $\mu g/m^3$	Holland-Stone (1965) Deane-Goldsmith-Tuma (1965)
Respiratory symptoms	0.2	Daily average	With particulates	McCarroll (1966)
Respiratory symptoms	0.9	Hourly average	With particulates	Cassell (1965)
Respiratory symptoms, plus impairment of lung function in children	>0.05	Monthly average	With particulates	Toyama (1964)

Table 1-1.7

AIR QUALITY CRITERIA FOR PARTICULATE MATTER

CONCENTRATION	MEASUREMENT METHODS	EFFECTS	CONDITIONS	REFERENCE
100 $\mu g/M^3$	Short-term average high volume sampling	Visibility restriction to $< 7\frac{1}{2}$ miles	Particle sizes in the range of 0.2-1.0μ and R.H. $< 70\%$	Charlson et al. Noll et al.
100 $\mu g/M^3$	High volume sampling	Damage to Materials	Long-term exposure	Larrabee et al. Copson
150-350 $\mu g/M^3$	Smoke stain calibration or long-term average high volume sampling	Impairment in lung function or increase in sputum volume of exposed populations	In the presence of 123-300 $\mu g/M^3$ sulfur oxides	Holland et al. Toyama et al. Lunn et al. Fletcher et al.
100-135 $\mu g/M^3$	Long-term average high volume sampling	Increased probability of chronic respiratory disease mortality when economic status has been corrected for	Upper temperate latitudes in presence of increased sulfation. Three ranges are given and the concentrations cited are the lower bounds of the two upper ranges	Winkelstein
> 130 $\mu g/M^3$	Long-term average Smoke stain calibration	Increased frequency and severity of lower respiratory tract disease in children followed from birth to 15 yrs.	In the presence of concentrations of sulfur oxides above 130 $\mu g/M^3$	Douglas et al.
> 300 $\mu g/M^3$	Smoke stain calibration 24-hr. average	Acute worsening of symptoms in bronchitic patients	Upper temperate latitudes in presence of more than 630 $\mu g/M^3$ sulfur oxides	Lawther
800-1000 $\mu g/M^3$	Smoke stain calibration 24-hr. average	Probability of increase in acute illness and death from respiratory and cardiac conditions, especially in persons with chronic cardiopulmonary diseases	In presence of 750-8000 $\mu g/M^3$ sulfur oxides	Martin et al. Martin Lawther Greenburg et al. Watanabe

Table 1-1.8

HYDROGEN SULFIDE ODOR, PHYSIOLOGICAL RESPONSE AND VEGETATION DAMAGE RELATED TO SPECIFIED CONCENTRATIONS

Concentration (ppm)		Reference
	Odor	
0.011	U.S.S.R. Atmospheric Standard for Maximum Average	4
0.036	U.S.S.R. Atmospheric Standard for Maximum Single Value	
0.072	Concentration not sensed by olfactory organs	
< 0.072	Concentration sensed by olfactory organs	
0.043-0.145	Odor definite and clearly perceptible	
0.022	No odor as determined by a panel of observers	5
0.13	Threshold odor level as determined by a panel of observers	
0.77	Faint odor, readily perceptible by a panel of observers	
4.6	Easily noticeable by a panel of observers	
0.025	First detectable odor	6
0.30	Distinct odor	
3-5	Offensive and moderately intense	
	Physiological Response	
0.07	Affects light sensitivity of eye	7
6.7	Chronic toxicity in rats	
20	Recommended threshold limit value for industrial exposures	8
50-100	Subacute poisoning, mild conjunctivitis and mild respiratory tract irritation after one-hour exposure	9
200-300	Subacute poisoning, marked conjunctivitis and respiratory tract irritation after one-hour exposure	
500-700	Subacute poisoning, dangerous in one-half to one hour	
700-1,000	Possible acute poisoning, rapid unconsciousness, death	
1,000-2,000	Acute poisoning, rapid unconsciousness, death in few minutes	

Table 1-1.8 (Cont)

Concentration (ppm)		Reference
70-150	Slight symptoms after several hours exposure	10
170-300	Maximum concentration that can be inhaled for one hour without serious consequences	
400-700	Dangerous exposure after 30 to 60-minute exposure	
600	Fatal after 30 minutes	
100	Slight symptoms may appear after several hrs.	11
200	Sufficient to cause symptoms in man	
1,000	Rapidly fatal	
	Vegetation Damage	
20-40	Slight damage to a few species fumigated for five hours	12
400	Some species escaped visible damage after five hours fumigation	

Appendix 2-1

A PROGRAM FOR THE LONG-RANGE PREDICTION OF POLLUTANT EMISSIONS FROM AUTOMOBILES

Automobiles are a major source of air pollutants, and their emissions are subject to Federal and State of California control programs (see Chapter 2). It would be advantageous to be able to calculate what the emission rates from automobiles will be in future years. This ability would allow evaluation of the present control programs or any future extensions of them. This appendix outlines a now existing program for use on a digital computer that will very rapidly calculate projections of pollutant emissions from automobiles for any control program. Such projections for CO, HC, and NO_x, based on California's automobile emission standards program, are shown in Chapter 2.

Basically, the program computes the annual emission rates (pounds per year) of the pollutant(s) of interest over the desired span of years and plots the emission rates for the various years. The variable inputs available to the user are:

(a) The span of years over which the calculations are to be made.

(b) The actual or projected annual car stock and car sales.

(c) The survival probability of cars (probability of the car still being driven) as function of car age. This survival profile appears to have been time (not age) independent over the past ten years or so.

(d) The average usage rate (miles driven per year) as a function of the car's age.

(e) The emission rate (pounds per mile) of the pollutants of interest for uncontrolled cars.

(f) The desired control levels and the years they are to be imposed.

(g) The deterioration of the emission control device with age.

The program treats all cars of the same age as equivalent; all cars of the same age are assumed to emit pollutants at the same rate and to have been driven the same number of miles. No finer time resolution than one year is considered; all cars sold during any year are assumed to have been sold at the beginning of that year.

Let Q(t) be the annual emission rate during year t for the pollution of interest. The program calculates Q(t) over the desired span of years t from the equation

$$A(t) = \sum_{n=1}^{n_{max}} S(t-n+1)\ P(n)q\ v(n)k\ (t-n+1)\ D(n)$$

Here n is an index representing the ages in years (n-1) of the automobiles involved in the calculation. The factors involved in the equation are discussed in the following paragraphs.

Car Sales

$S(t)$ represents the number of cars sold in the year t. These values can be read directly into the program, or they can be calculated by the program based upon any predicted sales pattern in future years. For example, Figure 2.2 of Chapter 2 shows that the car population of the Bay Area has been growing exponentially over the past 30 years. The emission projections shown in Figures 2.3a, 2.3b, and 2.3c were based on a continued increase in the car population at the same exponential rate. Assuming a time independent survival probability (see the following paragraph), this implies that car sales will also increase at the same rate. Thus the projected sales were computed as

$$S(t+1) = a\,S(t), \quad t \geq 1960$$
$$S(t) = S(t+1)/a, \quad t < 1960$$

where $S(1960)$ and a were input data to the program. $S(1960)$ was chosen so that the car stock $n(t)$ of the Bay Area, as shown in Figure 2.2 of Chapter 2, was correctly calculated by

$$n(t) = \sum_{n=1}^{n_{max}=40} S(t-n+1)\,P(n) \ .$$

The growth factor a was determined from Figure 2.2 from the relationship

$$n(t) = n(1960)\,e^{\alpha(t-1960)} = n(1960)\,a^{t-1960} \ ,$$

so that $\ln(a) = \alpha$ is the slope of the curve of Fig. 2.2.

Survival Probability

$P(n)$ is the probability that a car of age $n-1$ years is still being driven. This data can be read directly into the program or it can be internally calculated by any desired formula. Nationwide automobile registration data over the past 15 years indicate that the survival probability as a function of car age is not changing significantly. A composite of these data is shown in Figure 2-1.1. It has been arbitrarily extended so that the survival probability goes to zero at a car age of 40 years. This probability profile $P(n)$ was used to compute the projections shown in Chapter 2.

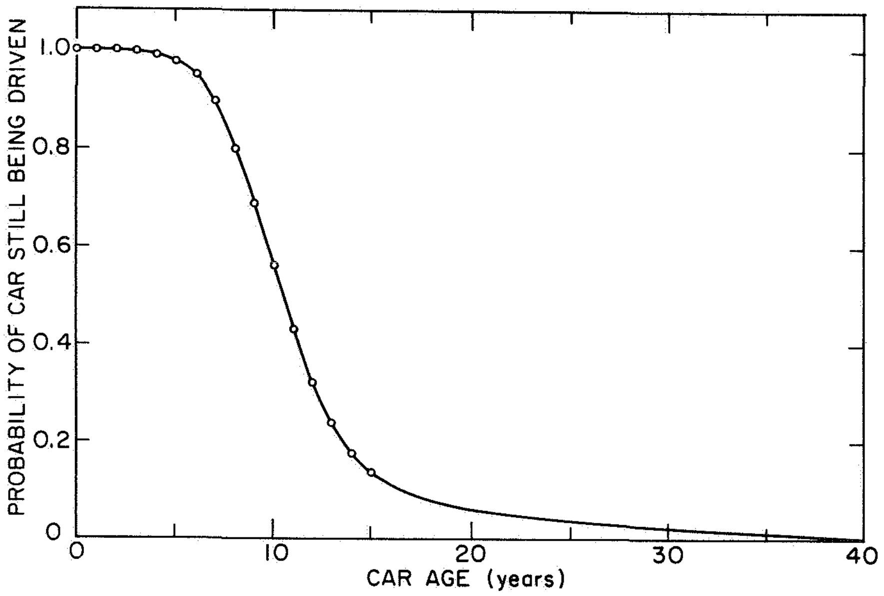

Figure 2-1.1. THE SURVIVAL PROBABILITY OF CARS AS A FUNCTION OF THEIR AGE. (Data taken from Automobile Facts 1969, Automobile Manufacturers Association, for car ages of 15 years or less. For larger ages, curve 15 is arbitrarily drawn to give zero probability at age 40 years.)

Uncontrolled Emissions Factor

q is the rate (pounds per mile) at which the pollutant of interest is emitted from an uncontrolled automobile. This factor is perhaps the major source of uncertainty in the calculated emissions projections. The values used in the projections of Chapter 2, which are shown there in Table 2.1, are based on an average urban driving cycle.

Annual Mileage

The annual mileage driven by a car of age n-1 years is represented by v(n). This input to the program can be allowed to vary with car age, or it can be treated as a single constant. The values used in the projections of Chapter 2 are shown in Table 2-1.1. The overall national average annual mileage for cars of all ages is 9350 miles per car per year. It has not varied appreciably over the last ten years.

Control Levels and Years

k(t) is the degree of control for the pollutant of interest imposed on the emissions from all cars sold during year t. Numerically, it is the ratio of the emission standard for year t to the uncontrolled emission rate; a value of 1.0 implies no control, while a value of 0.0

Table 2-1.1

DETERIORATION AND MILEAGE DATA[2] USED IN CALCULATING PROJECTED EMISSIONS FROM AUTOMOBILES

Car Age[*] (Years)	Miles Driven During Year	Deterioration of Control[**]	
		CO	HC
0	13,200	1.063	1.055
1	12,000	1.165	1.145
2	11,000	1.210	1.175
3	9,600	1.235	1.900
4	9,400	1.252	1.950
5	8,700	1.265	1.980
6	8,600	1.275	1.200
7	8,100	1.285	1.200
8	7,300	1.292	1.201
9	7,000	1.296	1.201
10	5,700	1.299	1.202
11	4,900	1.301	1.202
12	4,300	1.302	1.203
13	4,300	1.303	1.203
14	4,300	1.304	1.203
15 or more	4,300	1.305	1.203

[*] Age at the beginning of the year

[**] This is the factor by which controlled emissions level (grams per mile) is multiplied due to deterioration of control device.

represents total control. Any number of pairs k(t), t can be read into the program. The values of k(t) used in the projections of Chapter 2 were those determined from the State of California emissions control program, summarized in Table 2.1 of that chapter.

Deterioration of Control Devices

The program allows consideration of the deterioration of the emission control devices with age. The deterioration factor D(n) would have a value of 1.0 if there were no deterioration and would increase as deterioration occurs. Table 2-1.1 lists the values of D(n) for HC and CO control devices used in the projections of Chapter 2. They are based on studies made in Los Angeles. No data exist for NO_x devices, and consequently values of 1.0 were used in this case.

In addition to evaluating the results of present control programs, as discussed in Chapter 2, the program could be used to determine appropriate control programs, or the non-existence of them, to accomplish particular goals. For example, it could be used to determine what, if any, addition emission standards should be imposed, and when, to reduce emissions of NO_x in the Bay Area to 1940 levels and maintain them there.

Appendix 2-2

AUTOMOTIVE AIR POLLUTION SOURCES

Automobile exhaust is one of the major contributors to air pollution. Since cars are moving sources, locating the emission from automobiles is not easy. Common practice is to assign auto emissions on the basis of gasoline sales; i.e., it is assumed that about as much gas is burned in a certain area as is sold there, and that in any one year the amount of pollutants emitted for each gallon of gas burned is constant. These assumptions are reasonable as long as the areas considered are large. They are reasonably valid for the entire Bay Area, and probably pretty good on a county basis. However, if one wants auto emissions on a finer grid, a different method must be employed, not only because these assumptions become invalid, but also because it is difficult to obtain statistics on total gasoline sales for smaller subdivisions. This appendix describes a method for counting local automobile emissions based on statistical information of trips made, and its application to the Bay Area.

The method presupposes the existence of a detailed trip inventory. Fortunately, such an inventory exists. It was prepared by the Regional Transportation Planning Commission (RTPCO), formerly known as Bay Area Transportation Study Commission (BATSC), and is based on a 1965 survey of some 35,000 Bay Area households. Extrapolations to 1980 and 1990 also exist. Although RTPC has made many different breakdowns of their survey, the present work was concerned only with their tables for weekday trips of all vehicles. The original survey had broken the area, i.e., the nine Bay Area counties, into 291 districts, embedded in 30 super districts (Figure 2-2.1). Time and impatience did not permit use of the fine grid so the calculations were made for the 30 super districts (SD). RTPC furnished 30 × 30 matrices showing the number of trips from any one SD to any other SD as well as the trips within each SD.

Next estimates of the mileage for each of these 900 possible trips were made. To minimize this work, a table was constructed listing each target SD and the SDs adjacent to it from where traffic might come (see Table 2-2.1). Then, on large scale road maps, the mileage required to go through the target SD, and the mileage to a pre-selected center (see Table 2-2.2) within the target SD were measured. It should be emphasized that this table shows the mileage in the target SD, not in the SD from where the traffic comes.

Since the amount of pollution emitted depends on the type of driving as well as the mileage driven, actual mileages are multiplied by 1.5 if they represent congested city traffic, and by 0.7 if they represent uncongested highway or country driving. Normal traffic mileage is left unchanged.

Next a 30 × 30 routing matrix was prepared, showing the number of the last SD driven through when coming from the origin SD and before reaching the target SD. For example, going from SD 29 to SD 15, 16 is the number of the last SD driven through. If original and destination SD are the same or adjacent, the number zero is used.

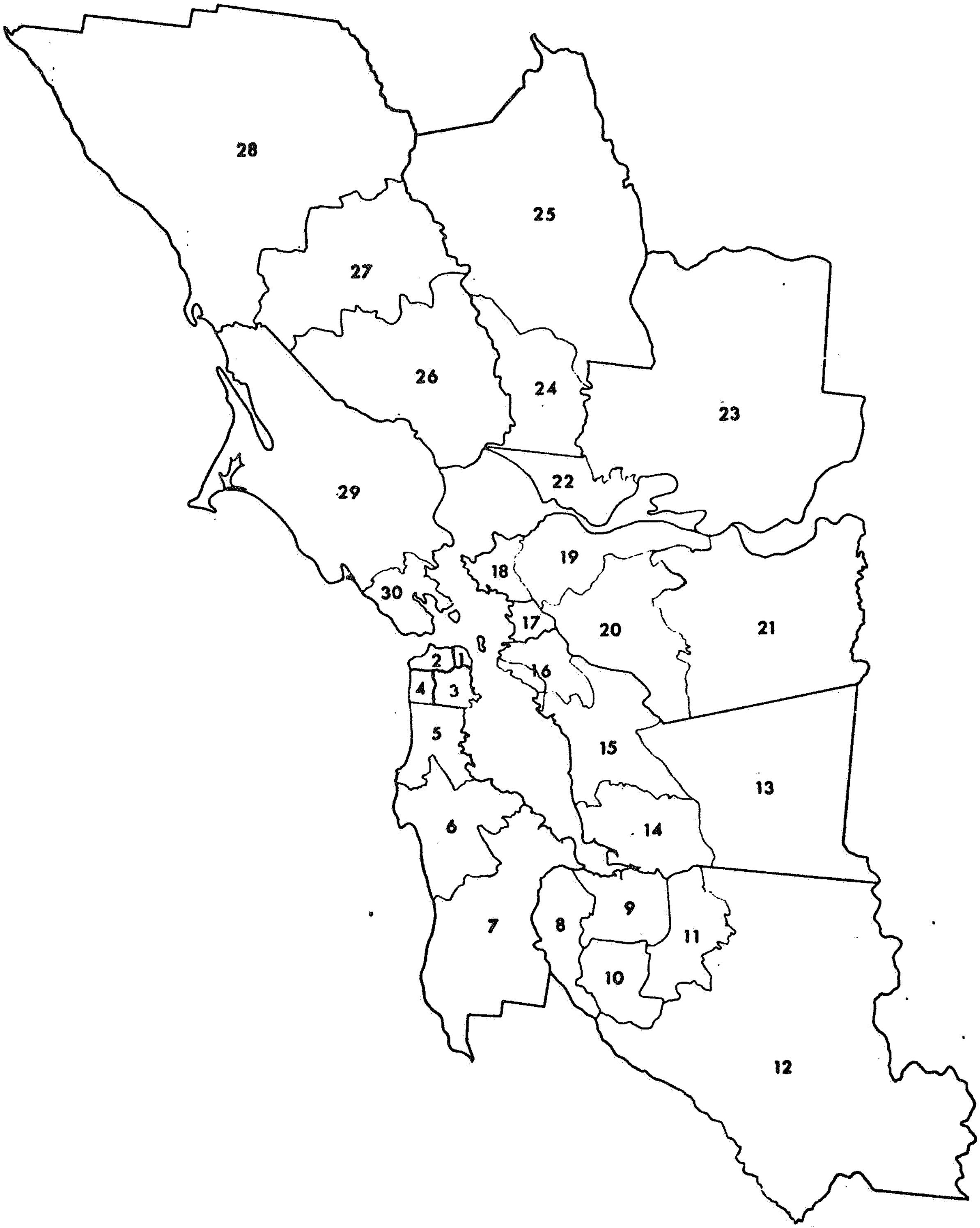

Figure 2-2.1. THE RTPC (BATSC) SUPER DISTRICTS.

Table 2-2.1

SECTION FROM MILEAGE CHART

Target SD	SD from which Traffic Comes	Miles Through Target SD	Miles to Center of Target SD
15	6	12.6	8.9
15	13	7.0	3.5
15	14	10.5	6.1
15	16	10.5	5.6
15	20	11.7	5.6
16	01	8.0	7.0
16	15	8.0	6.0
.			
.			
.			

With the matrix and the mileage table, one can compute the equivalent emission mileage for trips between any two SDs. For example, in going from SD 29 to SD 15, a driver would have gone through SDs 18, 17, 16, and accumulated

	9.8	equivalent	miles	in SD	29
	7	"	"		18
	6	"	"		17
	8	"	"		16
and	5.6	"	"		15

Since drivers do not usually start or end at the center of an SD, some mileage must be added to each end of the trip. Similarly, trips within a district must be assigned an "average" mileage. It was assumed that the average trip within a district is 7 miles, and that 3-1/2 miles are added to inter-district trips at each end. Thus, a trip from SD 29 to SD 15 consists of 9.8 + 3.5 = 13.3 miles in SD 29 and 5.6 + 3.5 = 9.1 miles in SD 15 plus the "through" mileages stated above in SD 16, 17 and 18. In this fashion, total mileages were computed for each SD.

Emission data for a "normal" mile were now needed. These were obtained from estimated data for Los Angeles(1) as follows:

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(1) Air Pollution in Los Angeles - L.A. County Air Pollution Control District, Jan. 1968.

Year	Estimated Emission lb/car-mile (×100) Particulates	HC	NO_x	CO
1969	0.068	2.55	1.28	14.2
1980	0.054	0.55	0.61	5.0

Multiplying mileage in each SD by estimated emissions leads to the emissions in each SD, Tables 2-2.3, and 2-2.4.

Table 2-2.2

DISTRICT CENTER

District	Center
1	Union Square
2	Rt. 1 at Geary
3	Rt. 200 and 101
4	Rt. 1 and 35
5	S.S.F. - El Ca. at Grand
6	S.M. - El Cam. at 3rd Ave.
7	M.P. - El Cam. at Sta. Cruz
8	L.A. - El Cam. at San Antonio
9	Santa Clara
10	Cambell
11	S.J. - 1st and San Carlos
12	Morgan Hill
13	Livermore
14	Fremont (Thornton & Fremont)
15	Castro Valley
16	Oakland - Lake Merritt
17	Berkeley - University and Shattuck
18	Richmond - McDonald & 23rd
19	Martinez
20	Walnut Creek
21	Clayton
22	Vallejo - 29th & Tennessee
23	Vacaville
24	Napa
25	Rt. 120 and Knoxville Rd.
26	Petaluma
27	Santa Rosa
28	Healdsburg
29	Rts. 37 and 101
30	Mill Valley

Table 2-2.3

ESTIMATES OF POLLUTANT EMISSIONS FROM AUTOMOBILES BY RTPC DISTRICTS - 1965

County	District	Mileage/day in millions	Emission - tons/day							
			CO		NO_x		HC		Particulates	
San Francisco	1	7.55	238.6	675.6	14.0	39.6	44.0	124.6	1.1	3.1
	2		166.9		9.8		30.8		0.8	
	3		155.4		9.1		28.7		0.7	
	4		114.7		6.7		21.2		0.5	
San Mateo	5	6.08	180.6	543.8	10.6	31.9	33.4	100.3	0.8	2.5
	6		134.1		7.9		24.7		0.6	
	7		229.1		13.4		42.2		1.0	
Santa Clara	8	11.17	183.8	999.3	10.8	58.6	33.9	184.2	0.8	4.5
	9		217.1		12.7		40.0		1.0	
	10		191.1		11.2		35.2		0.9	
	11		350.5		20.6		64.6		1.6	
	12		56.8		3.3		10.5		0.3	
Alameda	13	13.63	36.1	1220.0	2.1	71.6	6.7	224.9	0.2	5.5
	14		135.3		7.9		24.9		0.6	
	15		302.2		17.7		55.7		1.4	
	16		476.9		28.0		87.9		2.2	
	17		269.5		15.8		49.7		1.2	
Contra Costa	18	5.91	230.9	528.8	13.5	31.0	42.6	97.5	1.0	2.4
	19		73.6		4.3		13.6		0.3	
	20		173.4		10.2		32.0		0.8	
	21		50.9		3.0		9.4		0.2	

Table 2-2.3 (Cont)

County	District	Mileage/day in millions	Emission - tons/day						Particulates	
			CO		NO_x		HC			
Solano	22	1.70	111.9	152.0	6.6	8.9	20.6	28.0	0.5	.7
	23		40.1		2.3		7.4		0.2	
Napa	24	.76	52.8	58.2	3.1	4.0	9.7	16.6	0.2	.3
	25		15.4		0.9		2.8		0.1	
Sonoma	26	1.97	50.4	176.5	3.0	10.4	9.3	32.5	0.2	.8
	27		93.0		5.5		17.2		0.4	
	28		33.1		1.9		6.1		0.1	
Marin	29	2.28	107.9	204.0	6.3	12.0	19.9	37.6	0.5	.9
	30		96.1		5.6		17.7		0.4	
9 county total (includes Napa, Solano, and Sonoma)		51.0		4568		268		842		21.7
6 county total		46.6		4172		235		765		18.9

Table 2-2.4

ESTIMATES OF POLLUTANT EMISSIONS FROM AUTOMOBILES BY RTPC DISTRICTS - 1980

County	District	Mileage/day in millions	Emission - tons/day						Particulates	
			CO		NO_x		HC			
San Francisco	1	11.34	100.2	283.5	12.2	34.6	11.0	31.2	1.1	3.0
	2		66.5		8.1		7.3		0.7	
	3		73.1		8.9		8.0		0.8	
	4		43.7		5.3		4.8		0.5	
San Mateo	5	10.17	82.9	254.3	10.1	31.0	9.1	28.0	0.9	2.7
	6		64.4		7.9		7.1		0.7	
	7		107.0		13.1		11.8		1.2	
Santa Clara	8	17.64	66.8	440.9	8.2	53.8	7.4	48.5	0.7	4.8
	9		79.0		9.6		8.7		0.9	
	10		88.8		10.8		9.8		1.0	
	11		129.6		15.8		14.3		1.4	
	12		76.7		9.4		8.4		0.8	
Alameda	13	23.93	25.4	598.2	3.1	73.0	2.8	65.8	0.3	6.4
	14		85.9		10.5		9.5		0.9	
	15		147.5		18.0		16.2		1.6	
	16		216.4		26.4		23.8		2.3	
	17		123.0		15.0		13.5		1.3	
Contra Costa	18	10.35	89.4	258.8	10.9	31.6	9.8	28.5	1.0	
	19		44.4		5.4		4.9		0.5	
	20		92.9		11.3		10.2		1.0	
	21		32.1		3.9		3.5		0.3	

Table 2-2.4 (Cont)

County	District	Mileage/day in millions	Emission - tons/day						Particulates	
			CO		NO_x		HC			
Solano	22	3.66	54.2	91.6	6.6	11.2	6.0	10.1	0.6	1.0
	23		37.4		4.6		4.1		0.4	
Napa	24	1.54	26.7	38.5	3.3	4.7	2.9	4.2	0.3	.4
	25		11.8		1.4		1.3		0.1	
Sonoma	26	3.12	23.3	77.9	2.8	9.5	2.6	8.6	0.3	3.12
	27		38.1		4.6		4.2		0.4	
	28		16.5		2.0		1.8		0.2	
Marin	29	4.68	70.0	117.1	8.5	12.9	7.7	12.9	0.8	1.3
	30		47.1		5.7		5.2		0.5	
9 county total (includes Napa, Solano, and Sonoma)		86.4		2161		264		238		23.3
6 county total		78.1		1953		238		215		21.0

Discussion:

Many of the assumptions made in the analyses are open to question: the choice of routes between SDs, the estimates of mileage, the driving type correction factors, and the emission factors. They need to be confirmed or corrected by a careful study of driving in the Bay Area.

This appendix has outlined a technique for deriving automobile emission details by using the extensive surveys made by RTPC. These analyses could be extended to the 291 districts for which RTPC made its original survey. Such a study would be time-consuming but, we believe, it is the only method capable of establishing detailed auto emission maps for the District.

Appendix 3-1

AIR QUALITY INDICES

Various attempts have been made to describe the state of the air in terms of a single index. For example, the BAAPCD uses the combined pollutant index (CPI) discussed in Chapter 1. The CPI is the sum of several pollutant concentrations (CO, NO_x, oxidants) and the coefficient of haze, each weighted rather arbitrarily so that the CPI usually lies somewhere on a scale between 0 and 100. On particularly bad days the value can be greater than 100. The CPI weights most heavily those pollutants which reduce visibility; there is no real correlation between it and the various State air quality standards. This appendix describes two combined indices, a daily local air quality index (DLAQ) and an ambient air quality index (AAQ), which are based on these standards.

Consider an air cell, which may be either the entire airshed or a subdivision of it (see Chapter 3 and Appendix 8-1), and assume that the time-averaged concentrations have been measured for all pollutants for which air quality standards have been established. In this sense time averaging means that, for each pollutant, the concentrations (C_i for the i^{th} pollutant) have been averaged over the time specified in the standard; e.g., 8 hours for CO, 1 hour for SO_2, etc. (see Table 1.3). Further assume that maximum daily time-averaged concentration of each pollutant (C_{im}) has been determined. Then the ratio of C_{im} to the air quality standard (C_{is}) can be calculated for each pollutant. Then the daily local air quality index is defined as the arithmetic average of these ratios. That is, for the air cell under consideration

$$\text{DLAQ} \equiv \frac{1}{N} \sum_{i=1}^{N} (C_{im}/C_{is})$$

where N is the number of pollutants for which air quality standards have been established. Table 3-1.1 shows the breakdown of a hypothetical DLAQ determination. For this particular case

$$\text{DLAQ} = \frac{1}{7} [0.50 + 0.90 + 0.33 + 0.40 + 0.40 + 1.20 + 1.25] = 0.71 \quad .$$

The ambient air quality index is determined monthly on the basis of data collected in the previous month. The criterion is that for the i^{th} pollutant only one time-averaged measurement (C_i) per year is expected to exceed the state standard (C_{is}). Let T_i be the averaging time for this pollutant in hours. There will then be $365 \times (24/T_i)$ values of C_i obtained each year. A value C_i^* is to be

Table 3-1.1

A HYPOTHETICAL DAILY LOCAL AIR QUALITY INDEX TABLE FOR AN AIRCELL

i	Pollutant	California Standard C_{is}	Daily Maximum Time--Averaged Concentration	Normalized Maximum Concentration C_{im}/C_{is}
1	Oxidant (Corrected for Nitrogen Dioxide)	0.1 ppm for 1 hour	0.05 ppm	0.50
2	Carbon Monoxide	20 ppm for 8 hours	18 ppm	0.90
3	Hydrogen Sulfide	0.03 ppm for 1 hour	0.01 ppm	0.33
4	Nitrogen Dioxide	0.25 ppm for 1 hour	0.1 ppm	0.40
5	Sulfur Dioxide	0.04 ppm for 24 hrs.[†] 0.5 ppm for 1 hour	0.016 ppm	0.40
6	Particulate[‡] Matter	100 $\mu g/m^3$, 24 hour sample	120 $\mu g/m^3$	1.20
7	Atmospheric obscuration 1/visibility	1/10 $mi.^{-1}$, relative humidity less than 70%, max. for 24 hrs.	1/8 $mi.^{-1}$[**]	1.25
8	Total HC[*]	0.4 ppm[*]	*	*

[*] Note: State standards for Total Hydrocarbons have not yet been adopted in California. The 0.4 figure has been proposed.

[**] This entry is obviously not a concentration, but maximum obscuration as measured in inverse miles. It is shown in the concentration column for convenience of presentation.

[†] Applicable in areas where the particulate matter standard is exceeded.

[‡] Applicable in the San Francisco Bay Area Air Basin and South Coast Basin only.

determined so that only one of these values C_i is statistically expected to exceed C_i^*. In other words $T_i/(24 \times 365) = 1.15 \times 10^{-4} T_i$ is the fraction of the values C_i which are expected to be larger than C_i^*. (Note that for $T_i = 24$ hours, C_i values are determined daily; the value of the fraction is 1/365). The ambient air quality index is defined as the arithmetic average, over all pollutants, of interest of the ratios C_i^*/C_{is}. That is, for any given air cell

$$AAQ \equiv \frac{1}{N} \sum_{i=1}^{N} (C_i^*/C_{is})$$

where, as before, N is the number of pollutants for which air quality standards have been established.

Appendix 4-1

PUGET SOUND DISTRICT EMISSION INVENTORY

Attached is a map of part of the Puget Sound District overlaid by a grid. The density of the grid is changed to adjust for population and industrial densities. Once location and emission data have been obtained for all emitters in the District, they can be allocated to the grid squares, and a table similar to Table 4-1.1 can be produced. The analysis and prediction of air quality in the District is greatly aided by such data.

Table 4-1.1

KING, PIERCE, & SNOHOMISH COUNTIES
SUMMARY OF AREA SOURCE EMISSIONS FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100 m)	Vertical Coordinate (100 m)	Area (Km^2)	SO_x	Part	CO	HC	NO_x
1	5600	53300	400	.11	.31	20.89	4.23	1.37
2	5800	53300	400	.03	.07	5.35	.72	.33
3	6100	53200	1600	.11	.11	7.19	1.10	.46
4	5550	53150	100	.38	.26	3.74	.55	.46
5	5650	53150	100	.46	.52	24.41	.99	.97
6	5800	53100	400	.08	.23	15.16	3.26	.99
7	5550	53050	100	.25	.65	40.12	7.42	2.70
8	5650	53050	100	.09	.23	14.67	2.21	.96
10	5425	52975	25	.36	.03	0.00	0.00	0.00
11	5475	52975	25	.05	.11	8.32	1.27	.54
12	5525	52975	25	.06	.15	10.40	1.57	.68
13	5575	52975	25	.03	.07	5.54	.45	.35
14	5650	52950	100	.06	.14	13.40	1.48	.61
15	5425	52925	25	.36	.03	0.00	0.00	0.00
16	5475	52925	25	.31	.63	47.19	7.58	2.76
17	5525	52925	25	.20	.43	29.34	5.44	1.88
18	5575	52925	25	.06	.11	11.95	1.34	.56
19	5425	52875	25	.36	.03	0.00	0.00	0.00
20	5475	52875	25	.61	.42	34.87	5.42	1.83
21	5525	52875	25	.84	.79	58.22	8.92	3.34
22	5575	52875	25	.09	.15	15.74	1.69	.68
23	5650	52850	100	.13	.22	20.07	3.34	1.00
24	5800	52900	400	.03	.09	6.33	1.06	.42
25	5425	52825	25	.41	.07	1.44	.04	.05

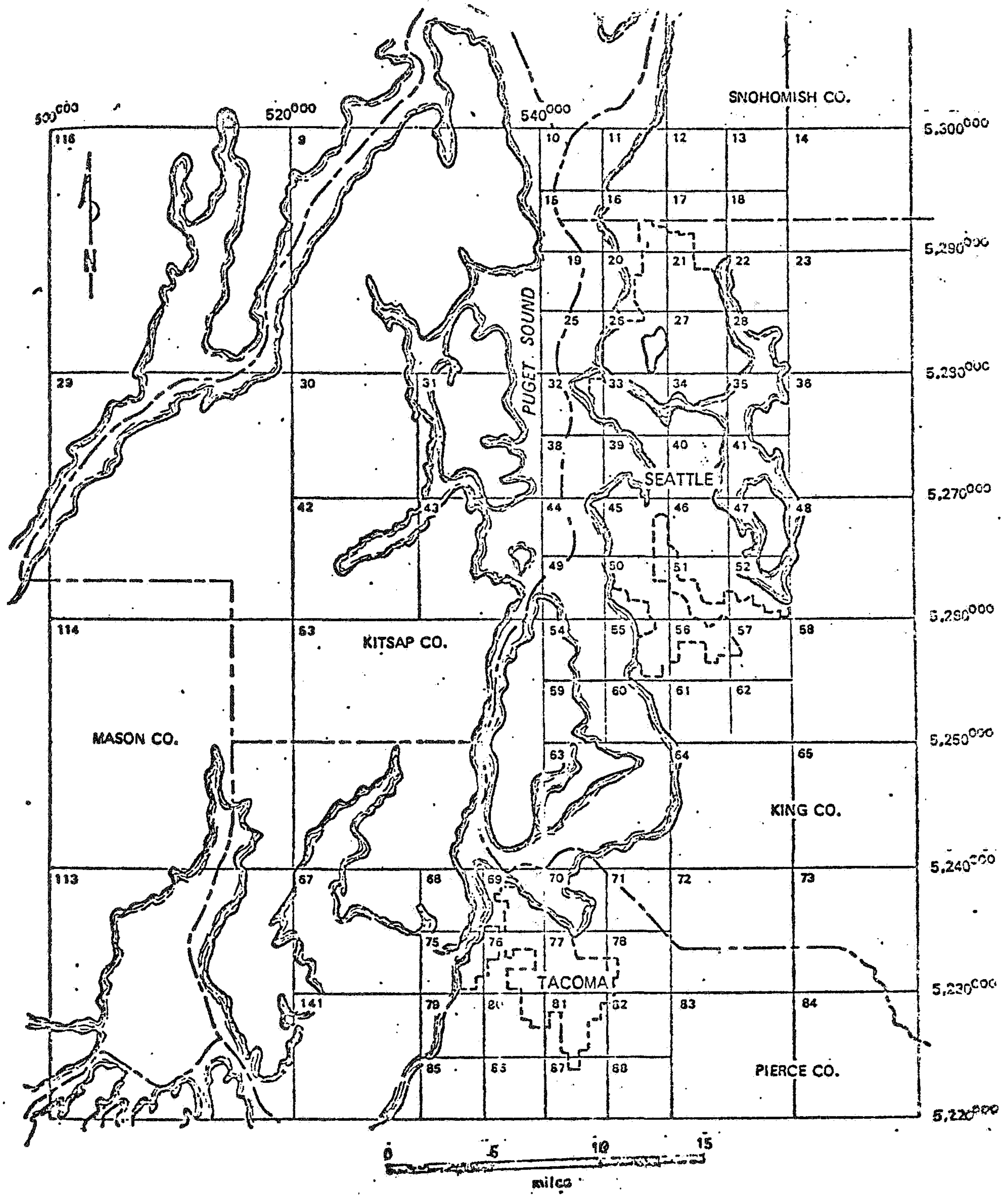


Figure 4-1.1. GRID COORDINATE SYSTEM.

Appendix 4-2

DETAILS FROM EMISSION REPORTS ON VIOLATORS

The following are estimated emissions from 32 emitters, for whom BAAPCD has published specific data. Also included is a summary of SO_2 and NO_x emissions.

Source	Month	Part.	SO_2	Org.	NO_x	CO
A. J. Raisch Paving San Jose	6	0.1				
Amer. Brass & Iron Oakland	1, 4, 5, 6, 7	0.1			0.1	0.1
Allied Chemical Port Chicago	6	0.2	3.0			
Amer. Smel. & Ref. Crockett	6, 7	0.4	78.0	0.1	0.2	0.3
Berkeley Asphalt Berkeley	4	0.2				
Bird & Sons Crockett	6					
Calif. & Haw. Sugar Crockett	5, 6	0.3	3.5		2.1	0.3
C. B. Hobbs Corp. Milpitas	7	0.1				
Certain-Teed Prod. Richmond	7	0.2	0.1	0.1		
Chevron Chem. Co. Richmond	4, 6, 7	0.1			0.1	
Collier Carbon & Chem. Rodeo	7		3.6		2.3	
Economy Ref. & Service Oakland	6			0.6		
SUB TOTALS (Page 1)		1.7	88.2	0.8	4.8	0.7

Source	Month	Part.	SO_2	Org.	NO_x	CO
Fibreboard Corp. Antioch	7	0.4	2.2	0.1	0.1	0.1
FMC Newark	5,6	0.4			0.1	
Glass Containers Hayward	4	0.1			0.4	
Industrial Chem. Allied Division Richmond	5	0.5	28.0		0.1	
Ideal Cement Redwood City	6	0.5	0.1	0.1	5.0	2.0
Judson Steel Co. Emeryville	4,5,7	0.1				
Lloyd A. Fry Roofing San Leandro	4,5,6,7	0.3	0.2	0.1	0.1	0.1
Myers Drum Co. Emeryville	6			0.1		
Owens-Corning Fib. Santa Clara	5	0.3		0.2	0.5	
Owens-Illinois Oakland	4,6	0.2			2.0	
PG & E Martinez	5,7	0.9	5.4	0.1	2.7	
Pacific State Steel Union City	6	0.2			0.2	
SUB TOTALS (Page 2)		3.9	35.9	0.7	11.2	2.2

Source	Month	Part.	SO_2	Org.	NO_x	CO
Phillips Petro. Martinez	6,7	3.7	34.0	15.6	18.0	1.0
Plant Gro. Corp. Milpitas	6	0.2				
Safeway Stores Oakland	5	0.3			0.1	
Shell Oil Martinez	4,6,7	1.7	18.3	9.9	11.0	0.7
Standard Oil Richmond	4,5,6,7	3.6	39.1	21.1	23.7	1.5
Stauffer Chem. Co. Richmond	5	0.1	8.6		0.1	
U.S. Pipe & Foundry Union City	5	0.1			0.1	
Trumbull Asphalt San Leandro	6		0.1	0.1		0.1
SUB TOTALS (Page 3)		9.7	100.1	46.7	53.0	3.4
GRAND TOTALS		15.3	224.2	48.2	69.0	6.3
District 1969		160	330	941	194	956
Total 1969		201	351	1899	564	6164
% District		9.6	68.9	2.5	12.2	0.0

SO_2 SUMMARY--THE BIG TEN

District (1969)	330
Total (1969)	351

Source		Tons/Day	% Total
1.	Asarco	78.0	22.2
2.	Standard Oil	39.1	11.2
3.	Phillips	34.0	9.7
4.	Industrial Chem. Allied Division	28.0	8.0
5.	Shell	18.3	5.2
6.	Stauffer	8.6	2.5
7.	PG & E, Martinez	5.4	1.5
8.	Collier	3.6	1.0
9.	C & H Sugar	3.5	1.0
10.	Allied Chem.	3.0	0.9
11.	Fibreboard Corp.	2.2	0.6
	12-15	0.5	
Important sources not on violator list			
Sulfuric Acid Plants		70.9	20.2
Utility Co. Boilers		34.4	9.8
TOTAL		329.5	93.5%

TOP 30 EMITTERS COMPRISE >90% OF TOTAL SO_2 EMISSION

NO_x SUMMARY

District (1969)	194
Total (1969)	564

Source	Tons/Day	% District	Cum. % District
1. Standard Oil	23.7	12.2	12.2
2. Phillips Pet.	18.0	9.3	21.5
3. Shell Oil	11.0	5.7	27.2
4. Ideal Cement	5.0	2.6	29.8
Utilities (10)	38.2	19.7	49.5
TOTAL 91	150.00	78%	

Other categories of note:

Domestic home use	21.7	11.2%
Non-Auto. Trans. & Constr.	16.6	8.6%

Appendix 4-3

RIDING SHOTGUN WITH INSPECTORS
Summary of Gleanings in No Special Order

1. I rode with four inspectors in all, most of the time being spent with one in Richmond and a second in Oakland.

2. The job of the inspectors begins when the District gets wind of a new plant or part of a plant going in somewhere. They may notice a new stack going up. City and county building permits are required and may give the District leads on new sources.

3. The District is not empowered to require permits for emission equipment nor to specify what sort of control equipment must be used by emitters. An inspector will visit the new plant and try to suggest what lessons have been learned in the past by other companies. If the company does not do a good job of selecting and installing control equipment, they will be cited in violation later and that may cause them to change the equipment as a way of coming into compliance.

   The inspector said he thought that a permit system might help. Industry, he said, responds in a variety of ways to emission control problems. Some companies do a good job of planning ahead. Others head straight toward what looks like lowest immediate cost. In many cases the plant designers are not experienced in emission control design and so louse it up. Then the District has to do source testing, catch them on Ringelmann and hassle after the problem until it is fixed.

4. Ralph Warner's hell-raising with the citizens of Richmond appears to have had an appreciable impact. More inspectors are to be added to the refineries.

5. Richmond, in the opinion of one inspector, is the heaviest pollution area in California.

6. The effect of written violation notices on refineries and publication of cited offenders was greater than the inspector expected. He said it really shook them up.

7. A problem source in the refinery areas is what is known as a "scavenger plant". Apparently, it takes in SO_2 and dirty H_2SO_4 from the refinery and after processing sells it back to the refinery as clean H_2SO_4. Its stack puts out droplets of H_2SO_4, according to the inspector.

   It happened that when he was showing me the plant the plant manager came out. From informal conversation between the three of us I gathered that the manager does his best to keep things clean. If he gets cited it embarasses him with his higher management. The plant manager believes the process could be cleaned up for a price, but he is not in a position to make that sort of decision for the company. His feeling is that it would be fair to crack down harder on his company only if all their competitors were similarly hit. This would probably cause all the managements to clean things up further and customers would pay more for gasoline. This company has in the past been cited and published on the offender report.

8. Combined plumes at one fertilizer company make it impossible to catch them with a Ringelmann. The inspector isn't sure why that loophole exists. His guess is that if the same volume of crud came out of one stack it would look less dirty than it does in the combined plume.

9. More interesting about this particular set of stacks is that one of them recently had an afterburner installed on it and the plume of that particular one is invisible, while all the rest even though they are putting out the same thing, are highly visible. For that company this promises to make the public pressure go away even though the emissions do not.

10. The way Ringelmann works is by calibration of the inspectors' eyeballs every three months. This is done for both white and black smoke at the University of California field station. When an inspector makes a Ringelmann test he doesn't use a chart or any other equipment.

11. Another loophole turns out to be R and D smoke.

12. In-stack Bailey Smoke Meters are being used. For instance, Standard Oil has 17 of them in operation now in its Richmond stacks. One of the inspectors has actually written a violation notice based on the recorder chart data from one of these meters. He claimed that with what the meter was reading there had to be an excessive Ringelmann. He thinks the company decided not to fight it at this point but may choose to later.

13. Standard is also operating two laser beam smoke detectors.

14. When a company phones in a breakdown that is occurring they get off the hook only if it is the pollution control equipment that broke down. Some inspectors may be more liberal, but at least one says that when he hears of a breakdown he tries to zip out to the company and if it is being caused by the wrong thing he cites them. He doesn't feel this deters the company from reporting its breakdowns because they will get worse flak from him if they don't and he catches them.

15. All the inspectors I talked to seemed to be in favor of tighter standards.

16. With more inspectors assigned to oil companies, one inspector said he thinks they can do an appreciably better job. There is a fine little gadget for sniffing hydrocarbons (it doesn't discriminate between reactive and non) which he would like to tote around the piping and valves to apply Reg. 3. (The gadget is made by Johnson and Williams in Mountain View.)

17. He would like similarly portable and easy to use sniffers for SO_x and H_2S. Telemetered information from remote meters around certain company sites would also be desirable in his view. Shell, he says, has such SO_2 meters (portable).

18. H_2S regulations would also be nice to have and he thinks they will come. Right now this man makes his own sensors out of beer cans and sets them up in sensitive spots. When a refinery triggers these alarms he gives them a hard time about their H_2S even though the law isn't clearly behind him. He says the companies know this but respond anyway because they can see such laws coming.

19. Another loophole is that when ships are ordered by the Coast Guard to "pop their valves" as part of the Coast Guard's inspection they may put out a lot of smoke and not be cited.

20. Another loophole is that moving ships are not cited, only stationary ones.

21. Every person who complains is contacted by the District. One inspector estimated that approximately 50% are contacted by phone and the other half in person. Every complaint is followed up on and checked out by an inspector. I rode along on one such complaint, which turned out to be an apartment house incinerator. When we got there it was no longer smoking. The inspector said that several complaints had been received on this one and he has been trying to check at a time when he might see the smoke. Unless he does, he can't cite it.

    His suspicion is that the cause of the smoke is that the man who burns the apartment's trash for them doesn't separate the plastics well enough because the load of garbage is too big for him to handle alone in the time he has. When the manager said "without this incinerator operating, we'd really be in trouble", the inspector asked why. "Because it would cost us more money to have it hauled away".

22. Having more citizens ride shotgun as I did would raise hell with his job in the opinion of one inspector. Pointing things out and answering questions slows him down. He cannot require companies to admit strangers when he goes in to make inspections. And there are questions about what is being emitted from stacks which the present respect of proprietary secrecy policy would not allow him to describe.

23. The inspector generally has no idea how much pollutant comes from his area or from a given stack. One of them wondered if I thought there was some way that would help him do his job better because he couldn't see how it would. Moreover, it seemed to him that if such knowledge led him to push harder on larger emitters that would be unfair. (Under the present rules I agree.)

24. The policy of the inspectors I rode with is to write up every violation they can. They expect that even if these are not prosecuted now they will form part of a useful body of evidence for the future as crackdown gets tougher.

25. The citation notice looks sort of like a traffic ticket. It can be sent through the mail, but one inspector told me he prefers to submit every one personally and explain why he wrote it. The man I watched him hand one to squirmed pretty hard (a junk dealer), saying he was trying to do all he could, he didn't know he was smoking, his employee must have made the mistake, cars make most of the pollution anyway, the small businessman can't hardly survive anymore, he'd like to get rid of his whole business, the inspector should have pointed out the smoke to his employee so the employee would understand, etc. But he still got the ticket.

26. The inspector believes that although not many tickets lead to fines now, more of them will in the future. He takes the potential $6,000 max on fines recently passed seriously and doesn't think it just a gesture. He once left this District and went to another where he said followup on compliance was not pushed as hard. This he didn't like and so he came back here.

27. One company with problems on his beat is one which re-processes drain oil from car crankcases so it can be used again. The premises stink and the company has employed 6 college students for the summer to clean and repaint things. But the stink won't go away.

28. How does an inspector spend his time? The man I asked hesitated to estimate percentages but guessed that the rank order from most to least was roughly as follows:

    1. Reinspections of control equipment to check proper functioning.
    2. Issuing violation notices and making first inspections.
    3. Following up on complaints.
    4. Patrolling to look for dirty plumes, etc.

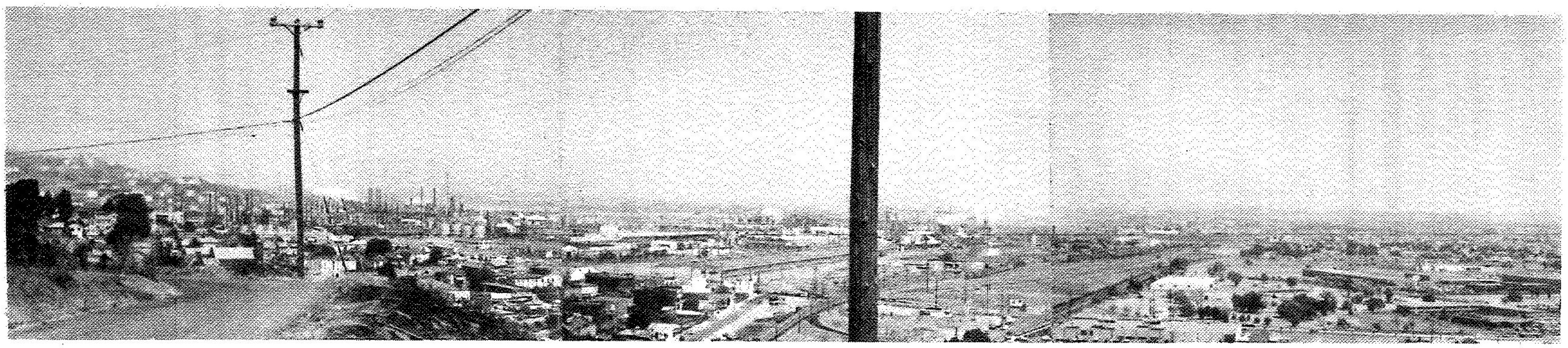
    He said that during a salary survey some years ago a more detailed study of inspectors' activities was made, but he didn't recall the distribution.

29. Airplanes can be cited by the District if they exceed Ringelmann 2 for more than 10 seconds.

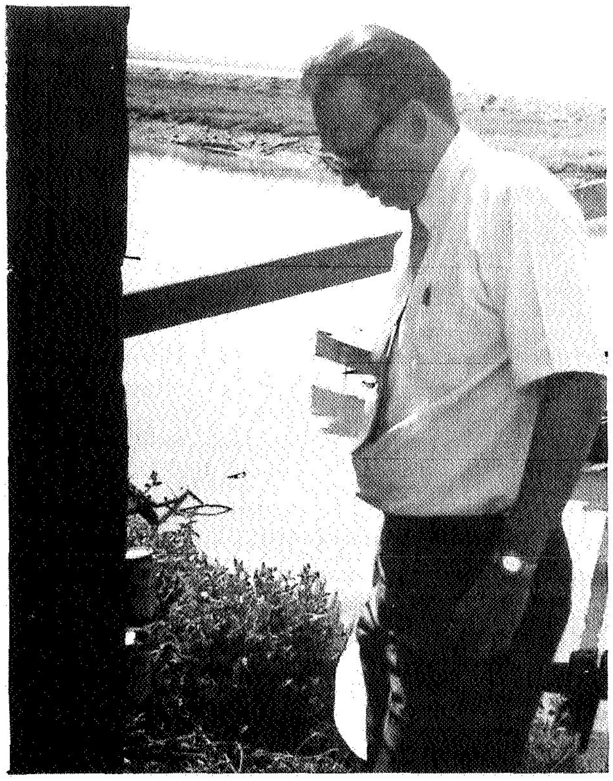
30. Another loophole is that this only applies to single county Districts.

31. Of the 4 inspectors I rode with 2 were former employees of refineries and 2 were former policemen.

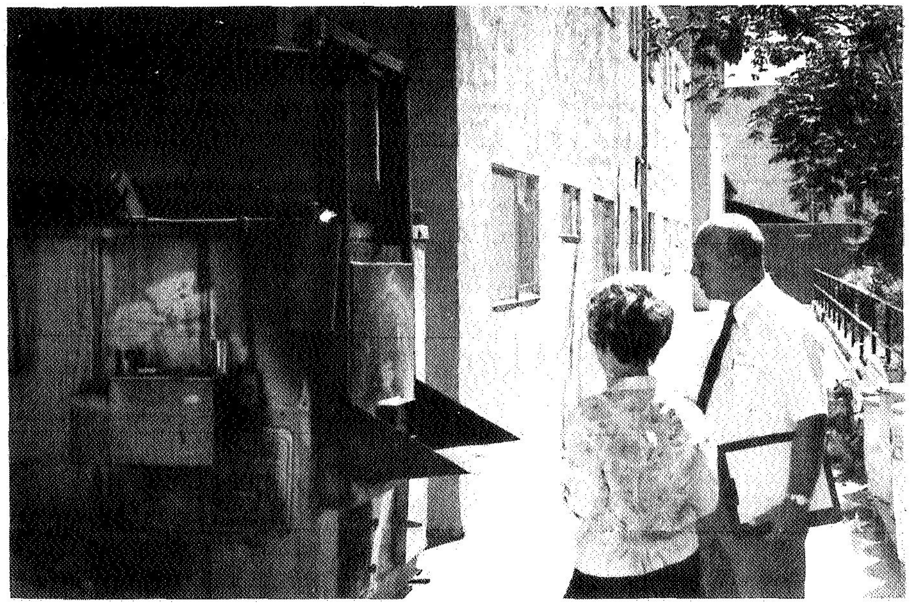
32. In general my impression was that these men like their work, enjoy taking an adversary position relative to the companies they deal with because they have a high respect for their "opponents" and find it challenging, enjoy continually learning more about the game, and take satisfaction from winning rounds. They try to be tactful with the emitters but are in no way obsequious. They would like to see tighter regulations and they aren't worried about these working undue hardships on companies. My overall feeling was that this phase of the District's operation is run well and ready to move on with future progress in other areas.



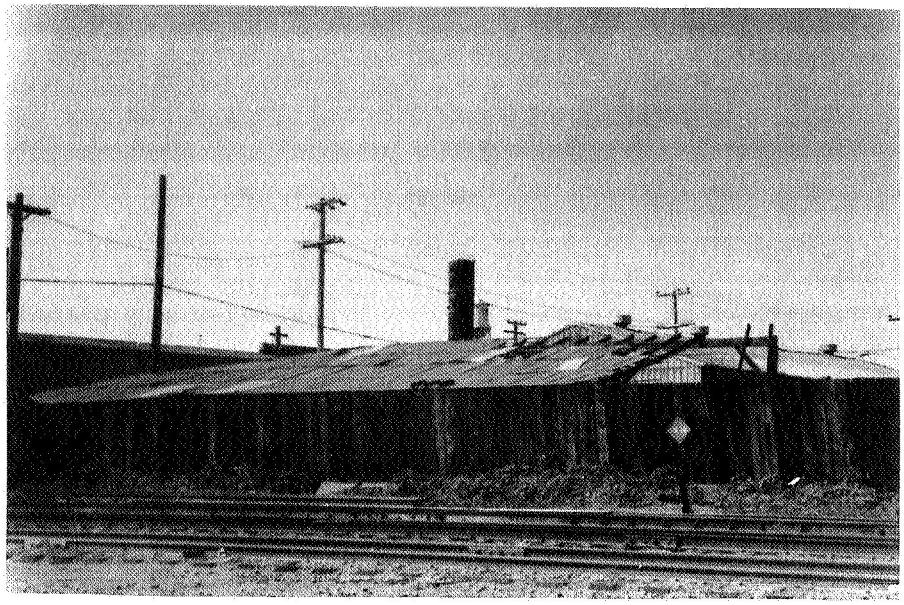
Some Overall Shots of the Richmond Refinery Area.



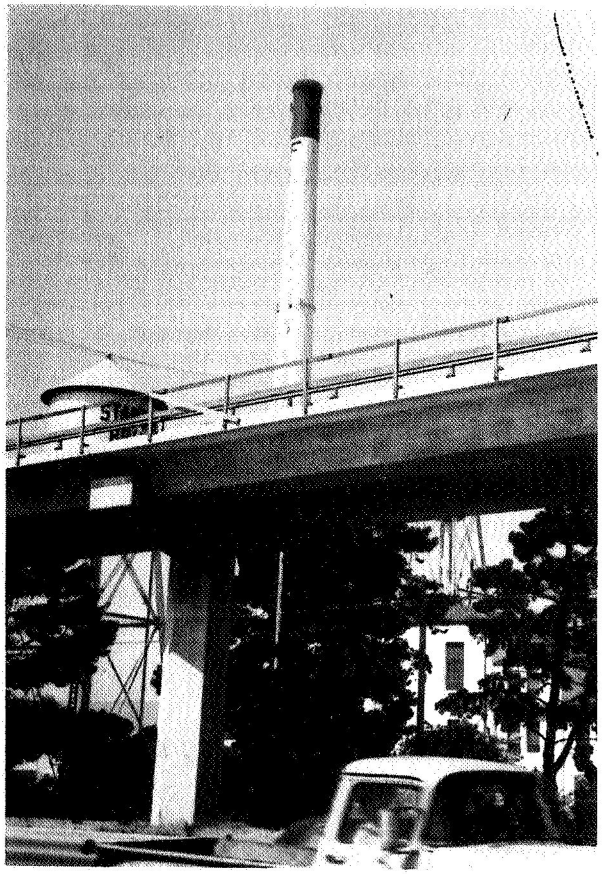
Inspector Initiative. This is a home-made H_2S Detector made out of beer cans. (Some inspectors use oil cans, but this one likes Ranier.) Although there are no legal enforcement provisions for H_2S at present, the inspectors put monitors like these around and beat on companies that put the stuff out.



Inspector Investigating a Complaint that this Apartment Incinerator was Smogging. His hunch was that the man who dumps their cans is overloaded to the point where he can't adequately separate out all the plastic and it gets in and smogs. The apartment manager at left said it would be uncomfortably expensive to have the garbage hauled away. Because the stack was not smoking when we got there, no citation was issued.



The Same Inspector had Issued a Citation Earlier in the Day on this Scrap Metal Company. The stack which had smoked (burning the insulation off of copper wire to reclaim the copper) is the stubby black one in the center. The citation was issued while the stack was smoking, but the operator of the incinerator didn't want to sign it. So the inspector came back (with me) later to present it to the company president who then did sign it.



The Inspector Called this one Ringlemann 1.

This he Called about Ringlemann 2½. He has cited the plant before, but did not at this time because he thinks the company got one a couple of days ago and is meeting with the District to discuss it and work out a compliance schedule this afternoon.

Appendix 5-1

A TEST OF LINE-INTEGRATED AMBIENT AIR POLLUTION DETECTION*

Introduction

The use of gas concentration data, obtained by a spatially integrated gas detection system, as representative of the air quality of a given area is now being advocated. To test the validity of this type of data, an experiment was undertaken by Environmental Measurements, Inc. to compare them with data simultaneously measured by a currently-accepted point monitor technique. This report describes that experiment.

Objective

The objective of this experiment was to compare and contrast the data measured by an NO_2 line-monitor system set up in a typical urban environment with the data obtained by an NO_2 point monitor system currently in operation as part of a standard air quality monitoring station.

Equipment

The line-monitor system used was a Barringer Correlation Spectrometer (Figure 5-1.1) and associated separate light source (Figure 5-1.2). The light source was a Varian Associate Xenon illuminator chopped at a 7.4 KHZ rate. The spectrometer was tuned to accept this modulation frequency and to reject daylight interference. There were no special requirements at the light site other than a 117 volt 60 HZ electrical outlet. Installation time was less than one hour.

The point monitor was the Saltzman NO_2 detection system currently in use by the Bay Area Air Pollution Control District at their main laboratory, 939 Ellis Street, San Francisco.

Location

One end of the line path was the Ellis Street office of the BAAPCD. On two separate three-day periods, the Barringer Correlation Spectrometer was set up in a fifth floor laboratory and aimed at the Xenon light mounted on top of downtown buildings in a standard long-line configuration (Figure 5-1.3).

Two line sites were selected for this experiment (Figure 5-1.4). The first line was southward between the Ellis Street laboratory and the California State Automobile Association building diagonally across Van Ness Avenue. The second was eastward toward the YMCA Hotel on Eddy Street almost perpendicular to Van Ness Avenue.

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*A paper by Anders F. Jepsen, Environmental Measurements, Inc.

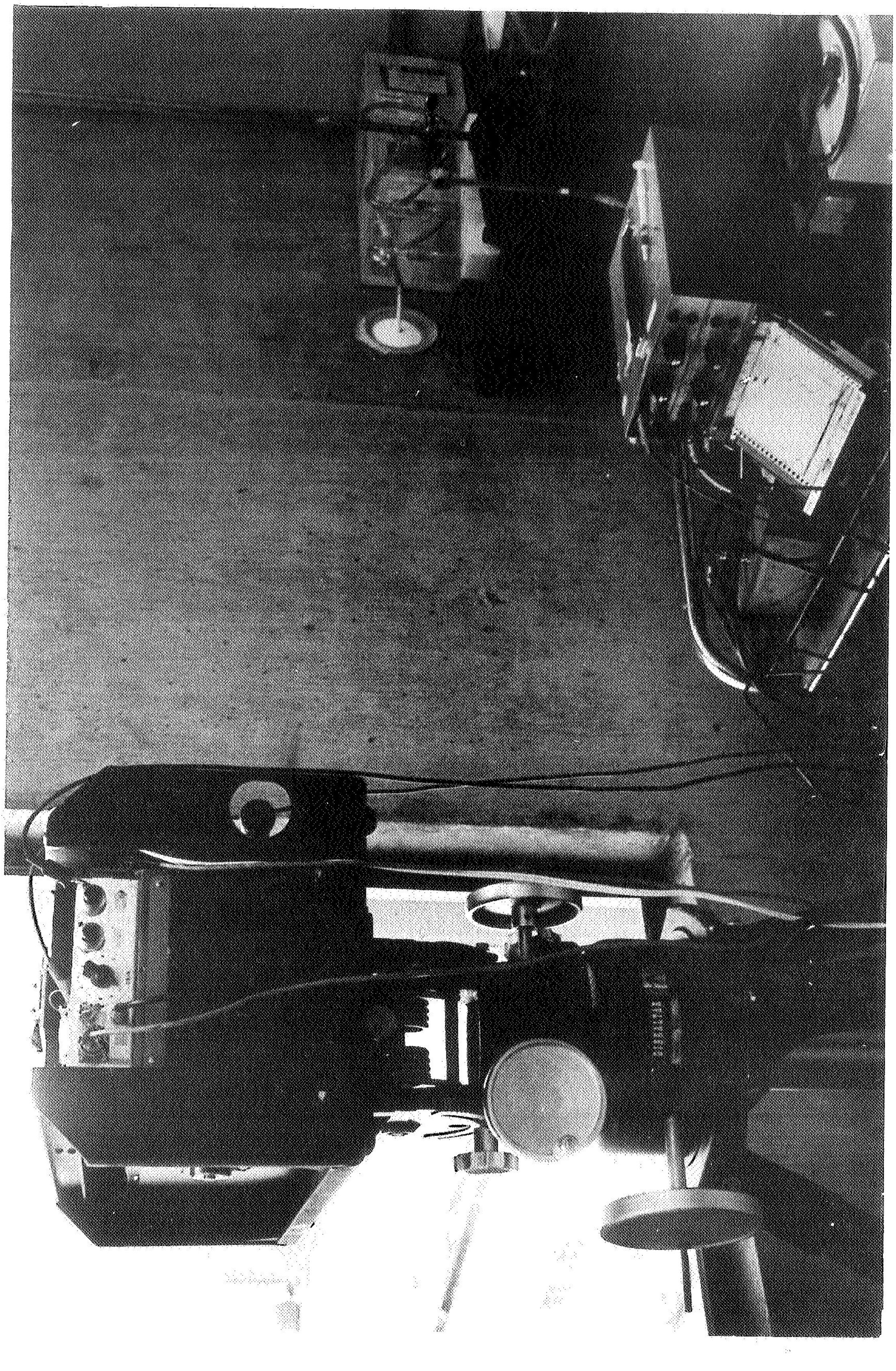


Figure 5-1.1. BARRINGER CORRELATION SPECTROMETER.

Figure 5-1.2. MODULATED LIGHT SOURCE.

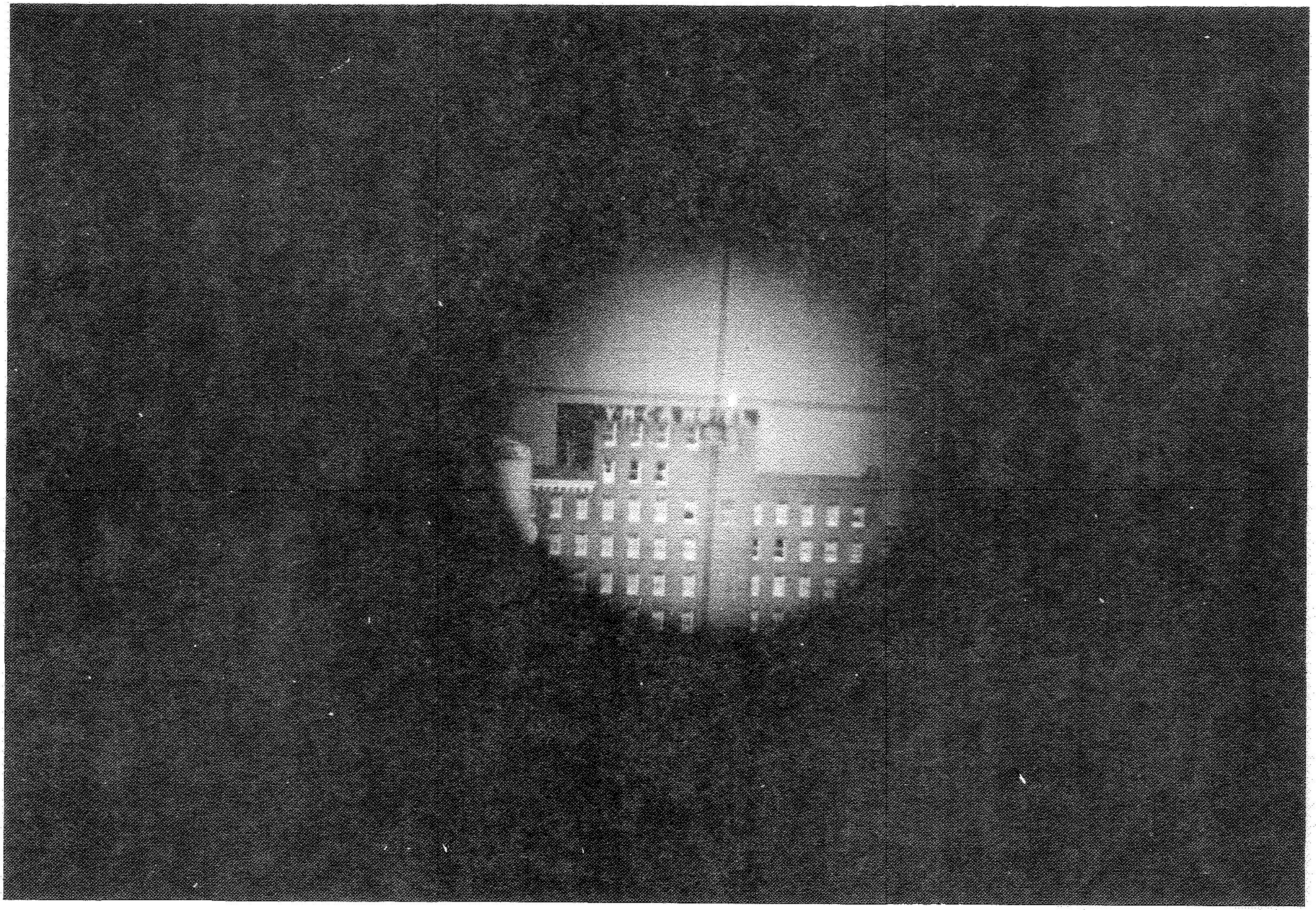
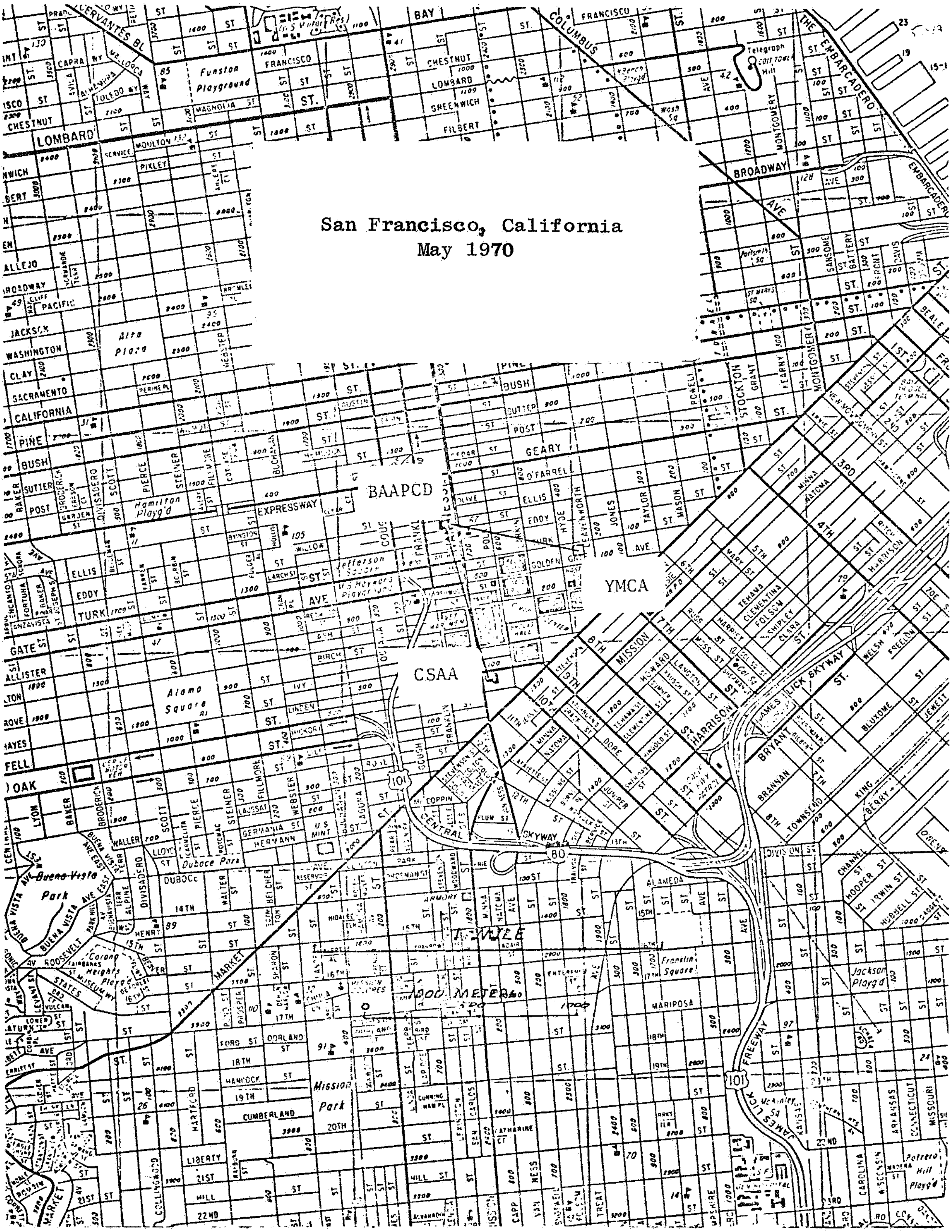


Figure 5-1.3. SIGHT ON LIGHT LOCATED ON YMCA ROOF-TOP.



Basic map reproduced by permission of the California State Automobile Association, Copyright Owner.

Figure 5-1.4. LONG-LINE PATHS NO_2 AMBIENT AIR MONITOR.

Results

Because of the almost instantaneous response of the Barringer Correlation Spectrometer compared to the relatively slow (20 minutes for 90%) response of the point monitor, the data were not expected to agree in time. Therefore, for one test the comparison was made between one-hour averages of both the long-line and point monitor records; for the other, both data sets were obtained by scaling the record at one-half hour intervals.

First Data Set

The data from the interval 15-17 May, when the long-line was almost directly along Van Ness Avenue, are displayed in Figure 5-1.5. Both long-line and point monitor data were scaled directly from the

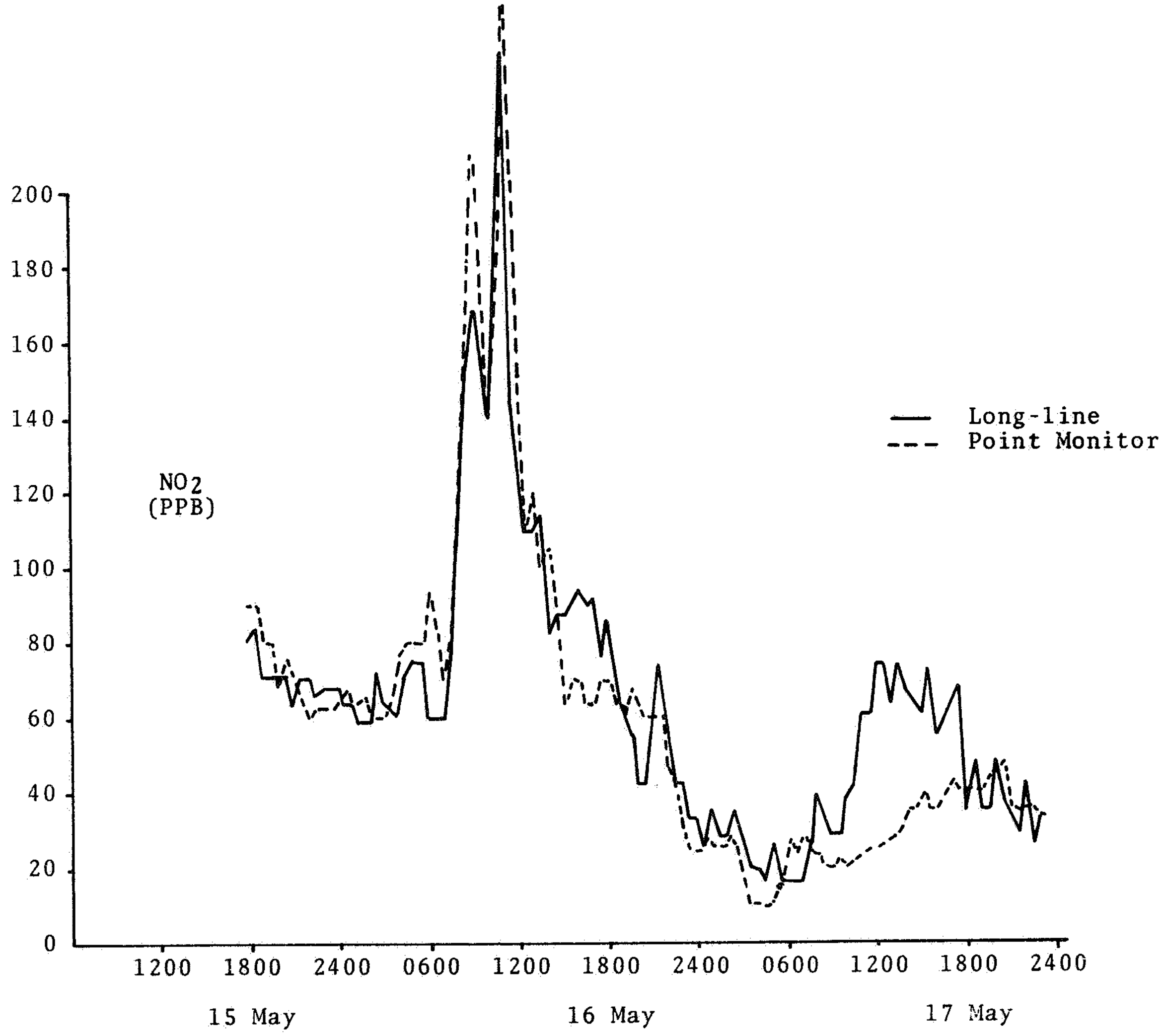


Figure 5-1.5. LONG-LINE VS POINT MONITOR NITROGEN DIOXIDE CONCENTRATIONS. BAAPCD-CSAA, May 1970.

records and show approximately the same peaks and troughs for part of the period, but the magnitudes are often quite different. The long-line data sometimes show larger peaks and sometimes smaller.

The major similarity between the two sets of data is the low NO_2 level in the nighttime hours and the high levels in mid-morning. The double-peaked morning event was detected by both systems, and the amplitudes of the two peaks are fairly similar, although the lesser peak at 0900 on 16 May is much larger on the point data than on the long-line data.

The major difference between the two sets of data is the lack of a high morning level in the point data on 17 May, a Sunday, while the long-line data does detect such a high peak. The Sunday high level was of lesser amplitude than on the previous day.

The long-line data also displays short term variations of greater amplitude than found in the point data. This is explained by the fast response time of the system.

Second Data Set

The data from the interval 22-24 May, when the long-line was perpendicular to Van Ness Avenue, are displayed in Figure 5-1.6. In

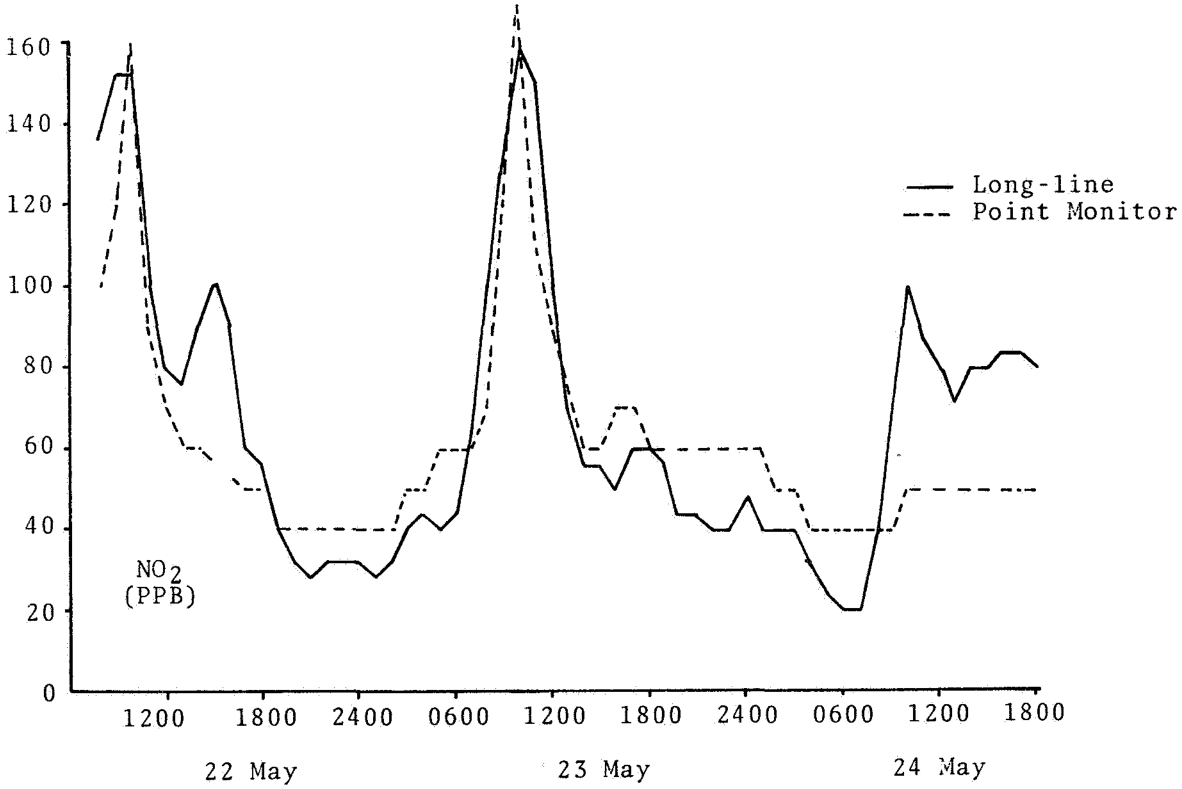


Figure 5-1.6. LONG-LINE VS POINT MONITOR NITROGEN DIOXIDE CONCENTRATIONS. BAAPCD-YMCA, May 1970.

this figure, the hourly averages calculated by the BAAPCD were used to display the point data rather than numbers scaled directly from the record. The long-line data was similarly treated for purposes of comparison.

As in Figure 5-1.6, the data from the two detection systems both show high NO_2 levels in mid-day and low NO_2 levels at night. The calculation of hourly averages effectively smooths both sets of data.

There are some major differences between the point and long-line data for this interval. On 22 May, a fairly substantial peak NO_2 concentration was detected in the late afternoon on the long-line system. This peak was not observed on the point data. The point monitor was inoperable for two hours during this event, and the low readings to either side of the off-time are perhaps also in error. During the early morning of 24 May, the long-line system reported a fairly low average concentration while the point monitor indicated that the NO_2 level was twice as high. A peak which was detected at mid-day on 24 May (a Sunday) by the long-line system went undetected by the point monitor.

Discussion

This experiment has compared the output from two very different air monitoring techniques. The point monitor yields time integrated data at a single point and has a delayed response to changes. The long-line monitor, with a rapid response, yields spatially integrated data which can also be averaged over time. Thus, differences between the resulting two sets of data are to be expected.

For most days, the systems both detected a high NO_2 level at mid-day and a low in the night. However, on the two Sundays of measurement the long-line system reported an NO_2 peak at mid-day which the point monitor did not detect. The lower long-line NO_2 peak on Sundays probably correlates with reduced automobile traffic. The lack of a peak in the point monitor data may indicate that the in-take pipe was located in such a position that on the Sundays it was upwind of the area of NO_2 build-up.

The 22-24 May data shows that the hourly-averaged point data was significantly lower in the afternoon on the 22nd of May and higher on the 23rd. This might reflect changing wind conditions. Whatever the cause, the long-line data did yield significantly different average NO_2 concentrations from the point monitor.

No effort has been made to correlate these two sets of data with the wind conditions which prevailed. It should be noted, however, that the dominant movement of air was from west to east, and that sources of gas upwind of the site were obviously influential. Furthermore, until more data have been gathered simultaneously over a wider area, one can only speculate on the effect specific stationary sources and local traffic patterns have on the ambient NO_2 concentrations.

Conclusions

1. Because of the basic differences in sampling method, the Barringer Correlation Spectrometer Long-line Configuration yields significantly different data from a wet chemical NO_2 point monitor. Because of the possibility that the point monitor was not located at the most representative site, it is suggested that the long-line data is more representative of local air quality.

2. The fast response of the long-line monitor provides a more accurate measurement of variations in NO_2 level than does data currently obtained with the point monitor.

3. Arrays of long-lines using mirrors would extend the area which could be covered by a single spectrometer. Thus, the sources of NO_2, be they particular traffic-laden streets or stationary sources, could be detected and their specific effect on ambient NO_2 levels under varying weather conditions could be studied.

Acknowledgments

The cooperation of the Bay Area Air Pollution Control District, the California State Automobile Association, and the YMCA Hotel are gratefully acknowledged.

Another Test with the Barringer Correlation Spectrometer, August 11, 1970

The Barringer van and the BAAPCD van were driven through San Francisco to Crockett and back. The Barringer van monitored SO_2 total burden on the trip east, NO_2 total burden coming back west. The BAAPCD van monitored point levels of SO_2, CO and oxidant at all times using standard techniques. Wet chemistry was used for SO_2 and oxidant, thus response time was slow. The Barringer NO_2 reading was compared with the BAAPCD measurement at Ellis Street on returning.

Results: Low level SO_2 was seen by both instruments. The Barringer showed about 20 ppm-m. A peak of about 50 ppm-m appeared on the Barringer leeward of PG & E. A peak was also shown by the BAAPCD van, but the response was too slow to make a comparison.

The Barringer showed NO_2 burdens varying from 10 ppm-m to 70 ppm-m. Changes of 20-30 ppm-m within a block or two were common. The Ellis Street reading was 0.06 ppm when the Barringer outside read about 60 ppm-m. If 0.06 ppm were the average concentration to the inversion layer and no NO_2 existed above within the range of the Barringer, the inversion height must be 1000 meters. However, the weather bureau reported an inversion height of 113 meters at Oakland. Thus, it seems that there are higher than ground level concentrations of NO_2 aloft.

Other: The Barringer has been used in direct line measurements of NO_2 using the blinking light for 3 days running. Comparison with Ellis Street readings are good. Some incidents are seen which were not seen by the BAAPCD, but the highs and lows were nearly identical.

Appendix 5-2

COST FOR AN EXPERIMENTAL MOBILE STATION

For the first year conversion of the mobile unit, the pollutant instrumentation required will be the NO_2-SO_2 spectrometer, and the total HC analyzer. A complete meteorological system will be required since the van is not presently instrumented for these data.

The cost of correlation spectrometer for NO_2, SO_2	$15,000
Total HC analyzer	2,700
Meteorological data, Dry and Wet Bulb temperature, wind velocity and direction	2,000
Retractable tower for above	1,000
Analog to digital converter and tape punch, 15 channels	6,500
Installation of equipment in van, voltage regulator, conversion from gasoline to LPG for low emissions	2,500
TOTAL COST OF REFURBISHING OF VAN	$29,700

Appendix 5-3

RECOMMENDATION FOR AN EPISODE WARNING SYSTEM

A proper episode warning system must act as a controllor system. If done properly, based on anticipation of dangerous levels such as 0.40 ppm, the public should be warned and proper action taken so that the danger level will never be reached. It is therefore recommended that the following episode control system be implemented.

(1) At the close of each day (by 5 p.m.) the episode control officer shall deliver to the Chief Administrative Officer (CAO) his prediction of the following: 1 - whether the State health standards will be exceeded on the next day for any pollutant, 2 - whether the possibility of reaching the episode level exists if no controls are placed on the system.

(2) If the episode control officer indicates a possibility that either of the two can occur, the CAO will notify the PI & E officer who shall notify the news media so that the public can be warned. If the prediction is for dangerously high levels, such as 0.40 ppm oxidant, the public will be requested to postpone non-essential auto travel on the following day.

(3) On the day itself, the PI & E officer shall notify the press when the first warning level is reached. This first warning level shall be the state health standard and for oxidant it shall be 0.10 ppm oxidant on an hourly average.

(4) If the oxidant level of 0.40 is reached it shall be considered a danger level, and warnings shall be transmitted to the media warning children not to play outside and ordering all non-essential traffic off the streets.

(5) At the close of the day, the episode control officer shall report to the CAO if his prediction failed, and indicate what data were lacking or misleading and how the error can be prevented in the future.

(6) In addition to the 24 hour forecast, the episode control officer shall, at the end of each day, and especially on Friday, report to the CAO his predictions for the evening and for the weekend. He shall recommend to the CAO which stations shall be manned during the evening or over the weekend, and shall authorize overtime for the attendants.

(7) The alert system shall be publicized so the public will know what to expect when the alert is called.

Appendix 5-4

RINGELMANN ALTERNATIVE

Introduction

Presently the Ringelmann test (Regulation 2) is used to limit the emission of particles from stationary sources. The Ringelmann test prohibits smoke darker than Ringelmann 2. The disadvantages of using the Ringelmann test are:

(1) It requires a trained observer and is subjective

(2) It requires the proper background

(3) It requires the sun to be in the proper position

(4) It does not work in the dark

(5) It can not be used if the humidity is greater than 60 per cent

(6) It can not be used if the plume contains water vapor

(7) It is not suitable for non-black smoke

(8) It can not be used for combined plumes

(9) It is not suitable for automation.

All these difficulties are primarily caused by two things: first, measurements must be made external to the stack; second, the Ringelmann test requires a human operator to make visual judgements.* If emissions are regulated, instead, on the basis of optical transmittance measurements inside the stack, the difficulties enumerated above would be alleviated. In addition, optical transmittance measurements can determine the size distribution of the particles as well as their number.

Current Optical Transmittance Instrument

Many of the large stacks in the Bay Area are monitored by in-stack densitometers manufactured by the Bailey Meter Co. (Wickliffe, O.) (the Baileymeter); these densitometers have been installed by the industries at their own volition.

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*The District itself is fully aware of these shortcomings and has requested research funds to develop a plume opacity under which would remain many of the faults of the Ringelmann test. Unfortunately these funds have not been granted.

The Baileymeter is a photoelectric densitometer which measures the amount of light transmitted through the stack gas inside the stack. It uses a sealed beam lamp as an optical source and a bolometer as a detector. The meter is calibrated by means of neutral density filters and shows good agreement with the Ringelmann system.

The Baileymeter operates in the infrared region (1 to 2 microns) and is not able to obtain an estimate of the number of particles going through the densitometer nor does it obtain any information on the particle size distribution.

Improved Densitometer

If the optical transmittance of the stack gas is measured at several wavelengths (instead of one band as in the Baileymeter) it is possible to estimate the particle size distribution as well as their number.

In this section the theory of an improved densitometer is discussed and the design of an appropriate instrument is presented.

Theory of Operation

The number of particles in a gas can be determined by measuring the optical transmittance of the gas with a calibrated densitometer. The Lambert-Beer law relates the number of particles to the transmittance T as

$$T = \frac{\text{Light flux received with particles present}}{\text{Flux which would be received if particles were not present}} = e^{-(naQ\ell)}$$

where n = number of particles per unit volume, ℓ = the path length, a = projected area of one of the particles, and Q = the extinction coefficient. If the particles are of different size and extinction coefficients, then a summation of the different values of a and Q must be made.

The extinction coefficient Q depends on the particle's refractive index, its shape, and the wavelength of the light. The extinction coefficient can be calculated by means of the Mie theory for spherical particles, Figure 5-4.1. For large particles $d \gg \lambda$, where d is the particle diameter and λ the wavelength, Q approaches 2 for both spherical and non-spherical particles and for all values of refractive index different from the transporting gas. For d on the order of the wavelength, Q reaches its maximum value of about 3 or 4 depending on the exact composition of the particle. For d much less than the wavelength, $Q \propto d^4$ and approaches zero rapidly.

For non-spherical particles, the Q curves are similar to those for spherical particles except in the resonant region where $d \simeq \lambda$ where the maximum will not be as prominent and the rise to the maximum will be slower.

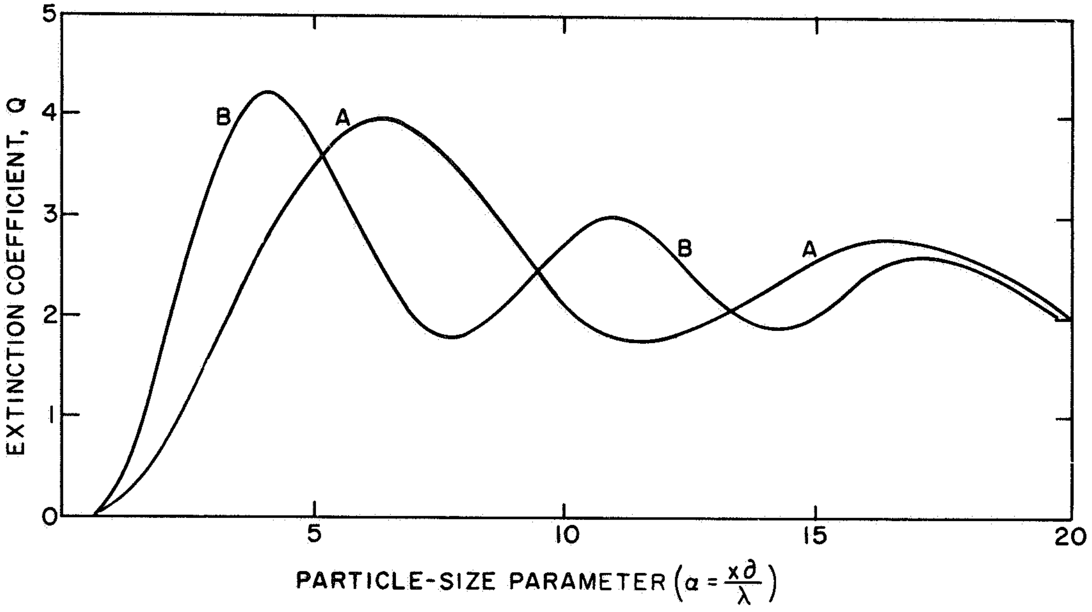


Figure 5-4.1. EXTINCTION COEFFICIENT FOR SPHERES.

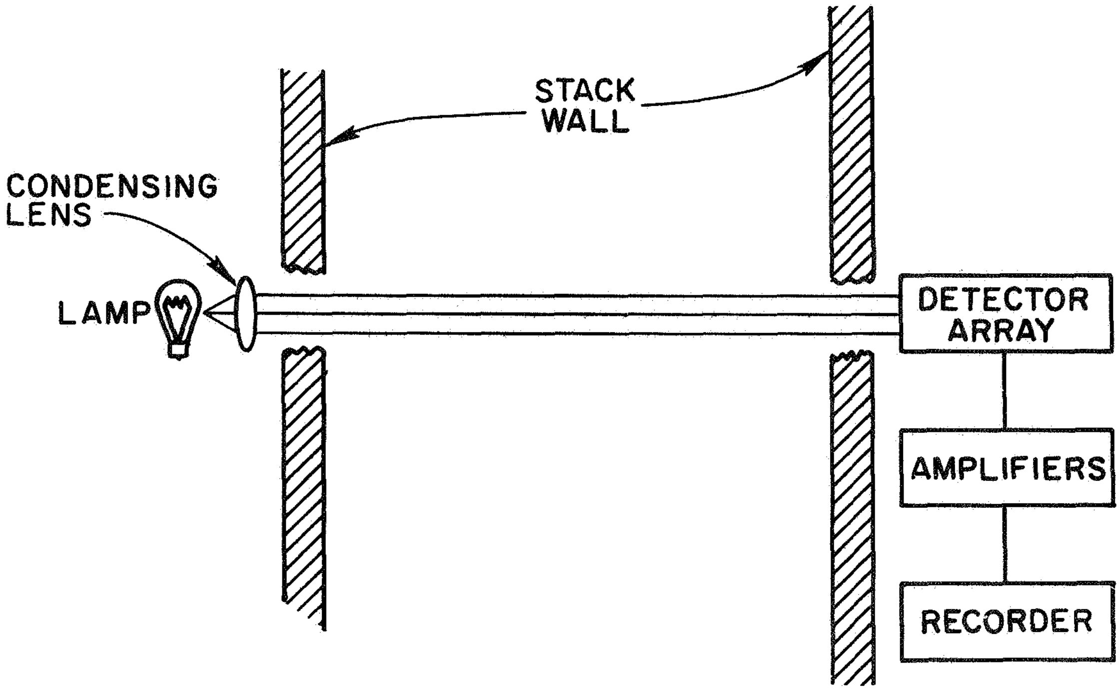
If the particle transmittance is found to vary with wavelength, then an estimate of the size distribution and the number of particles can be determined by comparing the measurements with the theoretical values of Q. If the transmittance does not vary with the wavelength, Q may be taken equal to two and the area-concentration (a • n) may be determined.

Instrument Design

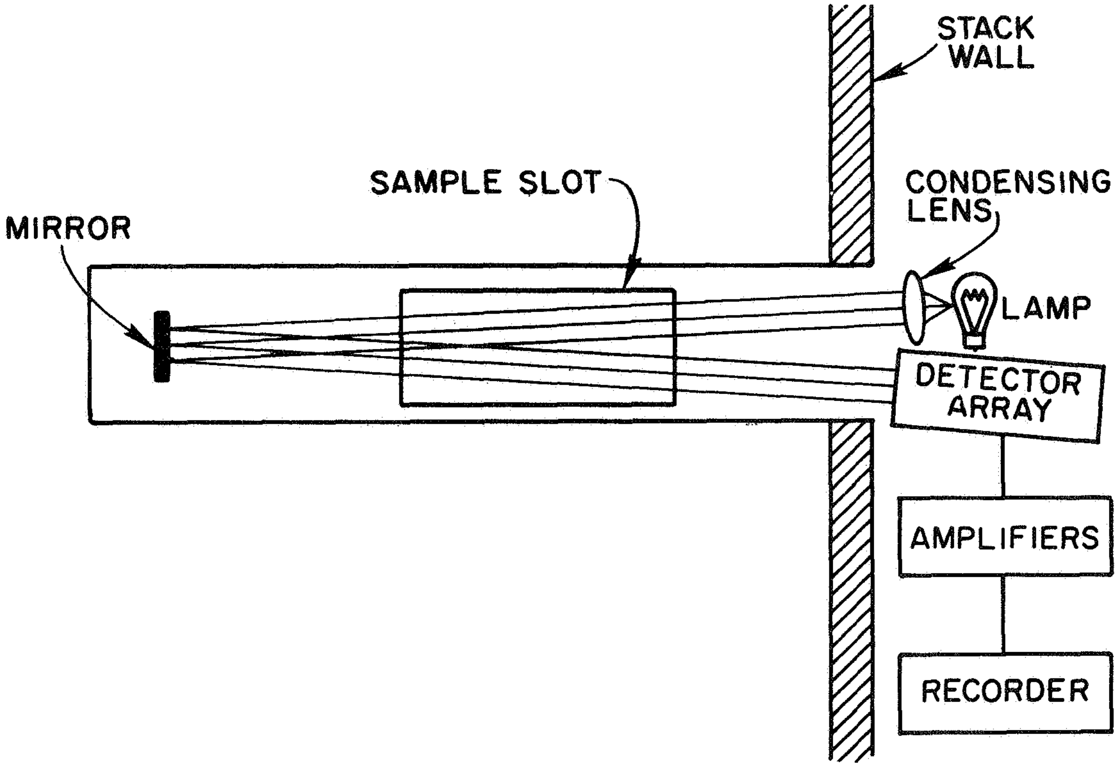
To determine the size distribution of the particles as well as their number it is necessary to make transmittance measurements at several different wavelength. The best measurements are obtained when the wavelengths used are on the order of the particle size. In this section the design of a suitable multiple wavelength densitometer which operates at five wavelengths from UV to IR is presented.

Physically the densitometer consists of a light source, a detector, electronics for the detector, and a recorder. Figure 5-4.2 shows two possible mounting configurations for the densitometer. Figure 5-4.2a is across stack mounting with the light source on one side of the stack and the detector on the other so the density of the stack gas flowing up through the stack can be measured. Figure 5-4.2b shows a configuration which can be inserted into the stack from one side, in this case the light travels in a shielded enclosure so that the affects of turbulence in the stack can be reduced.

The densitometer considered here works in the near ultraviolet to the near infrared region. For this band of wavelengths it is possible to use a tungsten lamp as a source. The wavelength distribution of light from a tungsten lamp is shown in Figure 5-4.3; the envelope of



a. Across stack mounting.



b. In stack mounting.

Figure 5-4.2. TWO POSSIBLE STACK MOUNTING METHODS.

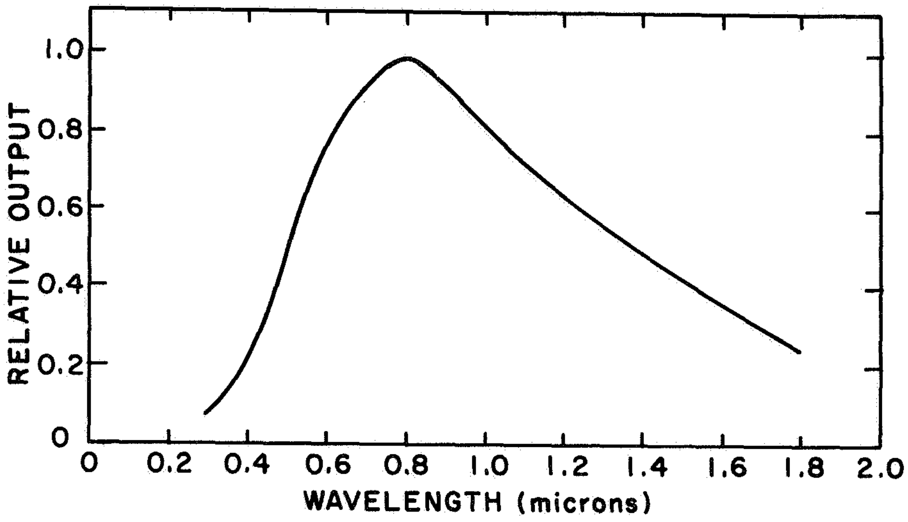


Figure 5-4.3. RELATIVE OUTPUT OF A 3.400°K TUNGSTEN LAMP.

the lamp, and the other optics, must be constructed from a material which will pass the wavelengths being considered (Glass Technology Inc. BSC-2 for example).

The detectors are sensitized to particular wavelengths by means of glass filters. Figure 5-4.4 shows the five particular filters proposed and their relative transmissions; these filters peak at 0.34 μ (UV), 0.44 μ (blue), 0.53 μ (green), 0.65 μ (red), and 0.8 μ (IR). The filters are placed over the photosensitive surface of the detector so that the detector will respond only at that wavelength.

Two types of photocells are necessary for detectors. Figure 5-4.5 shows the relative response of selenium and silicon photocells. The selenium cell is to be used with the UV, blue and green filters; the silicon cell is to be used with the red and IR filters. The photocells and filter can be arranged as in Figure 5-4.6.

Figure 5-4.7 shows schematically the construction of the densitometer. The output of each detector goes to an amplifier with variable gain so that the densitometer can be calibrated. The output of the amplifiers goes to a meter which indicates the present transmittance of the stack gas and to a recorder which provides the data logging.

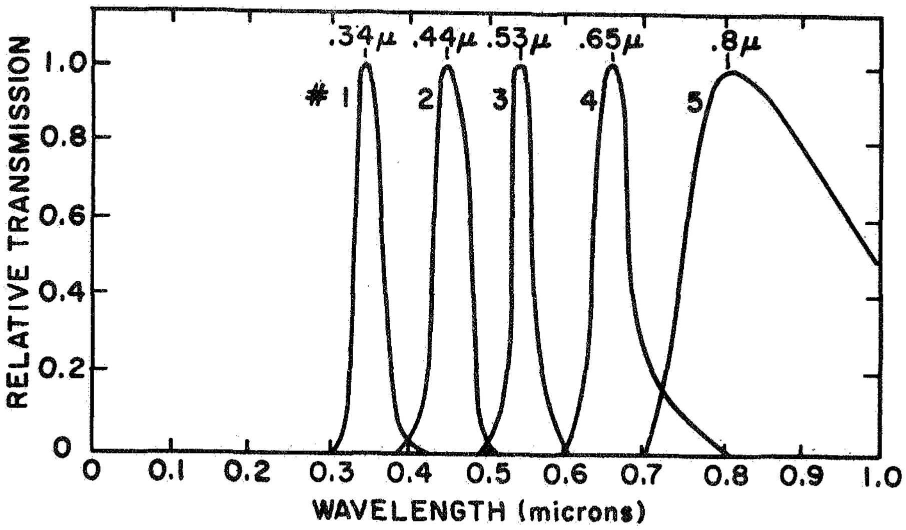


Figure 5-4.4. RELATIVE TRANSMISSION OF GLASS FILTERS.
#1 Ultraviolet transmitting (Corning 7-60)
#2 Blue filter (Eastman Kodak No. 47)
#3 Green filter (Eastman Kodak No. 58)
#4 Red filter (Eastman Kodak No. 29)
#5 Infrared transmitting (Corning 7-69)

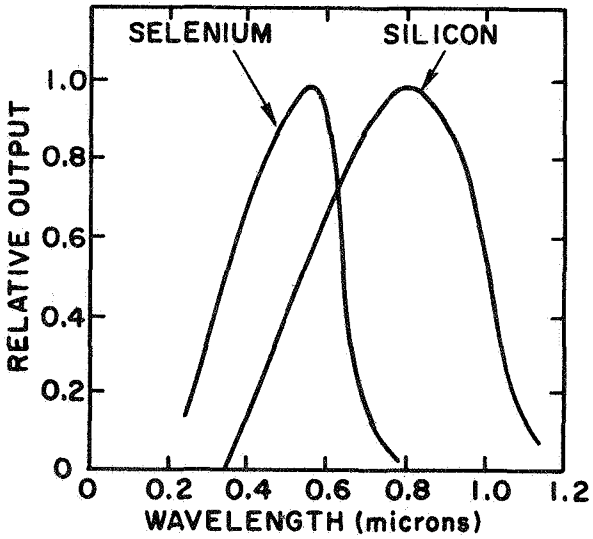


Figure 5-4.5. SPECTRAL RESPONSE OF PHOTOSENSITIVE MATERIALS.

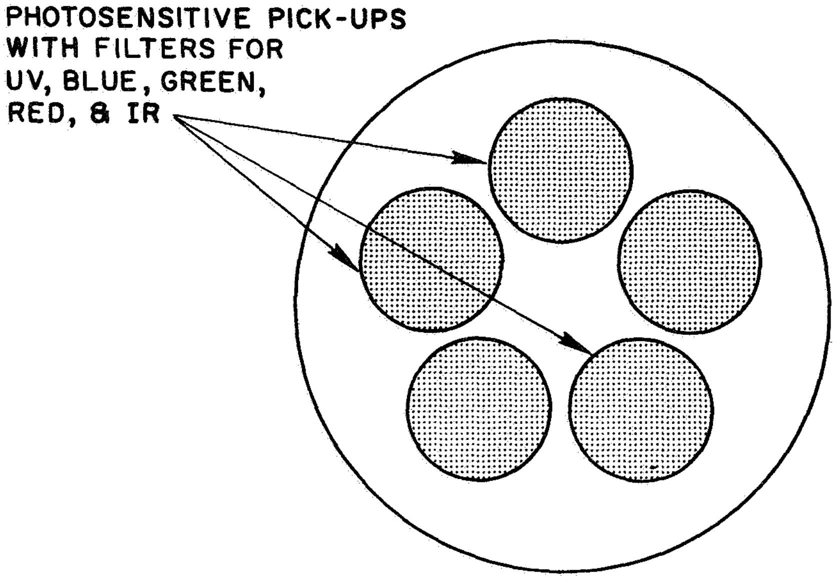


Figure 5-4.6. END VIEW OF DETECTOR ARRAY.

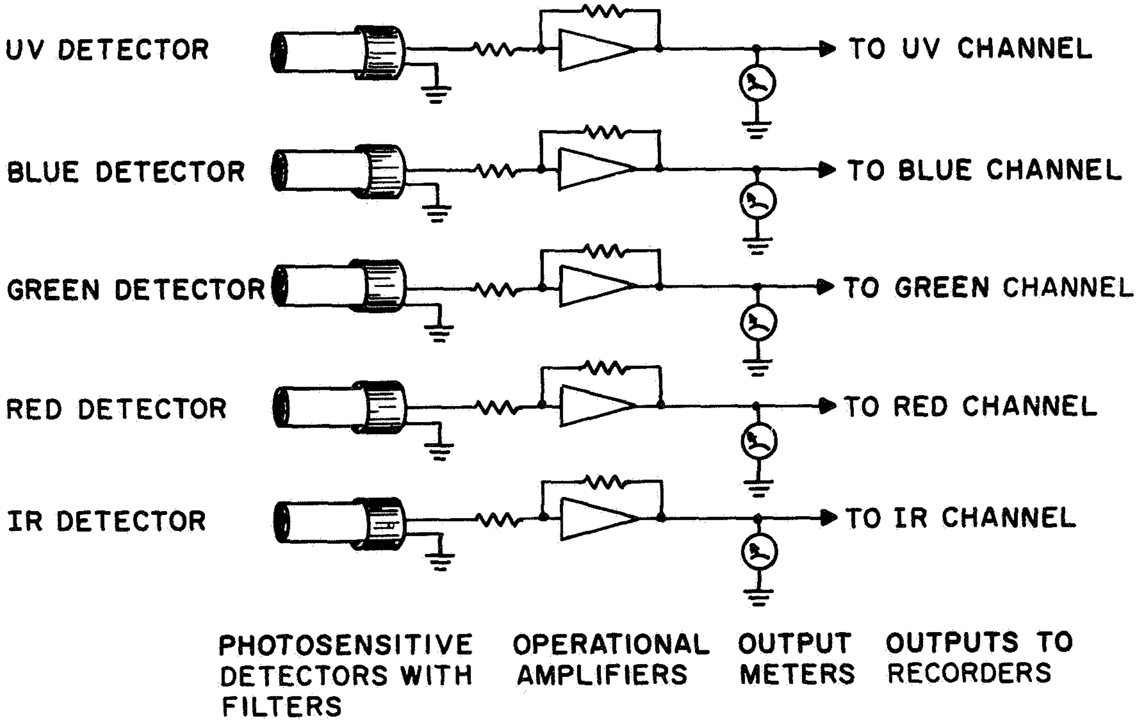


Figure 5-4.7. SCHEMATIC DIAGRAM OF MULTI WAVELENGTH DENSITOMETER.

The cost of the densitometer can be determined as follows.

Source		
Lamp	$ 8.00	
Housing	10.00	
		$18.00
Detector (6)		
Photocells	6.00	
Filters	6.00	
Housing	10.00	
Labor	12.00	
		$34.00
Electronics		
Amplifiers	18.00	
Meters	60.00	
Case	20.00	
Labor	12.00	
		$110.00
		$162.00

This corresponds to an estimated sales price of $500 in quantities of less than 5000 units.

Comments

The densitometer above operates at five wavelengths from 0.34 μ to 0.8 μ. It would probably be better if the more measurements were made in the IR region. Because of materials and absorption of oxygen, operation a densitometer operating at less than 0.2 μ is unlikely.

It may be necessary to protect the lamp and the detector with air curtains.

Appendix 6-1

THE METEOROLOGY OF THE BAY AREA AND ITS EFFECT ON THE AIR POLLUTION PROBLEM

The meteorology of the Bay Area is quite complex because of several interacting systems. The topography of the Bay Area produces a wide variety of meteorological conditions and climate in a relatively small area. An oceanic climate is produced over much of the Peninsula while much higher temperatures occur over the land mass to the east. Summer afternoon temperatures near Sacramento often exceed those of San Francisco by 50°F. Winter temperature inversions due to radiation from the earth's surface are more pronounced on the east side of the Bay Area than over the Bay or the Peninsula. Cold, moist, maritime air flows into the area from the west through the Golden Gate and through breaks in the mountains. This cold, dense air tends to be trapped in the Bay Area by the surrounding mountains. The top of this dense layer of air is usually less than 2000 feet above mean sea level, and the layer becomes quite thin at higher surface elevations.

A semi-permanent high pressure area is usually present over the eastern part of the Pacific Ocean. This high pressure cell moves to the north in late summer and back to the south in winter. The position of this high pressure area tends to block rain producing frontal systems from the California coast, especially during summer. Strong surface heating over the interior of California, Arizona, and Nevada produces a rather permanent low pressure area to the east, with maximum heating and pressure reduction during the late summer. A pressure gradient thus exists from west to east producing the strongest average winds in summer. Radiation cooling from this large land mass, especially in winter, produces strong nighttime surface temperature inversions and a reduction in the west-east pressure gradient. Surface winds are thus reduced in velocity concurrently with the maximum temperature inversions.

This high pressure area usually extends over the Bay Area. As a part of the general world circulation pattern, it is a subsiding air mass during most of the year. This subsidence produces heating and very nearly a dry adiabatic temperature lapse rate, approximately 5.4°F per thousand feet of elevation, above the 2000 foot level. A strong temperature inversion is thus produced with warm, dry air above a layer of cold, moist, stable air. This subsidence inversion is most pronounced in summer, but there is some combined effect of radiation and subsidence inversions throughout the year.

Because of the effects of terrain and local heating, the height of the inversion is quite variable and poorly documented (the only radiosonde readings regularly available for the Bay Area are obtained twice daily at Oakland for 0400 and 1600 PST). These readings indicate that the height of the inversion at Oakland is frequently 1400 feet or less in summer and only 300 feet in winter. Although the inversion persists most of the summer and only about 15% of the time in winter, the winter condition is much more serious from the viewpoint of a pollution accumulation near the surface. Winter ventilation is poor, especially at night, because of the low pressure gradient. Winds are light and variable one-third of the time during the winter months at the San Francisco International Airport. With a low ceiling, or lid, due to the inversions of 300 feet or less above mean sea level, there is little opportunity for movement of the pollutants out of the Bay Area to the east and south because of the terrain. Surface inversions frequently occur in the Bay Area in winter. Six years of data at Oakland show surface inversions for 15 days in December, 23 days in January, and 8 days in February (Smalley). Inspection of the radiosonde data obtained at Oakland for the years 1962-64 indicates a persistence of low level inversions. These persistent inversions at levels below 500 feet and lasting for periods of from two to four days tend to occur three or four times per year.

Air pollution and low visibility in the Bay Area are not limited to a well defined "smog season". Records obtained from the Bay Area monitoring station indicate a significant number of high readings in winter and fall months. For example, December 4-7, 1968 was a four-day period of low visibility and severe pollution associated with a low ventilation. On December 5, a particulate pollution maximum was recorded at six stations, the CO peak at Richmond was 28 ppm, and San Francisco and San Rafael recorded NO_2 peak values of 0.28 ppm. The records show that this four-day period was not an isolated occurrence. In February 1967, for example, San Jose had 128 peak hours with nitrogen dioxide readings in excess of 0.10 ppm and 115 such high hours in January. At San Francisco, the 1967 high periods with nitrogen dioxide readings in excess of 0.10 ppm totaled 62 hours in January and 40 hours in November. In Redwood City, the 1967 peak occurred in October with 106 hours in excess of 0.10 ppm.

Although surface inversions do occur, it is doubtful that they persist throughout the Bay Area for the entire day or on consecutive days. However, a 300 foot lid can reasonably be assumed with persistence for at least three days. The stagnation situation will do little to move the pollutants from the area during such a three-day period. Existence and persistence of inversions below 300 feet for three or more days with poor ventilation, low visibility, and high surface air pollution levels have been shown to occur during the winter months. Data are not adequate to prove continuity of the inversion over the entire Bay Area or to show that there is no break in the inversion during the twelve hour period between soundings at Oakland. The unfortunate lack of temperature and inversion data in the lower atmosphere can only be overcome by obtaining more information with additional stations in the future. Observation of clouds and sky conditions from the surface or from aircraft gives some indication of temperature inversions aloft. Likewise, high surface temperatures indicate likely locations of breaks in the inversion, but additional radiosonde soundings of the lower atmosphere are essential for any accurate estimate of atmospheric conditions. One suspects that the inversion heights and strengths are frequently quite variable over the Bay Area, but there is no way to substantiate or contradict this with the present inversion data.

With surface heating during the afternoon over the land mass in the eastern part of the Bay Area, breaks may occur in the inversion and allow some ventilation through the lid. Such breaks in the inversion would be expected in summer and may also occur in winter. More data are needed to document the existence of thermal convection through the inversion. In spite of the lack of data, a knowledge of the meteorology involved allows confidence that no break occurs in the inversion when Oakland data indicates a three-day inversion of 300 feet.

With a surface inversion, a common winter situation in the Bay Area, one might assume from the theory involved that all pollutants emitted would indeed lie on the ground or very near the surface. Such is hardly the case however. Even though the wind is light and variable, mixing does occur near the ground as a result of movement over and around surface obstacles. This mixing normally occurs in the lower 200 feet or so above ground level. Severe situations may occur, however, when almost no mixing occurs for six hours or so and the pollutants do indeed lie almost on the surface of the ground with the top of the layer at less than fifty feet. This condition has frequently been observed and photographed in connection with plumes from stacks.

Appendix 6-2

AN ATMOSPHERIC PHOTOCHEMICAL REACTION MODEL

A significant factor to consider, when modeling the effects of various emission sources upon the ambient air quality, is that very few of the contaminants emitted into the air are chemically inert, or nearly so. Chemical reactions among a number of pollutants are triggered by sunlight energy in the ultraviolet range, while a number of other reactions require only thermal energy. Therefore, it is not sufficient to consider how a pollutant is transported by prevailing meteorological effects from one point to another; one also must ask the question, "How much has been consumed, or generated, by chemical reaction?" Air pollution in California is largely the result of photochemical reactions; to a lesser extent this is also true on the East Coast.

For chemical reactions, the rate of reaction is proportional to the concentration of reactants:

$$\frac{dC_i}{dt} = k(T)C_i$$

where the concentration C_i of chemical component i changes with time t through a rate coefficient k(T), which is parametrically dependent upon temperature T. The dependence of concentration of a chemical species as shown above indicates: (1) not only is the amount of contaminant changing with time, but so is the rate of reaction itself, and (2) since concentrations may be expected to vary with distance from an emission source, spatial-dependence must also be considered in the reactions.

The form of the equation above may be used to express either a rate of formation, or a rate of decomposition, depending only upon whether the sign prefixed to the right hand side is positive or negative. Then,

$$\begin{matrix}\text{Net Rate of} \\ \text{Appearance}\end{matrix} = \begin{matrix}\text{Rate of} \\ \text{Formation}\end{matrix} - \begin{matrix}\text{Rate of} \\ \text{Decomposition}\end{matrix}$$

This equation points out another principle: there are a number of ongoing chemical reactions in the atmosphere, such as the photolytic cycle involving the oxides of nitrogen (see Figure 6-2.1). Without the addition of pollutants such as hydrocarbons and excess amounts of nitric oxide, the rates of formation and decomposition for ozone would be equal. Ozone concentration would therefore remain at some low level, in spite of the fact that it is simultaneously being formed and decomposed at very high rates. For primary pollutants, i.e., those which are directly

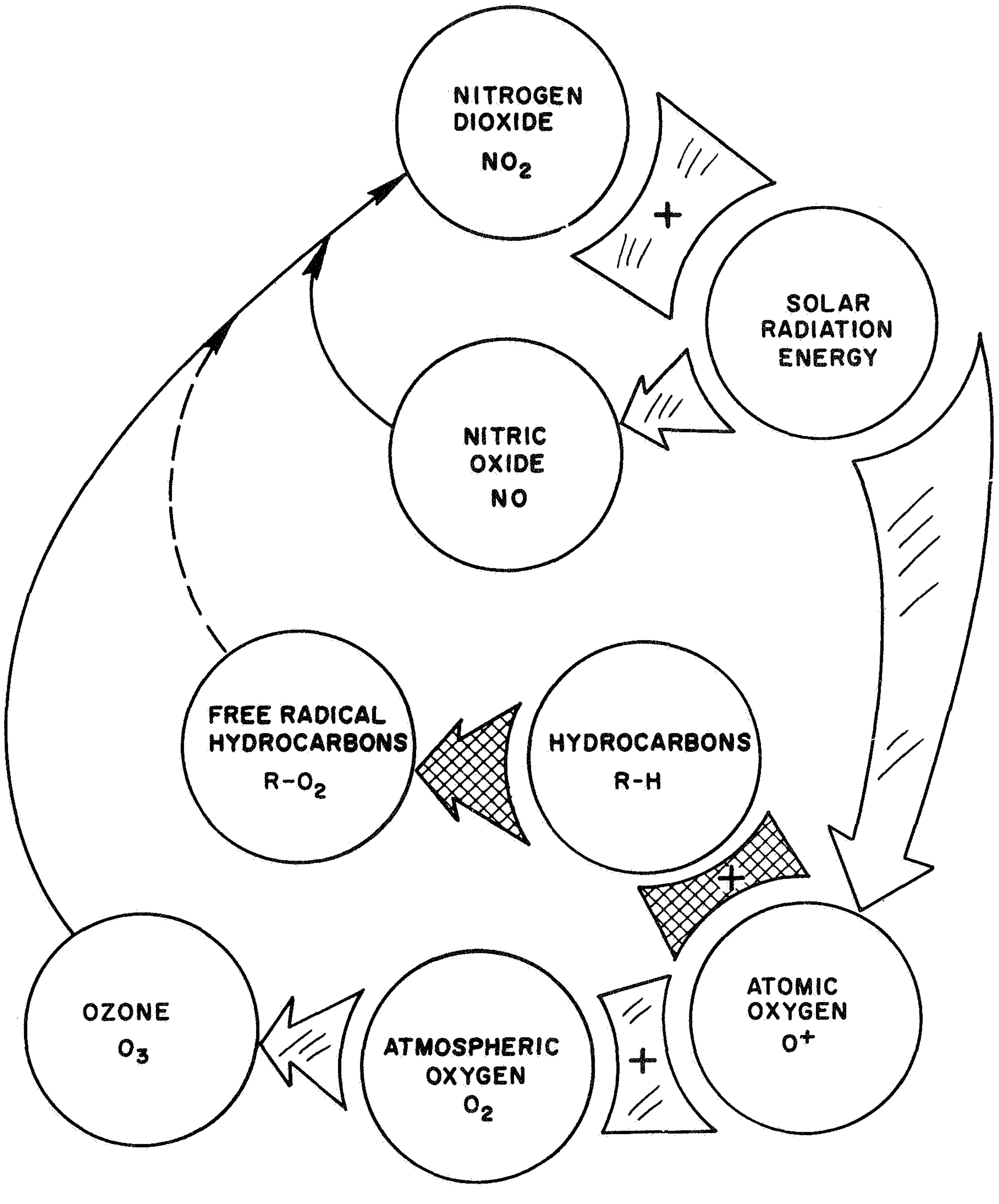


Figure 6-2.1. ATMOSPHERIC NITROGEN DIOXIDE PHOTOLITIC CYCLE SHOWING INTERACTION WITH HYDROCARBONS.

emitted into the atmosphere, it is sufficient to consider the rate of decomposition; while for secondary pollutants (those formed as a result of chemical reaction) it is necessary to take into account the rates of both formation and disappearance. It must be noted, especially in the ozone example, that small differences between formation and decomposition rates cause a sizeable concentration build-up.

There are several characteristics of photochemical reaction systems which present some difficulty in any modeling effort; some of these are listed below.

1. A large number of chemical components is involved. This arises from the involvement of hydrocarbons in the nitrogen-oxygen photolytic cycle (Figure 6-2.1). In addition to a number of different hydrocarbon components, the problem is further confounded by formation of hydrocarbon free-radicals which proliferate.

2. Computations for even a modest number of chemical components are a sizeable undertaking for even a large computer.

3. The reaction mechanisms for the major steps in the photolytic cycle are known, but those involving many of the hydrocarbons are still the subject of research. Least understood is the role played by free radicals.

4. Related to the variety of hydrocarbons is the different degree of reactivity of various hydrocarbons (see Figure 6-2.2). The more reactive hydrocarbons disappear more quickly, and while usually present in smaller quantities, conversely form compounds with orders of magnitude greater irritant capability than slowly-reacting compounds (see Figure 6-2.3). As an example, it was recently confirmed that peroxy-benzoyl-nitrate (PBzN) is 200 times the eye-irritant that formaldehyde is, making it the worst known such offender. It is produced by reaction between benzaldehyde and ozone, two common secondary pollutants. There are undoubtedly other such polynuclear aromatic hydrocarbons which have not as yet been identified.

One method which can be used to simplify the photochemical model is to ignore the spatial variations of chemical composition and examine only the time-dependent behavior. This leads to a "pot-type" reactor in which perfect mixing is assumed with uniform concentrations, or homogeneity. The ordinary differential equations which result are straightforward and the only computational difficulty is the number of equations, from number of chemical species, which must be coupled to reflect interactions. A more rigorous approach includes the spatial-dependence of concentrations as well, resulting in the "tubular" reactor wherein composition differs at each point in the reactor, i.e., a composition profile may be constructed. This latter approach therefore involves non-linear partial differential equations, and a significantly greater degree of computational difficulty.

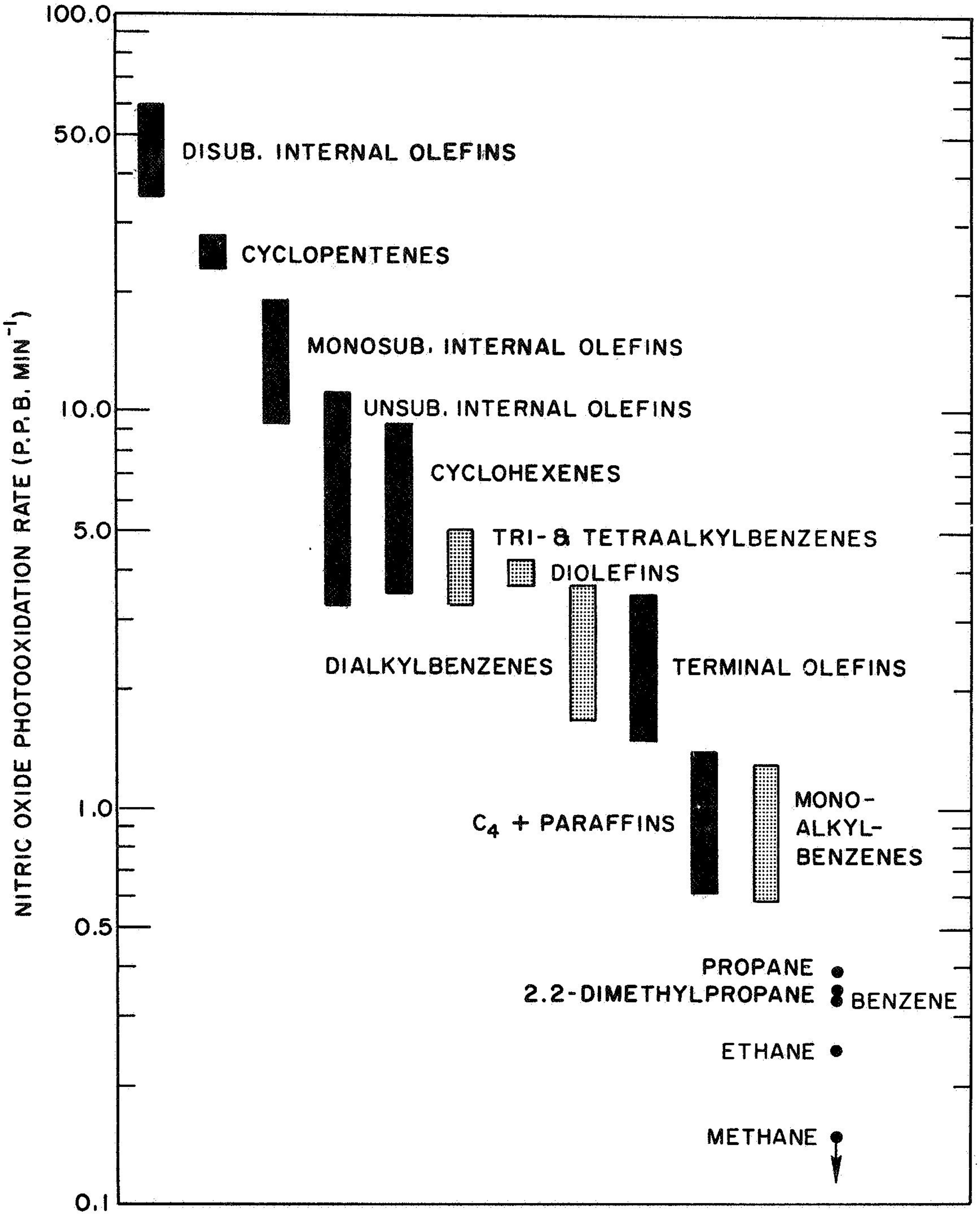


Figure 6-2.2. PHOTOCHEMICAL SMOG REACTIVITY OF VARIOUS HYDROCARBON TYPES.

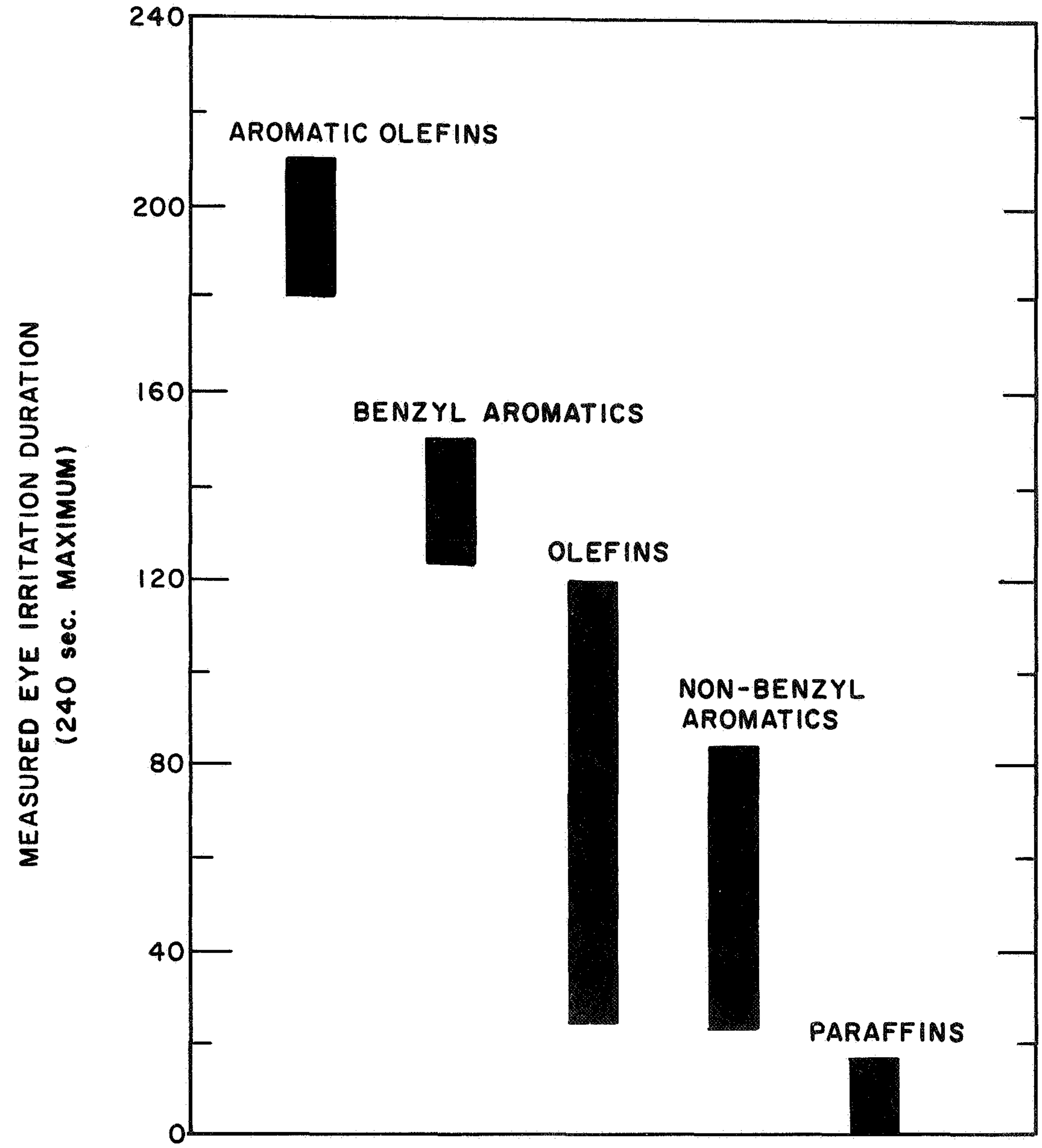


Figure 6-2.3. EYE-IRRITATION PROPENSITIES OF PHOTOCHEMICAL SMOG PRODUCTS FROM VARIOUS HYDROCARBON TYPES.

For the present work, the "pot" reactor approach was taken. To facilitate the programming, the simplified kinetics as proposed by Friedlander and Seinfeld (see Section 6.2) were adopted in this study. This consisted of three differential equations for the principal species, NO, NO2, and hydrocarbons, with pseudo-steady state relationships assumed for ozone, atomic oxygen, and free radicals.

The first model considered consisted of a homogeneous box which encompassed an area the size of the Bay Area and which extended to the height of the base of the inversion layer. The second model considered involved an element which was 100 feet square on the base and which also extended to the inversion layer. This smaller homogeneous element, referred to as a "cloud", was considered to travel in a corridor through a geographic area transported by horizontal wind. The effects of ventilation were added to both models. Vertical diffusion was approximated in both models by incorporating the assumption of Friedlander and Seinfeld (see Section 6.2), which permitted expansion of the cloud from some low level up to the inversion layer base according to some predetermined rate.

In the homogeneous box model, a high level of nitric oxide and corresponding values of hydrocarbons and nitrogen dioxide were taken as the initial conditions. Ventilation of the box by allowing clean air to flow in and dirty air, with pollutant concentrations equal to those in the box, to flow out at the same rate. In the moving cloud model, source emission rates were entered to represent both an initial source and an alternate source encountered at a later point in the corridor. Ventilating air entered the element with the pollutant concentrations of the trailing element; it flowed out with the concentrations existing in the cloud at that moment.

A record of the box-reactor model simulation is shown in Figures 6-2.4 and 6-2.5, with 0, 1, and 5 mph ventilation. In one case the volume is fixed, and in the other the volume is allowed to expand from a height of 100 feet to the inversion layer at 400 feet in 30 minutes and then the lid itself expands at 1 ft/min thereafter.

The record shown in Figure 6-2.6 is the results of the moving-cloud model, with ventilation effects (advection) of wind at 1 mph as well as 5 mph transport of the cloud through some hypothetical corridor. The cloud trajectory, therefore, covers 40+ miles in the allotted time span. The cloud size is 100 feet square and expands (at 10 ft/min) from an initial vertical height of 100 feet to the assumed inversion layer height of 400 feet in 30 minutes after start-up. After this period the inversion lid itself is allowed to increase at a rate of 1 ft/min.

The initial concentrations of NO and NO_2 are assumed to each be 0.1 ppm and hydrocarbons 0.2 ppm. The NO and hydrocarbons are assumed to increase initially, simulating the early-morning traffic generation of these materials. Emission rate itself was varied through half a sinusoidal cycle, with peak rate at 30 minutes after start-up. Concentrations actually peaked at about 50 minutes after start-up, with NO approximately at 0.78 ppm and reactive hydrocarbons (RH) at 1.14 ppm. The buildup of these materials is allowed to occur without photochemical reaction for 30 minutes after start-up at which time "the sun was turned-on," to start the photochemical reaction. This represents the fact that the solar energy in the U.V. range is not significant until 2 hours past sunrise, due to low solar zenith angle.

During its trajectory through the corridor, the cloud encounters another source some 180 minutes after start-up. The peaks are at about 200 minutes, with the NO at 0.3 ppm and RH at 0.9 ppm. This alternate source was assumed to be approximately 2000 ft long (i.e., 20 minutes) with peak emission rate (again sinusoidal) occuring as the cloud reached

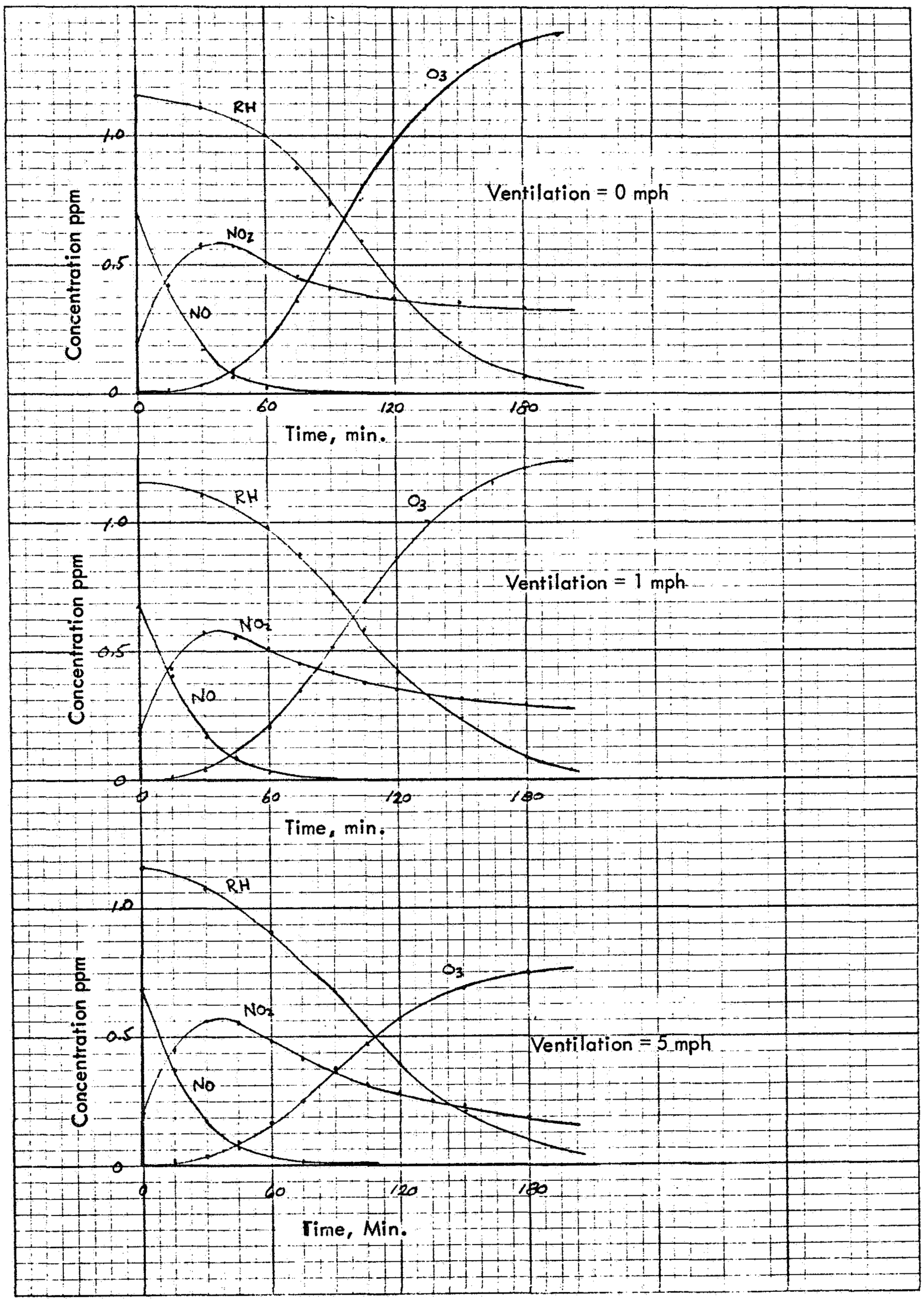


Figure 6-2.4. BATCH-BOX REACTOR MODEL, FIXED-VOLUME, SHOWING EFFECTS OF VENTILATION.

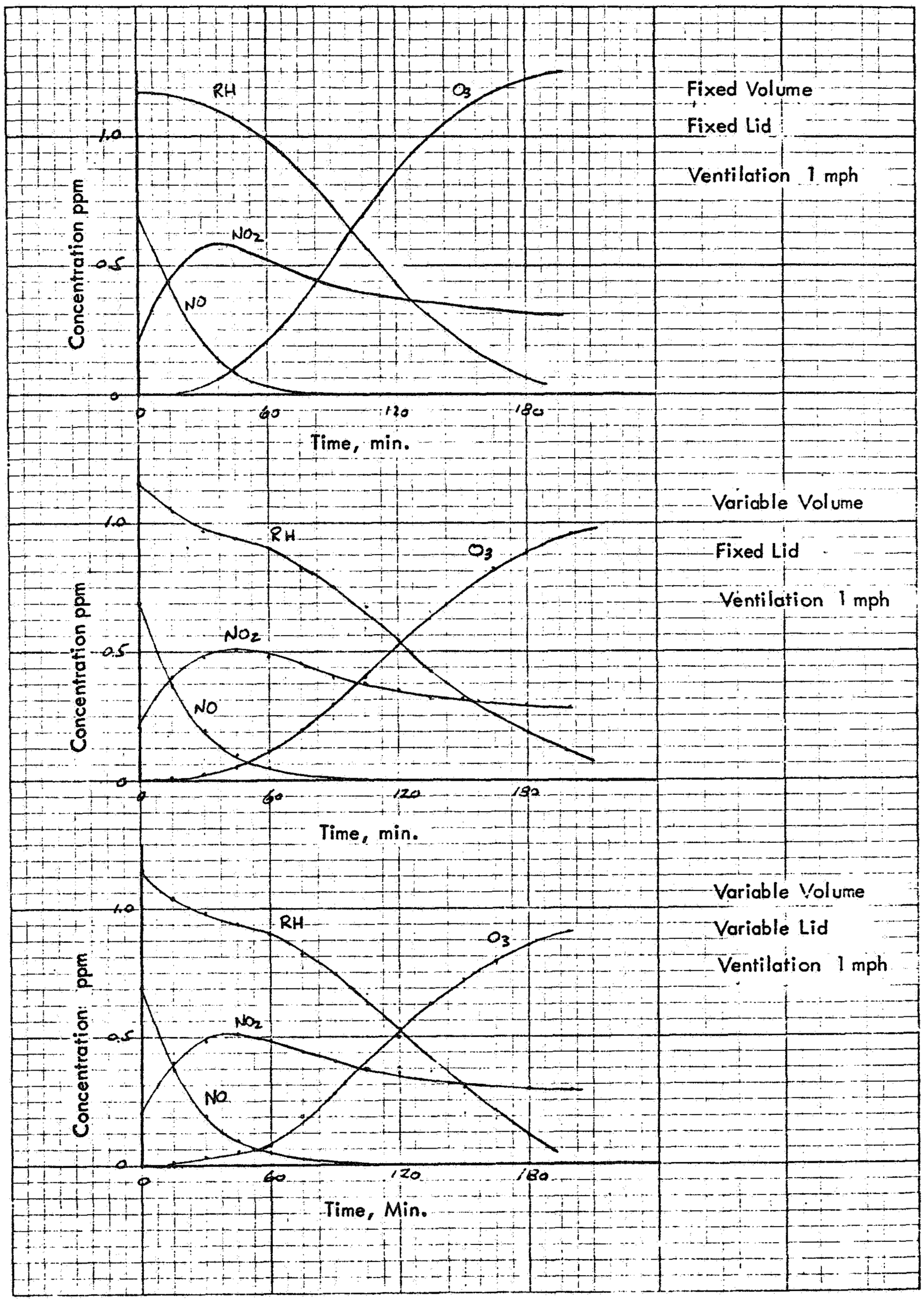


Figure 6-2.5. BATCH-BOX REACTOR MODEL, SHOWING EFFECTS OF VARIABLE VOLUME.

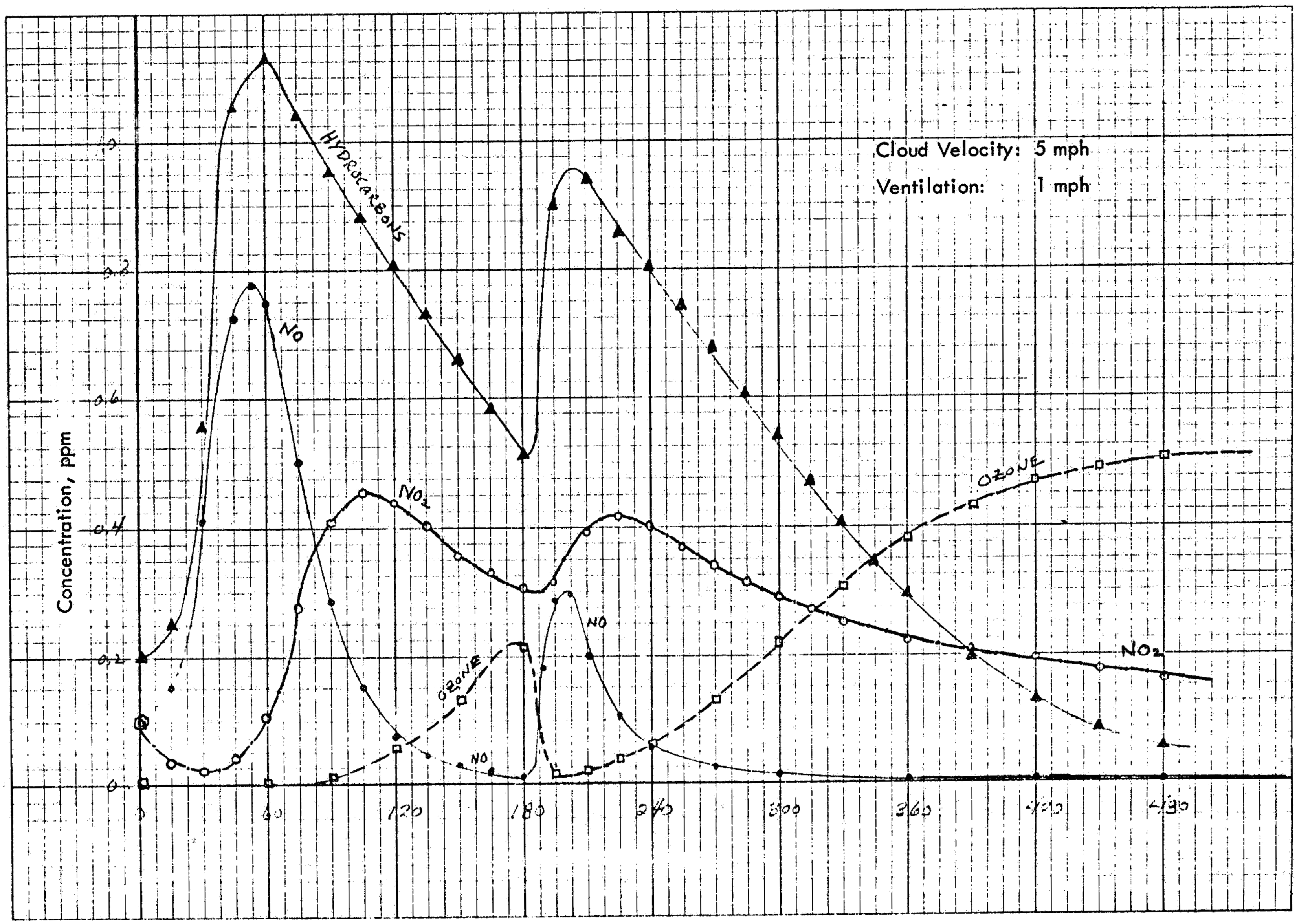


Figure 6-2.6. MOVING-CLOUD MODEL, SHOWING EFFECTS OF ALTERNATE SOURCE (at 190 min.).

the 190 minute point. The alternate source is not meant to imply that a cloud might meet only a single such source. In reality a number of sources would be encountered by a cloud. The model merely shows a basic technique for inclusion of other sources, and the general effects upon primary and secondary pollutants when such occur. Figure 6-2.7 shows the results of moving cloud simulations with ventilating winds of 0, 1, and 5 mph but no alternate source.

The moving cloud simulations show NO_2 peaking about 50 minutes after the initial NO peak and sooner after the NO peak due to the alternate source. As a secondary pollutant in the atmosphere, NO_2 increases following the introduction of solar energy; it later decays as other products such as aldehydes and ozone are produced.

The ozone concentration increases as NO_2 decreases. The effect of the alternate source, however, is to decrease the ozone concentration, a result of the reaction of the ozone with NO. The ozone concentration without alternate sources reaches steady-state after 8 hours. In actual experience, ozone (and oxidants) should begin to decrease. The simulation can easily be updated by the addition of accurate "late afternoon" traffic sources of NO, and other more distributed NO sources, which should cause the ozone to decrease by reaction with NO.

The results obtained from these simulation efforts lead to the conclusion that the use of a photochemical model-simulation obviously requires:

(1) A good source-emissions geographical model.

(2) Determination of solar energy patterns.

(3) Meteorological effects of wind, temperature, humidity, inversion as well as patterns in both horizontal and vertical directions.

(4) Histories of known contaminants, with latest information on reaction rates. The success achieved with the simplified scheme could undoubtedly be improved upon with the inclusion of additional equation. For example, solar energy was constant; i.e., either on or off. Hydrocarbons were lumped together with no attempt to discern between high and low reactivity fractions. An extension of the number of equations could also be made to include dynamic equations to predict other contaminant species such as PAN.

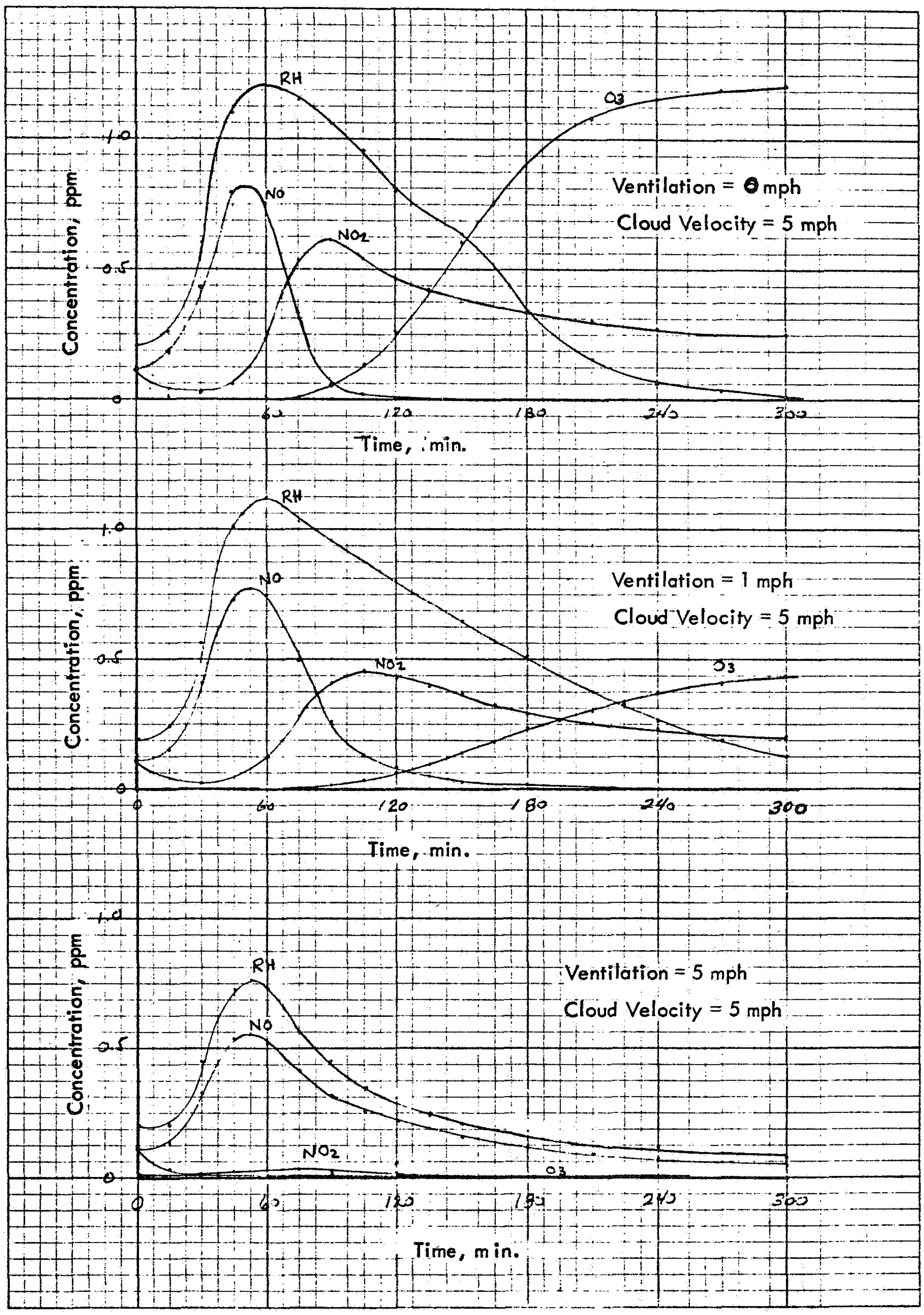


Figure 6-2.7. MOVING-CLOUD MODEL, SHOWING EFFECTS OF VENTILATION.

Appendix 7-1

DESCRIPTION OF PROPOSED SOURCE INVENTORY MASTERFILE RECORDS

The system as initially conceived would require four basic masterfiles.

1.	The basic equipment inventory masterfile	(File 1)
2.	The company information masterfile	(File 2)
3.	The unit factors and process weight factor masterfile	(File 3)
4.	The total emissions from all sources other than registered sources	(File 4)

(1) The Basic Equipment Inventory Masterfile

This masterfile would contain the information shown in Table 7-1.1 for all registered fixed source emitters. It would have approximately 15,000 records (one record for each registered source) requiring approximately 130 digits per record. There are 33 items stored on each record. This masterfile which would be the largest of the four masterfiles could easily be contained on one reel of magnetic tape.

The basic equipment masterfile would be updated monthly with any additions, deletions or changes that have occurred during the preceding month. The emission amounts for new or changed records would then be calculated from File 3, the unit factors and process weight factor masterfile. This updated equipment inventory masterfile would then be the basic building block from which other masterfiles (File 2) are developed or from which data concerning individual pieces of equipment can be retrieved.

(2) The Company Information Masterfile

This group of records is a summary of information on the basic equipment inventory masterfile (File 1) accumulated by company. Because much of the data necessary for enforcement must be related to the legal entity or firm it seemed appropriate to develop a smaller file (5,000 records, one record per company) so that more efficient preparation of reports would be possible. This masterfile would require 5,000 records, and 100 digits per record. Again one reel of magnetic tape would easily hold such a file.

The items of information presented in Table 7-1.2 would appear on the company information file. The number of items could easily be expanded if additional information was to be stored for each record.

(3) The Unit Factors and Process Weight Factor Masterfile (see Table 7-1.3)

This masterfile would carry the estimated emissions for particular pieces of equipment classified by registration number or basic equipment number. For those categories of equipment where the process weights are known the process weight factors would be multiplied by the process weight to determine the expected emissions for that equipment.

Table 7-1.1

BASIC EQUIPMENT INVENTORY MASTERFILE

Company Code
Registration No.
Area Code (County) 1st digit
Industry Code (SIC code)
Primary Activity Class
Basic Equipment Class
Registration Date
Date of Last Inspection
Inspection Schedule
Process Weight
Hours of Operation/Day
Variance Status
Year to Date Citations
Last Year Citations
Year to Date Breakdowns
Last Year Breakdowns
Particulate Emissions
  0 - 2 μ
  2 μ →
Reactive Organic Emissions (Tons/Day)
Non-reactive Organic Emissions (Tons/Day)
Nitrogen Oxides Emissions (Tons/Day)
Sulfur Oxides Emissions (Tons/Day)
CO Emissions (Tons/Day)
Other Emissions (Type Tons/Day)
Control Equipment Type
Control Equipment Age
Value of Control Equipment
Equipment Age
Equipment Value
Percent Control of Each Pollutant
Update Indicator

(4) The Total Emissions from All Sources Other Than Registered Sources

This masterfile will contain emission totals by pollutants for those activities that are not accounted for on File 1. These activities include such things as mobile sources, individual home sources (space heating, water heating, etc.), automobile filling operations, background, etc. The primary purpose of this information is the ultimate determination of total emissions released when combined with File 1 or File 2. Thus the total emission reports prepared annually could easily be prepared by computer.

As better models (probably requiring computer calculation) are developed to determine automobile emissions, it becomes relatively easy to incorporate the output of such a model into the total emission figures. The output of such a model would merely be the input to the

Table 7-1.2

COMPANY INFORMATION FILE

Company Code
Area Code
Company Name
Company Address
Name of Responsible Officer
Telephone No. of Responsible Officer
Net Worth
Nature of Business
Number of Employees
Number of Units of Equipment
Emissions (Tons/Day)
 Particulates
 0 - 2 μ
 2 μ →
Organics
 Reactive
 NO_x
 SO_x
 CO
Number of Citations (Year to Date)
Number of Citations (Last Year)
Number of Breakdowns (Year to Date)
Number of Breakdowns (Last Year)

Table 7-1.3

UNIT FACTORS & PROCESS WEIGHT FACTORS

Basic Equipment Class
Type of Factors   1 Unit Factor, 2 Weight Factor
Particulates
 0 - 2 μ
 2 μ →
Organic
 Reactive
 Non-reactive
 Oxy
NO_x
SO_x
CO

masterfile record just described. As the BAAPCD becomes more sophisticated it should be possible to determine the geographic origin of such source emissions and this information could easily be combined by area with the emission data from the basic equipment inventory masterfile.

Processing

The actual design of the programs and processing sequences would be the responsibility of the service bureau. The processing sequence shown in Figure 7-1.1 is one possible approach to the problem. This description of the processing of the source inventory system was utilized to facilitate the discussions of estimated costs with various computer service bureaus.

The four masterfiles will be stored on magnetic tape until processing is required. When processing begins the information on these tapes will be loaded on to large disk files. Between processings the information could be stored on the inexpensive magnetic tape reels and during processing the system would have the flexibility of random access storage on the disk files.

The reports that could be generated from this system are described in Table 7-1.4. The anticipated frequency of these reports is indicated on each report description.

Costs and Other Considerations

The costs of undertaking a computerized source inventory system were evaluated for three alternative methods of accomplishing the job. These three alternatives are:

1. Service bureau (batch-processing).

2. Service bureau (time-sharing).

3. BAAPCD in-house computer and support services.

The contracting of the job to a service bureau (batch-processing) is seen to be the least expensive approach with an estimated monthly cost of approximately $3,200 or $40,000/year after the major set-up costs have been paid. Similar cost for a time-sharing approach appears to be approximately $3,400/mo. or $41,500/year. These costs can be reduced if a substantial proportion of the monthly reports could be run quarterly.

All start-up costs such as the initial masterfile build-up, programming, and training have been amortized over the first year of operation. The difference in the start-up costs between batch-processing and time-sharing is primarily the need for an additional person for data input for the time sharing system.

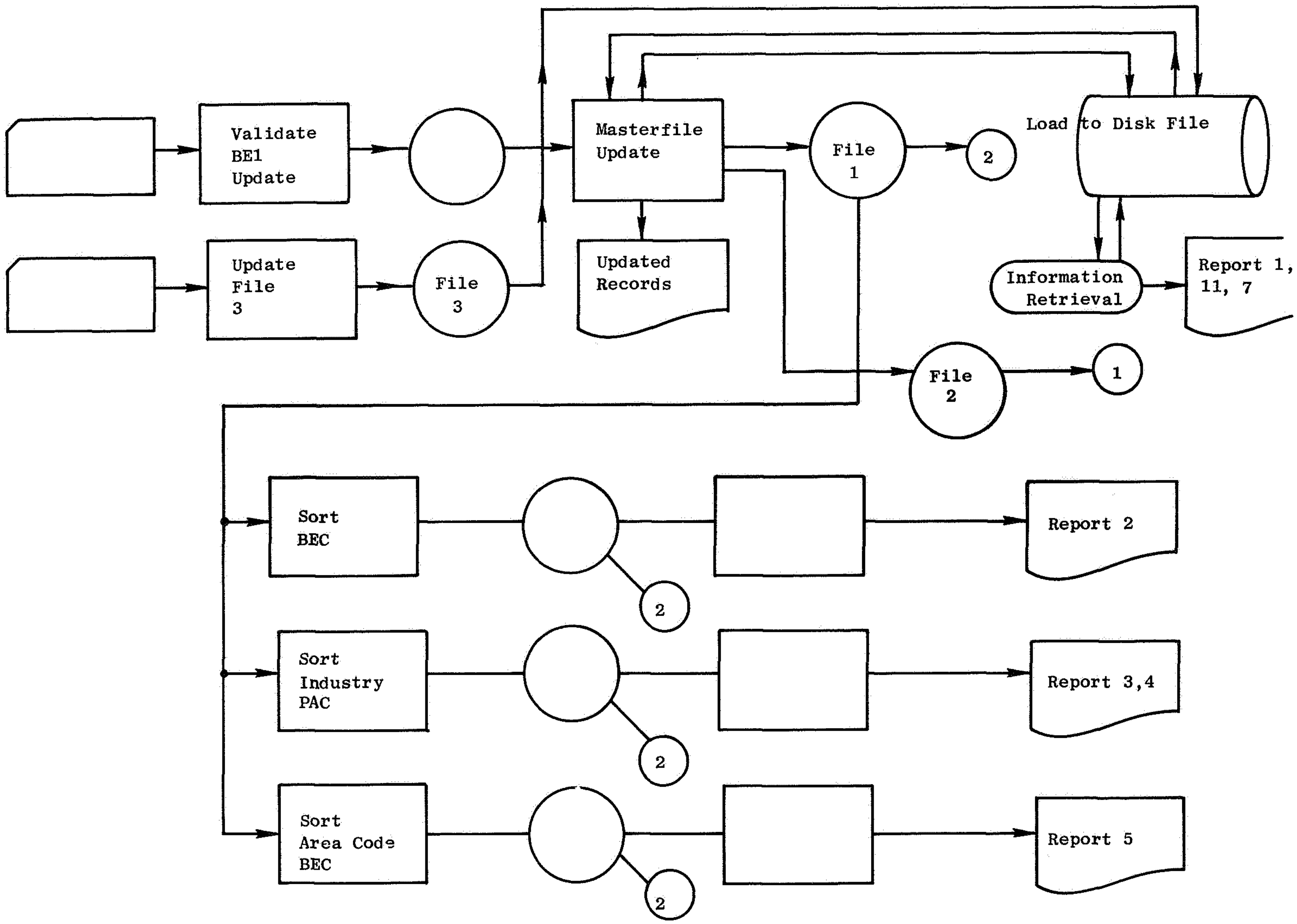


Figure 7-1.1. SOURCE EMISSION PROCESSING SEQUENCE.

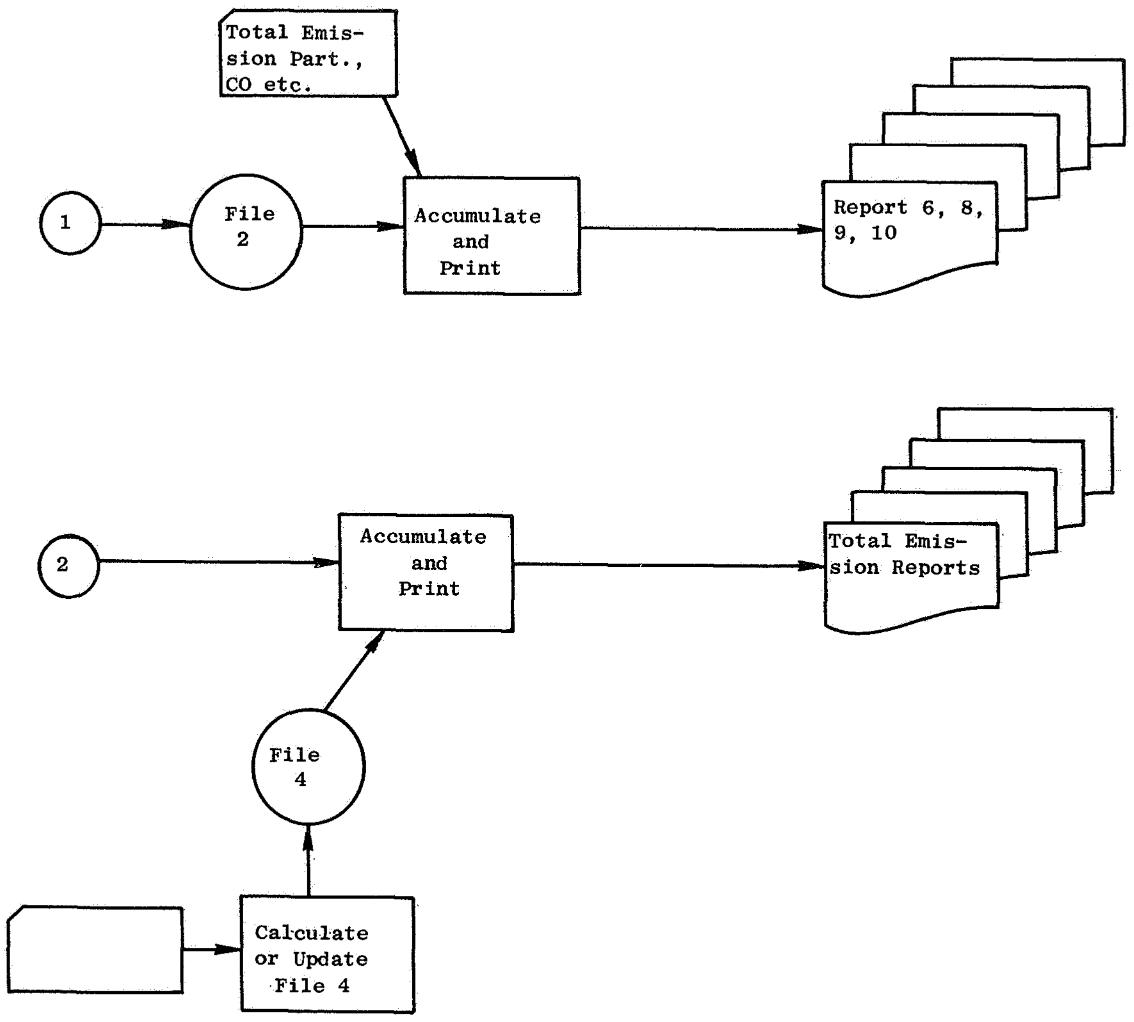


Figure 7-1.1. CONTINUED.

Table 7-1.4

REPORTS

The following reports would be prepared for the registered fixed sources.

Report 1 Pollutants by Registration Number (When Needed, Annual)

Registration No.	Particulates	Organics	NO_x	SO_x	CO	All other Information
0031	Tons/day	etc.				
0035	Tons/day					

Report 2 Total Pollutant Emissions by Basic Equipment Classification (BEC) (Monthly)

BEC No.	Particulates	Organics	NO_x	SO_x	CO	No. of Units
001	Tons/day					
002						
003						

Report 3 Total Pollutant Emissions by Industry (Monthly)

Industry	Particulate	Organics	NO_x	SO_x	CO	No. of Units
Agriculture	Tons/day					
Mining	Tons/day					
Contract Const.	Tons/day					
etc.						

Report 4 Total Pollutant by Primary Activity Class (PAC) (Monthly)

PAC	Particulates	Organics	NO_x	SO_x	CO	No. of Units
Catalytic Cracking						
Combustion						
etc.						

Report 5 Total Pollutant Emissions by Area Code by BEC with County Subtotals (Monthly)

Area Code	BEC	Particulates	Organics	NO_x	SO_x	CO	No. of Units

Report 6 Top 50-100 Companies by Pollutant (Monthly)

Particulates			Organics			
Co. No.	Emissions	% of Total	Co. No.	Emissions	% of Total	NO_x
62892	12 tons/day	2%	15679	0.8 TD	0.5%	...
13976	11 tons/day	1.9%	92163	0.7 TD	0.45%	...

Report 7 Age Distribution of Equipment by Industry, Company, and BEC (Annually)

Industry	Co. No.	BEC	No. of Units × Years Old								Mean Age
Agriculture			2,	4,	6,	8,	10,	12,	14,	16	
	32176	001	3,	7,	9,	14,	6,	2,	1,	0	7.5
		002									
		⋮									
	38965	001									
		002									
	⋮										
Mining											

Report 8 Top 25 Companies by Pollutant for No Control Systems (Monthly)

Particulates			Organics			
Co. No.	Emissions	% of Total	Co. No.	Emissions	% of Total	NO_x
35498	8 tons/day	1.6%	15679	0.8 TD	0.5%	

Report 9 Top 50 Companies by Citation Over Past Two Years (Quarterly)

Co. No.	Number of Citations This Year	Number Last Year
72541	9	0
31592	7	12
etc.		

Report 10 Top 25 Companies by Number of Upset-Breakdowns (Quarterly)

Co. No.	Number of Upset-Breakdowns	Emissions Due to Breakdowns

Report 11 Inspection Schedule for Fixed Sources (Monthly)

Registration No.	Location	Day	Month	Inspector	Date of Last Inspection

Although the cost difference between batch processing and time-sharing is not great, there seems to be no strong reason for having instant information retrieval capability for the source inventory program. In general, the data in this system would be rather static with few changes occurring in the data on a day by day basis. At present it appears that the ability to retrieve information from the source inventory within a week's time is sufficient for the needs of the district.

If, however, the BAAPCD has other computing applications that require time-sharing solutions, it may be that these additional applications would make the time-sharing a better bargain than batch-processing. In addition, the time-sharing system allows the user to do his own programming and new data input applications. Having this ability would also allow the District to take advantage of the large library of programs that most time-sharing systems have available. That is, programs for such things as forecasting, financial analysis, engineering, mathematics and statistics.

The third alternative, the development of an in-house computer capability, would be much more expensive than the same service provided by a service bureau. The largest expense would be computer rental ($2,000 to $7,000 per month) and personnel costs. Programmers, keypunchers, and a computer operator would have to be hired. Total costs would quite probably exceed $89,000 per year. Present data processing requirements would not justify such an expenditure.

The detailed cost estimates for Alternatives 1 and 2 are shown in Tables 7-1.5 and 7-1.6.

Table 7-1.5

COST ESTIMATES FOR SERVICE BUREAU CONTRACT (Batch Processing)

Tape Files		
Storage Costs	6 tape reels at \$20/ea. = \$120 Amortized 1 year	\$10/mo.
Terminal Cost		0
Delivery Cost	\$5/trip	\$20/mo.
Programming	\$4000 one time cost Amortized over 1 year	\$333/mo.
Masterfile Development	one time cost	
Keypunching	2,000,000 characters/4000 char. hr. = 500 hr. 500 hr. × 6/hr. = \$3000 Amortized over 1 year =	\$250/mo.
Processing	150,000 cards/500 card/min. = 300 min = 6 hrs × \$90/hr. = \$540 Amortized over 1 year =	\$45/mo.
Personnel (To be hired by BAAPCD)**		
1 person at \$15,000/year		\$1,250/mo.
1 person at \$10,000/year*		833/mo.

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* May not be needed for first year.

** Personnel Specifications

(\$15,000) Responsible for coordination between BAAPCD and the computer service bureau. During development of computer system this individual must make sure the system will do what it is intended to do. Once the system is operational the major activity will be the accumulation of accurate emission data for the source inventory. This person should have 4 years experience with computer data processing systems. Some computer programming experience is essential.

(\$10,000) Responsible for clerical activities related to the data input and output of the system. Experience related to data handling for computer systems would be desirable.

Processing

Masterfile Update

Keypunching (1600 changes/year) ≈ $40/mo.

Processing included with total processing charge.

Total Processing Charge $750/mo. + $0.02/mo (15,000 records) = $1050/mo.

Cost Per Month 1st Year $2998/mo.

Cost Per Month After 1st Year $3193/mo.

- Thuesen

Table 7-1.6

COST ESTIMATES FOR SERVICE BUREAU (Time-Sharing)

Random Files - Binary Storage Fixed Word Length

Storage Costs

Basic Equipment Inventory 495,000 words
4 Alphanumeric char./word = 1,970,000 char.

Maximum 1,970,000 × .39/100 = $772/mo.
$500/mo.
1,970,000 packed numeric × .13/100 = $256/mo.

Company Information File

200,000 words 4 Alphanumeric = 800,000

800,000 × .39/1000 = 312/mo.

$300/mo.

800,000 × $.13/1000 = 104/mo.

Unit Weight Factors

500 records × 10 words/record = 5000 words = 20,000 char.

20,000 × $.34/1000 = $8/mo.

Terminal Cost

Data Net 730 10 cps 1 - 0	Rent	$110/mo.
Including Service	Installation	$35/mo.
30 day agreement		
72 char./line		
Frieden 10 cps 1 - 0	Rent	$180/mo.
Including Service		
1 year agreement		
140 char./line		
TermiNet 300 10-15-30 1 - 0	Rent	$235/mo.
Including Service		
1 year agreement		
118 char./line		

Programming

Estimate contract cost	$4000	
Amortized over 1 year		$333/mo.

Masterfile Development

Amortized over 1 year	$295/year	

Personnel (to be hired by BAAPCD)*

2 people		
1 at $15,000/year		
1 at $10,000/year	$25,000/year	$2080/mo.

*Personal Specifications

($15,000) Responsible for coordination between BAAPCD and the computer service bureau. During development of computer system this individual must make sure the system will do what it is intended to do. Once the system is operational the major activity will be the accumulation of accurate emission data for the source inventory. This person should have 4 years experience with computer data processing systems. Some computer programming experience is essential.

($10,000) Responsible for clerical activities related to the data input and output of the system. Experience related to data handling for computer systems would be desirable.

Training

Programming Courses $145.00/student Amortize over 1 year	$300	$25/mo.

Processing Costs

Terminal time and processing time run approximately $15/hr.

Hours updating or input 4 hours/mo. at $15/hr.		$60/mo.
Report 1	$60/mo.	$60/mo.
Report 2 Offline $35/run		$35/mo.
Report 3 Offline $35/run		$35/mo.
Report 4 Offline $35/run		$35/mo.
Report 5 Offline $35/run		$35/mo.
Report 6, 8, 9, 10, 11		
Terminal 2 hr.	$14	
Processing Time	$60	$74/mo.
Report 7 Offline $35/run		$35/mo.
		$369/mo.
Cost per month 1st year		$3,930/mo.
Cost per month after 1st year		$3,367/mo.

Appendix 7-2

THE PROBLEM OF THE CURIOUS AND CONCERNED CITIZEN

In relating to the public the District faces a problem of satisfying requests for information without unduly draining its ability to work on its main task of cleaning the air. The problem seems to arise as follows.

1. A citizen or group of citizens becomes interested in air pollution and decides to dig into the subject.
2. It is a new subject to him, and possibly he has neither the background nor the time to become truly expert on the subject.
3. He comes to the District and asks for information about Air Pollution.
4. The District receptionist gives him the "usual" public literature and refers him to the public relations office if he wants more.
5. If the Public Relations office can't answer his question, he asks to see one or more of the staff.
6. If the staff thinks he can really help with a problem, they spend time with our citizen.
7. If they think that he, like some others they have encountered in the past, will only take their time from other work and either come up with nothing of help to the District, or use what he learns to go home and throw brickbats at the District, they will try to get rid of the visitor.
8. If then they do give the visitor short shrift, he may accept it or he may use his anger for fuel in mounting more hostile attacks on the District.
9. The District does not publish information about its weaknesses, although like any organization it has them. So our citizen will seek out such information from other sources.
10. One complaint he will have is that the District will not cooperate with him. Since the District will now tend to view him as an opponent, there will be some validity to this claim.
11. As a result of his attacks, the District will become more defensive, and this, in turn, will increase the probability of more such citizen enemies.
12. Eventually we find the District progressively at odds with citizens, although its whole reason for existing is to serve and to be responsive to them.

In our view this problem is a very important one and the present way of dealing with it is unsatisfactory. We did not recognize the mechanics of the problem in time to apply appreciable effort to solving it, although this problem is one whose symptoms we encountered early in our workshop when some members of the District avoided telling us about problems facing the District, tried to give us the impression that everything was well under control and deflected our requests for certain kinds of information. Our response was at least partly like that of the angered citizen, which led us to define our problem as how to persuade the District into cooperating with us rather than defining problems on which the District and we could effectively collaborate.

The problem of how to harness the potential helpfulness of citizens who want to learn and become involved in the District's effort is consequently one which we see as needing more effort. We don't know the best answer, whether to allocate more District funds to public information dissemination, or to publish more about its weaknesses and unsolved problems so its critics can't capitalize on such information as "discoveries", or to take some other approaches we have not though of. We are strongly under the impression, that the District's present approach to this problem, one which seems to say "we are the smog experts and the public should stay out of our affairs" is not the most effective approach that could be found and taken.

Consequently, we recommend that the District take a fresh look at this problem, consider all the other possible ways of dealing with it that they and others (possibly some of the hostile citizens themselves) can think of and reformulate their strategy for dealing with it. One way to rethink the problem might be to encourage some teams of students from one or more of the universities in the Bay Area to analyze the problem and make recommendations for how best to treat it. Such teams might be found in business or law schools, or better yet in a group of students from several disciplines. The expense to the District of doing this would be that of giving time to one more group of hummingbirds, who will nose around for information, taking people's time. In our view this time would be well spent and would lead to greater efficiency later which would more than compensate and would make life more pleasant for District employees as well.

Appendix 7-3

AUTOMOBILE INSPECTION

Each auto must be individually inspected. With about 2.5 million autos in the Bay Area this is a large task to take on.

A rough estimate on the magnitude of the undertaking is as follows.

2,500,000 automobiles

Autos can be inspected at the rate of 1 auto every 4 minutes

If we assume an eight hour day, five days a week, fifty weeks a year, and a load factor (percent time the equipment is used effectively) of 80%, the Bay Area would require 100 stations to inspect each car once a year. (It may be adequate to inspect only every two years!)

These should be located according to the auto populations in each county:

Alameda	24
Contra Costa	12
Marin	8
San Francisco	16
San Mateo	16
Santa Clara	24
	100

Estimated cost of a program to test vehicle emissions in the Bay Area:

<u>Operating</u>

Technicians' salary	$12,000
Helper	9,000
Land Lease	3,000
Shelter	5,000
Utilities	500
	$29,500

Equipment

Instrumentation which will measure and record

CO, NO_x, and HC (Beckman)	$10,000
Stickers	500
Dynamometer and Trailer	10,000
	$20,500

Total cost per station - 1st year	$50,000
Total cost per station - subsequent years	37,000

(Based on 7-year depreciation of equipment)

A charge of $2.00 per inspection would cover these costs.

It has been proposed that California start an auto safety inspection program. If this were to be implemented, the additional cost to analyze exhaust is at present about $10,000 per station for instrumentation to check and record NO_x, CO, and HC.

"A Study to Determine the Feasibility of Instituting a Periodic Motor Vehicle Inspection Program for the State of California" by Clayton Manufacturing Co. calculates that for the whole state:

Safety inspection only	$49,162,000
Safety plus emission	$49,634,000

It seems that since the Bay Area has about 1/4 of the autos in the state that 1/4 of the cost would be sufficient to do this in the Bay Area.

For the Bay Area:

Safety inspection only	$12,290,500
Safety plus emission	$12,408,500

It should not be assumed that an emission inspection system would cost $118,000. This is only the cost of additional equipment by Clayton's estimate.

Appendix 7-4

A PROPOSED MEASURE OF EFFECTIVENESS

The proposed measure of effectiveness is designed to utilize data that is presently prepared by the District. This data is the estimated air pollution emissions for each pollutant on a tons/day basis for previous years. An example of this data is shown below.

AIR POLLUTION EMISSIONS IN THE BAY AREA--1955-1969
in tons per day

	1955	1964	1965	1966	1967	1968	1969
District Jursidiction							
Particulates	285	154	149	154	160	161	160
Sulfur Oxides	404	357	354	372	409	375	330
Organic Gases	1,133	873	871	902	939	970	941
Nitrogen Oxides	170	204	222	255	240	210	194
Carbon Monoxide	2,142	1,329	1,296	1,332	1,286	950	956
TOTAL	4,134	2,917	2,892	3,015	3,134	2,666	2,581
Motor Vehicles							
Particulates	20	33	35	36	38	40	41
Sulfur Oxides	11	17	18	19	20	21	21
Organic Gases	736	1,088	1,130	1,072	1,027	1,028	961
Nitrogen Oxides	155	249	265	282	299	335	370
Carbon Monoxide	3,204	5,171	5,510	5,338	5,220	5,323	5,208
TOTAL	4,126	6,558	6,958	6,747	6,604	6,747	6,601
TOTAL							
Bay Area	8,260	9,475	9,850	9,762	9,738	9,413	9,182

Because a measure of effectiveness for the BAAPCD is reasonable only if it measures those factors over which the District exerts significant control, the emission data used in such a measure should be limited to emissions under District jurisdiction. When and if the District becomes more responsive to motor vehicle emissions, this data can be incorporated easily in the effectiveness measure.

The primary purpose of the proposed measure of effectiveness is to determine whether emissions are being reduced. However, the inevitable statistical fluctuations must be smoothed out. For this data from preceding years can be used, providing it is properly weighted. The weighting factors used for smoothing give more emphasis to the more recent results and less emphasis to the data that occurred in the past. At one extreme the weighting factor will completely ignore all past data and at the other extreme it will treat past and present data equally.

In order to avoid bias at least five years of data is required for the index of effectiveness to give a reasonable indication of District performance. A group of years less than the total number of years must be selected. For example, if the total years considered are 1964, 1965, 1966, 1967, 1968 and the span of years is selected to be 3, total weighted emissions will be calculated for the following groups of years.

Group 1	1964, 1965, 1966
Group 2	1965, 1966, 1967
Group 3	1966, 1967, 1968

If the span of years had been selected to be 2, the following groups that would be used are:

Group 1	1964, 1965
Group 2	1965, 1966
Group 3	1966, 1967
Group 4	1967, 1968

For each group of years a weighted emission total is calculated. The more recent years are given more weight, since it is the control that the board has exerted most recently that is most important.

The effectiveness is calculated as follows:

Let $E_{p,x}$ = Weighted effectiveness measure x for pollutant p

N = Number of periods in effectiveness measure time span

N' = Total number of periods being considered

α = Factor to discount a preceding period from the following period $0 \leq \alpha \leq 1$

When $\alpha = 0$ past data ignored

$\alpha = 1$ past data weighted equally with present data

$Q_{p,n}$ = Average quantity of emissions (tons/day) of pollutant p in year n.

For pollutant p

$$E_{p,x} = \sum_{n=x}^{N-1+x} Q_{p,n}\,\alpha^{n-N} \qquad \text{for } x = 1,2,3,\ \ldots,\ N' + 1 - N$$

$$\left.\begin{array}{lll} \text{If } (E_{p,xH} - E_{p,x}) \geq 0 & \text{let} & Y_{p,x} = 0 \\ \phantom{\text{If }}(E_{p,xH} - E_{p,x}) < 0 & \text{let} & Y_{p,x} = 1 \end{array}\right\} \quad \text{for } x = 1,2,\ \ldots,\ N' - N$$

$$\text{Effectiveness of control of pollutant } p = EC_p = \sum_{x=1}^{N'-N} Y_{p,x}$$

$$0 \leq EC_p \leq N' - N$$

$$\%\ \text{control}_p = \frac{EC_p}{N' - N}$$

$$\text{BAAPCD total effectiveness} = \sum_{\substack{\text{over all}\\ p}} EC_p$$

$$0 \leq \text{BAAPCD total effectiveness} \leq p(N' - N)$$

$$\%\ \text{total effectiveness} = \frac{\text{BAAPCD total effectiveness}}{p(N' - N)}$$

Example

Data from Air Pollution and the San Francisco Bay Area, p. 16.

Year	1964	1965	1966	1967	1968
n	1	2	3	4	5

p	1	2	3	4	5
	Particulates	SO_x	Organics	Nitrogen oxides	CO

$N' = 5$

$N = 3$

$\alpha = 0.5$

$E_{1,1} = 267$ $E_{1,2} = 274$ $E_{1,3} = 283$ $EC_1 = 0$

$E_{2,1} = 639$ $E_{2,2} = 683$ $E_{2,3} = 721$ $EC_2 = 0$

$E_{3,1} = 1557$ $E_{3,2} = 1608$ $E_{3,3} = 1622$ $EC_3 = 0$

$E_{4,1} = 417$ $E_{4,2} = 423$ $E_{4,3} = 447$ $EC_4 = 0$

$E_{5,1} = 2313$ $E_{5,2} = 2274$ $E_{5,3} = 1827$ $EC_5 = 2$

% $\text{control}_1 = 0.0$

% $\text{control}_2 = 0.0$

% $\text{control}_3 = 0.0$

% $\text{control}_4 = 0.0$

% $\text{control}_5 = 100$

% total effectiveness = 2/10 = 20%

Once the weighted emission total E_j has been calculated for each group of years j, the number of reductions in E_j for succeeding groups are counted. The number of reductions that occurred from group to group are then compared to the total possible reductions that are possible. The results are summarized below.

Groups	1964 1965 1966 E_1	1965 1966 1967 E_2	1966 1967 1968 E_3	1967 1968 1969 E_4	Number of Reductions	Total Possible Number of Reductions
Particulates	267	274	280	281	0	3
SO_x	638	683	673	619	2	3
Organics	1557	1608	1655	1656	0	3
NO_x	417	423	405	364	2	3
CO	2313	2274	1927	1752	3	3
					7	15

Control (Particulates) $= \frac{0}{3} = 0\%$

Control (SO_x) $= \frac{2}{3} = 66.7\%$

Control (Organics) $= \frac{0}{3} = 0\%$

Control (NO_x) $= \frac{2}{3} = 66.7\%$

Control (CO) $= \frac{3}{3} = 100\%$

Total Effectiveness $= \frac{7}{15} = 47\%$

The total effectiveness index indicates that the BAAPCD is only about 47% effective in affecting <u>reductions</u> in total emissions for each of the five major pollutants. This index of effectiveness considers each pollutant as equally important with regard to BAAPCD's responsibility to reduce emission of pollutants and should therefore be modified to account for the relative severity of each pollutant once this can be established.

Appendix 8-1

A PROPOSAL FOR EMISSION REGULATIONS BASED UPON AIR CELL AND AIR SHED CAPACITY

Background

An airshed is generally understood to mean that geographical area the boundaries of which form a more or less natural container for a large, contiguous air mass. Among several fine examples in California are the great central valley, the Los Angeles basin, and the San Francisco Bay Area. The boundaries of the state's many air pollution districts have been drawn to roughly coincide with its airshed boundaries, subject to the practicalities obvious in using established political boundaries where possible.

A given airshed may have within its boundaries certain topographic features, such as mountain masses, waterways, and valleys, which tend to either contain sub-masses of air which we might call "aircells" or to promote certain observable meteorological phenomena; for example, ventilation through mountain passes and river ways, and diurnal airmass oscillation in mountain valleys. Features such as these, and the accompanying diversity and non-uniformity of local meteorology, are plentiful within the boundaries of the BAAPCD.

Consider, now, the fact that the emission regulations of the District apply uniformly to all areas within its boundaries, independent of any and all physical factors of the kind noted above. One may reasonably conclude that a given emission regulation may represent "overcontrol" in a region of the district blessed with consistently good ventilation, while the same regulation might grossly undercontrol the problem in an aircell where ventilation is sluggish or where the topography is such that inversions are low and frequent.* A good example of the latter is the Livermore Valley aircell, one in which consistently high readings of ground level oxidant are thought to be a consequence of the fact that air laden with hydrocarbons, nitrogen oxides, and oxidants is funnelled into the Valley via Niles Canyon, there to meet a combination of higher elevations and higher temperatures. Inversion height above ground is thereby reduced, and the enhanced mixing at higher temperatures leads to ideal conditions for the photochemical reaction.

Another location that may bear attention is the upper Santa Clara Valley in the vicinity of Gilroy and Morgan Hill. No air quality measurements have been made in this part of the District, due mainly,

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*A District memorandum of January 6, 1970, on the North Richmond situation, states: "The air quality in North Richmond may indeed be different than the air quality of other areas but this is due to topography, prevailing winds and the proximity of the North Richmond area to one of the largest industrial complexes in the State."

according to the BAAPCD, to the fact that no plant damage has been observed here, and hence air quality must be quite acceptable. It would be unfortunate, to say the least, if plant damage were to occur after such benign neglect. The opportunity exists now to take steps that will help to ensure the maintainence of good air quality in this aircell. Certain elements of high pollution potential are present and should be quantified. The Santa Clara Valley narrows considerably at Morgan Hill and Gilroy; subdivision pressures from San Jose southward will be inevitable; the level of industrial activity could rise sharply as orchard and farmlands fold under the weight of taxes; careful meteorological studies could very well indicate a strong southward flow of Bay Area air into the narrowing valley during certain portions of the year. These and other factors should be dealt with now, not after actual damage has occured and necessitated the location of a monitoring station in Gilroy.

There is no doubt that at the time of formation of the BAAPCD, not enough information and knowledge of air pollution dynamics was available to do anything but establish uniform, district-wide emission regulations. The phenomena underlying these dynamics are now more clearly (though not completely) understood, and further, the means are now available to measure and quantify their cause, effect, and intermediate variables quickly, conveniently, and accurately.

Recommendations

In light of this emerging knowledge and ability to measure, the following recommendations are made:

1. that, by inspection of meteorological, air quality, and topographic data, the BAAPCD staff make a tentative division of the District airshed into its component aircells.

2. that there be initiated an ongoing program of source emission, air quality and meteorological monitoring, and modeling of such a nature and in such detail that the inherent capacity of each aircell to assimilate airborne pollutants is established.

3. that aircell boundaries be appropriately adjusted as new information and understanding evolve.

4. that those existing emission regulations based upon effluent concentration and process weight be retained for existing point source emitters only, as a means of "grandfathering" into new regulations.

5. that for each aircell a schedule of total mass emission regulations be drawn up on the basis of aircell capacity, geography, local agency land use zoning, and other pertinent factors to be fed to a formula, described below, whose output will be a figure for tons per day per acre for the aircell.

6. that where evidence exists of significant pollutant transport between adjacent aircells, these cells be coupled to appropriately account for mutual effects.

7. that individual aircell capacities be summed to describe the capacity of the entire district airshed as an improvement to the method outlined in the Box Model described in Chapter 6.

Comments and Expansion on Recommendations

1. The tentative designation of aircell boundaries should be no problem. Some may not be as obvious as the Livermore and Gilroy examples cited above, but their outlines are tentative and therefore flexible.

2. In other sections of this report there are discussions dealing with the value of air pollution surveillance and modeling. Here we have a very specific example, one which merits considerable elaboration. Let us elaborate in the context of the Livermore Valley.

Consider, first, the task of establishing a source inventory for the Valley. The more or less conventional sources, i.e., industry, autos/freeways, space heating, etc., present no particular problems other than the time and effort required for their enumeration and compilation. The Livermore Valley has, however, a source that is not so easily dealt with, namely the inflow through Niles Canyon of pollutant-laden air from the main air mass of San Francisco Bay. Knowledge of this pollutant inflow is a necessary ingredient for further analysis of the Livermore aircell.

Current developments in the measurement of air pollution parameters by long-path absorption spectroscopy point directly to the capability of measuring this pollutant inflow by a method now to be described. Figure 8-1.1 below shows a "for instance" cross-section of the Niles Canyon at a point selected for its relative narrowness. A light source and absorption spectroscope are mounted at equal elevations below the inversion on opposite sides of the canyon. The spectroscope will yield a measurement of the average concentration of a given pollutant over the horizontal distance between the light source and the spectroscope. By making similar concentration measurements at other elevations under the inversion, and by releasing balloons to determine wind velocity profiles, it is a straightforward task to compute an estimate of the pollutant inflow.

Now assume that source emission, pollutant inflow, and air quality data are being generated, and consider the use of these data for the determination of aircell capacity. Such a determination might proceed in a series of steps, at each of which an increasingly sophisticated mathematical or simulation model would be employed. The most elementary of these models would be the judgement and accumulated experience of the District technical staff. A typical output of the judgement/experience model might be the statement that the Livermore Valley could not possibly

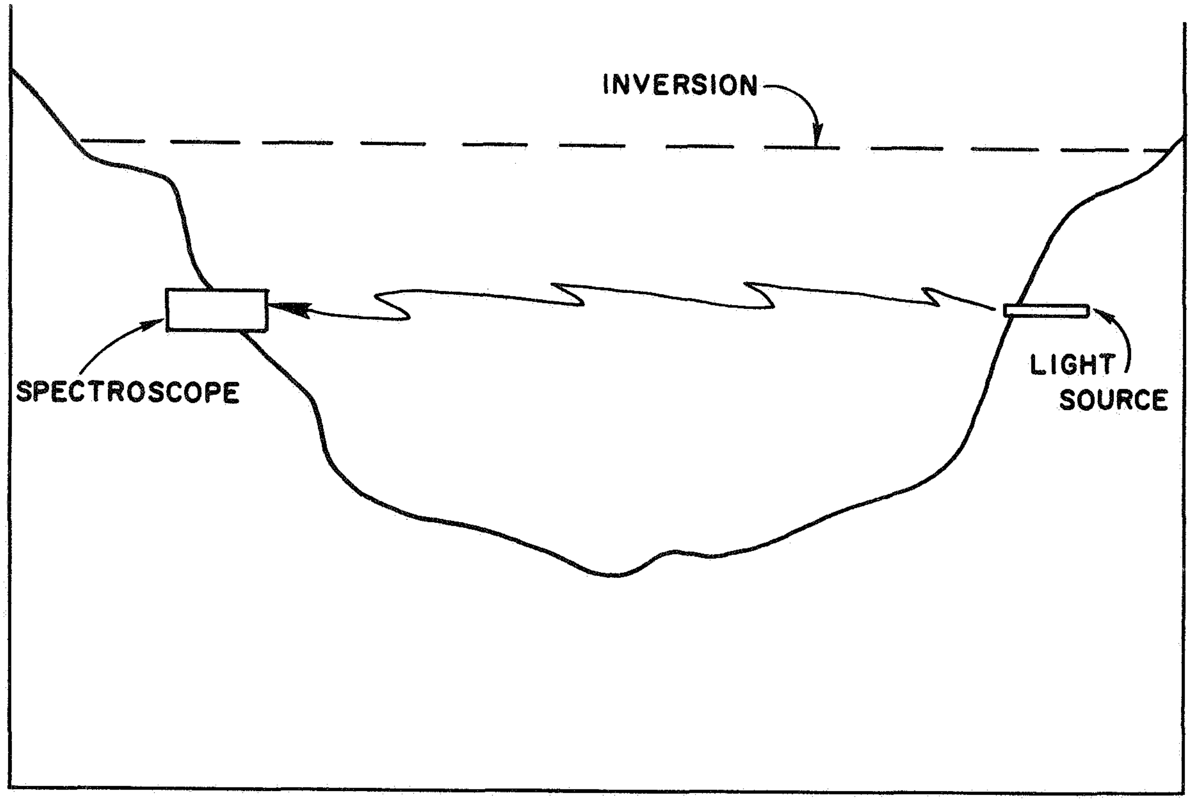

Figure 8-1.1. A TYPICAL CROSS-SECTION, NILES CANYON.

accommodate a population of, say, 400,000 without unacceptable degradation of air quality. The next step might be the construction of a Box Model (see Chapter 6), a process in which the valley floor, the mountain walls, and the inversion height act as the container of a volume of air into which all pollutants are introduced by emission or by inflow. Here, for the first time, one can get very crude answers to such questions as: "If the Livermore Valley cannot accommodate 400,000 people without destroying air quality, just how many can it hold?"

Other, more refined models could be used as they become available (see Chapter 6). The strongest contribution of modeling, in the present context of fashioning emission regulations, is the capability of extrapolation or prediction inherent in the mathematics of the model. This predictive capability, coupled with statistical profiles of meteorological data for the aircell, could lead to capacity statements of the following nature.

> Based upon topographic structure, statistical profiles of meteorological phenomena, and projections of pollutant inflow from outside the Valley, the Livermore Valley aircell is estimated to have, to within ±5%, the gross internal pollutant capacities, in tons per day, shown in Table 8-1.1.

Table 8-1.1

TYPICAL CAPACITY MATRIX FOR A GIVEN AIRCELL
Numbers are representative only

Capacity Matrix, Tons Per Day

% time compliance to ARB quality standards	Pollutant: NO_x	Reactive HC	SO_2	0 - 1 μ Part.	CO	etc.
95	A	B	C	D	E	
97	0.5 A	0.4 B	0.45 C	0.2 D	0.28 E	
99	0.15 A	0.21 B	0.18 C	0.11 D	0.09 E	
99.9	0.05 A	0.04 B	0.07 C	0.10 D	0.04 E	

These capacities are further based upon the constraint that the State of California air quality standards are to be met for a given percentage of measurement units (hourly average, daily maximum, etc.).

Continuing with the comments and expansions on the earlier recommendations:

4. It should be obvious that emission regulations, as presently constituted will not and cannot effectively guarantee a limit on emissions into an aircell. There is virtually no limit on the total tonnage of pollutants that a large number of large industries, each occupying a relatively small industrial site, can discharge to the atmosphere. Regulations of this type should therefore be scrapped and be replaced by new regulations which guarantee a ceiling on total emissions. Existing uses, of course, cannot be restricted in a confiscatory manner, and will have to continue operation under the old regulations until such time as the use is terminated or technological developments in control allow compliance with new regulations.

5. The question of capacity in the context of land use, planning, and zoning, is beginning to be raised; more often in public hearings, especially in California. Some ecologists have suggested, for example, that the capacity of the Los Angeles basin for people and people-by-products has long been exceeded. It has been suggested that regional planning, backed by regional government with the authority to implement such plans with precise zoning, is one answer to the trend of vanishing wisdom in land use policy.

There is more than a little uncertainty in how rapidly this transition to regional government will proceed. One might therefore proceed on the assumption that total mass emission regulations will have to be drafted for a given aircell without any basic changes in the way local agencies control land use within their boundaries.

The procedure might have the following steps. First, the District would approach the local agencies (cities, counties) within the aircell and determine from them their long-term land use and transportation plans. Assume that such plans can be summarized comprehensively and graphically by a diagram such as that shown in Figure 8-1.2. It must be emphasized that the percentage of total area to be devoted to a given use is still in the hands of the local agencies and is not subject to change or veto by the pollution control agency.

Once the information in Figure 8-1.2 is available, the next step consists of apportioning pieces of the total pollutant capacity pie to the three use categories. This would probably have to be done iteratively, as follows. The local agencies might tentatively decide to prescribe an average residential density of six units per acre to the 55% of the land area selected for ultimate residential and open space use. Using standard figures for pollutant production by domestic water and space heating, the total tonnages produced by these 33,000 dwelling units could be estimated. In similar fashion, standard figures would be applied to whatever mix of transportation modes was decided upon by the local agencies. They might, for example, decide to meet 25% of their intra-aircell transportation needs by public transit, and 75% by private auto. From the transportation mix and standard pollution factors would come estimates of total tonnage produced by the transportation sectors.

The sums of residential and transportation tonnages would then be subtracted from the respective capacity tonnages shown in Table 8-1.1, where % compliance would presumably be chosen no lower than 99%. The remainders would be the tonnage allowances for the 3,500 acres designated for industrial development.

The next step is an adjustment for existing industry which, as an example, presently occupies 1,000 of the 3,500 acres set aside for industry, and produces known tonnages of the respective pollutants. These tonnages are to be subtracted from the total industrial allocation, and in turn the difference is to be divided by the 2,500 net acres remaining for industrial development.

The preceding several paragraphs can be expressed in a compact equation, as follows. For oxides of nitrogen, for example,

$$d = \frac{0.05A - T_r - T_t - T_{pi}}{L_i - L_{pi}} ,$$

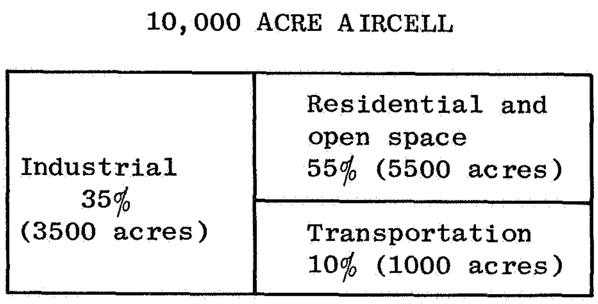

Figure 8-1.2. LAND USE PLAN FOR AN AIRCELL, SHOWING INDUSTRIAL, RESIDENTIAL, AND TRANSPORTATION CATEGORIES.

where

d is emission density in tons per day per acre,

0.05 A is the 99.9% compliance aircell capacity for NO_x, from Table 8-1.1,

T_r is residential tons per day,

T_t is transportation tons per day,

T_{pi} is present industry tons per day,

L_i is total land acreage designated industrial,

and

L_{pi} is the present land acreage occupied by industrial operations.

Again by applying standard pollution factors, the local agencies could at this point see that the remaining industrial tonnage, namely

$$T_{ri} = d \cdot (L_i - L_{pi}) \text{ tons/acre/day} \quad ,$$

would "buy" them an industrial "mix" of, for example, three one-megawatt fossil power plants, two 100,000 barrel oil refineries, and one large steel mill. Should they not like this mix, they are free to make adjustments in the allocations to residential and industrial uses. It is presumed that they will eventually reach a satisfactory apportionment, at which time the pollution control district will put into effect industrial emission regulations in terms of d tons/day/acre on the $(L_i - L_{pi})$ acres of undeveloped industrial land.

At this point the regulations would function as follows. An industrial applicant for use of land within the aircell would have to declare the daily tonnages that he anticipates will be emitted by his operation. Calculations supporting this declaration would be reviewed by the district technical staff. The applicant would then be required to purchase at least that number of acres determined by the equation.

$$L_{ia} = \max_{j} \left[\frac{T^{j}_{ia}}{d^{j}} \right] ,$$

where

L_{ia} is the minimum acreage required for the industrial applicant,

T_{ia} is the declared tonnage per day of the applicant's process for the j^{th} pollutant,

and

d^{j} is the tons per day per acre for the j^{th} pollutant as per the district's regulations.

This equation for acreage is to be applied for all primary pollutants in the applicant's declaration. The final required acreage will be based upon the largest result of repeated applications of the acreage equation over all primary pollutants.

Summary

The emission regulations as fashioned on paper in the paragraphs above admittedly are lacking many of the legalistic if's, and's, and but's. They do represent, though, one way in which lids might effectively be placed on the burden of pollutants that any given aircell and its inhabitants must endure.

The legality of such regulations within the framework of the present BAAPCD legislative mandate is a matter for speculation. Environmental law is very much in its infancy. There is some precedent for the regulations as described above, however. The legality of residential density control via zoning has been upheld against repeated assults, for example.

One thing seems sure, however. If such new laws and regulations are to survive, court tests of constitutionality, they will very likely have to be backed up by legitimate scientific theory and unimpeachable data. Now is the time to build upon that theory and to start collecting and using the data.

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EPILOGUE

This report has summarized the eleven-week, twenty-man study of the air pollution problem in the San Francisco Bay Area which was sponsored by NASA and ASEE and held at Stanford University during the summer of 1970. The report attempts to describe the Bay Area air pollution problem, outlines an improved surveillence system for both pollutant sources and air quality, suggests areas where improved modeling techniques can contribute to a better understanding of the relationship between pollutant sources and air quality, and makes recommendations for improvements in the present control programs.

Much of the report is devoted to the technical aspects of air pollution; in the light of the backgrounds of the participants in the study, this is perhaps as it should be. Yet it is widely recognized that the air pollution problem is largely a social, political, and economic one; to a large degree the necessary technology is already available.

Finally then, there remains the question, "Is the quality of air in the San Francisco Bay Area going to improve?" Unfortunately, the answer appears to be, "Probably not." Not until the control agencies, such as the BAAPCD, fully and completely dedicate themselves to the task; not until they refuse to accept the current roadblocks to effective pollution control: their own often narrow view of the proper scope of their activities; shortage of funds; insufficiently strong legislation (or insufficiently aggressive interpretation of existing legislation); the adverse pressures from vested interest groups; and, perhaps most important, public apathy (due in many instances to lack of awareness).

For just as people are the real source of the pollutants, so too must they be the ultimate source of the solution. The quality of air in the San Francisco Bay Area, or any other area, will only improve when an enlightened public is willing to pay the price for its improvement, when each citizen is willing to make the necessary individual sacrifices rather than "leaving it to the other guy", when he is truly able to say "Yes" upon asking himself, "Rather than paying lip service to the need for clean air, am I willing to drive my car less, to cut down on my use of such things as electric power, to actively promote more effective action by legislatures and control agencies, and to personally support the raising of the necessary revenues?"

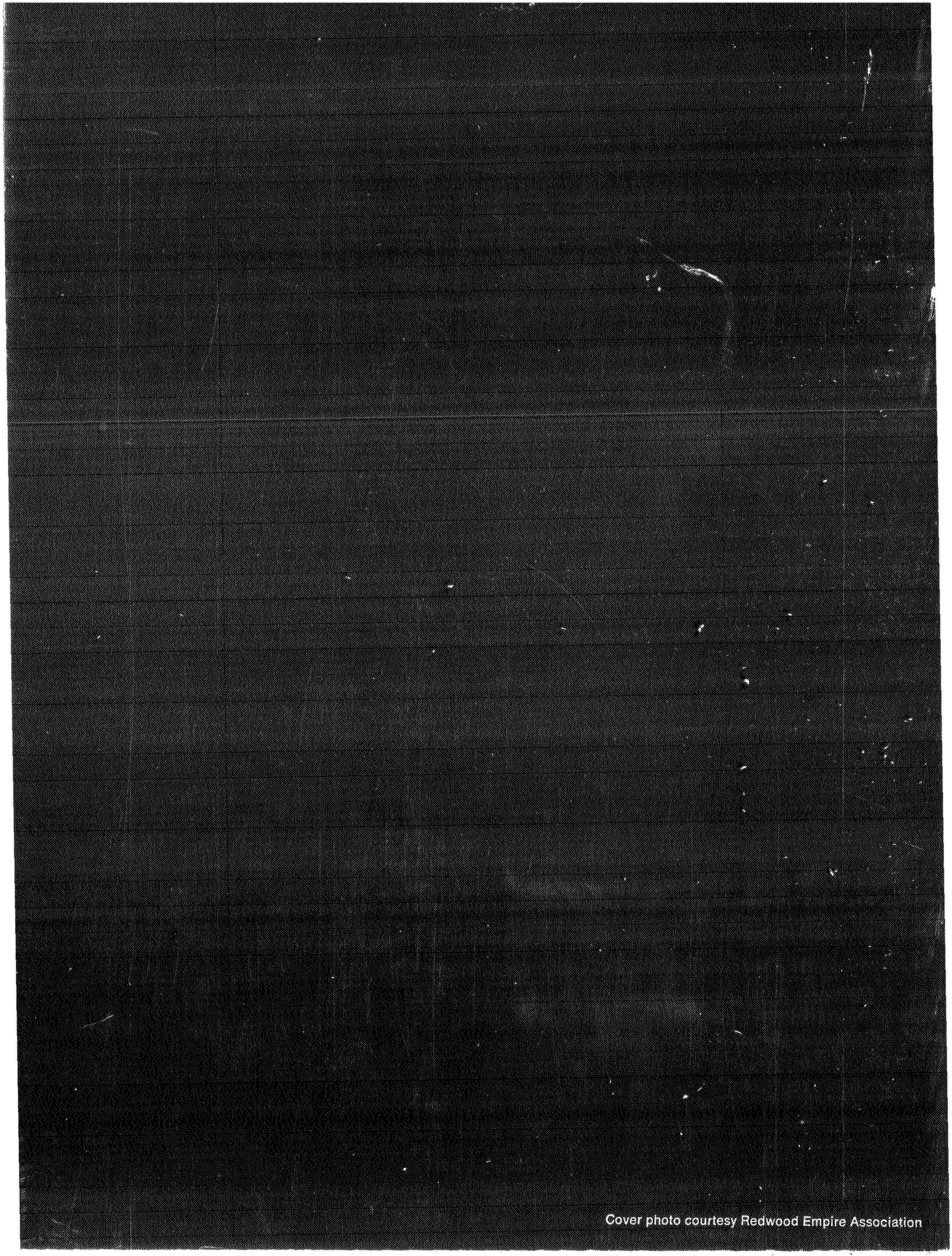
"WE HAVE MET THE ENEMY, AND HE IS US."

Pogo

ACKNOWLEDGMENTS

Above all we give cheers to Jim Adams, John Manning, and Wayne Ott, who organized and directed the project at Stanford. We acknowledge their superior judgement not only in having selected us over 140 other applicants but also in letting us find our way as a group and as individuals into this complex problem of air pollution with just enough guidance to keep us on the track--more or less.

We want to give thanks to those men from Stanford University, from NASA, from Stanford Research Institute, and from various government agencies who, early in the summer, talked to us on the subjects of their expertise and later gave freely of their time to answer our questions; to the staffs of the BAAPCD and the Regional Transportation Planning Committee who spent considerable time and effort in explaining their operations to us; and to both the National Aeronautics and Space Administration and the American Society for Engineering Education through whose organizational and financial assistance the entire enterprise became possible. We would like to thank Inga Lof for a beautiful job of organizing and typing. Lastly, a grateful hug from all of us for Nancy Kays and Liz Stein who deciphered our handwriting, typed and copied innumerable pages, and provided us with coffee and cheer throughout the eleven weeks.



Cover photo courtesy Redwood Empire Association