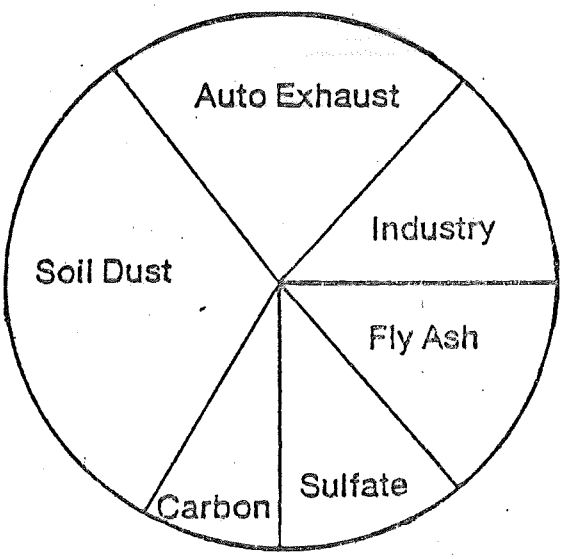
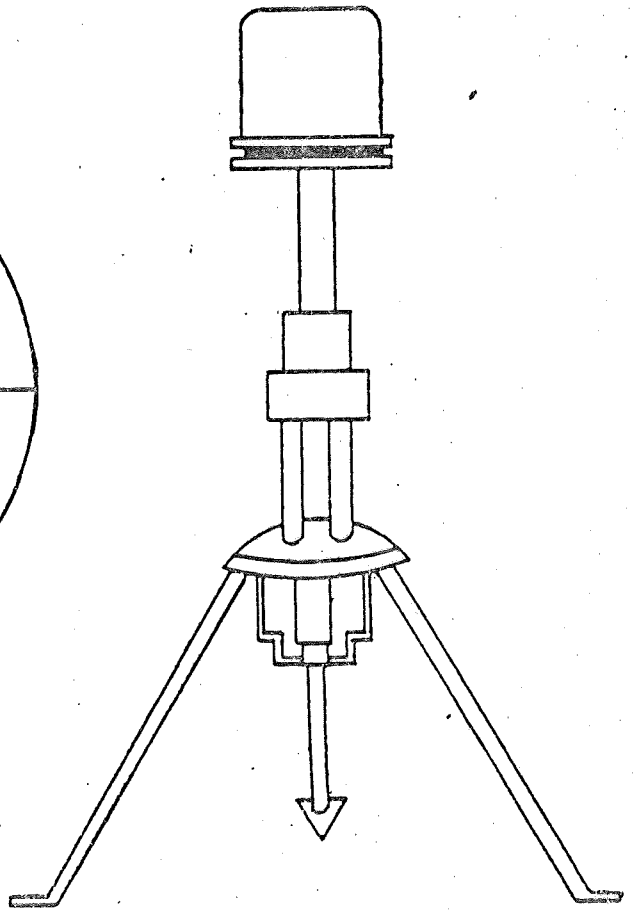
Principles of Air Pollution and Receptor Model Applications

Prepared For:
COMPANHIA DE TECNOLOGIA DE SANEAMENTO AMBIENTAL
SAO PAULO, BRAZIL





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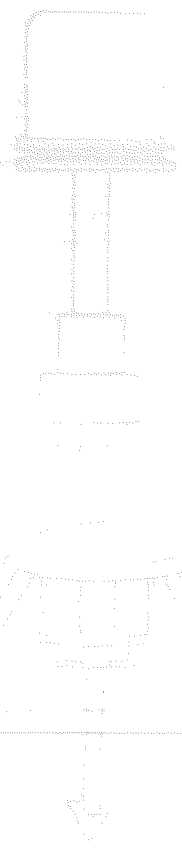

PRINCIPLES OF AIR POLLUTION
AND
APPLICATION OF RECEPTOR MODELS

--Compilation of Presentations--

Prepared For:

COMPANHIA DE TECNOLOGIA DE SANEAMENTO AMBIENTAL
(CETESB)

Sao Paulo, Brazil

May 24 - June 4, 1982

Instructors:

Dr. John A. Cooper
Mr. John E. Core

NEA, INC.
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Preface

This workshop provides an overview of the characteristics, source and effects of air pollutants and newly developed techniques useful in quantifying source impacts. The goal of the short course is to provide a basic knowledge of the major practical aspects of controlling urban air pollution problems through the selective application of source apportionment techniques, cost effective emission controls and flexible air resource management policies. Emphasis has been placed on the identification and control of particulate emissions using chemical receptor models.

New improvements in air sampling and analytical techniques have made available, for the first time, detailed information on the chemical and physical nature of the ambient aerosol and of source emissions. Using these chemical "fingerprints", particle morphology and the natural variability of airshed sources, recent developments in receptor models have provided new techniques of assigning source contributions within non-attainment areas. Application of these tools by regulatory agencies, promotion by consultants and increasing interest by industrial groups require that professionals understand the capabilities and limitations of these methods.

This manual is intended for use in conjunction with workshops presented by NEA, INC. The purpose of this manual, and the workshop, is to acquaint regulatory professionals with receptor models, their applications, limitations and potential value to regulatory programs. EPA is encouraging the use of these techniques in the development of future SIP programs.

AGENDA

Principles of Air Pollution and Receptor Modeling
May 24 - June 4, 1982
-Sao Paulo, Brazil-

Monday, May 24

	9:00 - 9:30	Class Introductions (Core)
	9:30 - 10:00	Overview of course objectives (Core)
Session 1	10:00 - 11:00	Introduction to air pollution (Core)
	11:00 - 11:30	Break
Session 1	11:30 - 12:30	Introduction to air pollution & receptor models (Core)
	12:30 - 2:00	Lunch
Session 2	2:00 - 3:30	Background to receptor modeling (Cooper)
	3:30 - 4:00	Break
Session 3	4:00 - 5:00	Sources and effects of air pollution (Core)
	5:00 - 5:15	Assigned reading (Core)

Tuesday, May 25

	9:00 - 9:15	Assigned reading quiz
	9:15 - 9:45	Quiz review (Cooper)
Session 4	9:45 - 10:15	Air quality standards (Core)
	10:15 - 10:45	Break
Session 5	10:45 - 11:45	Review of emission controls (Core)
Session 6	11:45 - 12:30	Fundamentals of chemical matrix theory (Cooper)
	12:30 - 2:00	Lunch
Session 7	2:00 - 3:30	Characteristics of source & ambient particles (Cooper)
	3:30 - 4:00	Break
Session 8	4:00 - 4:30	Measurement of stack emissions (Core)
Session 9	4:30 - 5:00	Air pollution meteorology (Core)
	5:00 - 5:15	Assigned reading (Cooper)

Wednesday, May 26

	9:00 - 9:15	Assigned reading quiz
	9:15 - 9:45	Quiz review
Session 10	9:45 - 10:45	Air quality management (Core)
	10:45 - 11:15	Break
Session 11	11:15 - 12:30	Relationship of emission sources to air quality (Core)
	12:30 - 2:00	Lunch
Session 12	2:00 - 3:30	Fundamental principles of receptor modeling (Cooper)
	3:30 - 4:00	Break
Session 12	4:00 - 5:00	Fundamental principles of receptor modeling (Cooper)
	5:00 - 5:15	Assigned reading (Core)

AGENDA
-Continued-

Principles of Air Pollution and Receptor Modeling
May 24 - June 4, 1982
-Sao Paulo, Brazil-

Thursday, May 27

	9:00 - 9:15	Assigned reading quiz
	9:15 - 9:30	Quiz review
Session 13	9:45 - 10:30	Application of chemical mass balance to control strategy development (Core)
	10:30 - 11:00	Break
Session 14	11:00 - 12:30	Review of receptor model studies (Core) • Portland Aerosol Characterization Study (PACS) • Medford Aerosol Characterization Study (MACS) • Iowa Aerosol Study
	12:30 - 2:00	Lunch
	2:00 - 2:45	PACS program design and results (Core) - slide show
Session 15	2:45 - 3:30	Review of receptor model studies II (Cooper) • Kellogg, Idaho Study • Lewiston, Idaho Study • East Helena, Montana
	3:30 - 4:00	Break
Session 16	4:00 - 4:30	Optimizing source resolution (Cooper)
Session 17	4:30 - 5:00	Development of study design (Core)
	5:00 -	Assigned reading (Core)

Friday, May 28

	9:00 - 9:15	Assigned reading quiz
	9:15 - 9:45	Quiz review (Cooper)
Session 18	9:45 - 11:15	Analytical methods and long range transport (Cooper)
Session 19	11:15 - 12:30	Model validation and Chemical mass balance (Core)
	12:30 - 2:00	Lunch
	2:00 - 5:00	Study Design Laboratory

SELECTED RECEPTOR MODEL REFERENCES

Reference	
1	Receptor Model Technical Series - Volume I
2	Receptor Model Technical Series - Volume II
3	Receptor Models Relating Ambient TSP to Sources
4	Review of the Chemical Receptor Model of Aerosol Source Apportionment
5	Receptor Oriented Methods of Air Particulate Source Apportionment
6	Receptor Models - How Great Thou Art!
7	New Models to Control Old Pollution Sources
8	Particulate Dispersion Model Evaluation: A New Approach Using Receptor Models
9	Minimizing the Cost of Air Pollution Control
10	Dilution Sampling for Chemical Receptor Source Fingerprinting
11	Portland Aerosol Characterization Study (2 papers)
12	Medford Aerosol Characterization Study
13	Iowa Source Apportionment Study
14	Air Particulate Control Strategy Development: A New Approach Using Chemical Mass Balance Methods
15	Determination of Source Contributions - Using the Receptor Model
16	Fundamental Principles of the Receptor Model - Gaseous Specie Source Apportionment

Reading Assignments

Evening	References
Monday	1, 4, 5, 7
Tuesday	3, 6, 9, 10
Wednesday	2, 8, 14
Thursday	11, 12, 13, 15, 16

Principles of Air Pollution
and
Receptor Modeling

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Historical Perspectives

Before Industrial Revolution in 1600-1700's

- Natural sources; forest fires, volcanoes, windblown dust.
- Smoke & fumes from cooking and heating fires within closed spaces, odors from decaying refuse.
- Health effects can be traced to the Egyptian empire, discoloration of buildings in early Rome. Records in Britian.

Pollution Problem	Earliest Reference
Health - Annoyance	1257 - Complaints about air in Nottingham
Economic Loss	1377 - Assize of Nuisance
Damage to Furnishings	1512 - Earl of Northumberland
Increasing Death Rate	1658 - Digby 1662 - Grant
Great Stinking Fog	1691 - Gadby

Major Air Pollution Episodes
1930 - 1952

	Meuse Valley Germany, 1930	Donora, PA 1948	London 1952	Poza Rica Mexico, 1950
Weather	Inversion - high pressure - fog	Inversion - high pressure - fog	Same	Inversion & fog
Topography	River Valley	River Valley	River Plain	River Plain
Probable Sources	Industry - steel & zinc plants	Industry - steel & zinc plants	Household coal burning	Unburned H_2S
Illnesses	Chemical irritations of exposed membrane surfaces	Same	Same	Same
No. deaths	60	18	4,000	22
Deaths among those with cardio-resp. disease	yes	yes	yes	no
Ratio Illness to death	100:1	75:1 - 300:1	Illness not in expected prop. to deaths	15:1
Pollutants	SOx, TSP	SOx, TSP	SOx, TSP	H_2S
Max. SO_2 Conc. Est.	40 ppm	2 ppm	1.34 ppm	-

1.2 Global Sources

Tropospheric Aerosol Production Rates

Source	Metric Tons/day	Percent
Natural		
Primary		
Windblown dust	$2 \times 10^4 - 10^6$	9.3
Sea spray	3×10^6	28
Volcanoes	10^4	0.09
Forest fires	4×10^5	3.8
Secondary		
Vegetation	$5 \times 10^5 - 3 \times 10^6$	28
Sulfur cycle	$10^5 \times 10^6$	9.3
Nitrogen cycle	2×18^6	14.8
Volcano (gases)	10^3	0.009
Subtotal		94%
Man-Made		
Primary		
Combustion, Industry	$1 \times 10^5 - 3 \times 10^5$	2.8
Cultivation dust	$10^2 - 10^3$	0.009
Secondary		
HC gases	7×10^3	0.065
SO_4^{2-}	3×10^5	2.8
NO_3^-	6×10^4	0.56
NH_4^+	3×10^3	0.028
Subtotal	6.7×10^5	6
TOTAL	10.7×10^6	100%

Sulfur Compounds - Global
(X 10^6 tons/year)

Industry, heating, transportation (SO_2, H_2S)	70
Fertilizer application to soil (SO_4)	11
Rock weathering (SO_4)	14
Biological decay (H_2S)	98
Sea spray (SO_4)	44
Volcanoes (H_2S, SO_2, SO_4)	Small
	237

Nitrogen Compounds - Global
(X 10^6 tons/year NO_2)

Nitrous oxide (bacterial action)	592
NO_2 (forest fires)	0.8
NO_2 (industrial)	
Coal	26.9
Petroleum	22.3
Natural gas	2.1
Incineration	0.5
Wood	0.3
TOTAL	645 X 10^6 TPY

Pollutant	Global Sink Processes, (typical)
SO_2	Precipitation scavenging, oxidation to SO_4, absorption by soils
H_2S	Oxidation to SO_4
O_3	Reaction with vegetation, soil, snow, ocean surfaces
N_2O	Soil absorption & microbial destruction
CO, NO_2	Soil reaction, conversion to NO_3^-, precipitation scavenging
CO	Stratospheric reaction to OH^-, soil uptake
CO_2	Absorption in oceans, photosynthesis
HC	Conversion to particles

1.3 Nature of Atmospheric Contaminants

I. Classified by Physical State
   - A. Gases
     1. Natural
     2. Asphyxiants
     3. Irritants
     4. Toxic
     5. Nartcotizing
   - B. Vapors
   - C. Aerosols

II. Most Important Contaminants
   - A. S Compounds
   - B. Fluorine Compounds
   - C. Chlorine Compounds
   - D. Carbon Compounds
   - E. NOx
   - F. Organic Compounds
   - G. Toxic Elements
   - H. Asbestos

III. Reaction Products

IV. Odors

V. Material Damage

VI. Visibility Reduction

VII. Health Effects

1.4 Air Pollutant Descriptions and Effects

SUSPENDED PARTICULATE

-Solid and liquid particles of soot, dust, aerosols and fumes ranging from 0.1 to 100 microns and averaging about 2 microns in size (1 micron = 1/2540").

-Sources: Combustion sources, cars, industry process losses, fugitive dust, field and slash burning and natural sources, such as ocean spray and wind-raised dust.

-Damage: Aggravates chronic lung disease, heart and lung disease symptoms. Causes material damage and visibility reduction.

SULFUR DIOXIDE

-A colorless, pungent irritating gas.

-Sources: Oil and coal combustion and industry process losses.

-Damage: Aggravates asthma, heart and lung disease in the elderly, irritates lungs, is corrosive to metals and marble, and causes plant damage.

HYDROCARBONS

-A large family of compounds consisting of hydrogen and carbon.
-Sources: Autos, evaporative fuel losses, industry and combustion processes.
-Damage: Hydrocarbons actively participate in oxidant formation and cause plant damage. Methane is produced naturally by decay of organic matter and is not significant in oxidant formation.

NITROGEN DIOXIDE

-A reddish-brown gas, toxic in high concentrations.
-Sources: Formed by conversion of nitric oxide (from autos & combustion sources) and from industrial sources.
-Damage: Increases chronic bronchitis and irritates lungs.

CARBON MONOXIDE

-A colorless, odorless gas that is highly toxic.

-Sources: Incomplete combustion sources, mostly cars.

-Damage: Interferes with the blood's ability to carry oxygen, causing heart difficulties in those with chronic diseases, reduces lung capacity and impairs mental abilities.

PHOTOCHEMICAL OXIDANTS

-Mostly consists of ozone which is an odorless, toxic gas.
-Sources: Photochemical processes in the atmosphere by reaction between oxides of nitrogen and hydrocarbons in the presence of sunlight.
-Damage: Eye irritation, damage to lung tissue and lung functions; material damage and plant damage.

1.5 The Atmosphere

Composition of the homosphere is:

78.09 % N_2	0.93 % Ar	CH_4 1.5 ppm	H_2 0.5 ppm
20.94 % O_2	0.032 % CO_2	N_2O 0.5 ppm	He 0.52 ppm

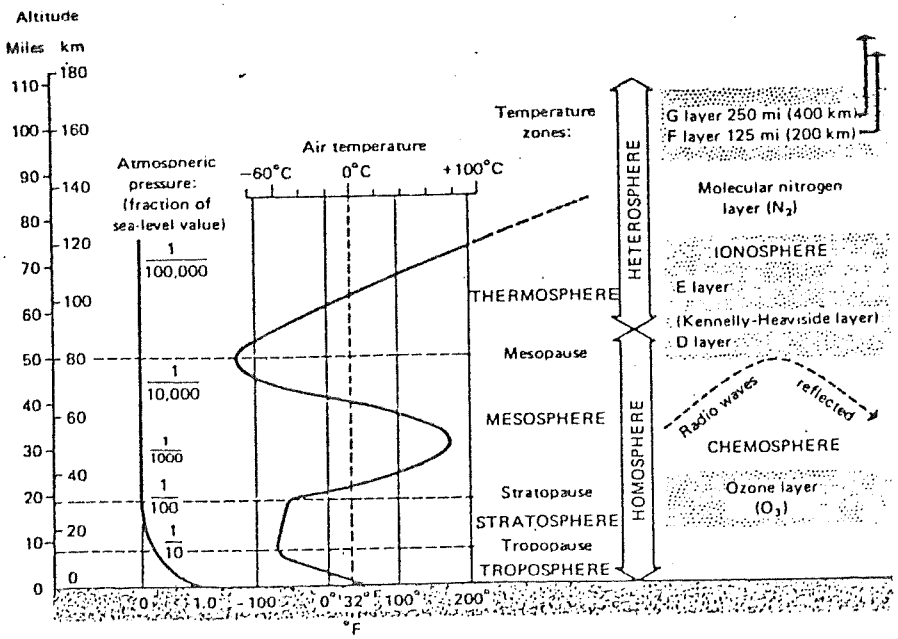


Figure 2. Structure of the atmosphere (3). (A. N. Strahler, "The Earth Sciences," 2nd ed., pp. 18–62. Copyright 1971. Reprinted by permission of Harper and Row.

1.6 The Polluted Atmosphere

Comparisons of Trace Gas Concentrations (ppm)

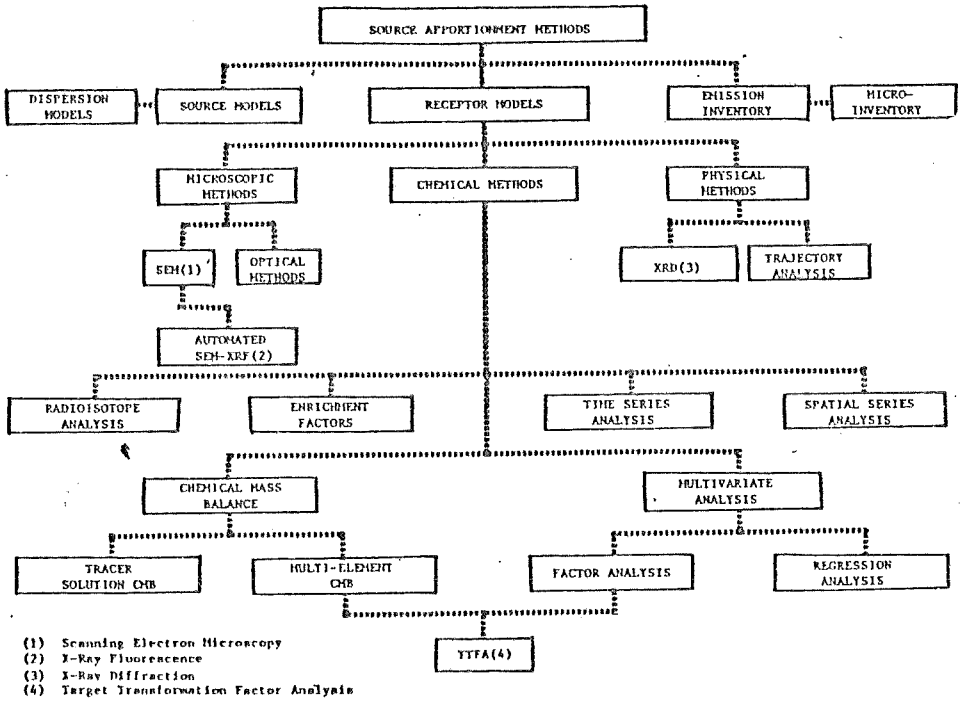
Pollutant	Clean Air	Polluted Air	Ratio
CO_2	320	400	1.3
CO	0.1	40–70	400–700
CH_4	1.5	2.5	1.3
N_2O	0.25	?	–
NO_2	0.001	0.2	200
O_3	0.02	0.5	25
SO_2	0.0002	0.2	1000
NH_3	0.01	0.02	2

Table III Summary of Sources, Concentrations, and Major Reactions of Atmospheric Trace Gases (*20*) [E. R. Robinson and R. C. Robbins, *in* "Air Pollution Control" (W. Strauss, ed.), Part II, pp. 1–93. Copyright 1972, Wiley (Interscience), New York. N[illegible] York. Reprinted by permis[illegible]ion of John Wiley & Sons, Inc.]

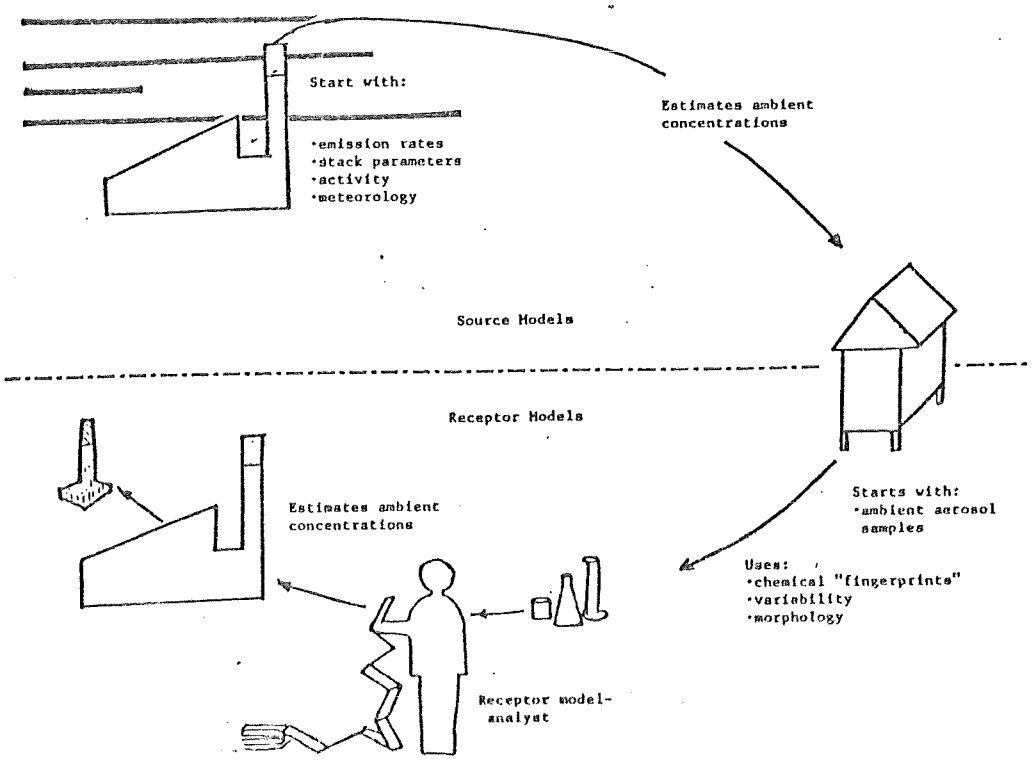
Contaminant	Major pollution sources	Natural sources	Estimated emissions (tons)		Atmospheric background concentrations	Calculated atmospheric residence time	Removal reactions and sinks	Remarks
			Pollution	Natural				
SO_x	Combustion of coal and oil	Volcanoes	146×10^6	No estimate	0.2 ppb	4 days	Oxidation to sulfate by ozone or, after absorption, by solid and liquid aerosols	Photochemical oxidation with NO_x and HC may be the process needed to give rapid transformation of $SO_x \rightarrow SO_4$
H_2S	Chemical processes, sewage treatment	Volcanoes, biological action in swamp areas	3×10^6	100×10^6	0.2 ppb	2 days	Oxidation to SO_x	Only one set of background concentrations available
CO	Auto exhaust and other combustion	Forest fires, oceans, terpene reactions	304×10^6	33×10^6	0.1 ppm	<3 years	Probably soil organisms	Ocean contributions to natural source probably low
NO/NO_2	Combustion	Bacterial action in soil (?)	53×10^6	NO: 430×10^6 NO_2: 658×10^6	NO: 0.2–2 ppb NO_2: 0.5–4 ppb	5 days	Oxidation to nitrate after sorption by solid and liquid aerosols, hydrocarbon photochemical reactions	Very little work done on natural processes
NH_3	Waste treatment	Biological decay	4×10^6	1160×10^6	6 ppb to 20 ppb	7 days	Reaction with SO_x to form $(NH_4)_2SO_4$, oxidation to nitrate	Formation of ammonium salts is major NH_3 sink
N_2O	None	Biological action in soil	None	590×10^6	0.25 ppm	4 years	Photodissociation in stratosphere, biological action in soil	No information on proposed absorption of N_2O by vegetation
Hydrocarbons	Combustion exhaust, chemical processes	Biological processes	88×10^6	CH_4: 1.6×10^9 Terpenes: 200×10^6	CH_4: 1.5 ppm non CH_4: <1 ppb	4 years (CH_4)	Photochemical reaction with NO/NO_2, O_3; large sink necessary for CH_4	"Reactive" hydrocarbon emissions from pollution = 27×10^6 tons
CO_2	Combustion	Biological decay, release from oceans	1.4×10^{10}	$.10^{11}$	320 ppm	2–4 years	Biological adsorption and photosynthesis, absorption in oceans	Atmospheric concentrations increasing by 0.7 ppm/year

1.7 Introduction to Receptor Models

1.7.1 Development of Control programs requires knowledge of source impacts or source apportionment analysis



1.7.2 Major Differences Between Receptor and Dispersion Models



Source Models	Receptor Models
• Predictive in Nature	• Accurate analysis of fugitive dusts
• Useful to evaluate alternative scenarios of control	• Useful for 24 hour worst case impacts
• Can identify impact from one specific source	• Identifies uninventoried source impacts
	• Useful in complex terrain
	• Independent of emission inventory

1.7.3 Elements of Source-Oriented Studies

Limitation of Source Studies

1.7.4 Elements of Receptor-Oriented Studies

Limitations of Receptor-Oriented Studies

1.7.5 Monitoring Considerations

1.7.6 Types of Receptor Studies

1.7.7 Model Validation

1.7.8 Source Apportionment Method Selection

	-Capabilities-			-Resource Requirements-			
Method	Coarse	Fine	Episodes	Man-power	Skill	Com puter	Data
PLM-Optical Microscopy	Sq	-	x	4	5	1	2
SEM Microscopy	Sq	Sq	x	4	5	1	2
Automated SEM	Qn	-	x	5	5	3	2
Enrichment Factor	Sq	Sq	x	1	2	2	3
CMB	Qn	Qn	x	4	5	2	5
Multivariate	Qn	Qn	-	3	5	2	5
Dispersion Models	Qn	Qn	-	2	4	3	5
XRD	Qn	-	x	4	5	1	2
Microinventory	Sq	Sq	-	3	2	1	2
Radiocarbon	Qn	Qn	x	5	5	1	2

Table 2. Source Apportionment - Receptor Model Advantages and Disadvantages

Source Apportionment Tools	Techniques Advantages	Disadvantages
Microscopy		
Optical	Use of color, surface texture and optical properties for particle identification	Limited to particles >2 μm, semi-quantitative, highly dependent on operator skill
SEM	Can be used with particles <1 μm	Costly to use on large numbers of particles, not useful for amorphous species
Automated SEM-XRF	Classifies particles by size, shape and elemental composition. Analytical speed, ability to count large numbers of particles	Still in early stage of development. Costly. Not reliable for organics, coarse fraction only
Chemical		
Enrichment Factors	Provides evidence of a source's impact by changes in aerosol composition. Simple	Semi-quantitative method; requires source composition data. Often not specific
Time Series Analysis	Provides clues to sources; simple, inexpensive	Generally does not provide specific source impact information
Spatial Series Analysis	Provides clues to sources, simple, inexpensive	Does not provide source impact information
Chemical Mass Balance	Provides quantitative estimates based on real data. Impact uncertainties provided	Source composition data required; chemically non-descriptive sources cannot be identified
Multivariate Analysis	No prior knowledge of sources needed to resolve element patterns, compositon required to identify sources by common names	Large data sets required, cannot provide short-apportionment
Radioisotope Analysis	Direct, quantitative measure of fossil carbon	Costly. Limited to fossil-"modern" carbon apportionment
Physical		
X-Ray Diffraction	Direct quantifaction of crystalline particles	Coarse particles only. Not useful for amorphous aerosols
Other		
Dispersion Modeling	Estimates impact from future and hypothetical sources	Difficulty in preparing accurate emission inventory and transport input data
Trajectory Analysis	Helps identify approximate source location	Cannot quantitatively estimate specific source impacts
Emission Inventory	Traditional method of source contribution analysis. Simple to use	Fugitive sources impossible to inventory, background aerosol not known; source impacts incorrectly assumed to be proportional to emissions
Microinventory	Qualitative estimate of nearby fugitive dust and point source impacts	Does not provide specific source short term periods.

2. BACKGROUND TO RECEPTOR MODELING

Overview

The physical and mathematical foundation for receptor models will be developed in this session. Evaluation of receptor model principles will be reviewed from before its first application in 1967 to the present, and trends for future evolution discussed. The physical world and the mathematical model describing the source-receptor relationship will be developed. Optional approaches to applying the model to source apportionment will be briefly presented and the concept of source resolution developed.

Specific topics to be discussed include:

1. Introduction
   - 1.1 Objectives of Source Apportionment Methods
   - 1.2 Source Apportionment Methods
2. Evolution of Receptor Model Principles
   - 2.1 Pre-1967
   - 2.2 1967-1978
   - 2.3 1978 to the present and beyond

Break

3. Physical and Mathematical Basis
   - 3.1 Fundamental Receptor Model Equation
   - 3.2 Basics of Vector and Matrix Concepts
   - 3.3 The Model in Vector Space Graphics
4. Approaches to Model Solution
   - 4.1 Mass Balance Methods
   - 4.2 Multivariate Methods
5. Source Resolution
6. Overview of Model Requirements

ULTIMATE OBJECTIVE OF SOURCE APPORTIONMENT

"IMPROVED AIR QUALITY THROUGH ATTAINMENT OF AMBIENT AIR QUALITY STANDARDS"

OPTIONAL APPORTIONMENT INTERESTS

INHALABLE PARTICLES (< 10μm)
RESPIRABLE PARTICLES (< 2.5μm)
VISIBILITY DEGRADATION
HAZARDOUS CHEMICALS (Cd, POM, ETC.)

ULTIMATE OBJECTIVE OF SOURCE APPORTIONMENT

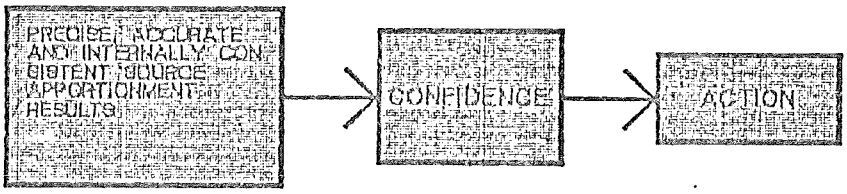
"IMPROVED AIR QUALITY THROUGH ATTAINMENT OF AMBIENT AIR QUALITY STANDARDS"

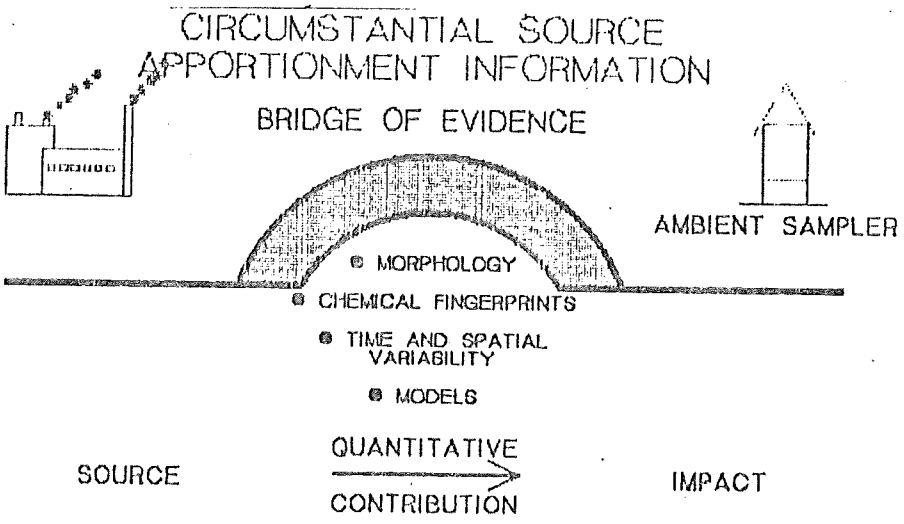
STANDARDS

24 HOUR TSP	260 (150) $\mu g/m^3$
ANNUAL TSP	75 (69) $\mu g/m^3$
QUARTERLY LEAD	1.5 $\mu g/m^3$

WHAT IS REQUIRED TO MEET OBJECTIVE?

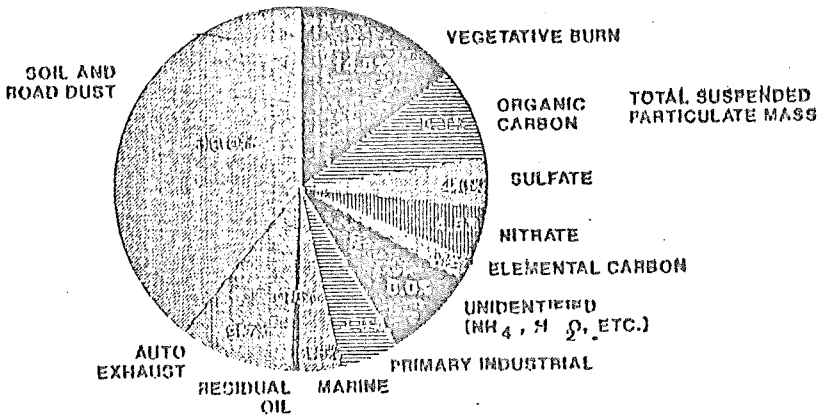
ACTION!

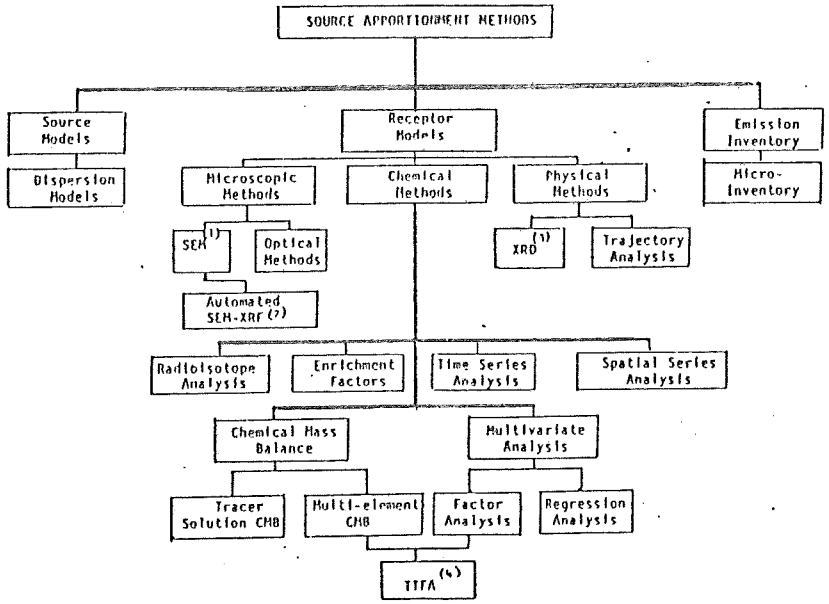




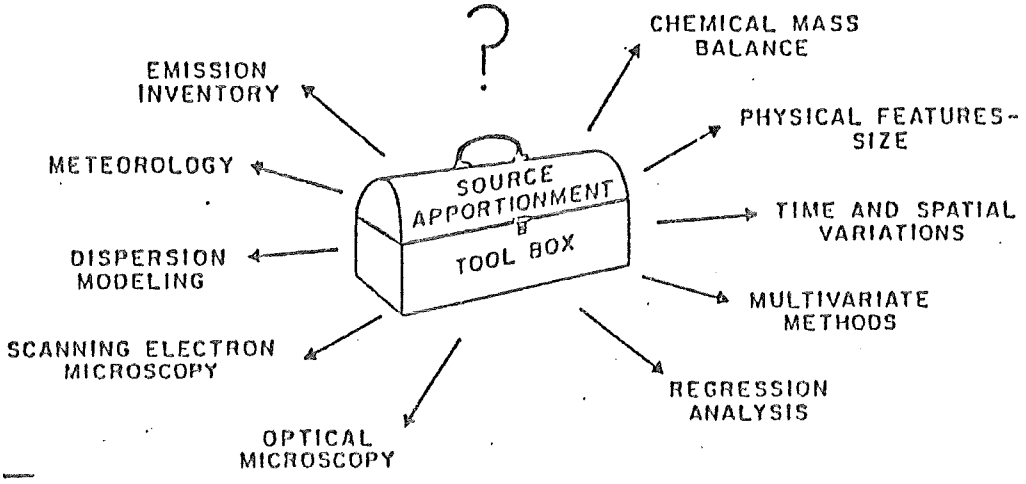
CONTRIBUTION BASED ON ESTABLISHING OTHER CIRCUMSTANCES WHICH AFFORD REASONABLE INFERENCE OF THE SOURCE CONTRIBUTION

AEROSOL SOURCE IMPACTS PORTLAND, OREGON
ANNUAL AVERAGE





WHICH TOOLS SHOULD BE USED ?



PRE–1967 ACTIVITIES

1927 1935	SPEARMAN THURSTON	SPEARMAN–THURSTON APPROACH TO FACTOR ANALYSIS
1947	THURSTON	MULTIPLE FACTOR ANALYSIS
1956	LORENZ	EMPIRICAL ORTHOGANAL FUNCTIONS AND STATISTICAL WEATHER PREDICTIONS
1967	BLIFFORD AND MEEKER	A FACTOR ANALYSIS MODEL OF LARGE SCALE POLLUTION

1967–1978

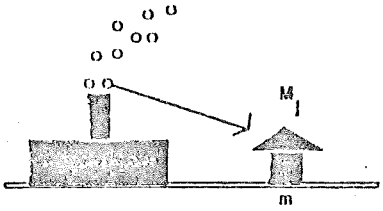
1967 – BLIFFORD & MEEKER, FIRST APPLICATION OF RECEPTOR MODEL, MULTIVARIATE
1968 – PRINZ AND STRATMANN, FACTOR ANALYSIS
1969 – WINCHESTER AND NIFONG, CHEMICAL EMISSIONS
1970 – HIDY AND FRIEDLANDER, CHEMICAL TRACERS
1972 – MILLER, FRIEDLANDER AND HIDY, CMB FORMALISM ESTABLISHED
1972 – 1978 LARGE URBAN AEROSOL CHARACTERIZATION AND SOURCE IDENTIFICATION STUDIES

- ACHEX – SOUTHERN CALIFORNIA
- RAPS – ST. LOUIS, MISSOURI
- NYSAS – NEW YORK, NEW YORK
- WASHINGTON, D.C.
- TUCSON, ARIZONA
- PACS – PORTLAND, OREGON

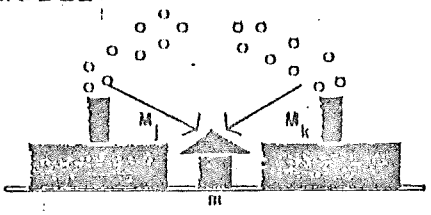
1978 AND BEYOND

1978	WATSON	RECEPTOR MODEL SYSTEMATICS ESTABLISHED
1980	QUAIL ROOST WORKSHOP	RECEPTOR MODELS RECOGNIZED AS A DISTINCT DISCIPLINE
1980	OREGON STATE	CMB METHODS USED AS ROUTINE TOOL FOR AIRSHED MANAGEMENT
1981	APCA	FIRST APCA SESSIONS ON RECEPTOR MODELS
BEYOND		● DEVELOPMENT OF SOURCE FINGERPRINT LIBRARY AND CATALOG ● DEVELOPMENT OF UNIFIED APPROACHES TO SOURCE APPORTIONMENT ● DEVELOPMENT OF MORE COST–EFFECTIVE METHODS ● NATIONAL TECHNICAL DOCUMENTS

REAL WORLD PHYSICAL MODEL



DISPERSION MODEL



RECEPTOR MODEL

MATHEMATICAL MODEL

$$M_j = D_j E_j$$

$$M_j = D_j E_j$$

SOURCE

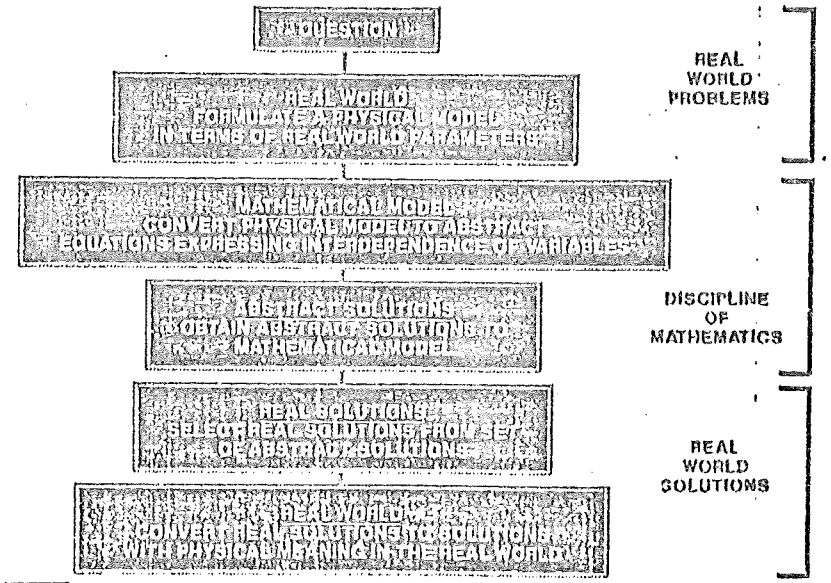
SOURCE MASS IS DEPENDENT VARIABLE

$$m = \sum_j M_j$$

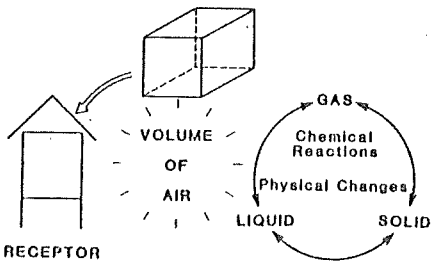
$$m_i = \sum_j F_{ij} M_j$$

RECEPTOR

RECEPTOR MASS IS DEPENDENT VARIABLE

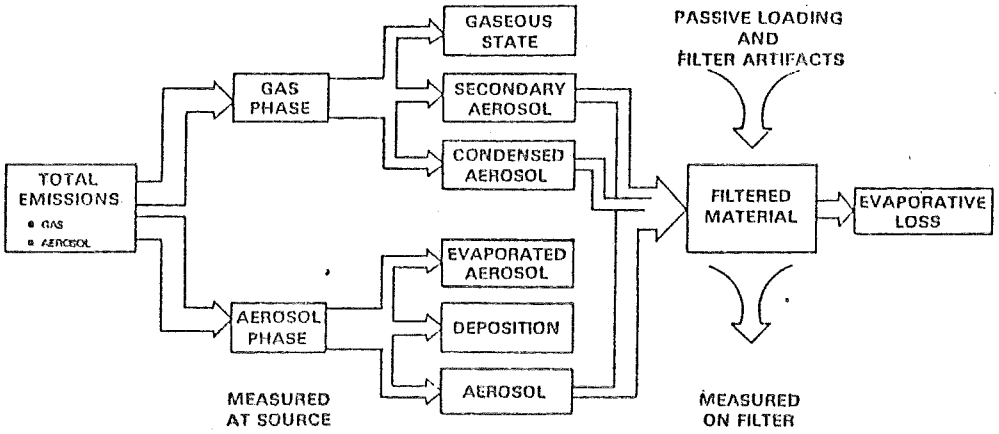


SUBJECT OF STUDY



- TIME
- LOCATION
- FEATURES
  - Chemical Concentration
  - Elemental Concentration
  - Particle Concentration
  - Particle Type Concentration
  - Size
  - Color
  - Light Scattering/Absorption Properties
  - Etc

AEROSOL MASS BALANCE



DATA MATRIX

AMBIENT DATA TABLE
MASS
(ug/m^3)

CHEMICAL SPECIES	FILTER ID 1	2	3	4	5
C	10	8	2	15	20
SO_4	6	4	2	10	15
Na	1	0.5	0.1	3	3
Si	6	3	1	2	4
Fe	1	0.5	0.1	2	4
Pb	0.1	0.5	1	0.1	0.2

AMBIENT DATA MATRIX

$$\begin{bmatrix} 10 & 8 & 2 & 15 & 20 \\ 6 & 4 & 2 & 10 & 15 \\ 1 & 0.5 & 0.1 & 3 & 3 \\ 6 & 3 & 1 & 2 & 4 \\ 1 & 0.5 & 0.1 & 2 & 4 \\ 0.1 & 0.5 & 1 & 0.1 & 0.2 \end{bmatrix}$$

6 X 5

3. SOURCES, MEASUREMENT AND EFFECTS OF AIR POLLUTION

3.1 Gaseous Pollutants

3.1.1 Hydrocarbons

Source Category (U.S. X 10^6 tons/year, 1970)	
Fuel combustion, stationary source	0.6
Transportation	19.5
Solid Waste disposal	2.0
Industrial process losses	5.5
Agricultural burning	2.8
Miscellaneous	4.4
TOTAL	34.7

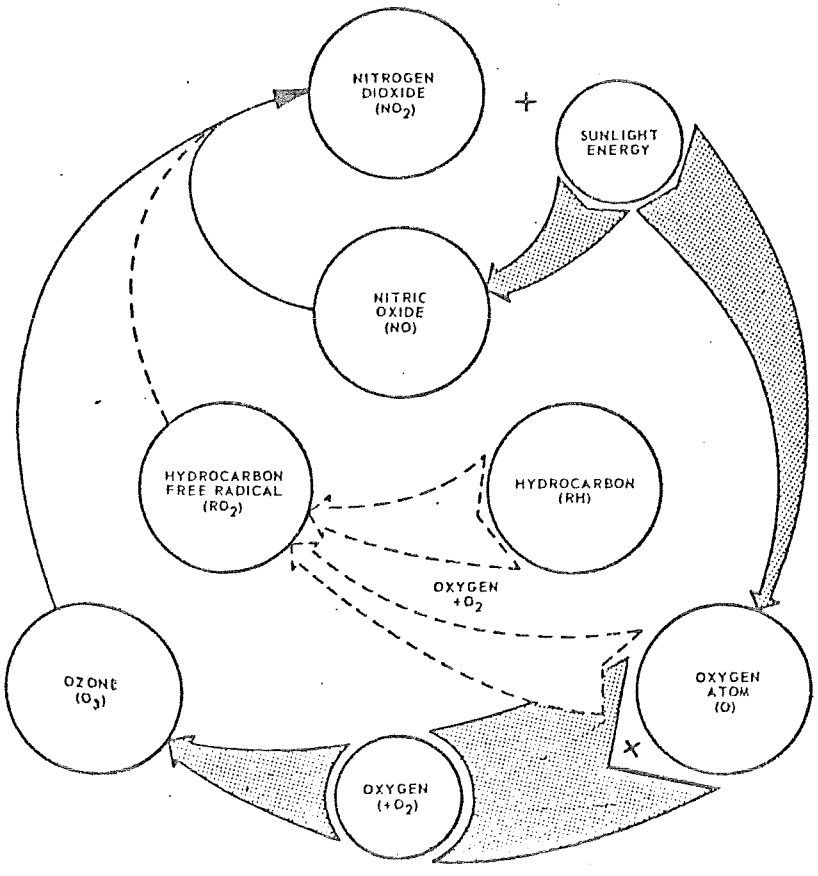


Figure 2-3. Interaction of hydrocarbons with atmospheric nitrogen dioxide photolytic cycle.

MEASUREMENT: Flame Ionization Detection (FID)

- Hydrocarbon analyses using FID detectors mix the sample air in a hydrogen fuel. The sample passes through a small jet with air supplied around it to support combustion. The carbon-containing compounds carried into the flame results in the formation of ions which are collected by a voltage across the flame. The ion current is electronically measured, amplified and recorded.

3.1.2 Carbon Dioxide

Source Category	Emissions (X 10^9 TPY) U.S., 1970
Coal	7.40
Petroleum	5.28
Natural Gas	1.62
Incineration	0.51
Wood Fuel	0.68
Forest Fires	0.39
Total	15.88

3.1.3 Carbon Monoxide

Source Category	Emissions (10^6 TPY, 1970) U.S.
Fuel combustion - stationary sources	0.8
Transportation	111.0 (75%)
Solid waste disposal	7.2
Industrial process losses	11.4
Agricultural burning	13.8
Miscellaneous	3.0
Total	147.0

Formation of Carboxyhemoglobin (COHb)

$$CO + Hb \rightleftharpoons COHb$$

CO Effects

- 2.5% COHb Effects on Central Nervous System
  - Impairment in time-interval discrimination
  - Changes in visual activity
  - Impaired psycomotor ability and visual discrimination
- Above 5% COHb
  - Increased cardiac output
  - Changes in coronary blood flow patterns
  - Changes in myocardial tissue metabolism

MEASUREMENT: Nondispersive Infrared (NDIR)

- Carbon monoxide gas absorption of infrared energy is used as the basis of the method. Infrared energy is absorbed by the CO gas along the length of the sample cell (40") and simultaneously through a reference cell containing a nonabsorbing gas. The infrared energy impinges on a detector causing a temperature and pressure increase to an equilibrium condition. Carbon monoxide in the sample absorbs some of the energy, creating an out-of-balance condition in the detector. The imbalance is proportional to the amount of carbon monoxide in the sample air and is electronically amplified and recorded.

3.1.4 Sulfur Dioxide

Source Category	Emissions (10^6 TPY, 1970) U.S.
Fuel combustion sources	26.5
Transportation	1.0
Solid waste disposal	0.1
Process losses	6.0
Agricultural burning	Neg.
Miscellaneous	0.3
Total	33.9

Welfare Effects

Vegetation

- Crop yield reductions at SO_2 concentrations 0.05-0.06 ppm, 2 weeks
- Undesirable ecological effects on forests at seasonal or annual SO_2 concentrations of 0.05 ppm
- Cellular damage (necrosis) in a variety of agricultural crops as SO_2 increases to 0.25 ppm
- Damage to many specie of forest trees at 0.25 ppm or less for 2 hours

Acid Precipitation

Visibility

Climate

Material Damage

Health Effects
Health effects, in summary, include breathlessness, throat and eye irritation, increased severity of bronchitis and respiratory disease, aggravation of cardiac disorders and death. Effects have been noted in association with SO_2 concentrations (long term) from < 0.10 ppm often in association with elevated aerosol concentrations.

MEASUREMENT: Continuous Methods

- Flame Photometric Detection (FPD): Measurements are based on the intensity of spectral lines resulting from excitation of sulfur atoms in a hydrogen flame. Emissions from sulfur in the flame are detected by a photomultiplier tube, amplified and recorded.
- Colorimetric Detection: A chemical solution, when mixed with ambient air containing SO_2 turns from a clear to a magenta color which is continuously recorded by passing a light beam through the moving solution column. Light not absorbed by the colored solution is detected by a photomultplier, amplified and recorded.
- Noncontinuous (Bubbler Method):
Pararosaniline Method: A nonautomated version of the colorimetric method is used. Air is bubbled through an SO_2 absorbing solution for 24 hours. Upon return to the laboratory, the light absorbtion measurements are made as before and the sulfur dioxide concentration calculated.

3.1.5 Oxides of Nitrogen

Include N_2O, NO, NO_2, NO_3 and others. Worldwide emissions are approximately 53 X 10^6 tons per year of NO and NO_2 combined.

Source	Emissions (10^6 tons/ year, 1970) U.S.
Fuel combustion - stationary sources	10.0
Transportation	11.7
Solid waste disposal	0.4
Industrial process losses	0.2
Agricultural burning	0.3
Miscellaneous	0.1
Total	22.7

Welfare Effects

Vegetation

Health Effects

MEASUREMENT: Chemiluminescent Detection

- The air sample is continuously pumped into two paths within the analyzer: One leading through a converter to reduce nitrogen dioxide (NO_2) to nitric oxide (NO) while the other path bypasses the converter. Both samples reach reaction chambers where the NO is detected by its chemiluminescent (light emitting) reaction with ozone. The light emissions are detected by photomultiplier tubes, amplified and recorded.

3.1.6 Ozone (Secondary Pollutant)

Vegetation Effects

Projected O_3 (ppm) producing a 5% Injury to Economically Important Crops

Time (hrs)	Sensitive	Intermediate	Resistant
1	0.10-0.25	0.20-0.40	> 0.35
2	0.07-0.20	0.15-0.30	> 0.25
4	0.05-0.15	0.10-0.25	> 0.20
8	0.03-0.10	0.08-0.20	> 0.15

Material Damage

Health Effects

MEASUREMENT: Chemiluminescent Detection

- Photochemical oxidants are measured by a method specific for only ozone. The chemiluminescence method is based on the intensity of light emissions resulting from the reaction between ozone and ethylene. Air is pumped into a chamber, mixed with ethylene and the light emissions are measured on a photomultiplier tube, amplified and recorded.

3.2 Suspended Particulate Mass

Sources include natural processes (volcanoes, windblown soil, forest fires, biological sources, meteoric dust, sea spray, secondary aerosols and anthropogenic sources from fugitive dusts, combustion processes and process losses.

TSP Particulate Emissions (U.S.)

Source	Tons Per Year (10^9)
Unpaved road dust	123,500
Industrial processes	6,200
Fuel combustion	3,800
Transportation	1,300
Solid waste disposal	500
All other	700
Total	136,000

Selected Specific Sources

Source	Tons Per Year (10^9)	
Electrical utilities - coal	2,350	(61% of combustion)
Crushed stone	1,340	
Highway vehicles	900	
Iron and steel	830	
Cement	780	
Grain milling and storage	730	
Industrial boilers - coal	700	
Forest fires	500	
Primary non ferrous smelters	480	

Material Effects

Vegetation

Health Effects

Visibility Reduction

MEASUREMENT: Hi-vol Sampler

- Samples are collected with High-Volume samplers (HV's) which operate somewhat like a vacuum cleaner. The method uses preweighed 8" x 10" glass fiber filters mounted on the sampler. Air is drawn through the filter at about 50 cubic feet per minute. After 24 hours of sampling (midnight to midnight) the sample filter is weighed and the micrograms of particulate deposited on the filter per cubic meter of air sampled is determined. Samples are routinely taken every sixth day at each monitoring site.

- Dichotomous Sampler
The dichotomous sampler is a low flowrate (16.7 lpm) sampler that divides the air stream passing through a 10 or 15 μm inlet into two portions that are filtered separately. It is referred to as a "virtual" impactor since the particle size separation is accomplished by pseudo-impaction into an airstream of differing velocity, rather than onto an impaction surface. Current designs cut at 2.5 μm. 37 mm teflon filters are used to allow gravimetric and chemical analysis .

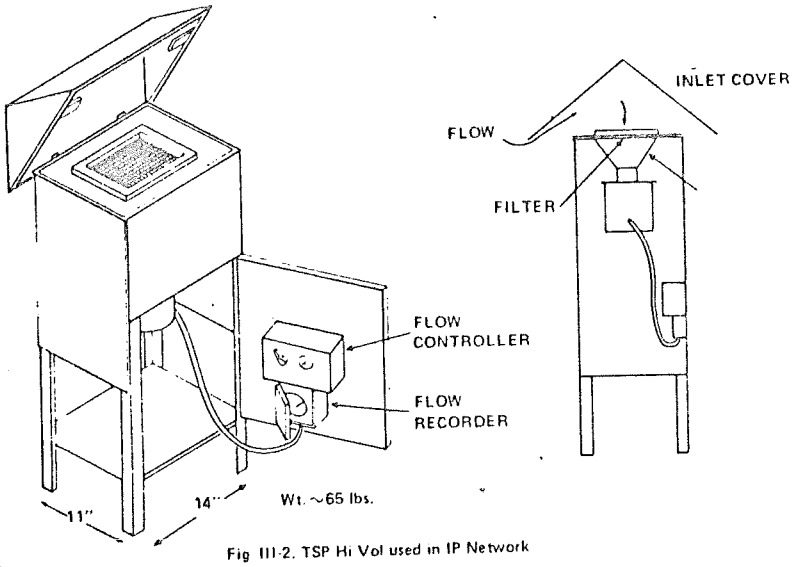


Fig III-2. TSP Hi Vol used in IP Network

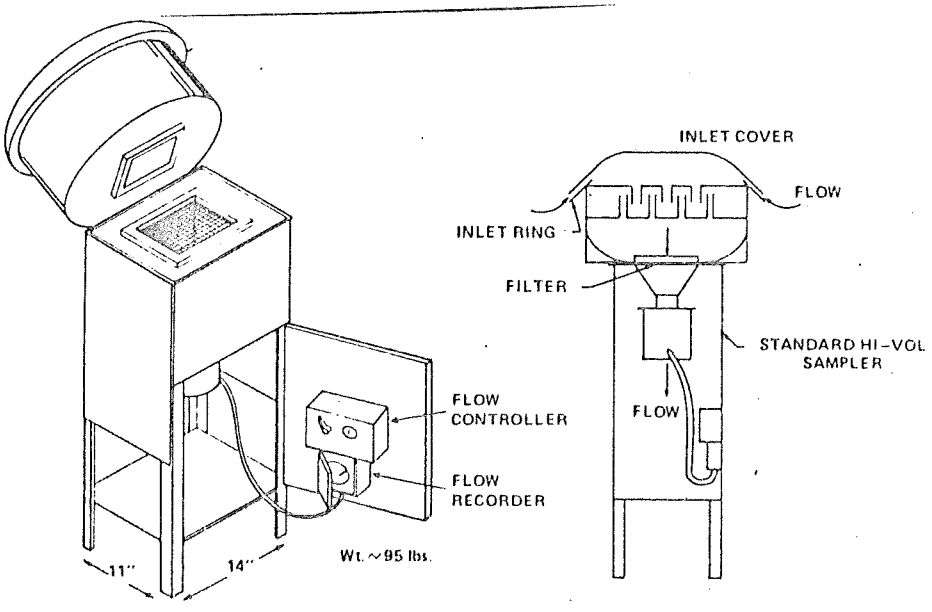
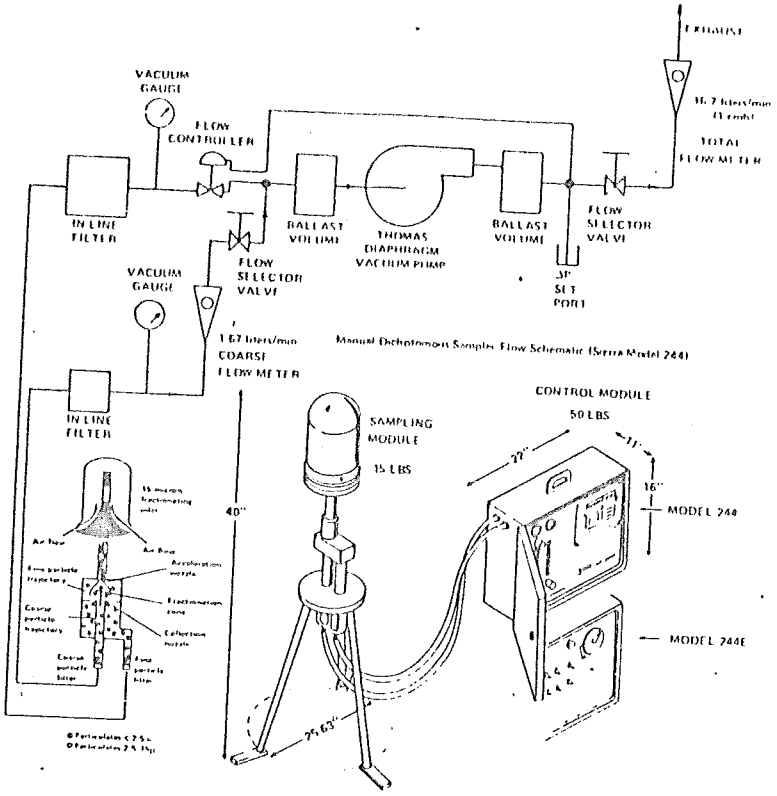


Fig. III-3. SSI Hi Vol used in IP Network



Manual Dichotomous Samples Flow Schematic (Sierra Model 244)

Fig III 4 Manual Dichotomous Samplers used in IP Network

4. AIR QUALITY STANDARDS

Table 1

Ambient Air Quality Standards for Oregon

Pollutant	Averaging Time	Federal Standards Primary (Health)	Federal Standards Secondary (Welfare)	Oregon Standards
Total Suspended Particulate	Annual Geometric Mean	75 ug/m^3*	60 ug/m^3	60 ug/m^3
	24 hours (1)	260 ug/m^3	150 ug/m^3	150 ug/m^3
	Monthly (2)	-	-	100 ug/m^3
Ozone (4)	1 hour	235 ug/m^3 (3)	235 ug/m^3 (3)	160 ug/m^3 (3)
Carbon Monoxide	8 hours (1)	10 mg/m^3**	10 mg/m^3	10 mg/m^3
	1 hour (1)	40 mg/m^3	40 mg/m^3	40 mg/m^3
Sulfur Dioxide	Annual Arithmetic Average	80 ug/m^3	-	60 ug/m^3
	24 hours (1)	365 ug/m^3	-	260 ug/m^3
	3 hours	-	1300 ug/m^3	1300 ug/m^3
Nitrogen Dioxide	Annual Arithmetic Average	100 ug/m^3	100 ug/m^3	100 ug/m^3
Hydrocarbons (Nonmethane)	3 hours (1) (6-9 a.m.)	160 ug/m^3	160 ug/m^3	160 ug/m^3
Lead	Monthly	-	-	3 ug/m^3
	Calendar Quarter	1.5 ug/m^3	1.5 ug/m^3	-

NOTES:

* Micrograms of pollutant per cubic meter of air.

** Milligrams of pollutant per cubic meter of air.

(1) Not to be exceeded on more than one day per year.

(2) 24-hour average not to be exceeded more than 15 percent of the time.

(3) A statistical standard, but basically not to be exceeded more than an average one day per year based on the most recent three years of data.

(4) The federal standards were revised in February, 1979, and the state standard changed from photochemical oxidant to ozone in June, 1979.

Proposed PM-10
Annual Arith mean 50-110 ug/m^3
24 hr. max. 150-350 ~ 275-250 ug/m^3 probable

Air Quality Standards for Selected Pollutants in Several Countries of the World[a]

Country	Carbon monoxide	Nitrogen oxides	Suspended particulates	Sulfur oxides
Austria	38.9/1h 10.3/8h		Zone I (specially protected) 0.12/24h (7 days/yr—not consecutive) Zone II (Urban) 0.20/24h	Zone I 0.07–0.15/30min 0.07–0.10/24h Zone II 0.20–0.30/30min 0.30–0.30/24h
Bulgaria	3/30min 1/24hr	0.085/30min 0.85/24h	0.5/30min 0.15/24h *Soot*—0.15/30min 0.05/24h	(SO_2) 0.5/30min 0.05/24h
Czechoslovakia	6/30min 1/24h	NO_2 0.3/30min 0.1/24h	0.5/30min 0.15/24h *Soot*—0.15/30min 0.05/24h	0.50/30min 0.15/24h
Federal Republic of Germany	10/yr	NO_2 0.08/30min NO 0.2/30min	0.15/24h	0.14/yr
Finland	40/1h	NO_2 0.500/1h (1% in 30 days)	0.15/24h (2 times/60 days or 2% of the time) 0.08/yr	0.300/24h (2 times/30 days or 2% of time in 1 yr) 0.07/yr
	10/8h	0.200/24h (2 times in 30 days)		0.650/yr (1% of time in 30 days)
France	114.5 instantaneous 57.3/8h	NO_2 0.200/24h (5% of the time)	0.15/24h (5% of the time)	0.25
Hungary	6/30min 2/24h	NO_2 0.5/30min 0.15/24h 0.15/30min specially 0.05/24hr protected zones	0.2/24h	0.5/30min 0.15/24h
Israel	35/30min 11.5/8h (1% of the time in 1 yr)	1/30min 0.6/24h	0.2/24h 0.075/1yr *Soot*—0.3/30min 0.1/24h (1% of the time in 1 yr)	0.75/30min 0.26/24h (1% of the time in 1 yr)
Italy	57.2/30min 22.5/8h (1 time in 8 h)	NO_2 0.6/30min 0.2/24hr (1 time in 8 h)	0.75/2h 0.3/24h (1 time in 8 h)	0.75/30min 0.38/24h (1 time in 8 h)
Japan	23/8h (average of hourly values in 8 consecutive hours) 11.5/24h (average of hourly values)	NO_2 0.075–0.1/24h	0.2/1h 0.10/24h	0.26/1h 0.1/24h
Norway		0.4/1h 0.2/24h (2% of the time) 0.1/6mo (Oct to Mar)	0.150/24h 0.06/6mo (2% of the time)	0.4/1h 0.2/24h 0.06/6mo (2% of the time)
Rumania	6/30min 2/24h	NO_2 0.3/30min 0.1/24h	0.5/30min 0.15/24h *Soot*—0.15/30min 0.05/24h	0.75/20min 0.25/24h
USSR	3/30min 1/24h	NO_2 0.085/min 0.085/24h 0.085/24h	Inert nontoxic dusts 0.50/30 min 0.15/24h *Soot*—0.15/30min 0.05/24h	0.5/30min 0.05/24h
Yugoslavia	3/30min 1/24h	NO_2 0.085/30min 0.085/24h		0.5/30min 0.15/24h

[a] Derived from P. Jarrault, *Limitation des Emissions de Polluants et Qualite de l'Air—Valeurs Reglementaires en 1980 dans les Principaux Pays Industrialises. Volume I: Normes de Qualite d'Aire.* Institut Francais de l'Energie, Publ. I.F.E. No. 66, 1980. Values shown are in mg/m^3.

Air Quality Standards are adopted on the basis of criteria documents summarizing the scientific evidence relating pollutant concentrations to health and welfare effects. The criteria documents are descriptive characteristics of the receptor. Standards are prescriptive in that they prescribe exposure or levels of effects that a political jurisdiction has determined should not be exceeded in a specific area. Air quality standard attainment then becomes the driving force behind control programs and enforcement actions. Air Quality Standards are legally enforceable regulations in the U.S.

Other Standards	Comments
Soiling Index	1.5 COH/24 hours
Dust fall	10 $mg/m^2/mo.$
HF, particulate	Fluoride, forage fluoride
Sulphation	0.4 mg $SO_3/100\ cm^2/30$ days
Be, As, Cd, Hg, Ni, V	0.01, 25, 2.0, 2.0, 2.0, 2.0 $\mu g/m^3$ 24 hr., respectively
H_2S	15 $\mu g/m^3$, 1 hr. average
Odors	Less than threshold, 2 tests 15 minutes apart
PSI	Composite index of 100

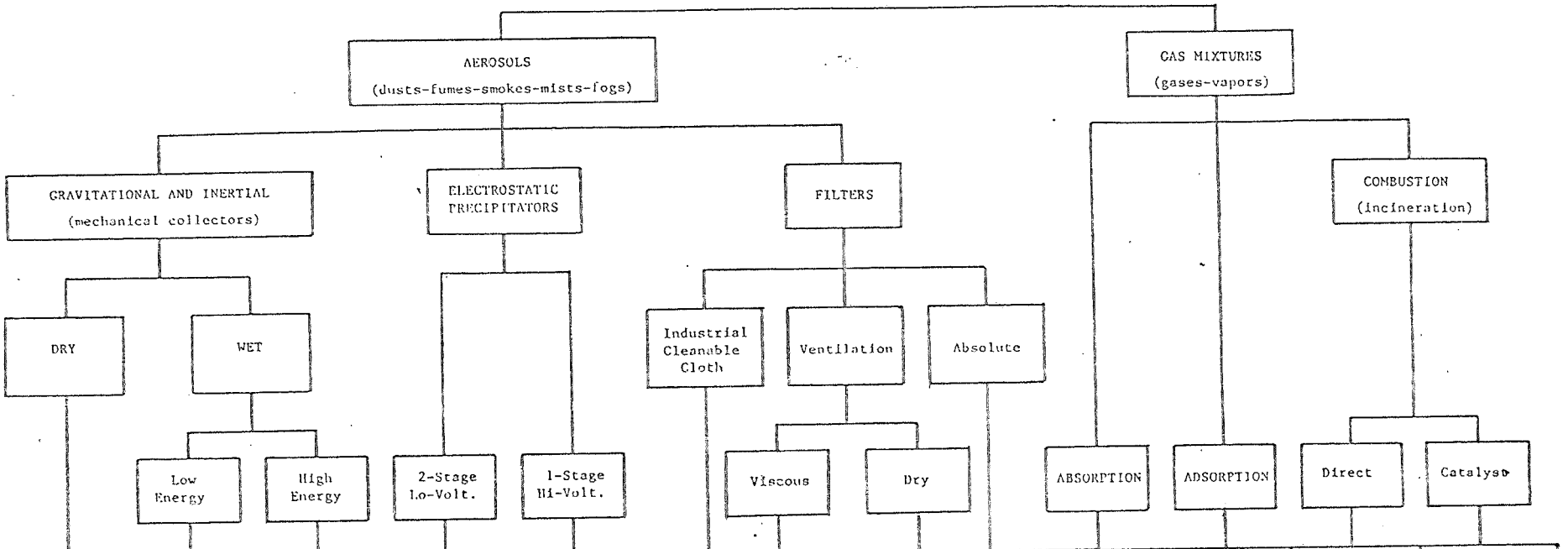
5. REVIEW OF EMISSION CONTROLS

5.1.1 Filtration - Fabric Filters

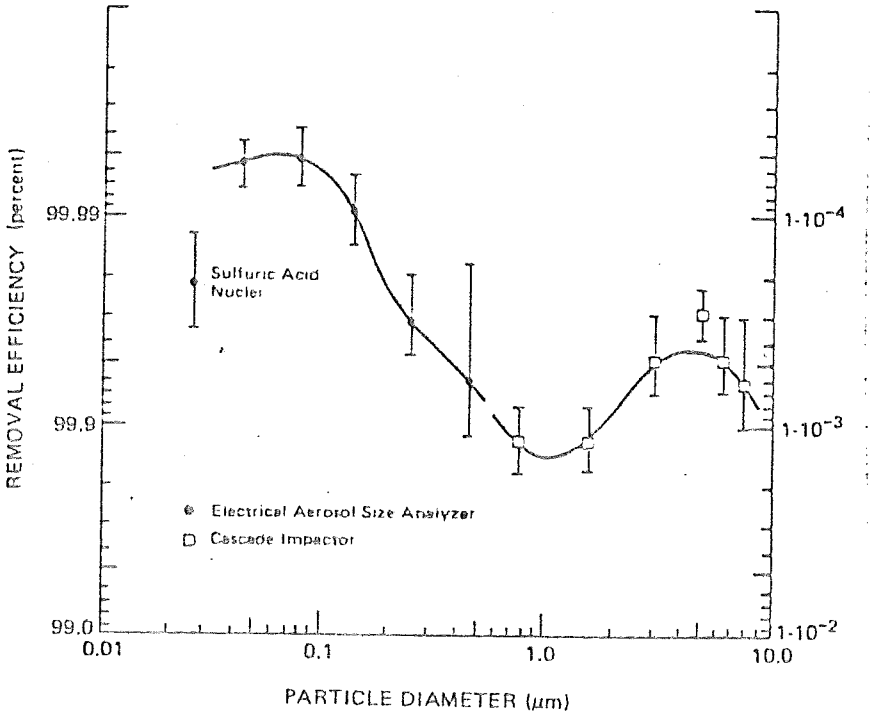
Fabric	Maximum Continuous Operating Temperatures	Flexibility
Cotton	82°C	Very Good
Dacron	135°C	Very Good
Orlon	127°C	Very Good
Teflon	233°C	Fair
Nylon	93°C	Excellent

5.1.2 Precipitation

Characteristics of Gas-cleaning Methods and Equipment



	Settling chambers. Inertial separators. Cyclones Dynamic (Fan & Sep.)	Wetted baffles Wetted cyclone Wetted dynamic Ejector	Venturi scrubber Fog tower	Furnace air cleaner	Plate and wire Tube and wire		Cleanable Throwaway	Pleated filters Automatic renewable	Paper Deep bed	Packed tower	Carbon bed	Direct flame incinerator	Catalytic converter
TYPES OF CONTAMINANTS	Crushing Grinding Machining	Same as dry	Chemical & Metallurgical fumes	atm. air oil mist	flyash tar H_2SO_4	all dry powders	atm. air	atm. air	pre-cleaned atm. air	inorganic gases(HCl, HF, SO_2, Cl_2)	organic gases & vapors (odors)	organic gases & vapors (odors)	organic gases & vapors (odors)
LOADINGS	.1-100 g/m³	.1-100 g/m³	.1-100 g/m³	<0.1 g/m³	.1-2 g/m³	.1-20g/m³	<.01g/m³	<.01g/m³	<.001g/m³	ppm to %	ppb to %	ppb to %	ppb to %
COLLECTION EFFICIENCY	high for >10 μm	high for >2 μm	high for >.25 μm	high for >.25 μm	high for >.1 μm	high for >.1 μm	high for >.1 μm	high for >.5 um	high for all sizes		95-99+	90-99	90-99
SERVICEABILITY DURABILITY	good (erosion)	good (corrosion)	good (corrosion)	poor	fair		good	poor	fair to poor	poor	fair	good	poor



SOURCE: After Ensor et al. (1976).

FIGURE 4.2 Removal efficiency as a function of particle size for a fabric filter installed on a coal-fired power plant.

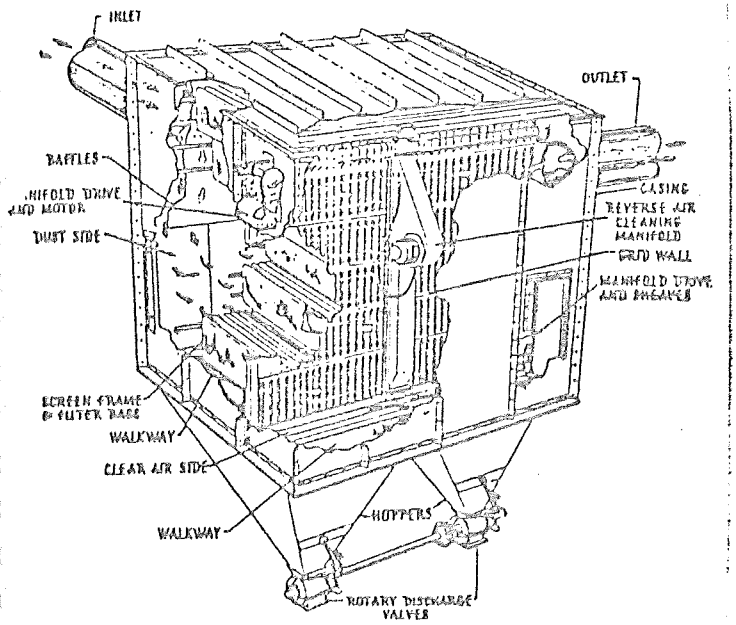
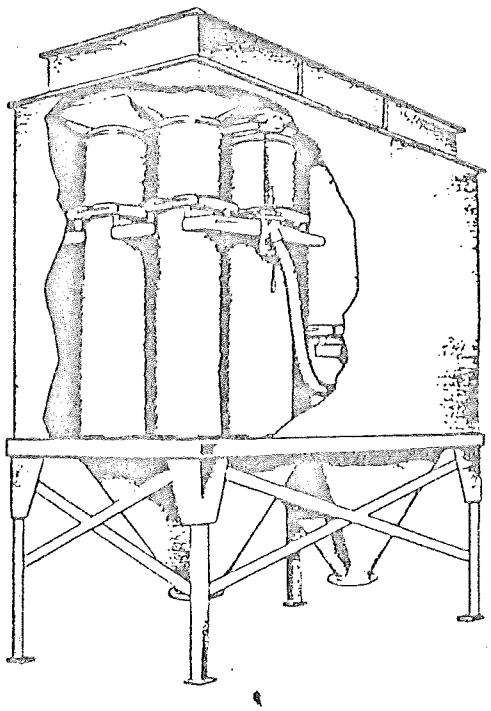


Figure 1.6 CONTINUOUS OPERATING ENVELOPE COLLECTOR WITH REVERSE-FLOW CLEANING MANIFOLD



REVERSE JET

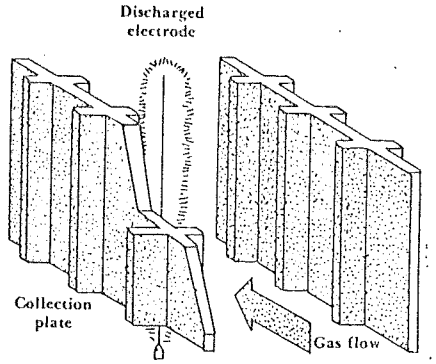


Figure 7-4. Gas flow through a wire and plate precipitator.

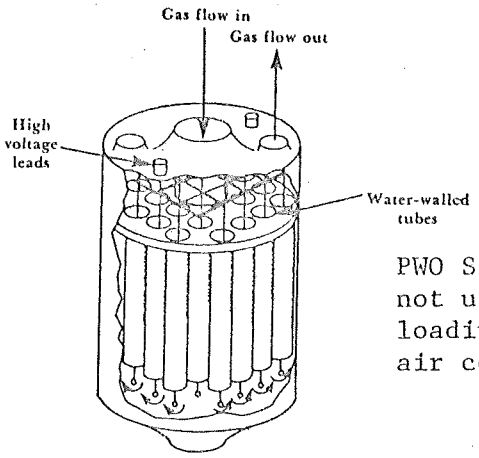
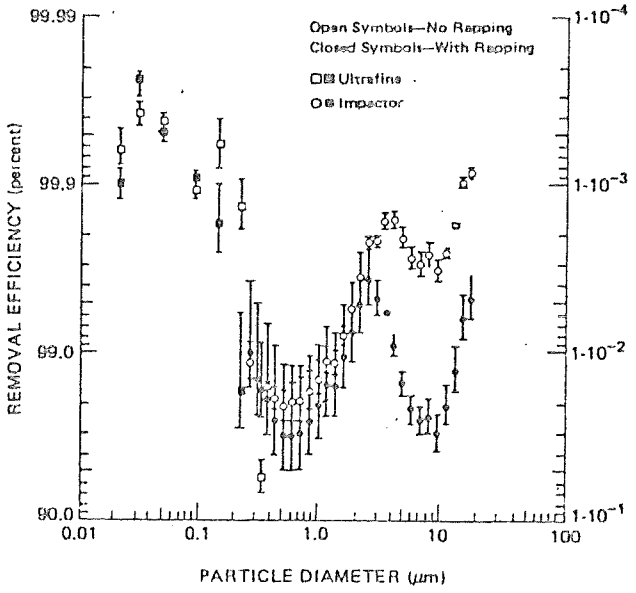


Figure 7-3. Gas flow through wire and tubular pipe precipitators.

PWO Stage precipitators not useful for heavy dust loading. Used mostly in air conditioning plants.

Fractional Efficiency Equation:

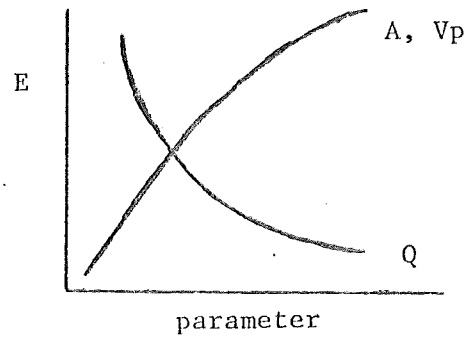
$$E = \left[1 - e^{-\frac{A}{Q} V_p}\right] 100$$



SOURCE: After Gooch (1978).

FIGURE 4.3 Removal efficiency as a function of particle size for an electrostatic precipitator on a coal-fired power plant.

Decreased efficiency during rapping due to reintrainment of particles - can be minimized by placing units in series with different rapping cycle times.



5.1.3. Particle Scrubbing

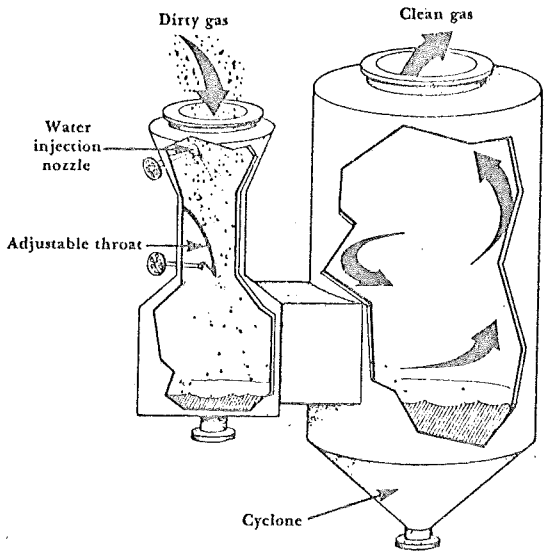


Figure 9-19. Variable throat venturi scrubber.

5.2 Gaseous Emissions

Control of SO_2, NOx and condensible vapors that form secondary particles.

5.3 Fugitive Emissions

<u>Traffic-related</u>	
Paved road dust	Reduced VMT, curbing, washing, sweeping (?)
Unpaved road dust	Paving, chemical surface treatment, soil stabilizers, watering
Construction trackout	Enforced cleanup, truck washing, paved roads
Ice & snow control	Rapid removal of materials
Unpaved parking lots	Paving, chemical stabilizers
<u>Industry-related</u>	
Material transfer and storage	House cleaning, watering, stabilizers, covers
Process losses	Enclosure
On-site traffic	Paving, stabilizers
Construction	Watering, truck bed covers, chemical stabilizers permits
<u>Other</u>	
Tilling	Moist fields, enclosures over implements
Wind entrainment from bare fields	Continuous cropping, wind breaks, soil stabilizers, irrigation, mulch

CONTROL TECHNIQUES FOR FUGITIVE DUST SOURCES

Source	Practicality of Regulation*	Control Method	Control Efficiency
Unpaved Roads	2-3	Paving and right of way improvement	85%
	4	Surface treatment with penetration chemicals	50%
	3	Soil stabilization chemicals worked into the roadbed	50%
	1-2	Speed control	25 mph-25% 20 mph-35% 15 mph-40%
Construction Activity	1-2	Watering	50%
	2	Chemical stabilization of completed cuts and fills	80%
	3	Treatment of temporary access and haul roads on or adjacent to site	50%
		Minimal exposure periods (controlled by permit; good practice with watering or chemical stabilization)	
Agriculture	3	Continuous cropping	25%
	3	Limited irrigation of fallow fields	20%
	5	Windbreaks	5%
	5	Inter-row plantings of grain on widely-spaced row crops	15%
	5	Stubble, crop residue, or mulch left on fields after harvest for wind protection	10%
	5	Spray-on chemical stabilization	40%
Tailings Pile	2	Chemical stabilization	80%
	2-3	Vegetation	65%
	2	Combined chemical-vegetative stabilization	90%
Aggregate Storage	2	Continuous spray of chemical on material going to storage piles	90%
	1-2	Watering of haul roads and storage areas	50%
	3	Treatment of haul roads and traffic areas	50%
	2	Watering (sprinklers or truck)	80%
Cattle Feed Lots	5	Manure scraping	80%
	4	Chemical stabilization and water alone	40%

1 = Excellent 2 = Good 3 = Fair 4 = Poor 5 = Not Recommended

Control Method	Cost
Paving (no curbs)	
3" bituminous surface	$20,000-$26,000/mile
single chip seal - prepared bed	$8,500-$14,000/mile
Chemical stabilizers	
prepared surface	$2,000-$3,000/mile
unprepared surface	$1,000-$2,000/mile
Speed control	negligible
Construction site watering	$2-$5/acre/day manpower, expand H_2O
Stabilizing cuts and fits	$150-$400/acre
Material storage - chemical sprays	$150-$400/acre
Trackout manual street cleaning	$7,000/site (30% efficiency assumed)
Reduction in VMT	
Ridesharing programs	1¢/VMT reduction
Expanded bus services	40¢/reduced VMT
Composite program (70% ride share 30% bus)	13¢/reduced VMT
Benefits (fuel saving, maintenance roads)	$53 million/5% VMT reduction, Portland, OR

5.4 Mobil Sources

Auto Exhaust Control Measures

Recirculation of crankcase gases

Reduction in Lead content of fuel

Regulation of visible emissions

Inspection and maintenance programs

Catalytic converters (secondary aerosols)

VMT reductions

Diesel Exhaust

Engine maintenance and proper fuel system adjustment

Fuel modifications - additives (?); use of fuels with lower certain numbers

Reduced VMT

Control of visible emissions

5.5 Control System Costs

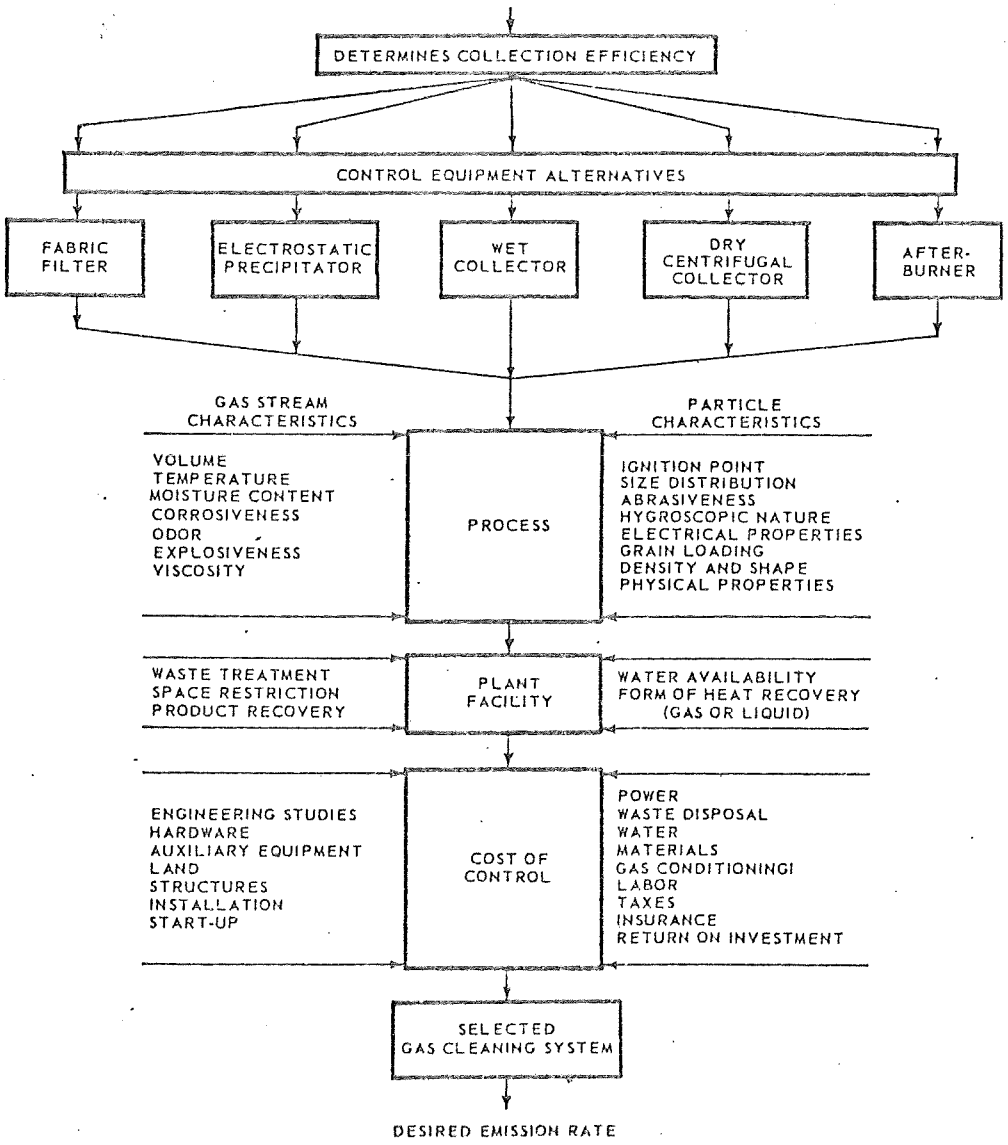


FIGURE 6-1. Criteria for selection of gas cleaning equipment.

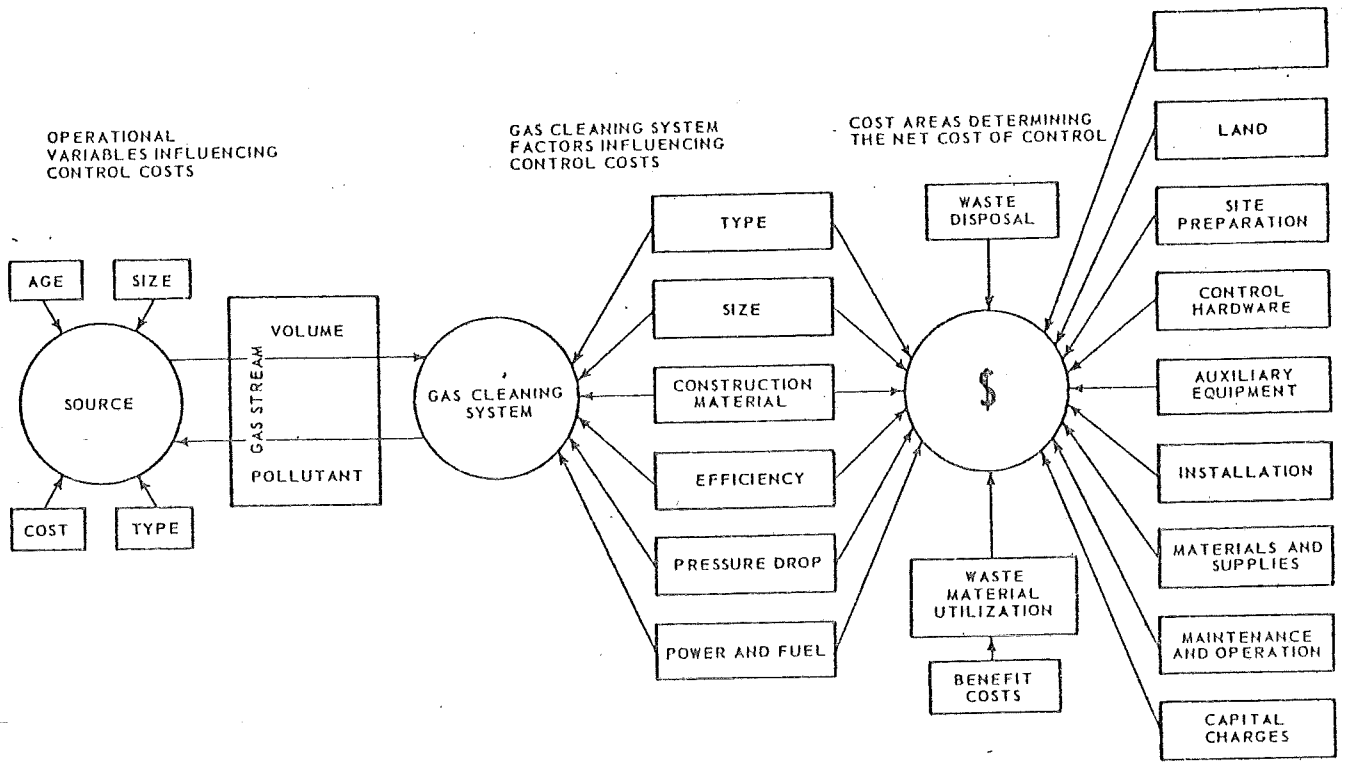


FIGURE 6-4. Diagram of cost evaluation for a gas cleaning system.

Control System Costs can be broken down as follows:

- Capital Investment

  Engineering studies, land, control hardware, auxillary equipment, operating supplies, installation, startup testing, structural modifications

- Maintenance and Operation

  Utilities (electrical, water, etc.), labor, supplies, treatment and disposal of waste materials

- Capital Charges

  Taxes, insurance, interest

Capital Investment - Approximate Installed Cost of Control Systems in 1970
(100,000 ACFM, $U.S., medium efficiency)

Control System	Installed Cost	Annualized Cost*
Wet scrubbers	$ 50,000	$ 50,000
High voltage ESP	$110,000	$ 17,000
Low voltage ESP	$200,000	$ 30,000
Baghouse (medium temp.)	$ 80,000	$ 25,000

* Include depreciation, taxes, interest, insurance, maintenance and operation

6. FUNDAMENTALS OF CHEMICAL MATRIX THEORY

PHYSICAL BASIS FOR RECEPTOR MODELS

In general, the aerosol mass, M_j, collected at a receptor during a sampling period of length T due to a source j, with constant emission rate E_j, is

$$M_j = D_j E_j \tag{1}$$

where

$$D_j = \int_0^T d[u(t), \sigma(t), x_j]dt \tag{2}$$

is a dispersion factor depending on wind velocity, u, atmospheric stability, $\sigma(t)$, and the location of source j with respect to the receptor, x_j. If a number of sources exist, P, the total aerosol mass measured at the receptor, m, will be a linear sum of the contributions from individual sources.

$$m = \sum_{j=1}^{P} M_j = \sum_{j=1}^{P} D_j E_j \tag{3}$$

Similarly, the mass of element i, m_i, is given by

$$m_i = \sum_{j=1}^{P} F'_{ij} M_j \tag{4}$$

$$m_i = \sum_{j=1}^{P} F'_{ij} D_j E_j \tag{5}$$

where F'_{ij} is the fraction of mass contributed by source j composed of element i.

Source-Dispersion Model (Equation 5)

- E_j measured
- D_j determined from meteorological measurements and Equation 2
- m and/or M_j calculated

Receptor Model (Equation 4)

- m_i measured
- F_{ij} measured and/or calculated
- M_j calculated

CRITICAL REVIEW OF BASIC ASSUMPTIONS

- Linear combination
- Omition of unique factor
- Conservation of mass and chemistry
- Independent variables

CHEMICAL MATRIX EQUATIONS

Data Tables

Imput Data Matrices

Approaches to the solution of the chemical matrix equations

MATRIX NOTATIONS

MATRIX OPERATIONS

GENERALIZED LEAST SQUARES SOLUTION

GENERALIZED MULTIVARIATE SOLUTIONS

BASIC MATRIX DEFINITIONS

1. Column matrix: A single column of ordered numbers

$$C = \left[C_{i1} \right]_{nx1} = \begin{bmatrix} C_{11} \\ C_{21} \\ | \\ C_{i1} \\ | \\ C_{n1} \end{bmatrix}$$

2. Row matrix: A single row of ordered number

$$R = \left[r_{1j} \right]_{1xm} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} & \cdots & r_{1m} \end{bmatrix}$$

3. Vector: A row or column matrix

4. Null or zero matrix: A matrix in which every element is zero

5. Diagonal matrix: A square matrix (n=m) in which all off-diagonal entries are zero

$$\begin{bmatrix} 3 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 5 \end{bmatrix}$$

6. Scalar matrix: A diagonal matrix with equal diagonal entries

$$\begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix}$$

7. Transpose: The transpose of a matrix $A_{nxm} = \left[a_{ij} \right]_{nm}$ is a matrix obtained from A by interchanging rows and columns so that

$$\text{Transpose } A = \left(A_{nxm} \right)^T = \left(a_{ij} \right)^T_{nxm} = \left(a_{ji} \right)_{nxm} = A^T_{mxn}$$

$$\text{If } A = \begin{bmatrix} 1 & 4 \\ 2 & 5 \\ 3 & 6 \end{bmatrix}, \text{ then } A^T = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$$

8. Symmetrix Matrix: A square matrix which is equal to its transpose

$$A = \left(a_{ij} \right) = \left(a_{ji} \right) = A^T$$

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 2 & 0 & 5 \\ 3 & 5 & 3 \end{bmatrix} \quad A^T = \begin{bmatrix} 1 & 2 & 3 \\ 2 & 0 & 5 \\ 3 & 5 & 3 \end{bmatrix}$$

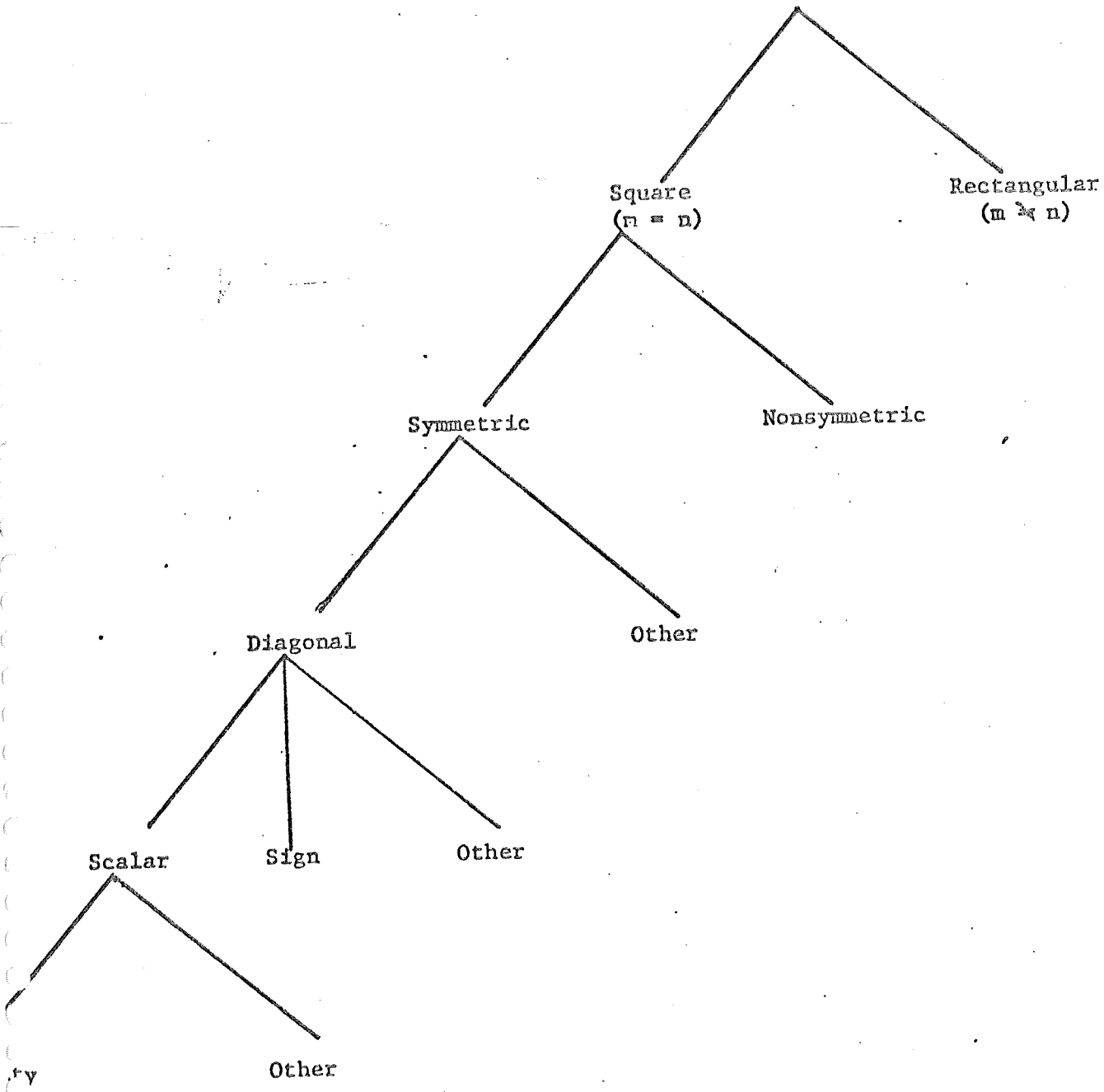
9. Identity matrix: A scalar matrix in which each diagonal element is equal to unity

$$I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

10. Sign Matrix: A diagonal matrix with some -1 diagonal elements and the rest + 1

$$A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

RELATIONSHIP OF SPECIAL MATRICES



BASIC MATRIX OPERATIONS

1. ADDITION: Matrix addition is accomplished by adding corresponding entries assuming they are of the same order

$$C_{nxm} = A_{nxm} + B_{nxm}$$

if and only if

$$C_{ij} = a_{ij} + b_{ij}$$

for $i = 1,2---n$; $j = 1,2---m$

Examples:

$$A = \begin{bmatrix} -2 & 4 & 3 \\ 1 & -1 & 5 \end{bmatrix} \qquad B = \begin{bmatrix} 5 & 3 & 5 \\ 2 & -2 & -2 \end{bmatrix}$$

$$C = A + B = \begin{bmatrix} -2 + 5 & 4 + 3 & 3 + 5 \\ 1 + 2 & -2 - 1 & 5 - 2 \end{bmatrix}$$

$$C = \begin{bmatrix} 3 & 7 & 8 \\ 3 & -3 & 3 \end{bmatrix}$$

2. SCALAR MULTIPLICATION OF A MATRIX: The scalar product of a scalar k and a matrix A is a matrix whose entries are the product of the scalar k and each entry in A. That is

$$D_{nxm} = kA_{nxm}$$

if and only if

$$d_{ij} = ka_{ij}$$

for $i = 1,2,---n$; $j = 1,2---m$

Example:

$$C = 5A = 5\begin{bmatrix} -2 & 4 & 3 \\ 1 & -1 & 5 \end{bmatrix} = \begin{bmatrix} -10 & 20 & 15 \\ 5 & -5 & 25 \end{bmatrix}$$

3. SUBTRACTION: Matrix subtraction is defined as a two-step process in which the matrix to be subtracted is first multiplied by -1 and then the two matrices summed

$$C = A - B = A + [(-1).B]$$

if and only if

$$C_{ij} = a_{ij} - b_{ij}$$

for $i = 1,2,---m$; $j = 1,2,---p$

4. PROPERTIES OF MATRIX ADDITION AND SCALAR MULTIPLICATION

- Commutative

$$A + B = B + A \qquad \text{and} \qquad A(kB) = (kA)B$$

- Associative

$$A + (B + C) = A + B + C = (A + B) + C \qquad \text{and}$$

$$k_1 (k_2 A) = (k_1 k_2) A$$

- Scalar multiplication is distributive

$$(k_1 + k_2)A = k_1 A + k_2 A$$

- Matrix subtraction is neither commutative nor associative

5. MATRIX MULTIPLICATION

Each entry of a product matrix, C, is the sum of the products obtained by multiplying the entries of each row of the prefactor, A, by the corresponding entries of each column of the postfactor, B.

Matrix multiplication is defined as

$$C = AB$$

$$C_{ij} = \sum_{k=1}^{n} a_{ik} b_{kj}$$

for $i = 1,2,---m$; $j = 1,2,---p$

Example

$$A_{2x3} = \begin{bmatrix} -1 & 3 & 2 \\ 2 & 5 & 4 \end{bmatrix} \qquad B_{3x3} = \begin{bmatrix} -1 & 2 & 1 \\ -2 & 4 & 1 \\ 5 & 2 & 2 \end{bmatrix}$$

$$C_{2x3} = A_{2x3} \; B_{3x3}$$

$$C_{2x3} = \begin{bmatrix} [(-1x-1) + (3x-2) + (2x5)] & [(-1x2) + (3x4) + (2x2)] & (-1x1) + (3x1) + (2x2)] \\ [(2x-1) + (5x02) + (4x5)] & [(2x2) + (5x4) + (4x2)] & [(2x1) + (5x1) + (4x2)] \end{bmatrix}$$

$$C_{2x3} = \begin{bmatrix} 5 & 14 & 6 \\ 8 & 32 & 15 \end{bmatrix}$$

6. CONFORMABILITY: The condition of conformability is necessary for matrix multiplication. A prefactor matrix A_{nxk} and a postfactor B_{jxp} are conformable if and only if k = j.

$$A_{nxk} \quad B_{kxp} = C_{nxp}$$

Interior Dimensions

7. PROPERTIES OF MATRIX MULTIPLICATION

- In general, matrix multiplication is noncommutative, i.e.

$$AB \neq BA$$

- Associativity - assuming conformability

$$(AB)C = A(BC)$$

- Distributivity - assuming conformability

$$A(B+C) = AB + AC$$

$$(B+C)A = BA + CA$$

- Transpose product

$$(AB)^T = B^T A^T$$

- The product of any matrix and its transpose is symmetrix, i.e. both AA^T and A^TA are symmetric.

MAJOR DIFFERENCES BETWEEN SCALAR AND MATRIX ALGEBRA

Scalars	Matrices
1. ab = ba	1. AB ≠ BA in general
2. If ab = ac and a = o then b = c	2. If AB = AC and A = 0, then it is not necessary that B equals C
3. If ab = 0, then either a = 0 or b = 0 or both a and b = 0	3. If AB = 0, then it is not necessarily the case that either A = 0, B = 0 or A,B = 0
4. If ab = 0, then ba = 0	4. If AB = 0, then BA does not necessarily equal 0

DISTANCE BETWEEN TWO VECTORS

(Euclidean Distance)

$$\left\| A - B \right\| = \left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + \text{---} + (a_n - b_n)^2 \right]^{\frac{1}{2}}$$

$$= \left[\sum_{i=1}^{n} (a_i - b_i)^2 \right]^{\frac{1}{2}}$$

For a position vector

$$\left\| A \right\| = \left[\sum_{i=1}^{n} a_i^2 \right]^{\frac{1}{2}}$$

DIRECTION COSINES

$$\text{COS } \alpha = \frac{a_1}{\left[a_1^2 + a_2^2 + a_3^2 \right]^{\frac{1}{2}}} = \frac{1}{3}$$

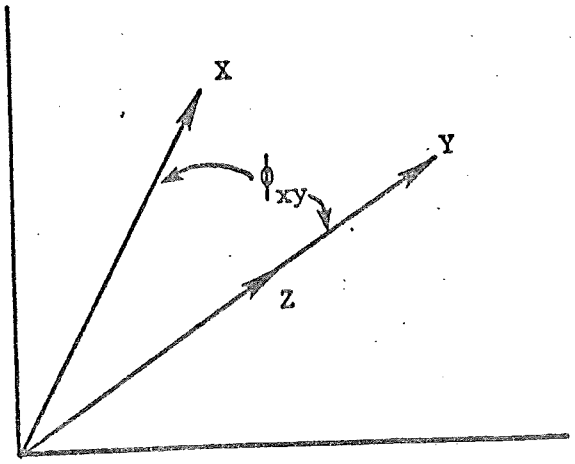
$$\text{COS } \beta = \frac{a_2}{\left[a_1^2 + a_2^2 + a_3^2 \right]^{\frac{1}{2}}} = \frac{2}{3}$$

$$\text{COS } \alpha = \frac{a_3}{\left[a_1^2 + a_2^2 + a_3^2 \right]^{\frac{1}{2}}} = \frac{2}{3}$$

$$\text{COS } \phi_i = \frac{a_i}{\left\| A \right\|}$$

If COS $\phi_i = 0$, then the angle is 90° and the vector is said to be orthogal (perpendicular) to the ith reference axis.

COVARIANCE AND COORELATION



$$\text{Covariance Matrix} = C_{mxm} = \frac{1}{m} A^{T}_{mxn} A_{nxm}$$

where A = mean corrected data matrix

$$\text{Correlation Matrix} = R_{mxm} = \frac{1}{m} S^{T}_{mxn} S_{nxm} = V^{-\frac{1}{2}}_{mxm} C_{mxm} V^{-\frac{1}{2}}_{mxm}$$

where S = standardized data matrix

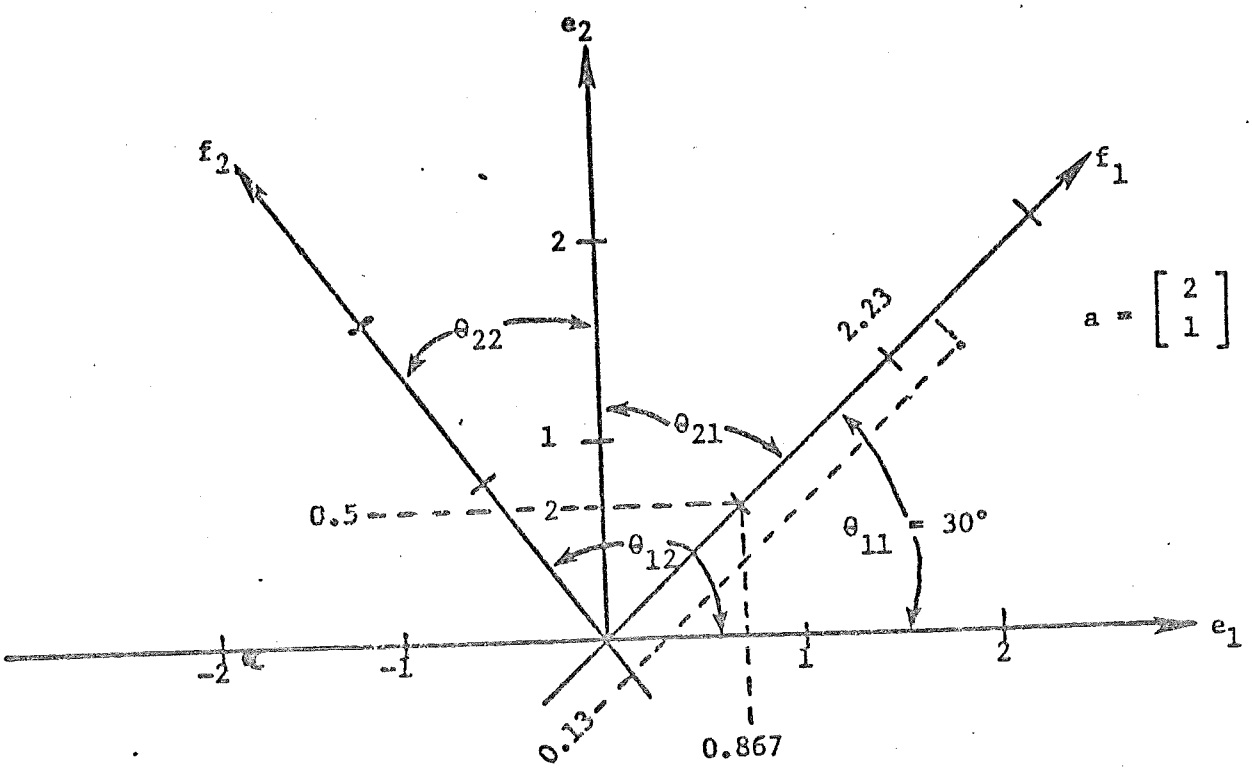
V = diagonal matrix of variances, σ^2.

C and R are square, symmatric matrices

$$\gamma_{xy} = \frac{\Sigma Y_i X_i}{\left[\Sigma Y_i^2\right]^{\frac{1}{2}} \left[\Sigma X_i^2\right]^{\frac{1}{2}}} = \cos \phi_{xy}$$

$$\gamma_{zy} = \cos \phi_{zy} = 1$$

$$\gamma_{xx} = \cos \phi_{xx} = 1$$



$$\cos \theta_{11} = \cos \theta_{22} = 0.867 \qquad \cos \theta_{12} = -0.5 \qquad \cos \theta_{21} = 0.5$$

$$f_1 = \cos \theta_{11}\, e_1 + \cos \theta_{21}\, e_2 = 0.867 \begin{bmatrix} 1 \\ 0 \end{bmatrix} + 0.5 \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 0.867 \\ 0.5 \end{bmatrix}$$

$$f_2 = \cos \theta_{12}\, e_1 + \cos \theta_{22}\, e_2 = -0.5 \begin{bmatrix} 1 \\ 0 \end{bmatrix} + 0.867 \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} -0.5 \\ 0.867 \end{bmatrix}$$

$$a_2 = 2 \begin{bmatrix} 1 \\ 0 \end{bmatrix} + 1 \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 1 \end{bmatrix} \text{ one basis}$$

a_2 = ? on f basis

$$f_1 = \cos \theta_{11}\, e_1 + \cos \theta_{21}\, e_2$$

$$f_2 = \cos \theta_{12}\, e_1 + \cos \theta_{22}\, e_2$$

$$\begin{bmatrix} f_1 \\ f_2 \end{bmatrix} = \underbrace{\begin{bmatrix} \cos\theta_{11} & \cos\theta_{21} \\ \cos\theta_{12} & \cos\theta_{22} \end{bmatrix}}_{\text{Transformation (Rotation) Matrix}} \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

$$a^* = \begin{bmatrix} a_1^* \\ a_2^* \end{bmatrix}$$

$$\begin{bmatrix} a_1^* \\ a_2^* \end{bmatrix} = \begin{bmatrix} \cos\theta_{11} & \cos\theta_{21} \\ \cos\theta_{12} & \cos\theta_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$\begin{bmatrix} a_1^* \\ a_2^* \end{bmatrix} = \begin{bmatrix} 0.867 & 0.5 \\ -0.5 & 0.867 \end{bmatrix} \begin{bmatrix} 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 2.23 \\ -0.13 \end{bmatrix}$$

$$A^* = TA$$

DETERMINANT

Determinant of A = $|A|$

If $A = \begin{bmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{bmatrix}$

then $|A| = X_{11} X_{22} - X_{12} X_{21}$

If $A = \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix}$

then $|A| = X_{11} X_{22} X_{33} - X_{11} X_{32} X_{23} + X_{21} X_{32} X_{13} - X_{21} X_{12} X_{33} + X_{31} X_{12} X_{23} - X_{31} X_{22} X_{13}$

In General

$$\left|A\right| = X_{i1} C_{i1} + X_{i2} C_{i2} + \text{---} + X_{ip} C_{ip}$$

where C_{ij} = the ith jth cofactor

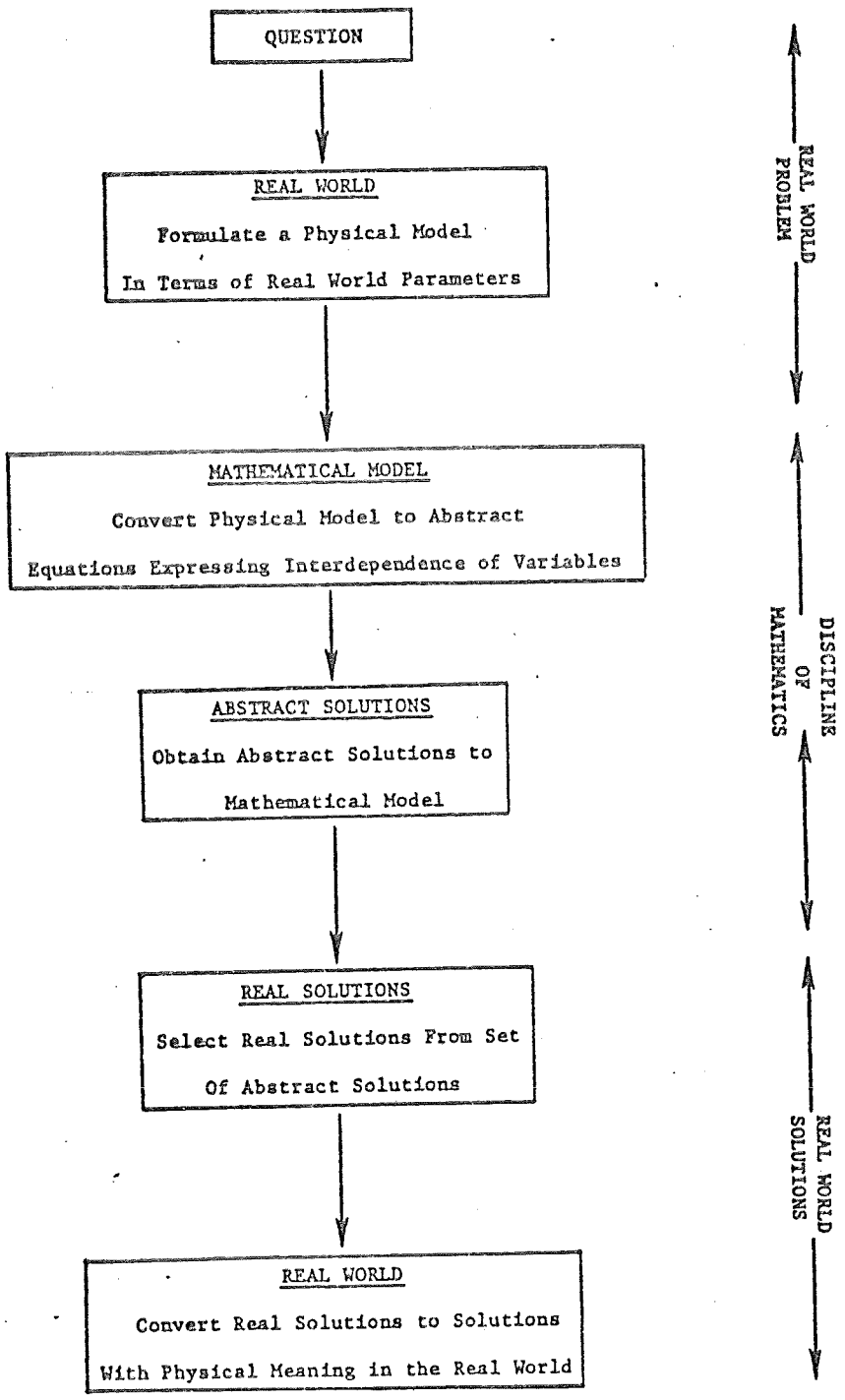
$C_{ij} = (-1)^{i+j}$ times the determinant formed from A by removal of the ith row and the jth column

If A_{nxn} is symmetric

An orthogonal transformation T can be found such that A can be made diagonal, i.e.

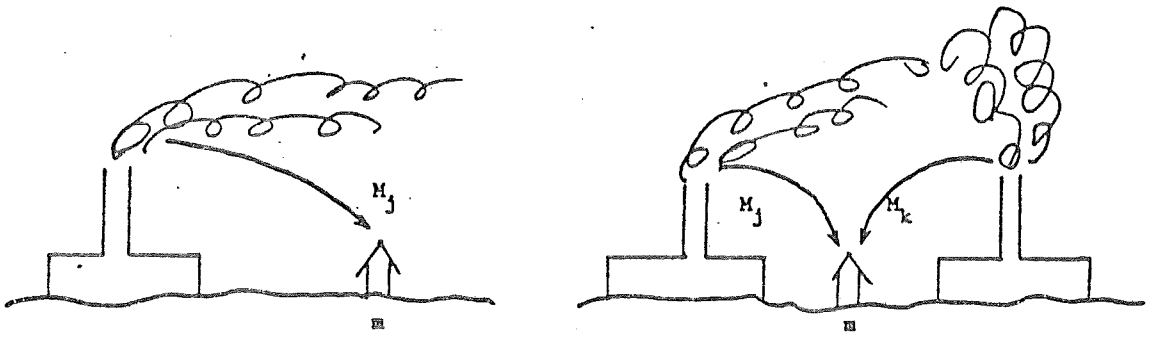
$$D = T^T A T$$

where D is diagonal, and the columns of T are eigenvectors of A.


QUESTION
REAL WORLD
Formulate a Physical Model
In Terms of Real World Parameters
MATHEMATICAL MODEL
Convert Physical Model to Abstract
Equations Expressing Interdependence of Variables
ABSTRACT SOLUTIONS
Obtain Abstract Solutions to
Mathematical Model
REAL SOLUTIONS
Select Real Solutions From Set
Of Abstract Solutions
REAL WORLD
Convert Real Solutions to Solutions
With Physical Meaning in the Real World
REAL WORLD PROBLEM
DISCIPLINE OF MATHEMATICS
REAL WORLD SOLUTIONS

QUESTION How much of the aerosol mass collected on a high volume TSP sampler was contributed by source j?

REAL WORLD PHYSICAL MODEL



Dispersion Model Receptor Model

MATHEMATICAL MODEL

$$M_j = D_j E_j \qquad m = \sum_j M_j$$

$$M_j = D_j (\mu, \sigma, x_j) E_j \qquad m_i = \sum_j F'_{ij} M_j$$

SOURCE

Source mass is dependent variable

RECEPTOR

Receptor mass is dependent variable

DATA MATRIX

AMBIENT DATA TABLE

MASS

($\mu g/m^3$)

Chemical Species	Filter ID 1	2	3	4	5
C	10	8	2	15	20
SO_4	5	4	2	10	15
Na	1	0.5	0.1	3	3
Si	5	3	1	2	4
Fe	1	0.5	0.1	2	4
Pb	0.1	0.5	1	0.1	0.2

AMBIENT DATA MATRIX

$$\begin{bmatrix} 10 & 8 & 2 & 15 & 20 \\ 5 & 4 & 2 & 10 & 15 \\ 1 & 0.5 & 0.1 & 3 & 3 \\ 5 & 3 & 1 & 2 & 4 \\ 1 & 0.5 & 0.1 & 2 & 4 \\ 0.1 & 0.5 & 1 & 0.1 & 0.2 \end{bmatrix}$$

6 x 5

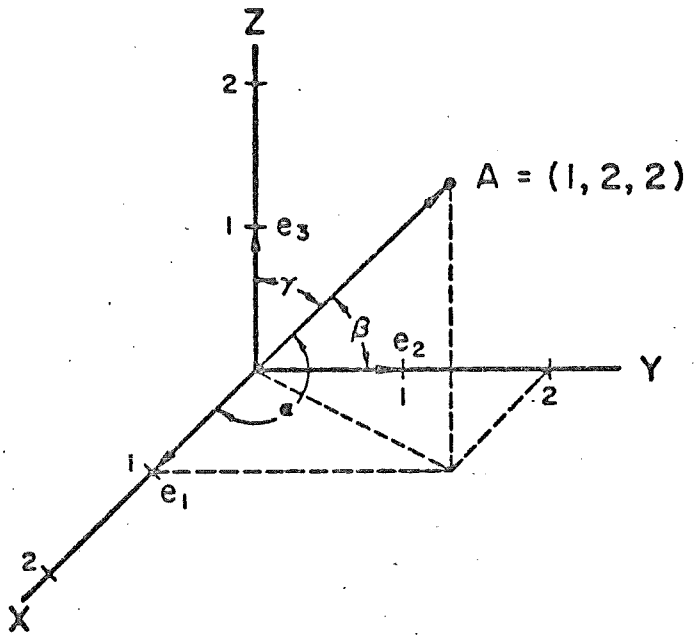
A MATRIX IS AN ORDERED SET OF REAL NUMBERS (SCALARS)
ARRANGED IN RECTANGULAR ROWS AND COLUMNS

DATA MATRIX = $D_{nxm} = [d_{ij}]_{nxm}$ =

$$\begin{bmatrix} d_{11} & d_{12} \cdots d_{1k} \cdots d_{1m} \\ d_{12} & \\ \vdots & \\ d_{i1} & d_{i2} \cdots d_{i2} \\ \vdots & \\ d_{n1} & d_{n2} \cdots d_{in} \cdots d_{nm} \end{bmatrix}_{nxm}$$

row, column, rows, Columns

BASIS VECTORS



$e_1 = (1, 0, 0)$

$e_2 = (0, 1, 0)$

$e_3 = (0, 0, 1)$

$A = 1e_1 + 2e_2 + 2e_3$

$$A = \sum_{i=1}^{n} k_i e_i$$

INPUT DATA

1. Ambient Chemical Data Set

$$C_{nxm} = \begin{vmatrix} C_{11} & C_{12} \cdots C_{1k} \cdots C_{1m} \\ C_{21} & \\ \vdots & \\ C_{i1} & C_{i2} \cdots C_{ik} \\ \vdots & \\ C_{n1} & C_{n2} \cdots C_{nk} \cdots C_{nm} \end{vmatrix} = [C_{ik}]_{nxm} = \begin{vmatrix} C_{Na,1} & C_{Na,2} \cdots C_{Na,m} \\ C_{Mg,1} & \\ C_{Al,1} & \\ \vdots & \\ C_{Pb,1} & \end{vmatrix}$$

Time or Location →

Chemical Species ↓

2. Source Composition Data Set

$$F_{nxp} = \begin{vmatrix} F_{11} & F_{12} \cdots F_{1j} \cdots F_{1p} \\ F_{21} & \\ \vdots & \\ F_{i1} & F_{i2} \cdots F_{ij} \\ \vdots & \\ F_{n1} & F_{n2} \cdots F_{nj} \cdots F_{np} \end{vmatrix} = [F_{ij}]_{nxp} = \begin{vmatrix} F_{Na,Auto} & F_{Na,Marine} & F_{Na,Kraft} \cdots \\ F_{Mg,Auto} & & \\ F_{Al,Auto} & & \\ \vdots & & \\ F_{Pb,Auto} & & \end{vmatrix}$$

Source →

Chemical Species ↓

UNKNOWN

$$S_{pxm} = \begin{vmatrix} S_{11} & S_{12} \cdots S_{1k} \cdots S_{1m} \\ S_{21} & \\ \vdots & \\ S_{j1} & S_{j2} \cdots S_{jk} \cdots S_{jm} \\ \vdots & \\ S_{p1} & S_{p2} \cdots S_{pk} \cdots S_{pm} \end{vmatrix} = [S_{jk}]_{pxm} = \begin{vmatrix} S_{Auto,1} & S_{Auto,2} \cdots S_{Auto,m} \\ S_{Marine,1} & \\ S_{Kraft,1} & \\ \vdots & \\ S_{p,1} & \end{vmatrix}$$

Time or Location →

Source ↓

APPROACHES TO THE SOLUTION OF THE CHEMICAL MATRIX EQUATION

$$[C_{ik}]_{nxm} = [F_{ij}]_{nxp} \; [S_{jk}]_{pxm}$$

$$C_{ik} = \sum_{j=1}^{p} F_{ij} \, S_{jk}$$

- AMBIENT CORRELATIONS (Time, Space, Other)
  - MULTIVARIATE METHODS
- CHEMICAL MASS BALANCE METHODS
  - TRACER
  - LEAST SQUARES

HYBRID METHODS

7. CHARACTERISTICS OF SOURCE AND AMBIENT AEROSOLS

Overview

A brief description of source categories and their chemical and physical features will be presented. The chemical and physical features of ambient aerosols will be reviewed and specific features discussed.

Topics to be presented include:

Source Emissions

1. Distinguishing Features of Source Emissions
   - 1.1 Physical (Aerodynamic size, radioactivity, shape, color)
   - 1.2 Chemical Composition
   - 1.3 Time Dependence (Diurnal, weekly, seasonal)
2. Source Categories According to Size and Chemistry
   - 2.1 Large Particles (> 2.5 μm)
   - 2.2 Small Particles (< 2.5 μm)
3. Regulatory Source Categories
   - 3.1 Point Sources
   - 3.2 Area
   - 3.3 Mobil

Ambient Aerosol

1. Aerodynamic Size Distribution
2. Chemical Composition
3. Typical Ambient Aerosol Characteristics
   - 3.1 Urban
   - 3.2 Industrial
   - 3.3 Mining
   - 3.4 Remote
   - 3.5 Indoor

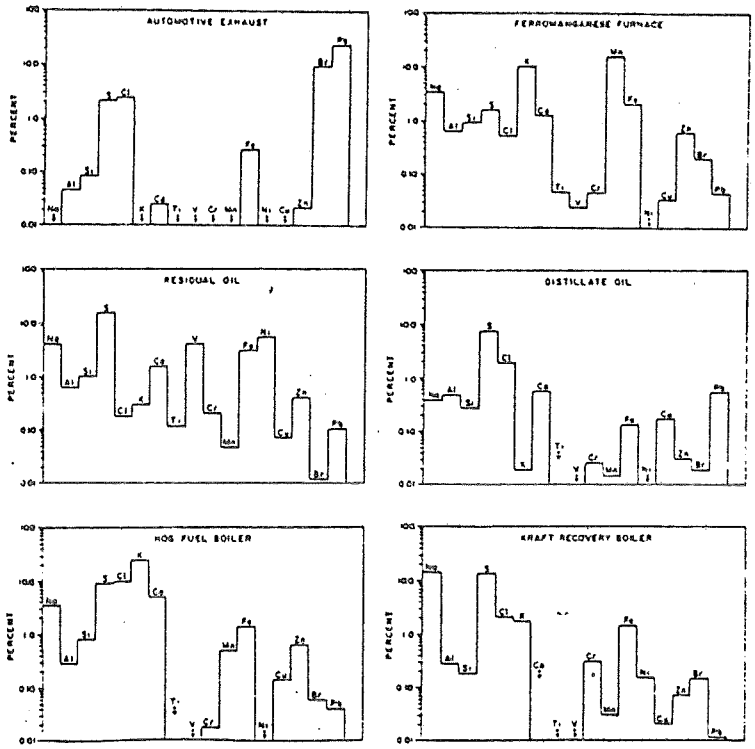
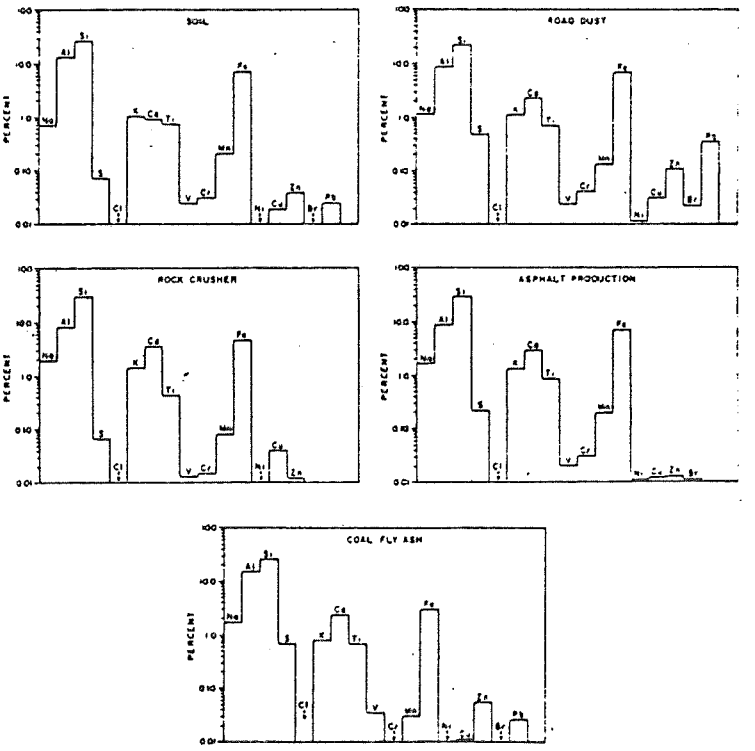


Figure 4. Comparison of selected fine particle (<2.5 um) source composition patterns measured during the Portland Aerosol Characterization Study (PACS). Particulate material from each of these sources can be distinguished on the basis of the unique elemental fingerprints.



MOTOR VEHICLE EXHAUST COMPOSITION SUMMARY FROM LITERATURE VALUES

SPECIE	ST. LOUIS,MO % OF MASS	PORTLAND,OR % OF MASS	WASH.,DC % OF MASS	MEDFORD,OR % OF MASS
TOTAL CARBON	56.3	53.8	–	62.26
Mg	0.8	–	–	0.25
Al	–	1.1	–	.06
Si	–	0.82	–	0.25
P	0.09	–	–	–
S	0.6	0.4	–	1.53
SO4	–	1.3	–	1.49
Cl	1.0	3.0	1.0	1.53
K	–	0.72	–	–
Ca	–	1.25	0.5	0.00
Mn	0.06	–	–	–
Fe	1.0	2.1	0.5	0.53
Ni	–	0.018	–	–
Cu	–	0.073	–	–
Zn	3.0	0.350	0.15	0.28
Br	3.7	5.00	3.8	3.44
Ba	0.09	–	0.13	–
Pb	14.80	20.00	10.0	8.00
NO3	–	0.91	–	12.60
TOTAL	82.1%	90.8%	16.1%	99.8%

CHEMICAL MASS BALANCE INPUT SOURCE COMPOSITION CONSIDERATION

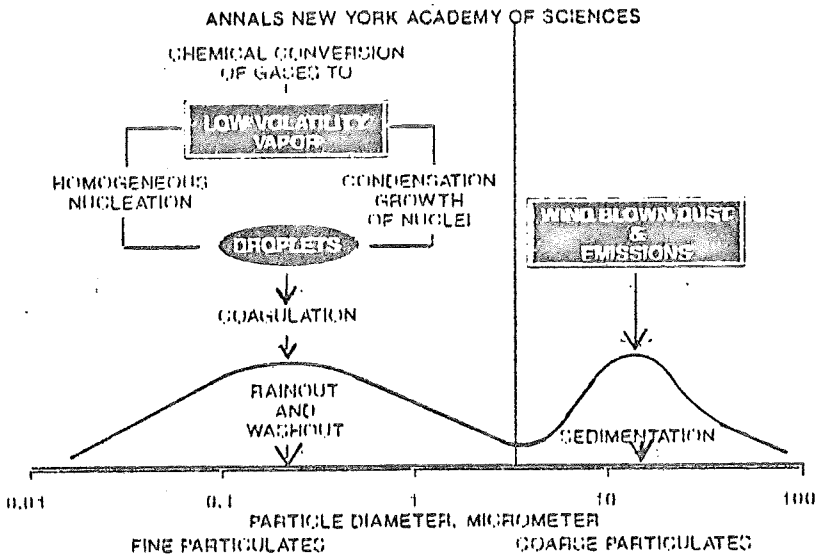
SOURCE CLASS	LITERATURE REVIEW CONSIDERATIONS
MOTOR VEHICLES	● LEADED/UNLEADED/DIESEL VEHICLE MIX ● Br/Pb RATIO (FRESH OR AGED AEROSOL) ● SMOKE SUPPRESSANT USE IN DIESEL FUELS ● TRANSPORTATION SOURCE MIX NEAR THE RECEPTOR
SOILS	● STUDY AREA SOIL CHEMICAL "ENRICHMENT" BY LOCAL EMISSION DEPOSITION ● LOCAL SOIL COMPOSITION CONSISTENCY WITH LITERATURE VALUES ● IMPORTANCE OF LIMESTONE TO LOCAL SOILS

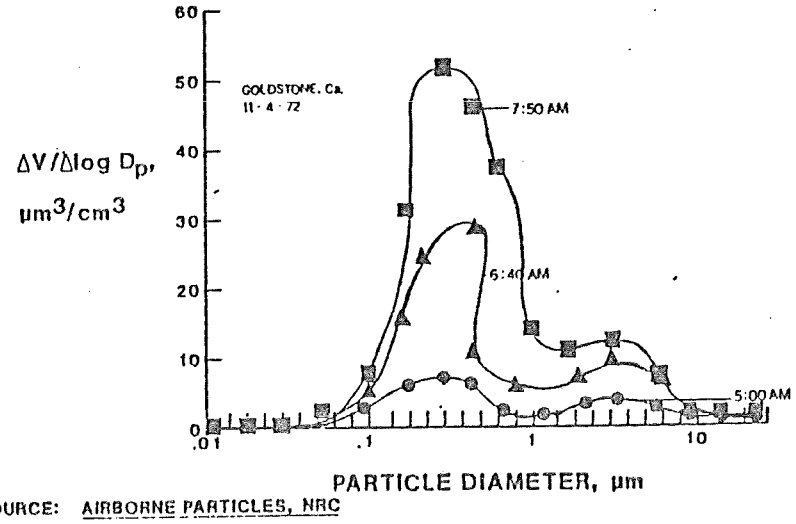
CHEMICAL MASS BALANCE INPUT SOURCE COMPOSITION CONSIDERATION

SOURCE CLASS	LITERATURE REVIEW CONSIDERATIONS
RESIDUAL OIL COMBUSTION	● SIMILARITY IN THE FUEL ELEMENTAL COMPOSITION ● USE OF FUEL ADDITIVES ● COMBUSTION SYSTEM SIMILARITY
COAL COMBUSTION	● SIMILARITY IN CHEMICAL COMPOSITION OF INPUT FUEL ● SIMILARITY IN COMBUSTION PROCESS AND CONTROL SYSTEM TYPE AND EFFICIENCY

CHEMICAL MASS BALANCE INPUT SOURCE COMPOSITION CONSIDERATION

SOURCE CLASS	LITERATURE REVIEW CONSIDERATIONS
VEGETATIVE BURNING	• SIMILARITY IN TYPE OF FUEL BURNED • POINT(S) WITHIN THE COMBUSTION CYCLE WHERE SAMPLING OCCURRED
METALS INDUSTRY	• SPECIFIC PROCESS SAMPLED, CONTROL EQUIPMENT USED AND CHEMICAL COMPOSITION OF THE ALLOY • POINT(S) WITHIN THE PROCESS CYCLE SAMPLED

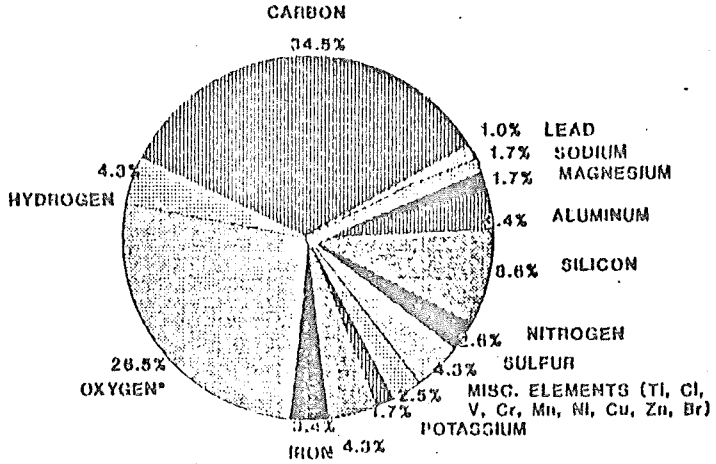




SOURCE: AIRBORNE PARTICLES, NRC

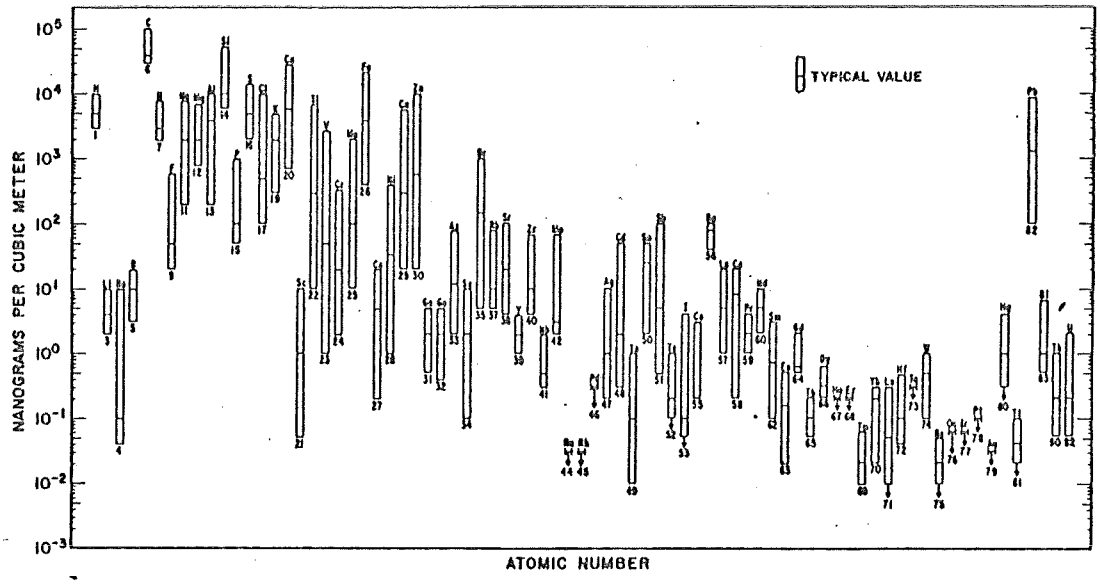
CHEMICAL COMPOSITION OF TYPICAL URBAN AEROSOL

NOTES



*PERCENT OXYGEN ESTIMATED FROM OXIDES OF MEASURED ELEMENTS

URBAN AEROSOL TRACE ELEMENT RANGES AND TYPICAL VALUES



TYPICAL URBAN AIR PARTICULATE CONCENTRATIONS

ELEMENT	AIR(UG/M^3)	PARTICULATE(%)	FILTER (PPM)*
TOTAL	100.000	100	10,000
Si	10.000	10	1000
S	.5000	5	500
Fe	.4000	4	400
Pb	1.500	1.5	150
Ti	.300	0.3	30
Br	.150	0.15	15
Ba	.080	0.08	8
Zr	.010	0.01	1
Hg, Bi, Ag	.001	0.001	0.1
Be, In, Hf	.0001	0.0001	0.01

* 1 m^3/cm^2 on 10mg/cm^2 Filter

AEROSOL LEAD CONCENTRATIONS

LOCATION	$\mu g/m^3$
PRISTINE ATMOSPHERE	.0006
NORTH CENTRAL PACIFIC	.0010
NORTH INDIAN OCEAN	.0040
ANTARCTIC	.0005
WHITE MOUNTAIN, CALIF. (MIN)	.0012
REMOTE CONTINENTAL U.S. (AVG OF 10 SITES)	.022
URBAN LOCATION (TYPICAL)	2.000
SMELTER REGION	20.000

COMPOSITION OF URBAN AEROSOLS CHARLESTON, W. VA. ($\mu g/m^3$)

SPECIES	FINE	COARSE
Mass	33.400	27.100
O	6.200	3.200
N	3.300	0.460
So_4^{-2}	8.900	1.020
Na	0.190	0.094
Al	0.074	1.100
Si	0.410	2.800
Cl	0.040	3.080
K	0.100	0.290
Ca	0.100	0.960
Ti	0.011	0.077
V	0.002	0.002
Mn	0.007	0.010
Fe	0.016	0.690
Cu	0.020	0.004
Zn	0.032	0.010
As	0.026	–
Se	0.007	–
Br	0.160	0.039
Pb	0.660	0.120

COMPOSITION OF URBAN AEROSOLS PORTLAND, OR ($\mu g/m^3$)

	URBAN		RURAL	
SPECIES	FINE	COARSE	FINE	COARSE
Mass	25.000	39.000	14.300	16.300
C	6.800	6.900	4.100	3.000
N	0.350	0.360	0.250	0.240
So_4^{-2}	2.500	1.360	1.830	0.710
Na	0.280	0.750	0.250	0.400
Al	0.190	1.900	0.110	0.690
Si	0.200	6.000	0.180	2.200
Cl	0.840	0.810	0.390	0.320
K	0.150	0.320	0.120	0.155
Ca	0.120	1.270	0.065	0.410
Ti	0.009	0.160	0.004	0.048
V	0.012	0.012	0.004	0.009
Mn	0.032	0.055	0.008	0.016
Fe	0.200	1.800	0.060	0.430
Cu	0.026	0.056	0.017	0.052
Zn	0.062	0.070	0.019	0.012
As	0.004	0.001	0.003	–
Se	0.002	0.001	0.001	–
Br	0.240	0.095	0.038	–
Pb	0.645	0.410	0.100	0.040

COMPOSITION OF URBAN AEROSOLS
ST. LOUIS, MO. (µg/m3)

SPECIES	URBAN		RURAL	
	FINE	COARSE	FINE	COARSE
Mass	23.100	23.100	17.000	16.200
C	–	–	–	–
N	–	–	–	–
So_4^{-2}	8.500	0.980	7.400	0.460
Na	–	–	–	–
Al	0.170	0.980	0.070	0.600
Si	0.260	3.400	0.170	2.400
Cl	0.165	0.320	0.020	0.100
K	0.180	0.300	0.110	0.240
Ca	0.190	2.600	0.100	1.800
Ti	–	0.190	–	0.055
V	–	–	–	–
Mn	0.024	0.027	0.005	0.014
Fe	0.240	1.000	0.110	0.515
Cu	0.045	0.011	0.010	0.003
Zn	0.140	0.110	0.060	0.024
As	–	–	–	–
Se	0.003	–	0.002	–
Br	0.145	0.030	0.025	005
Pb	0.630	0.190	0.170	0.030

8. MEASUREMENT OF STACK EMISSIONS

8.1 Receptor Model Source Testing Requirements

- Sources selected must be representative of others in the airshed
- Samples must be taken at representative times during the process cycle and should represent important emission events
- A sufficient number of samples must be taken to reflect actual variability in emission chemical composition
- Sampling protocol must be consistent with analytical requirements
- Sampling size cuts should be compatible with ambient sampling methods
- Documentation on process materials (fuels), process conditions and control equipment status should be obtained
- Source samples should be representative of the emissions as perceived by the receptor due to condensation, agglomeration and vaporization. (organics, Se, Hg, As)

8.2 Categories of Sources Requiring Sampling

8.2.1 Point Source Sampling

8.2.2 Process Fugitive Sources

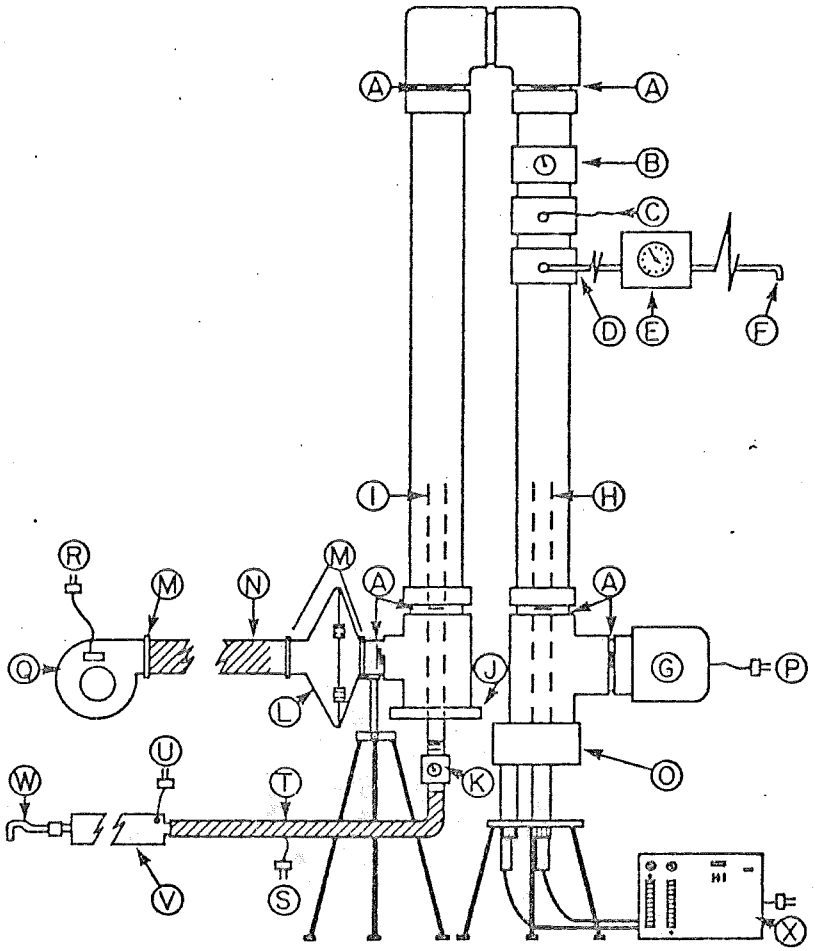
8.2.3 Passive Fugitive Samples

8.3 Source Characterization Costs

Cost Assumptions (Point Sources)

- Required equipment is on-hand
- Scaffolding - source access is available
- 4 sources per site are to be characterized, 5 sample sets obtained per source (2 filters/sample set)
- Analysis of all samples by XRF, NAA, IONS, organic/elemental carbon to provide full characterization
- Transportation and per diem costs not included

On-site - Direct Labor	4 days, 2 persons @ $40/hr	$2,560
Preparation - Direct Labor	1 day, 1 person @ $40/hr	320
	Subtotal	$2,880
Analytical (10 samples)		$2,700
Reporting & Documentation		2,000
	Total	$7,580

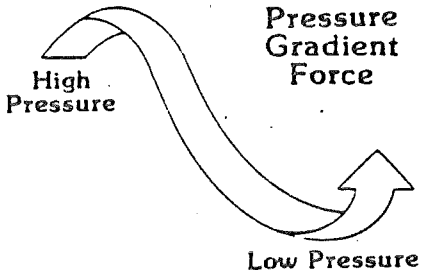


A. Threaded Connector
B. Thermometer
C. Thermal Anemometer
D. Static Pressure
E. Magnehelic
F. Pressure Sensor (in stack)
G. Blower Motor
H. Dichot Inlet Pipe
K. Thermometer
L. Filter Holder
O. Dichot Head
X. Dichot Control Unit

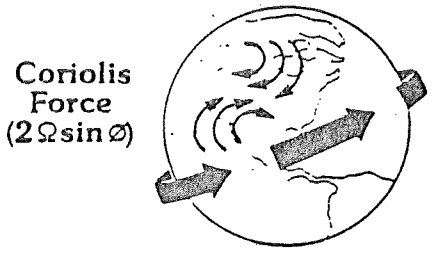
10.2 cm ⌀ PVC pipe

9. AIR POLLUTION METEOROLOGY

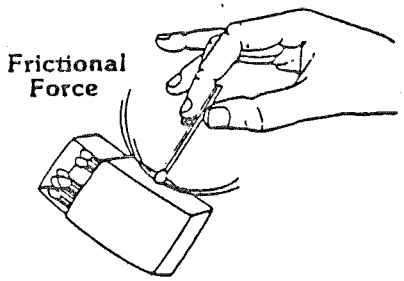
9.1 Wind Speeds & Direction



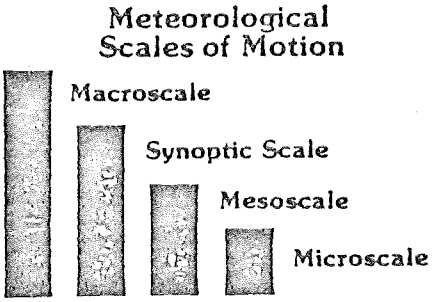
Predominant force influencing wind speeds - caused by the mass of the atmosphere.



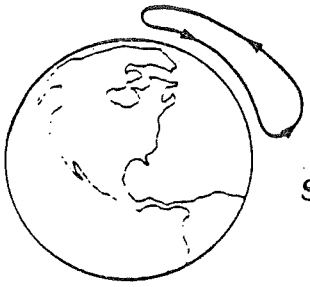
Force depends on latitute - turns winds to the right in northern hemisphere and left in southern.



Depends on surface roughness which decreases with height.

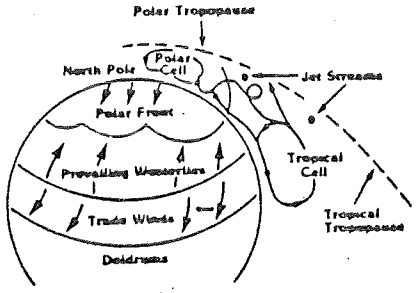


Macro - 3000 km to planetory (global)
Synptic - 200-1000 km (weather systems)
Meso - 2-200 km appliable to area sources
Micro - less than 2 km building turbulence



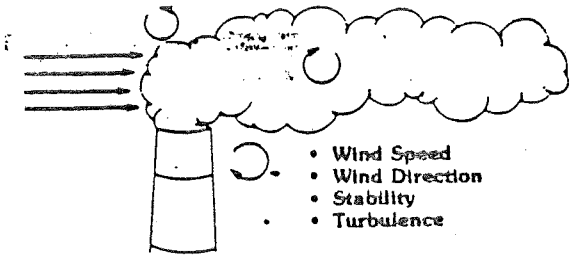
Single Cell

Without rotation - caused by differential heating at the equator. Would result in weather only at the equator.

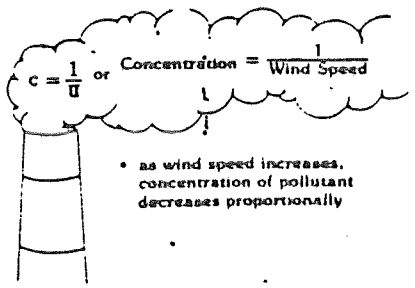


With rotation. Results in development of cellular patterns and zonal flow creating complex and varied weather.

METEOROLOGICAL FACTORS AFFECTING DISPERSION

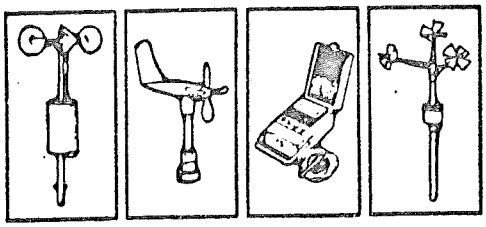


Effects on pollution.



Dilution inversely proportional to $\bar{u}$ reduces concentrations.

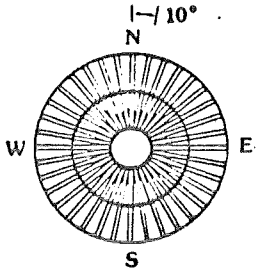
Wind Speed Instruments

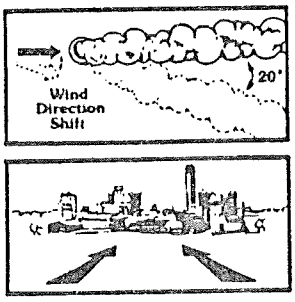


Cup | Propeller | Hot Wire | UVW

Wind Direction

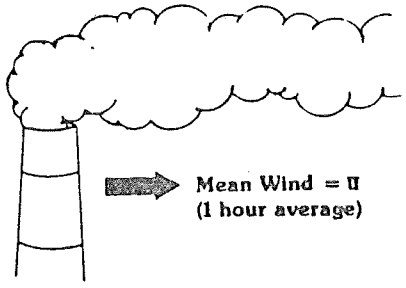
36 point



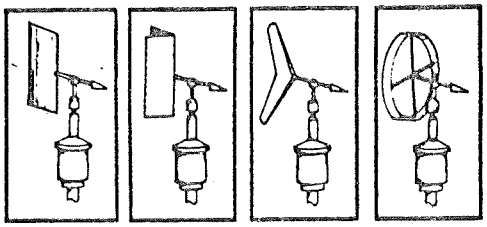


Point Source

Area Source

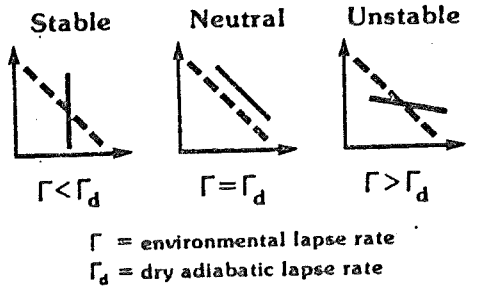


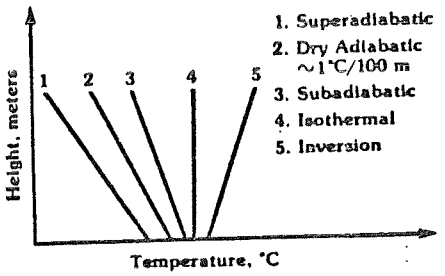
Wind Direction Instruments

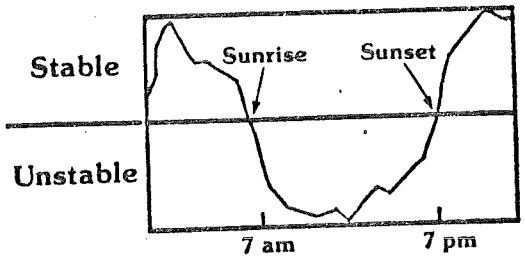


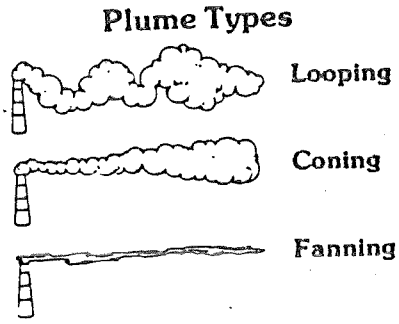
Flat Plate Vane | Splayed Vane | Airfoil Vane | Bivane

9.2 Atmospheric Stability

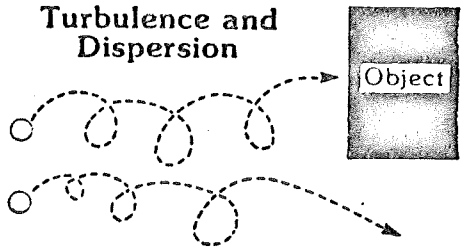


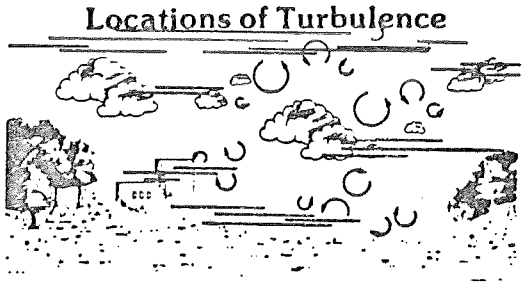


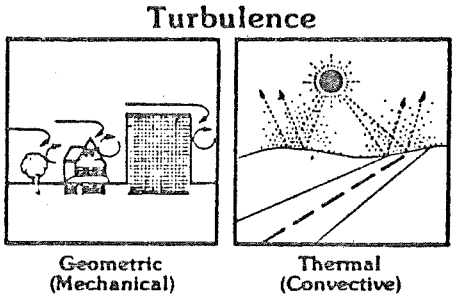


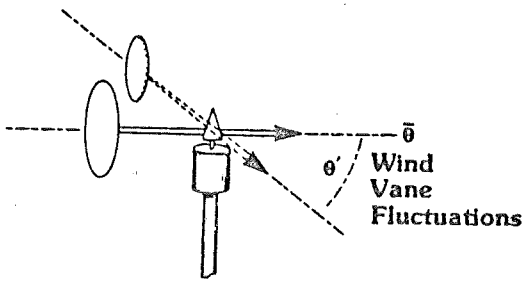


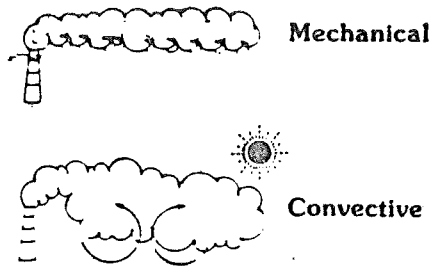
9.3 Turbulence and Dispersion

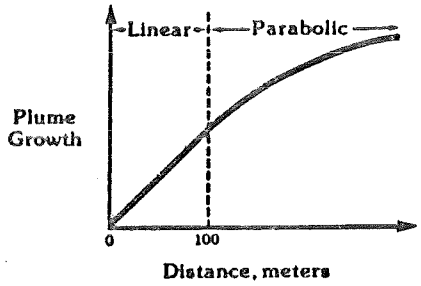




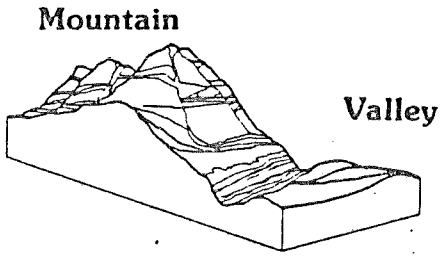


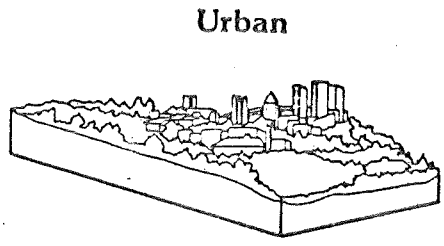


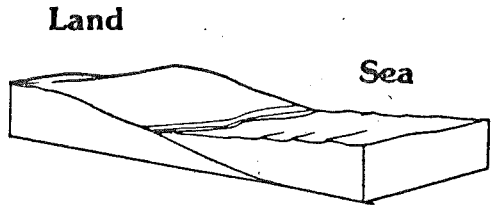


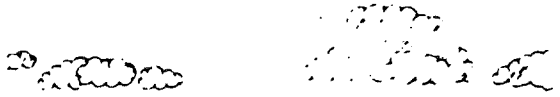


9.4 Effects of Topography on Dispersion

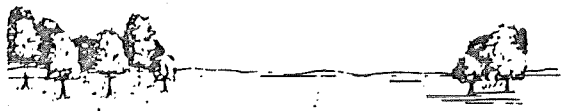




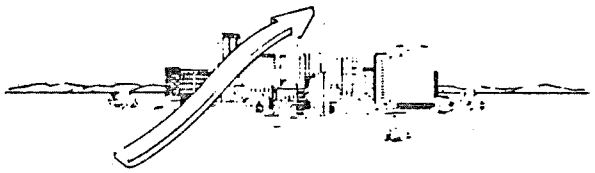




Roughness Factor

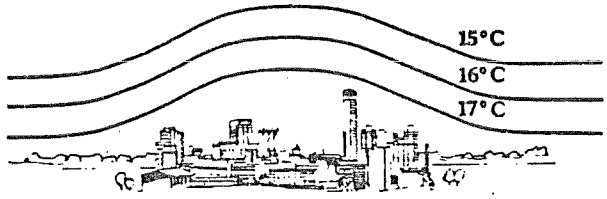


Roughness Factor

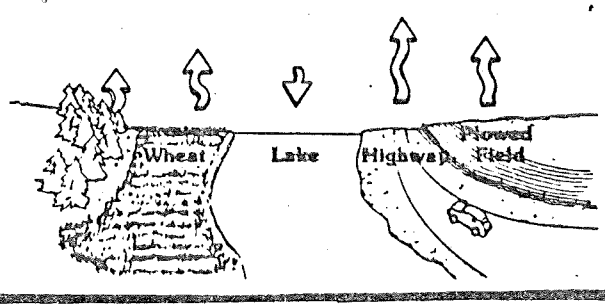


Stability: neutral to unstable

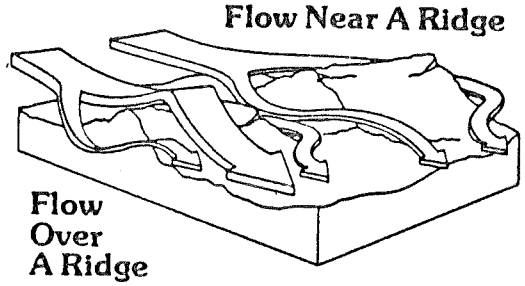
Geometric Effect



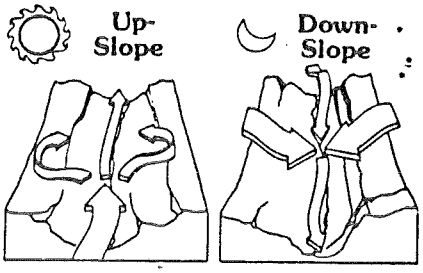
Thermal Effect

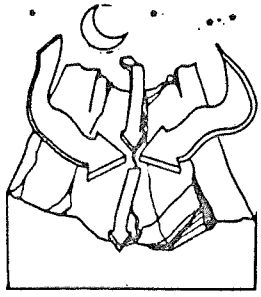


Flow Near A Ridge



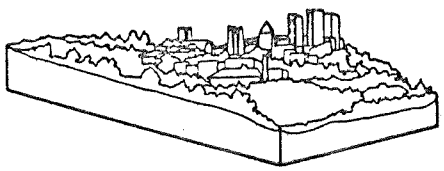
Flow
Over
A Ridge



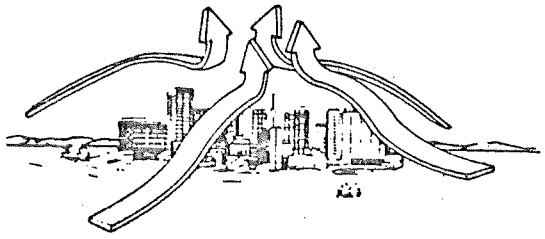


- air cools near surface causing denser air to sink along slopes

Urban



Geometric Effect



10. AIR QUALITY MANAGEMENT

10.1 Managing Air Resources

MANAGING THE AIR RESOURCE

- Air Resource Management Concept

Air Resource Management

Systems Approach:

- analysis / description of effects
- determination of air quality standards
- control of emissions
- monitoring / assessment of air quality
- revision of control strategy

Purpose

- control of nature / rate / location of emissions
- explicit conditions for control strategy and its evaluation
- efficient allocation of resources

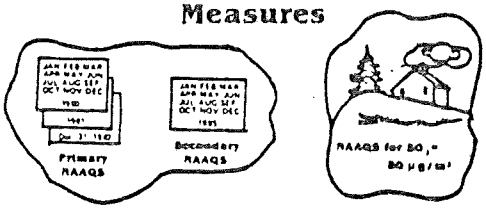
Implementation

- Air Quality Control Regions (AQCRs)
- Air Quality Criteria and Control Techniques
- National Ambient Air Quality Standards (NAAQS)
- Implementation Plans
- Continuing Monitoring and Cross-Checking

MANAGING THE AIR RESOURCE

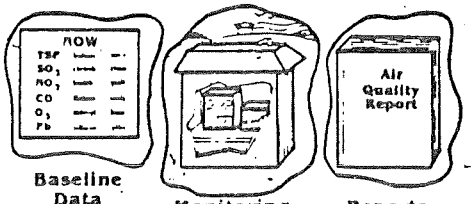
- Air Resource Management Concept
- Other Concepts
  - Best Practicable Means Approach
  - Economic Strategies
  - Land Use Control

Attainment and Maintenance Measures



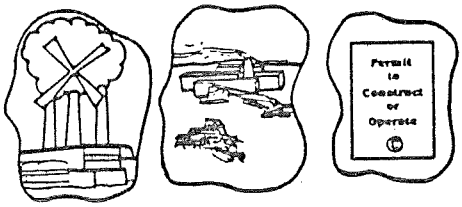
Attainment Maintenance

Air Quality Data

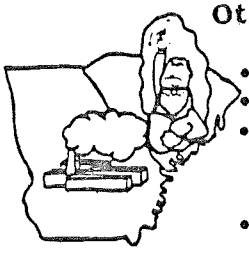


Baseline Data | Monitoring Network | Reports to EPA

Enforcement Program

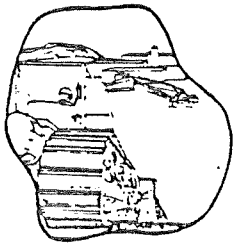


Non-Interference with Other States



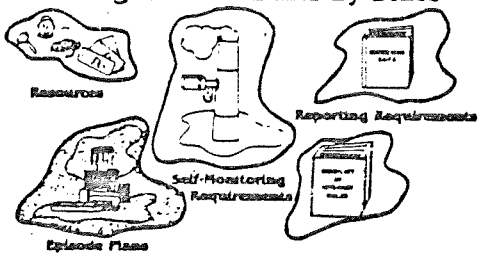
- NAAQS
- PSD
- notification of new sources with interstate impacts
- petition to EPA

New Source Review



- is for compliance with State standards
- interlocks with Federal programs
- relates to §111 review and Federal/State environmental impact review

Binding Commitments by State



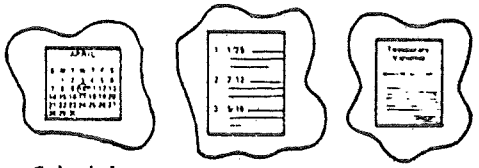
Control Strategies

- purpose
  - attainment / maintenance of NAAQS
- approach
  - development of emission reductions / limitations

Control Strategies (continued)

- methods
  - region-by-region
  - emission data
  - air quality data
  - emission reductions / limitations
- demonstration
  - example region
  - modeling

Compliance Schedules



Emergency Episode Prevention

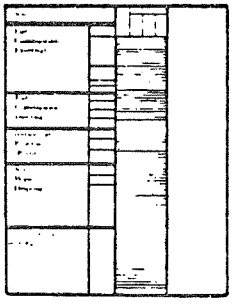
- purpose
  - to prevent pollutant concentration from reaching high levels "which could cause significant harm to the health of persons"

Emergency Episode Prevention (continued)

- requirements
  - at least 2 levels of action
  - public announcement
  - adequate emission control actions
  - forecast data from NWS
  - source inspection
  - communications procedures

10.2 Program Elements to Assessing Source Impacts

Traditional approaches to source impact assessment are based on regional Emission Inventories and dispersion modeling as key tools to identify and track source impacts.



Emission Inventories

- information base for strategy development and validation
- quantitative description of sources and amounts of emissions

Uses of Emission Inventories

- ambient monitoring network design
- control strategy design
- dispersion modeling input
- control strategy progress evaluation

Requirements for Emission Inventories

- Nonattainment Area Plans
  - comprehensive
  - current
  - complete
- General
  - categorization
  - criteria pollutant coverage
  - units
  - location

Revision of Emission Inventory

- continuing
- periodic

Air Quality Data

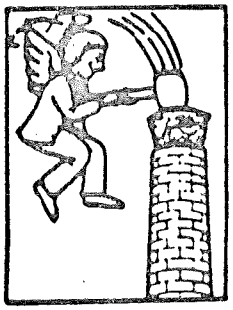
- information base for initial or nonattainment area strategy development and evaluation

Existing Data

- baseline for initial or nonattainment area strategy development
  - monitoring network
  - measurements

Projected Data

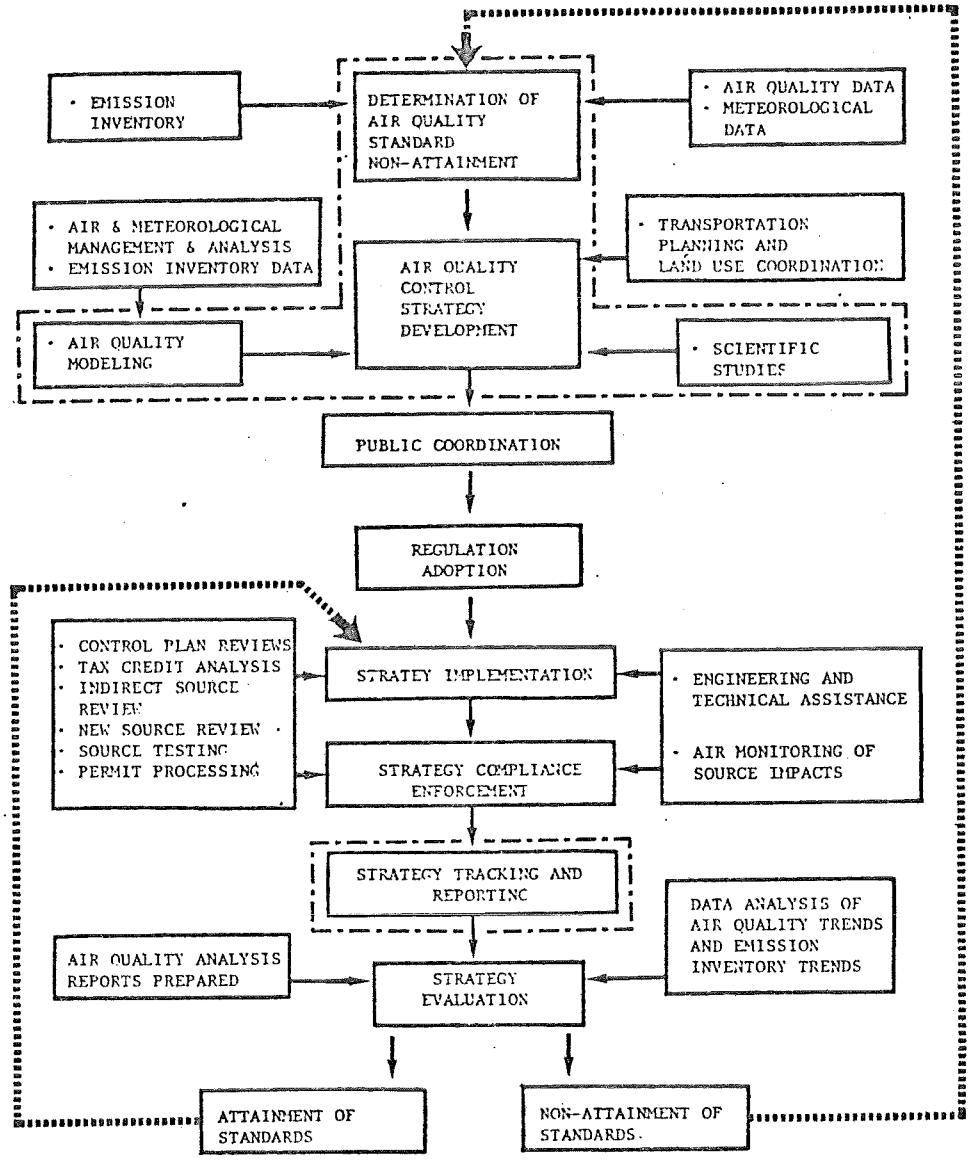
- data for evaluation of control strategy
  - monitoring network
  - measurements



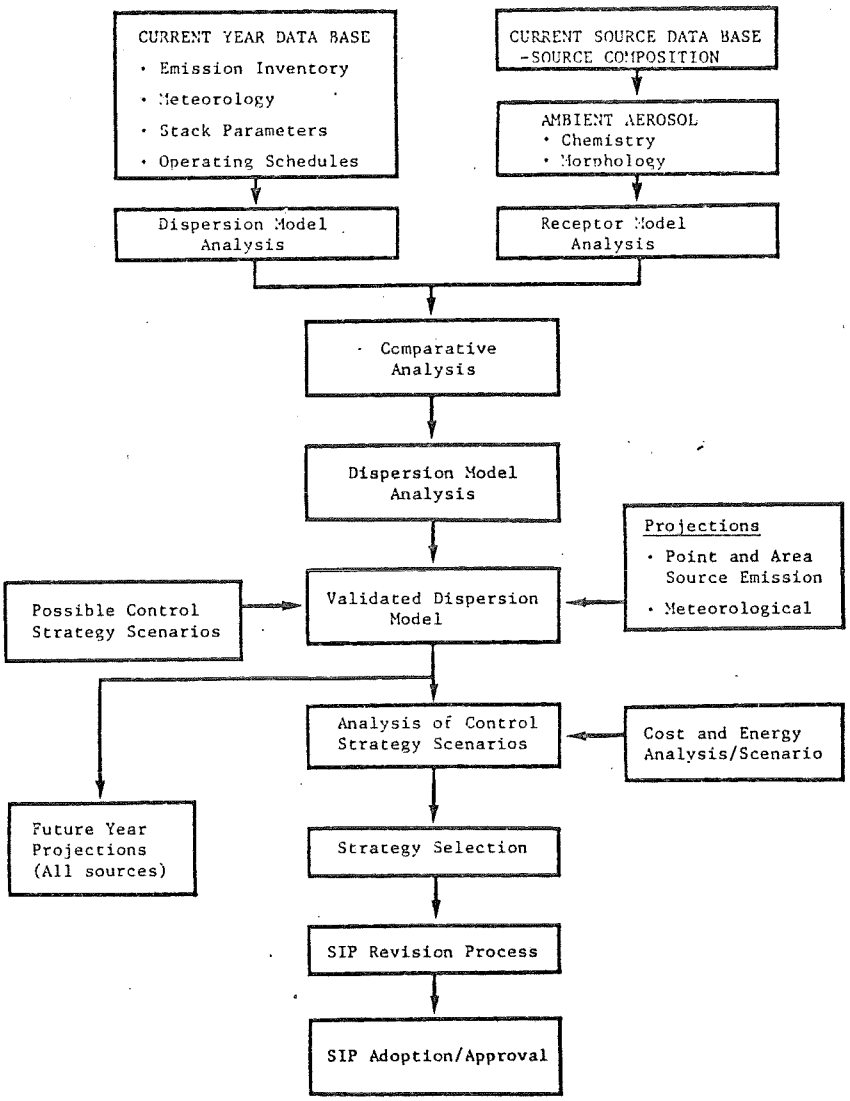
Control Strategy

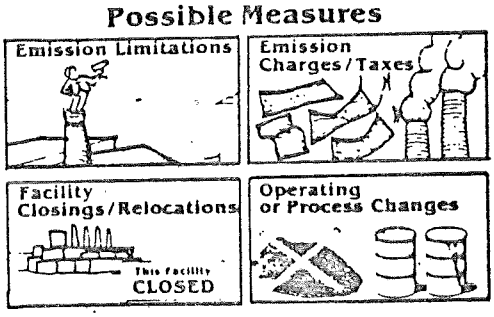
- combination of measures to achieve overall emission reductions needed for NAAQS attainment and maintenance

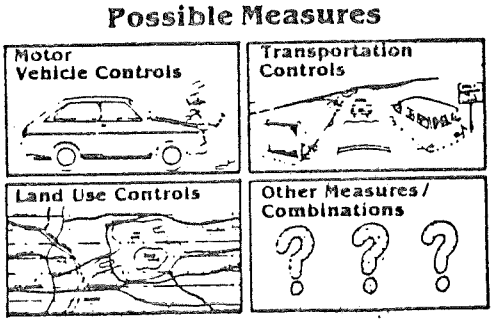
10.3 Control Program Overview



10.4 Control Strategy Development







Reduction Estimates

- Methods
  - rollback
  - dispersion modeling
  - simulation modeling, EKMA, etc.
- Allocation
  - to areas
  - to source categories
  - to specific sources

10.5 PSD and Alternative Air Management Techniques

- Area Classifications
  - mandatory Class I or II
  - initial Class II for all others better than secondary NAAQS or unclassifiable

- Ceilings and Increments
  - for TSP and SO_2
  - increments - maximum permissible increases in concentration
  - ceilings - concentration in no case to exceed lowest NAAQS
  - special cases

PSD INCREMENTS

	Class I	Class II	Class III
TSP			
Ann. geom. mean	5	19	37
24-hr. max.[b]	10	37	75
SO_2			
Ann. arith. mean	2	20	40
24-hr. max.[b]	5	91	182
3-hr. max.[b]	25	512	700

Figure 15-2. Basic PSD increments[a].

[a]Concentration increases (in $\mu g/m^3$) not to be exceeded for class and pollutant in question.
[b]Not to be exceeded more than once per year.

Emission Trading Policy

Purpose - to encourage use of emission trades to permit greater flexibility in meeting NAAQS. Includes bubbles, netting, offsets as well as banking.

Bubble Policy

Allows existing plants to decrease or eliminate needs for controls at 1 or more source in exchange for compensating increases in control of other sources if the emission limits of the bubble proposal is equivalent in terms of ambient impact and enforceability. Bubbles cannot be used to meet requirements placed on new sources.

Netting

Removes requirements of New Sources Review from expanding plants in PSD and nonattainment areas as long as increases in plant-wide emissions are insignificant. Sources may thereby be exempted from preconstruction permits including modeling and monitoring, installation of BACT or LAER and offset requirements.

Emission Offsets

Major new sources in nonattainment areas may be required to secure significant surplus emission reductions to more than "offset" their increased emissions. This allows industrial growth in nonattainment areas while improving air quality.

Emission Reduction Banking

Banking lets firms store qualified emission reductions for later use in bubble, netting or offset transactions. Banked Emission Reduction Credits (ERC) can then be sold to others. ERC's must be surplus, enforceable, permanent and quantifiable. Surplus ERC's are those not required by law-established by defining an emission baseline against which surplus emissions are calculated. Quantifications can include emission factors, monitored impact or by modeling. All trades must be for the same pollutant and not increase hazardous pollutants.

11.0 RELATIONSHIP OF EMISSION SOURCES TO AIR QUALITY

Urban air quality simulation models are numerical techniques based on physical principles, for estimating pollutant concentrations in space and time as a function of emissions and meteorology. They are typically used to answer:

Model Applications

- Emission reductions required to meet standards
- Relative contributions from various sources
- Siting of new sources
- Air quality improvements associated with alternative scenarios
- Projections of future air quality

11.1 Alternative Models (Particulate)

Proportion "roll-back" Models

$$\% \text{ Reduction Required} = \frac{\text{Existing AQ} - \text{Standard}}{\text{Existing AQ} - \text{Background}} \times 100$$

- Numerical Model

Gaussian Models: Crosswind plume concentration districution is Gaussian in form.

$$X(x,y) = \frac{Q}{\pi\sigma_y\sigma_z U} \exp - \left[\frac{y^2}{2\sigma_y{}^2} + \frac{h^2}{2\sigma_x{}^2}\right]$$

where:

X = Ground level concentration at coordinates (x,y)

Q = Emission rate

U = wind velocity in x direction

$\sigma y, \sigma_2$ = Std. dev. of concentration function in y and z directions

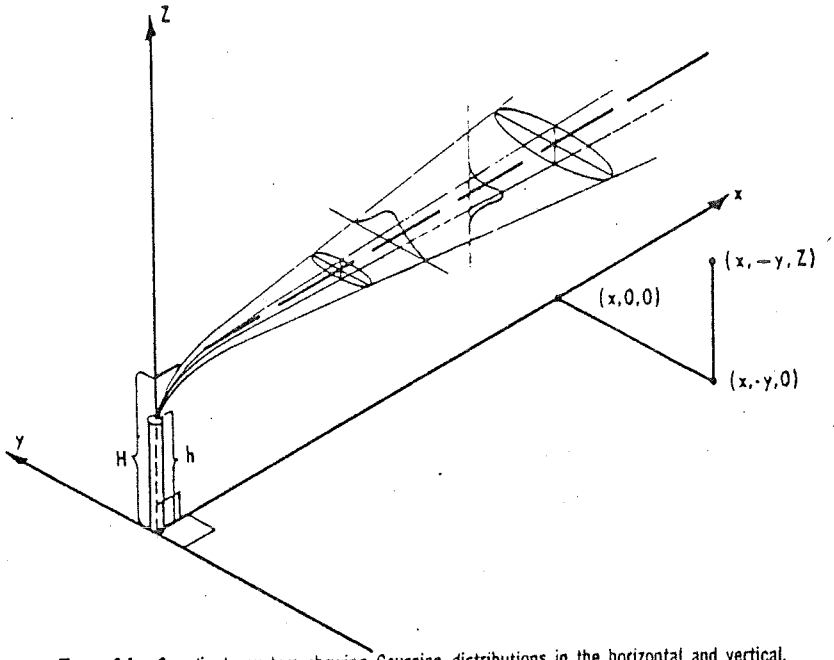


Figure 3-1. Coordinate system showing Gaussian distributions in the horizontal and vertical.

Gaussian Model Disadvantages

- Concentrations are not time dependent; they are quasi-steady state in that input variables are changed at fixed intervals (hourly)
- Spatial variability in meterology cannot be incorporated (terrain)
- Calculations become unstable at low wind speeds
- Does not account for reaction, deposition
- Intended for use in relatively flat terrain (dispersion coefficients σ_x, σ_y, σ_z at default are for level topography)

Conservation of Mass Models: Eulerian and Lograngian

Eulerian/Lagrangian Model Advantages/Disadvantages

Advantages

- More accurate area source treatment than Gaussian models
- Cost-effective if a large number of receptors are specified
- Able to simulate terrain influences on surface meteorology

Disadvantages

- Data-intensive
- Computational costs are much higher than Gaussian
- Tend to "smear" out point source impacts with a grid or cell
- Most cannot track individual source impacts

Common Dispersion Modeling Deficiences

- Inadequacy of area source emission inventories
- Inadequacy of meteorological data bases
- Dry and wet deposition, secondary aerosol algorithms
- Bias in TSP data used to validate urban models
- Inability to compensate for terrain and meteorological complexity
- Difficulty in constructing actual, 24 hour inventories for worst case analysis

Multiple Source Particulate Dispersion Models

Model	Type	Averaging Annual	Time 24 hour	Source Point	Type Area	Terrain Type	Depo-sition	Plume Point	Rise Area	Wind Fields
CDMQC*	G	x	(Larsen) x	x	x	Flat	Exp.	Briggs	none calculated	Constant
RAM (urban)	G		x	x	x	Flat	Exp.	Briggs	-	Constant
ISC	G	x	x	x	x	Flat	Deposition, Downwash	Briggs	Finite Crosswind	Constant
Valley(s)	G	x	x	x	x	Flat or Complex	Algorithm Exp.	Briggs or Assigned	Line source Assigned	Constant
Grid	E	x	x	x	x	Complex	Exp.	Briggs	mixed in lst cell	Wind flex through terrain

Notes: G = Gaussian
E.= Eulerian
Exp = Exponential
S = Screening Model

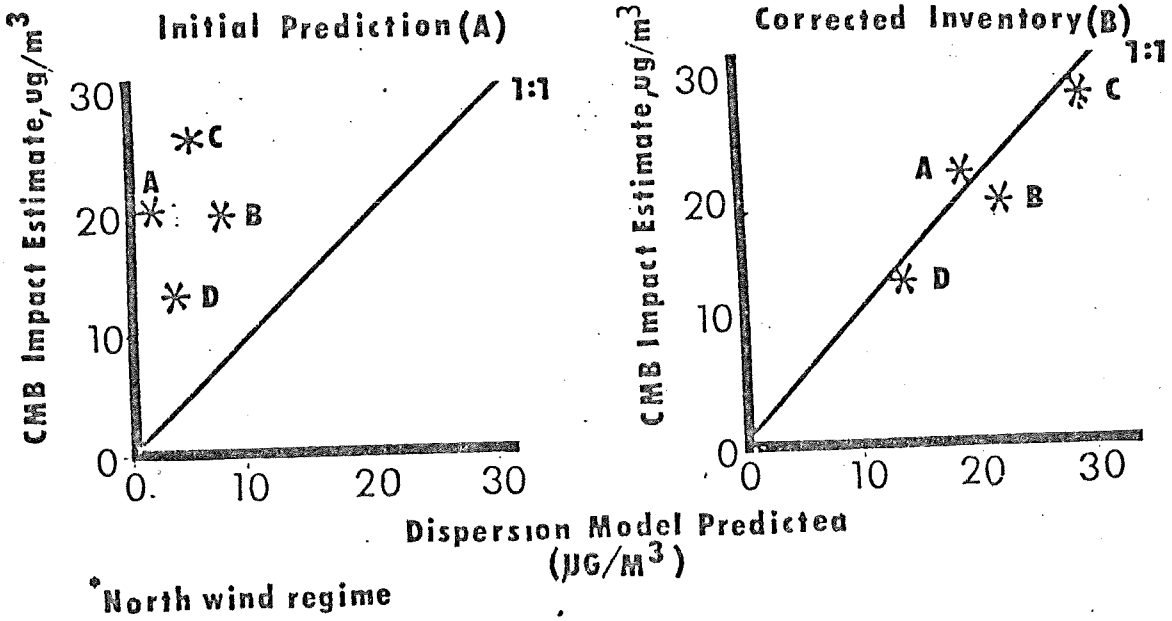
* Recommended by EPA for urban multi-source complexes in the absence of complex terrain or meteorology.

11.2 Joint Application of Source and Receptor Models

Model Validation Protocol

1. Identification of "target" sources
   - Availability of good source tracers
   - An important contributing source
   - Point and area sources
2. Program Design Elements
   - Key data elements
   - Concurrent data sources
   - Sampling network design
3. Independent Dispersion Modeling Effort
4. Independent Receptor Modeling Program
5. Comparison of Source Apportionment Results
   - Correction of EI and met deficiencies
   - Correction of model assumption errors

Portland, Or. Dispersion Model — Predicted Road Dust Impact*

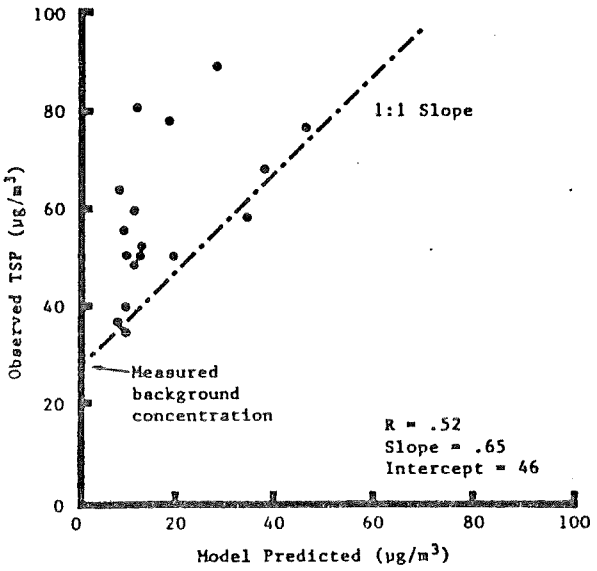


*North wind regime

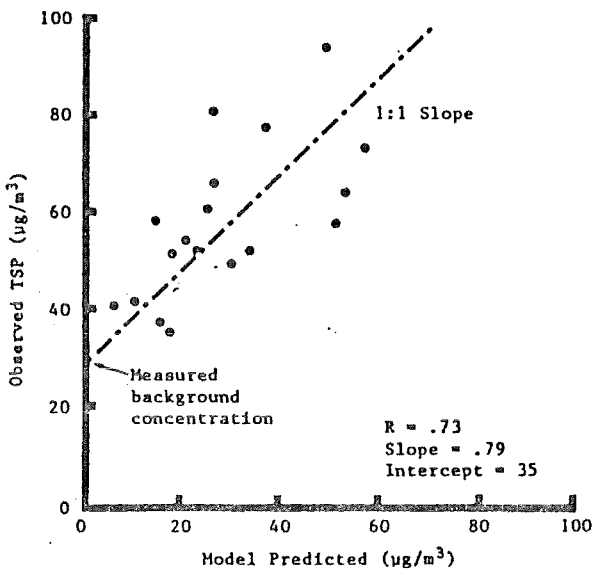
Portland, Oregon Dispersion Model

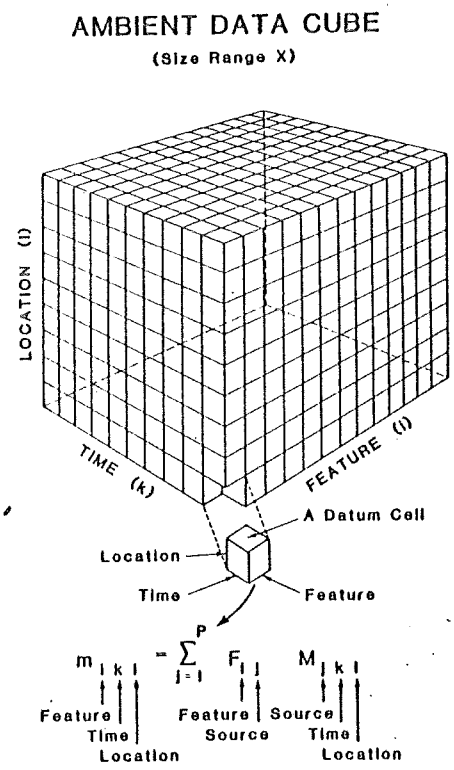
Annual Predictions

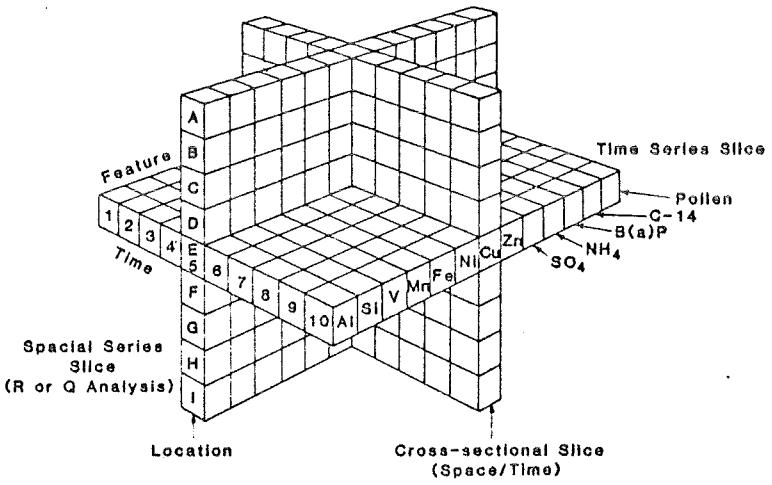
Initial Simulation



Following EI Improvements







GRAPHICAL REPRESENTATION OF DATA CUBE INFORMATION

HISTOGRAMS

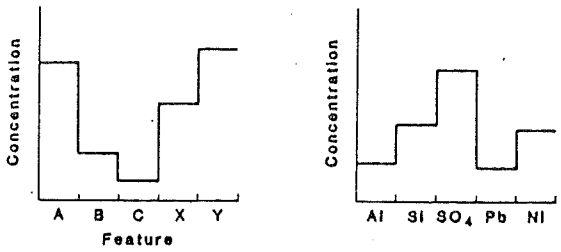
- Feature Pattern
- Feature Variability

VECTORS

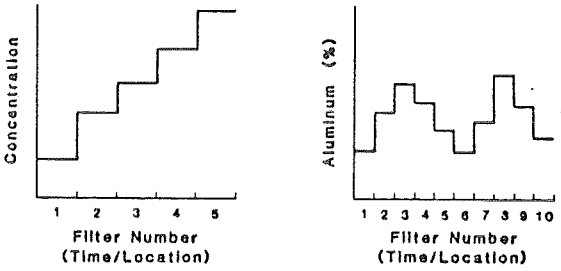
- Feature Vector in Filter Space
- Filter Vector in Feature Space

HISTOGRAMS

FEATURE PATTERN

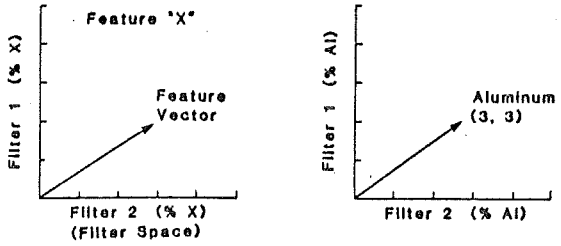


FEATURE VARIABILITY

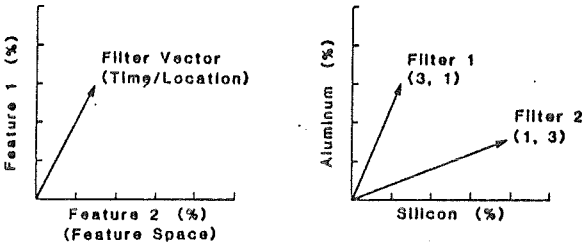


VECTORS

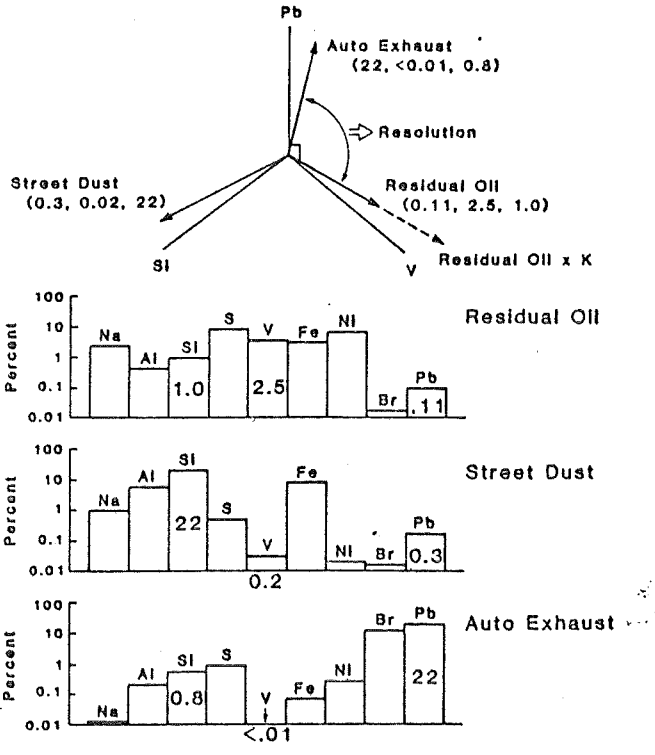
FEATURE VECTOR IN FILTER SPACE

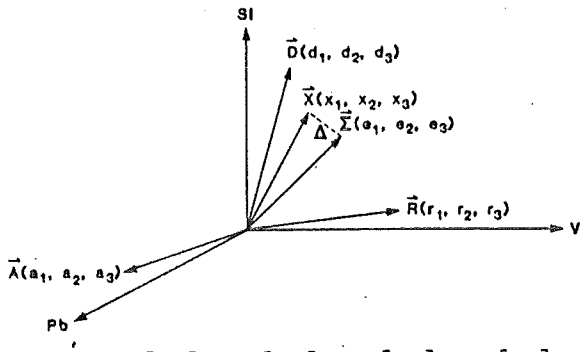


FILTER VECTOR IN FEATURE SPACE



ELEMENTAL SPACE (Pb, V, Si)

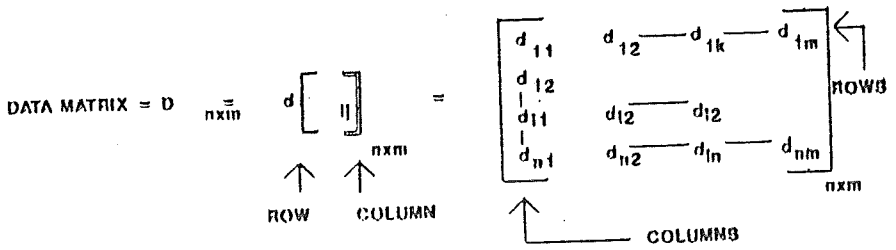




$$\vec{\Sigma} = \begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix} = b_1 \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} + b_2 \begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix} + b_3 \begin{bmatrix} r_1 \\ r_2 \\ r_3 \end{bmatrix}$$

$$\vec{\Delta} = \vec{X} - \vec{\Sigma}$$

A MATRIX IS AN ORDERED SET OF REAL NUMBERS (SCALARS) ARRANGED IN RECTANGULAR ROWS AND COLUMNS



INPUT DATA
AMBIENT CHEMICAL DATA SET

$$C_{nxm} = \begin{vmatrix} C_{11}\ C_{12}\ \cdots\ C_{1k}\ \cdots\ C_{1m} \\ C_{21} \\ \vdots \\ C_{i1}\ C_{i2}\ \cdots\ C_{ik} \\ \vdots \\ C_{n1}\ C_{n2}\ \cdots\ C_{nk}\ \cdots\ C_{nm} \end{vmatrix} = [C_{ik}]_{nxm} = \begin{vmatrix} C_{Na,1}\ C_{Na,2}\ \cdots\ C_{Na,m} \\ C_{Mg,1} \\ C_{AL,1} \\ \vdots \\ C_{Pb,1} \end{vmatrix}$$

CHEMICAL SPECIES ↑ ↓

TIME OR LOCATION

INPUT DATA
SOURCE COMPOSITION DATA SET

$$F_{nxp} = \begin{vmatrix} F_{11}\ F_{12}\ \cdots F_{1j}\ \cdots F_{1p} \\ F_{21} \\ \vdots \\ F_{i1}\ F_{i2}\ \cdots F_{ij} \\ \vdots \\ F_{n1}\ F_{n2}\ \cdots F_{nj}\ \cdots F_{np} \end{vmatrix} = [F_{ij}]_{nxp} = \begin{vmatrix} F_{Na,AUTO}\ F_{Na,MARINE}\ F_{Na,KRAFT} \\ F_{Mg,AUTO} \\ F_{AL,AUTO} \\ \vdots \\ F_{Pb,AUTO} \end{vmatrix}$$

CHEMICAL SPECIES ↑ ↓

<---SOURCE--->

UNKNOWN

$$S_{pxm} = \begin{vmatrix} s_{11} & s_{12} & \cdots & s_{1k} & \cdots & s_{1m} \\ s_{21} & & & & & \\ \vdots & & & & & \\ s_{j1} & s_{j2} & \cdots & s_{jk} & \cdots & s_{jm} \\ \vdots & & & & & \\ s_{p1} & s_{p2} & \cdots & s_{pk} & \cdots & s_{pm} \end{vmatrix} = [S_{jk}]_{pxm} = \begin{vmatrix} s_{AUTO,1} & s_{AUTO,2} & \cdots & s_{AUTO,m} \\ s_{MARINE,1} & & \text{SOURCE} & \\ s_{KRAFT,1} & & & \\ s_{p,1} & & & \end{vmatrix}$$

TIME OR LOCATION

CHEMICAL MATRIX SOLUTIONS

$$[C_{ik}]_{nxm} = [F_{ij}]_{nxp} \quad [S_{jk}]_{pxm}$$

$$C_{ik} = \sum_{j=1}^{p} F_{ij} S_{jk}$$

AMBIENT CORRELATIONS (TIME, SPACE, OTHER)

MULTIVARIATE METHODS

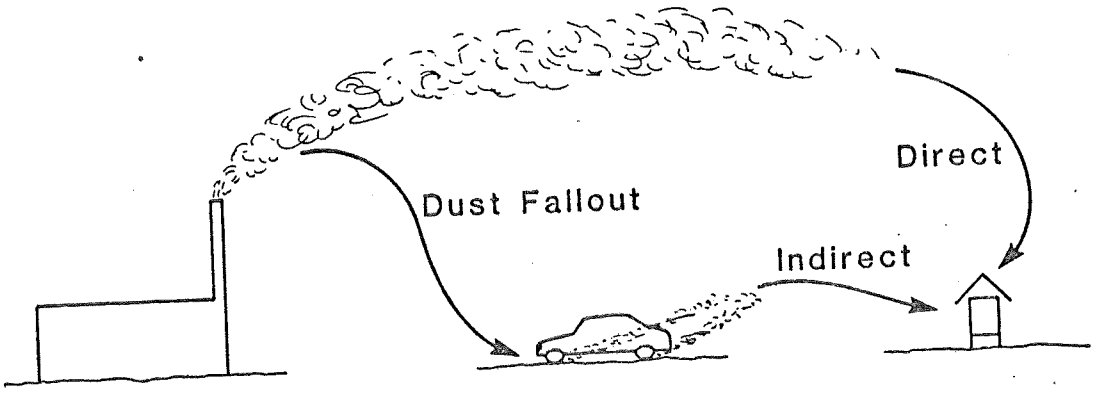
CHEMICAL MASS BALANCE METHODS

TRACER

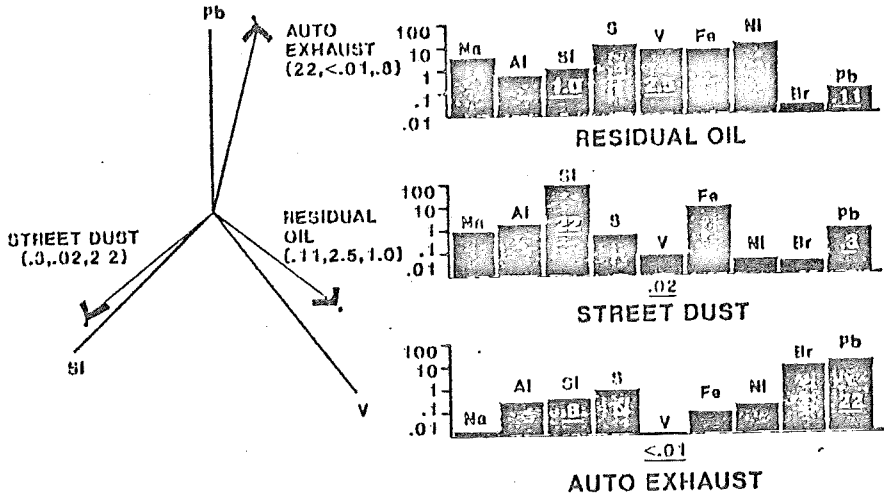
LEAST SQUARES

HYBRID METHODS

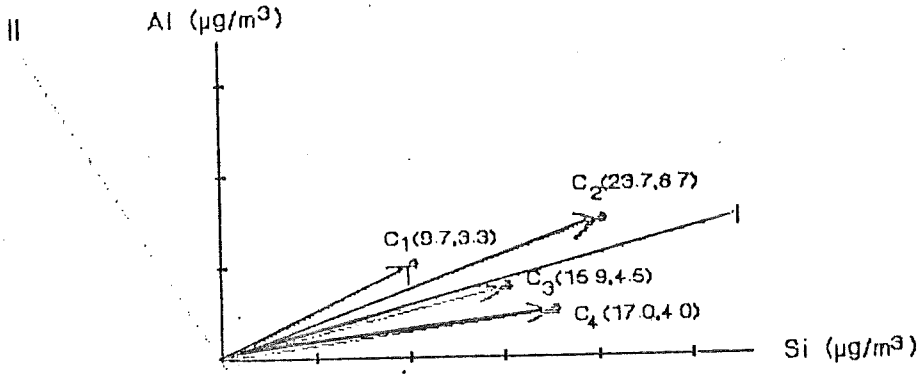
DIRECT AND INDIRECT CONTRIBUTIONS TO SUSPENDED PARTICULATE MASS



ELEMENTAL SPACE (Pb, V, Si)



SUMMER COARSE FRACTION (PACS)



1. NUMBER OF FACTORS
2. CHEMICAL NATURE OF FACTORS

SPACE

DATA TABLE (μg/m3)

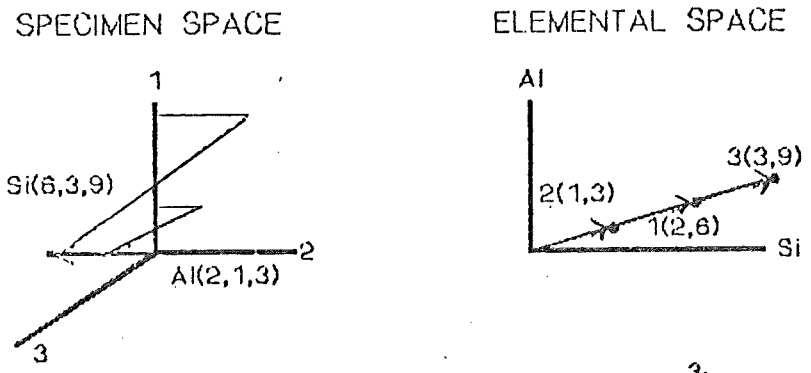
	SPECIMEN NUMBER		
ELEMENT	1	2	3
Al	2	1	3
Si	6	3	9

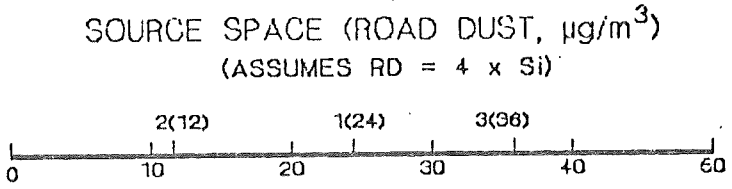
ELEMENTAL VECTORS

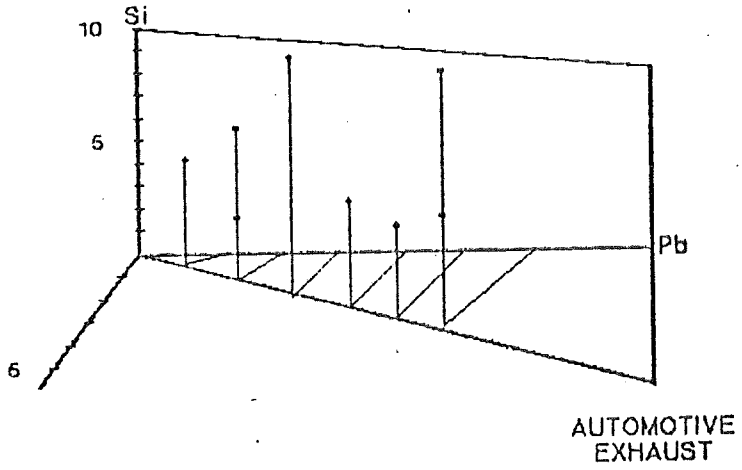
(2, 1, 3,)
(6, 3, 9)

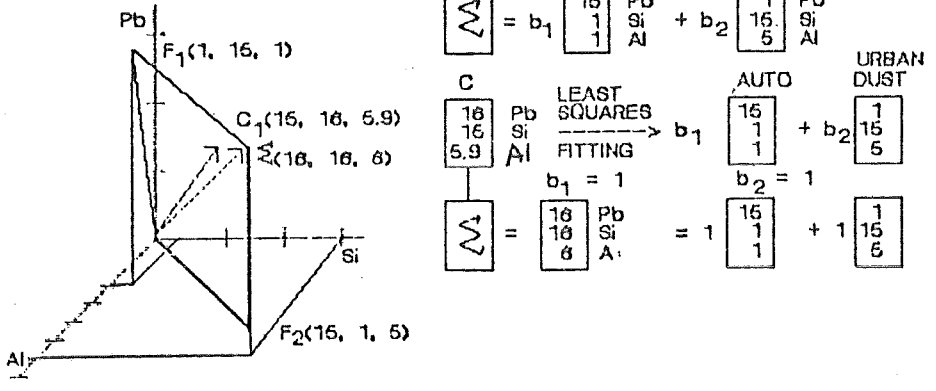
SPECIMEN VECTORS

$\begin{bmatrix} 2 \\ 6 \end{bmatrix} \begin{bmatrix} 1 \\ 3 \end{bmatrix} \begin{bmatrix} 3 \\ 9 \end{bmatrix}$


SPECIMEN SPACE
ELEMENTAL SPACE
1
Si(6,3,9)
2
Al(2,1,3)
3
Al
3(3,9)
2(1,3)
1(2,6)
Si

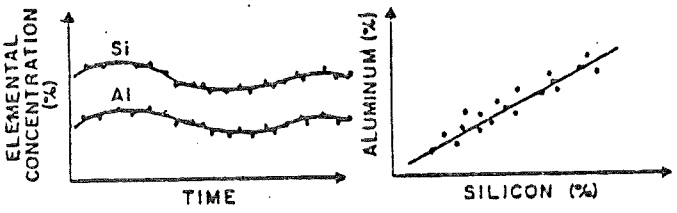

SOURCE SPACE (ROAD DUST, μg/m3)
(ASSUMES RD = 4 x Si)
2(12)
1(24)
3(36)
0
10
20
30
40
60


10
Si
5
Pb
6
AUTOMOTIVE
EXHAUST


Pb
F1(1, 16, 1)
C1(15, 16, 5.9)
(16, 16, 6)
Si
F2(15, 1, 5)
Al
AUTO
URBAN DUST
= b1
16
1
1
Pb
Si
Al
+ b2
1
16
5
C
16
16
5.9
LEAST SQUARES FITTING
b1 = 1
b2 = 1
= 1
+ 1

METHODS OF PRESENTING

TIME DEPENDENT DATA



- Al and Si from Common Source
- Average Al/Si ratio
- Quantitative Source Apportionment
  if • Si, Al ⇒ R. Dust, etc.
  • Si − 25% (Tracer)

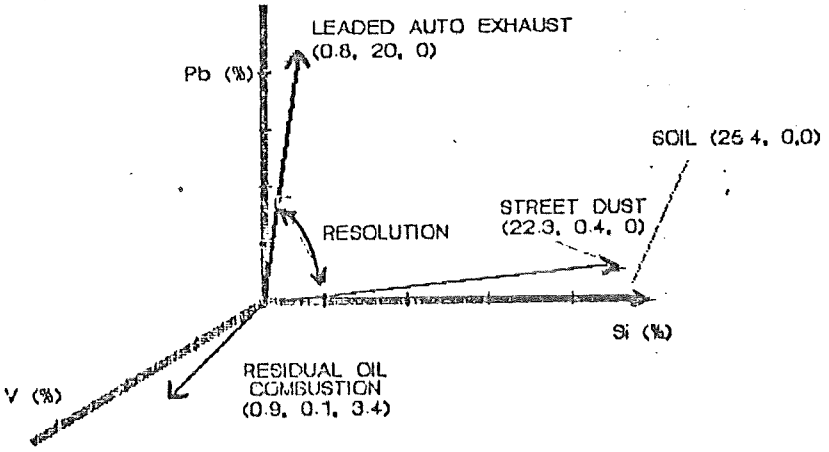
AMBIENT DATA MATRIX

+

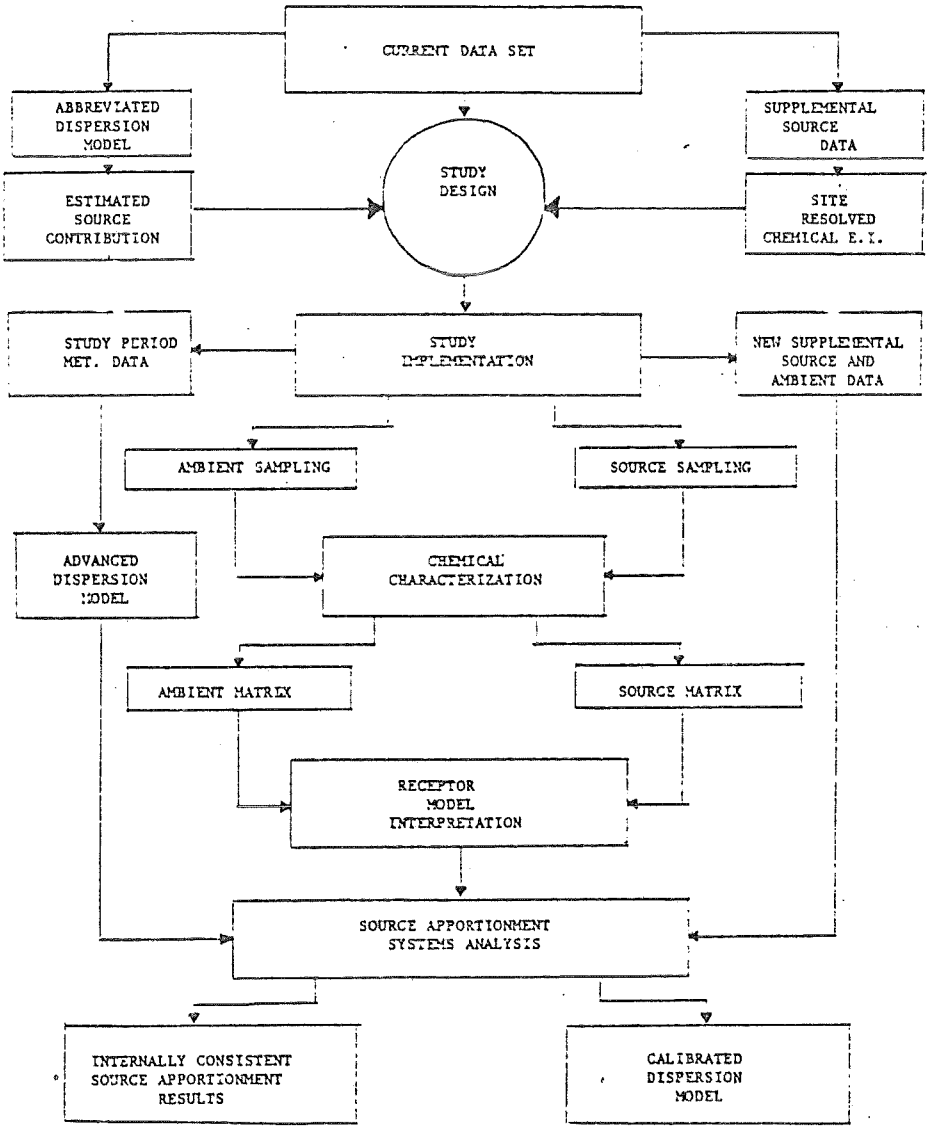
FACTOR ANALYSIS

↓

1. Al AND Si FROM COMMON SOURCE
2. AVERAGE Al/Si RATIO
3. SOURCE IDENTIFICATION IF Si, Al ⟶ R. DUST, ETC.
4. FRACTION OF VARIABILITY CAUSED BY SOURCE



UNIFIED SOURCE APPORTIONMENT AND MODEL CALIBRATION STUDY



13. APPLICATION OF CHEMICAL MASS BALANCE TO CONTROL STRATEGY DEVELOPMENT

14. REVIEW OF RECEPTOR MODEL STUDIES

14.1 Purpose of Studies

Portland Aerosol Characterization Study (PACS) 1975-78

- Identify sources contributing to TSP nonattainment
- Quantify source impacts on visibility
- Isolate impacts to fine particle fraction influencing public health
- Provide a state-of-the-art data base for dispersion model validation
- Improve technical basis for regulatory policy

Medford Aerosol Characterization Study (MACS) April 79-March 80

Iowa Source Apportionment Study 1980

- Quantify impact of fugitive dust on TSP attainment
- Measure concentrations of toxic trace elements
- Chemically characterize the IP & TSP aerosol between sites

Williamette Valley Study 1978

- Quantify impacts from field and slash burning on the valley
- Impacts on nonattainment areas
- Determine short-term impacts from smoke intrusions
- Measure the geographical extent of smoke impact

14.2 Summary of Study Designs

STUDY	COST	NO. SITES	SAMPLING METHODS	NO. SAMPLES	SIZE RANGES	AVERAGING TIMES	ANALYTICAL METHODS	SOURCE PROFILES	DISP. MODEL VALIDATION	MET DATA
PACS	$1,000,000	6	HV, LVTSP, HV Impactor, cyclone seq.	2,000	< 2, 2-30 μ	4, 8, 24 hours	IC, XRF NAA, EC/OC ^{14}C	37 sources, special EI	yes	upper air & surface
MACS	$ 214,000	4	HV, LVTSP, HV Impactor, SFU, dichot. cyclone seq.	300	< 2.5 2.5-30 μ	12, 24 hours	IC, XRF ^{14}C, EC/OC, NAA	11 sources, special EI	yes	upper air & surface
IOWA	$ 21,000	8	HV, SSI	175	< 15, < 30 μm	24 hours	XRF, IC, EC/OC, CO_3, XRD	soils only	no	none
WILLIAMETTE VALLEY	$ 611,000	11	HV, LVTSP SFU, dichot HV impactor	10,462	< 2, 2-15, < 30 μm	2, 24 hours	IC, XRF TC, ^{14}C	soils, 10 point sources	no	surface

Key Design Features

- All major chemical species determined
- All major source emissions characterized
- High level of Quality Assurance
- CMB calculations include major errors
- Fine and TSP sources included
- Results directly applicable to standards
- Concurrent development of dispersion model data base (optional)

Criteria for Sample Analysis Selection

	Study
• Air pollution episodes (worst case)	P, M, WV
• Occurrence of pre-selected meteorological patterns (regimes)	P
• Sample mass exceeds air quality standard	WV, I
• Days of visibility reduction below minimum criteria	WV
• Source activity criteria	
• Periods of source shutdown	M
Periods of atypical emissions or weather	WV
• Routine schedule (6th day)	M, WV
• Intensive sampling periods	P, M, WV

Typical Program Budget

Air monitoring capital outlay	$117,800	20.3%
Meteorological capital outlay	13,000	2.2%
Operating supplies	43,000	7.4%
Program planning & data analysis	53,000	9.1%
Elemental analysis	30,000	5.2%
Other analytical costs	15,026	2.6%
Project manager	45,000	7.7%
Field & Lab personnel	142,788	24.7%
Mobil monitoring van & staff*	37,100	6.4%
Air monitoring equipment*	12,400	2.1%
Aircraft program*	50,500	8.6%
Laboratory* services*	21,000	3.7%

* in-kind support

Comparison of Program Results
(% of Aerosol Mass)

Source	PACS (1) TSP	PACS (1) Fine	MACS (1) TSP	MACS (1) Fine	WILLIAMETTE VALLEY (2) TSP	WILLIAMETTE VALLEY (2) Fine	IOWA (3) TSP	IOWA (3) Fine
Soil Dust	53.7	10.1	29.9	4.3	54.9	7.1	27.1	19.8
Burning	8.5	16.4	31.1	65.7	26.5	48.8	-	-
Auto Exhaust	6.7	14.3	2.8	3.4	3.2	5.5	1.7	2.6
Industry	4.6	3.7	14.8	19.4	5.3	12.3	4.2	8.3
Residual Oil	0.7	1.5	-	-	-	2.3	0.1	-
Marine	2.3	3.0	-	-	0.5	-	-	-
Nitrate	4.1	6.9	3.0	1.3	0.5	0.5	7.5	11.0
Sulfate	4.1	9.1	1.9	1.4	1.0	1.0	9.4	11.2
Organic C	6.6	14.2	-	-	3.8	5.5	19.5	not meas.
Elemental C	1.9	3.9	1.1	-	-	-		
Other	-	-	6.8	0.3	13.6	-	2.8	0.5

(1) Annual Average
(2) 4 month average (summer)
(3) Davenport average

15. REVIEW OF RECEPTOR MODEL STUDIES II

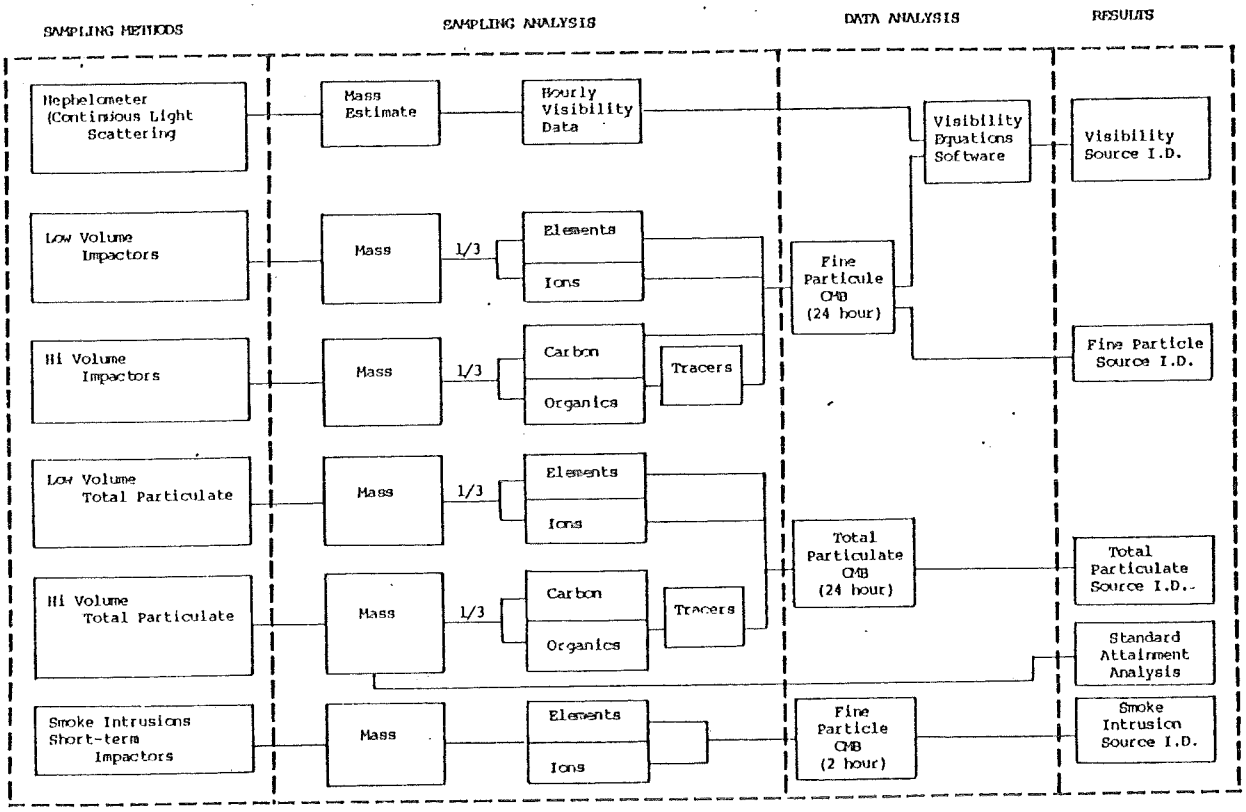
16. OPTIMIZING SOURCE RESOLUTION

The objective of optimizing source resolution is to maximize the impact of source(s) of interest while minimizing the impact of other interfering sources. Analagous to optimizing signal to noise ratio.

Opportunities for Improved Source Resolution During Study Design

- Source Characterization
  - Testing process cycles that may emit uniquc tracers
  - Choice of sampling protocol compatible with analytical methods for tracer elements
  - Optimizing size cuts that will maximize the tracer component
- Analytical Program Design
  - Choice of filters with low blanks for species of interest
  - Low area mass density filters for improved sensitivity
  - Choice of appropriate techniques for optimum precision and sensitivity
- Quality Assurance
  - Short term samples
  - Optimized size resolution
  - Intensive sampling during source shut downs
  - Locating sampling site in maximum impact areas
  - Locating sites between 2 similar sources with wind stratification
  - Selection of samplers with adequate flow rates

17. DEVELOPMENT OF STUDY DESIGN



PURPOSE OF DESIGN

- DEFINE OBJECTIVES
- ASSESS ADEQUACY OF EXISTING DATA
- ESTIMATE MANPOWER AND FUNDING
- ASSIGN RESPONSIBILITIES
- COMPONENT COMPATIBILITY

DESIGN AREAS

- EXISTING DATA
- AMBIENT SAMPLING
- SOURCE SAMPLING
- LABORATORY ANALYSIS
- DATA MANAGEMENT
- QUALITY ASSURANCE
- DATA INTERPRETATION
- REPORTING
- MANAGEMENT

TYPICAL PROGRAM COSTS

STUDY	SCALE	APPROX. COST
ACHEX	URBAN	$3,000,000
SURE	REGIONAL	$7,000,000
PACS	URBAN	$1,000,000
MACS	URBAN	$250,000
DENVER	URBAN	$700,000
EVANSVILLE, IND.	URBAN	$35,000
BRIDESBURG, PA.	NEIGHBORHOOD	$40,000
INDUSTRY X	MICRO	$5,000
INDUSTRY Y	MIDDLE	$800,000

DESIGN AREAS

- EXISTING DATA
- AMBIENT SAMPLING
- SOURCE SAMPLING
- LABORATORY ANALYSIS
- DATA MANAGEMENT
- QUALITY ASSURANCE
- DATA INTERPRETATION
- REPORTING
- MANAGEMENT

STUDY DESIGN

SOURCE REVIEW	$30,000
MET & AQ DATA REVIEW	$20,000
SITE SELECTION & MICROINVENTORY	$1,000/SITE
SAMPLING, ANALYSIS, QA & MANAGEMENT PLAN	$15,000

FIELD SAMPLING

SAMPLING DEVICES	$6,000/SAMPLER
INSTALL & TAKEDOWN EQUIPMENT	$4,000/SITE
SITE MAINTENANCE	$500/SITE/MONTH
FIELD SERVICING	$50/SITE/DAY

SOURCE SAMPLING

STACK OR DUCT	$1,000/SAMPLE
SOURCE "GRAB" SAMPLE	$100/SAMPLE

STANDARD LABORATORY ANALYSIS

FILTER PROCESSING	$10/SAMPLE
X-RAY FLUORESCENCE	$40/SAMPLE
NEUTRON ACTIVATION ANALYSIS	$120/SAMPLE
AUTOMATED COLORIMETRY (IONS)	$20/SAMPLE
ION CHROMATOGRAPHY	$30/SAMPLE
ELEMENTAL & ORGANIC CARBON	$35/SAMPLE

SPECIALIZED LABORATORY ANALYSIS

X-RAY DIFFRACTION	$100/SAMPLE
OPTICAL MICROSCOPY	$400/SAMPLE
CARBON-14	$500/SAMPLE
AUTOMATED SEM	$600/SAMPLE
GCMS FOR ORGANIC SCREENING	?

DATA MANAGEMENT

MICROCOMPUTER & SOFTWARE	$25,000
SYSTEM SETUP	$20,000
DATA PROCESSING	$3.00/sample/analysis

QUALITY ASSURANCE

STANDARD OPERATING PROCEDURES	$2000/PROCEDURE
REPLICATE,BLANK & STANDARD ANALYSIS	12% OF ANALYSIS COSTS
FIELD AUDITS	$5/SITE/DAY
LABORATORY AUDITS	5% OF ANALYSIS COSTS
DATA VALIDATION	
• LEVEL I	$.50/SAMPLE/ANALYSIS
• LEVEL II	$1.00/SAMPLE/ANALYSIS
• LEVEL III	$.50/SAMPLE/ANALYSIS
INTERLABORATORY COMPARISONS	?

DATA INTERPRETATION

RECEPTOR MODEL SETUP	$20,000/MODEL
CMB CALCULATIONS	$25/BALANCE
MULTIVARIATE/STATISTICAL	$100/RUN
THINKING & WRITING	$60/HOUR

REPORTING

TYPING	$5.00/PAGE
FIGURES	$50/FIGURE
TABLES	$30/TABLE
COPYING	$.05/PAGE
BINDING	$1.00/COPY
EDITING	$5.00/PAGE

PROGRAM MANAGEMENT

10% OF ALL OTHER COSTS

CASE STUDY

SAMPLING ASSUMPTIONS

- 6 SAMPLING SITES
- 12 MONTHS OF SAMPLING
- 3, 8-HR. SAMPLES/DAY
- 2 SIZE RANGES
- 2 FILTER SUBSTRATES
- 120 DAYS OF SAMPLING (TOTAL)
- 30 DAYS FOR CHEMICAL ANALYSIS
- 30 SOURCE CHARACTERIZATIONS IN 2 SIZE RANGES
- 15 NEW PROCEDURES

CASE STUDY

ANALYTICAL ASSUMPTIONS

- 4320 AMBIENT FILTER PROCESSING (2 SUBSTRATES)
- 180 SOURCE FILTER PROCESSING
- 1260 XRF, ION, CARBON ANALYSES
- 20 OPTICAL MICROSCOPY
- 90 X-RAY DIFFRACTION
- 90 INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS
- 10 CARBON-14

DATA INTERPRETATION AND REPORTING ASSUMPTIONS

- 2 MODELS (CMB AND MULTIVARIATE)
- 1260 CMB CALCULATIONS
- 100 MULTIVARIATE CALCULATIONS
- 500 HOURS OF THINKING AND WRITING
- 200 PAGES OF TEXT
- 15 FIGURES
- 25 TABLES
- 50 REPORT COPIES

TOTAL COSTS

DESIGN	$71,000
FIELD SAMPLING	$168,000
SOURCE SAMPLING (GRAB)	$9,000
LABORATORY ANALYSIS	$184,900
DATA MANAGEMENT	$70,500
QUALITY ASSURANCE	$82,000
DATA INTERPRETATION	$70,300
PROGRAM MANAGEMENT	$65,600
TOTAL COST	$721,300

COST SAVINGS

EXISTING RESOURCES	SAVINGS
SOURCE, MET AND AQ DATA REVIEW ON-HAND	$50,000
AMBIENT SAMPLERS ON-HAND	$36,000
ION & CARBON ANALYSIS ON-HAND	$69,300
DELETE CARBON-14 ANALYSIS	$6,000
COMPUTER SYSTEM ON-HAND	$25,000
IN-HOUSE DATA INTERPRETATION	$70,300
IN-HOUSE PROJECT MANAGEMENT	$65,600
TOTAL SAVINGS:	$322,200
REVISED COSTS:	$999,100

FUNDING STRATEGY

- PRESENT COST-BENEFIT ANALYSIS
- VALUE OF ORIGIONAL RESEARCH
- MULTIPLE PURPOSES

OTHER FUNDING SOURCES

- LOCAL INDUSTRY ORGANIZATIONS
- CHAMBER OF COMMERCE
- TRADE ORGANIZATIONS
- EPA
- UNIVERSITIES

Aerosol Study Design Support Documents

1. Regulatory Requirements

   1.1 Descriptions of ambient air quality standards. The study will be designed to address, regulatory deadlines or schedules that study results must meet.

   1.2 Geographical areas that must attain air quality standards.

2. Airshed Characteristics

   2.1 Topographical maps of the airshed showing terrain features, the location of major sources (map index number and accompanying description), location of air monitoring and meteorological sites, areas exceeding air quality standards. One map should be 21 X 28 cm in size for use in reports.

   2.2 Air Quality summaries of pollutant concentrations (annual and 24 hour) by site, data on seasonal trends concentrations or spatial variability by pollutant.

   2.3 Air Quality data analysis reports describing source-receptor relationships (dispersion modeling, statistical analysis, sample analysis).

3. Airshed Meteorology

   3.1 Descriptions of the available meteorological data base - number and location of sites, parameters measured, length of record available.

   3.2 Summaries of dispersion characteristics - wind roses, seasonal variation in mixing heights and air pollution episodes.

   3.3 Description of the meteorological quality assurance program (if any).

4. Aerosol Data Base

   4.1 Papers describing the mass size distribution; chemical or morphological nature of the aerosol. Trace element, ion and carbon analysis is especially valuable.

   4.2 Summary of the length of record for measurements.

   4.3 Identity, and data for, background or non-urban sampling sites.

   4.4 Sampling site location criteria.

   4.5 List of site numbers and names.

   4.6 Quality Assurance program description, standard operating procedures.

   4.7 Is the data in machine-readable format?

5. Air Sampling Analytical Capabilities

   5.1 Inventory of the air sampling and analytical equipment that will be available for use in the project.

   5.2 Analytical quality assurance procedures, especially as related to aerosol trace element, ion and carbon analysis.

6. Emission Inventory

   6.1 A summary EI describing particulate and gaseous emissions by major source class (one page) based on actual emissions.

   6.2 An evaluation as to the adequacy of the EI (how current is the data, are fugitive emission included, is a spatially resolved area source EI available?)

   6.3 Information on the trace element content of fuel oils, Pb in gasoline, diesel fuel additives.

   6.4 Any information on the chemical composition (weight percent) of point, area or fugitive dust emissions.

   6.5 A list, in order of priority based on expected source impact, of sources that should be chemically characterized.

   6.6 A brief description of major point source processes, expected periods of shut down, degree of variability in the chemistry and mass emission rate, control systems used.

7. Data Management

   7.1 A description of current air quality/meteorological data flow computer facilities and data auditing procedures.

   7.2 Describe available data analysis software.

8. Available Resources

   8.1 Describe total project funding, person-hours of internal and external staff time, equipment loans and in-kind support available for use in the project.

   8.2 Describe limitations that may exist in expenditure of funds abroad.

9. Project Objectives
   Describe, as fully as possible, program objectives including:

   9.1 Particle size fractions to be studied.

   9.2 Specific, priority source impacts that must be accurately identified.

   9.3 Averaging periods that must be addressed (annual, seasonal, monthly, 24 hour, 3 hour, etc.)

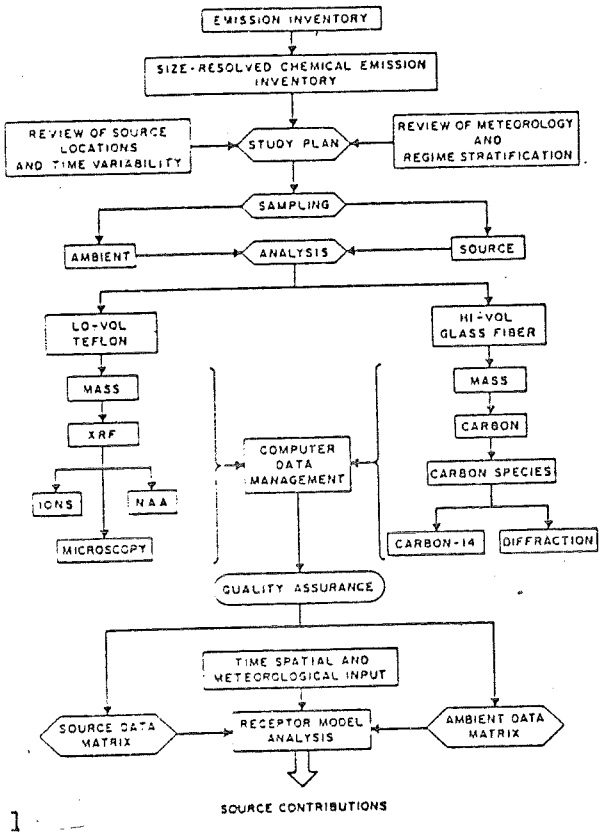
   9.4 Intent of use of the aerosol study results to validate an urban dispersion model.

   9.5 Critical areas (sites) within the airshed that must be more thoroughly studied than other (i.e., maximum concentration sites).

   9.6 Critical periods of the year, meteorological conditions or source activity periods that are of specific importance.

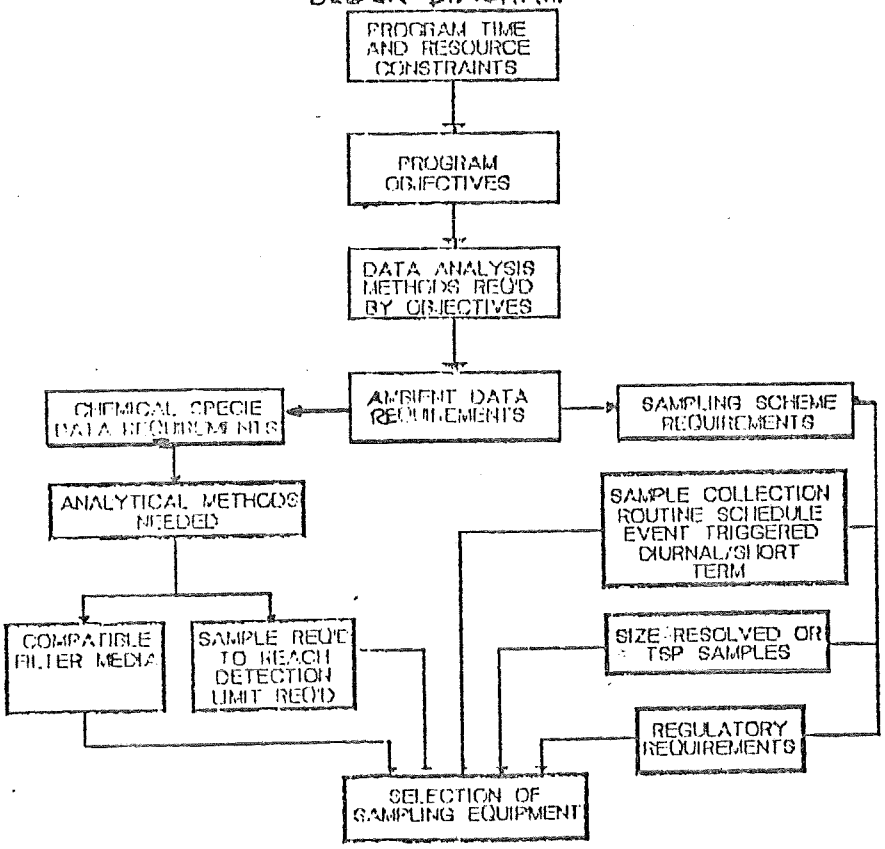
18. ANALYTICAL METHODS AND LONG RANGE TRANSPORT

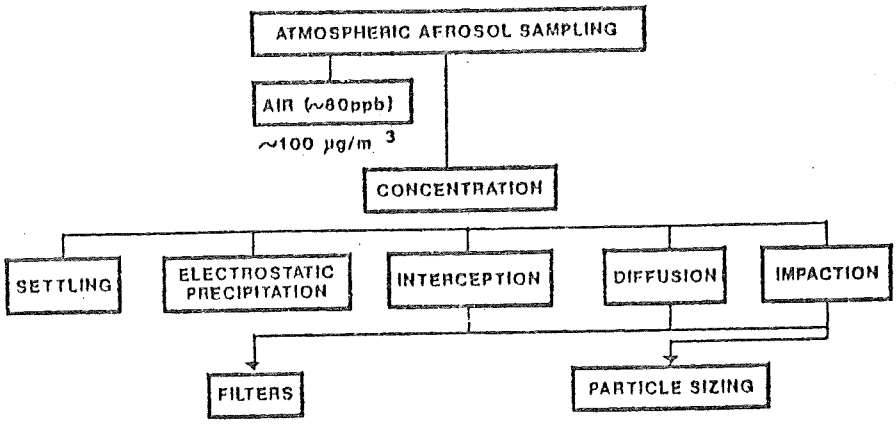
SOURCE APPORTIONMENT FLOW DIAGRAM



1

SAMPLING EQUIPMENT SELECTION BLOCK DIAGRAM





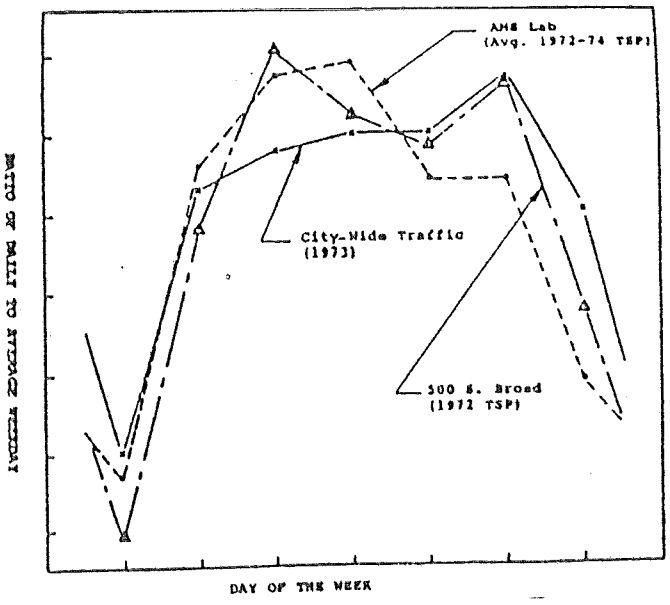
IMPACT ON RECEPTOR MODEL'S ABILITY TO RESOLVE SOURCES

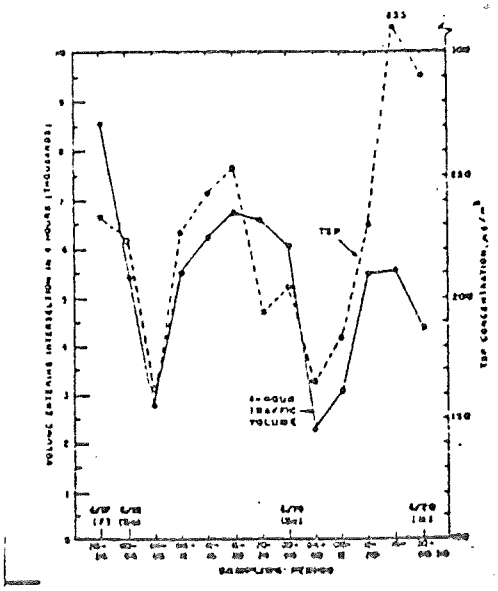
IMPACT ON RECEPTOR MODEL'S ABILITY TO RESOLVE SOURCES

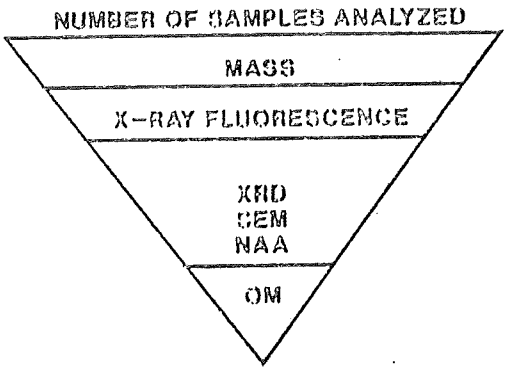
VOLUME SAMPLED
EFFICIENCY
BLANK CONTENT
REPRODUCIBILITY OF TARE WT
ANALYTICAL COMPATIBILITY
FLOW RATE
PRESSURE DROP

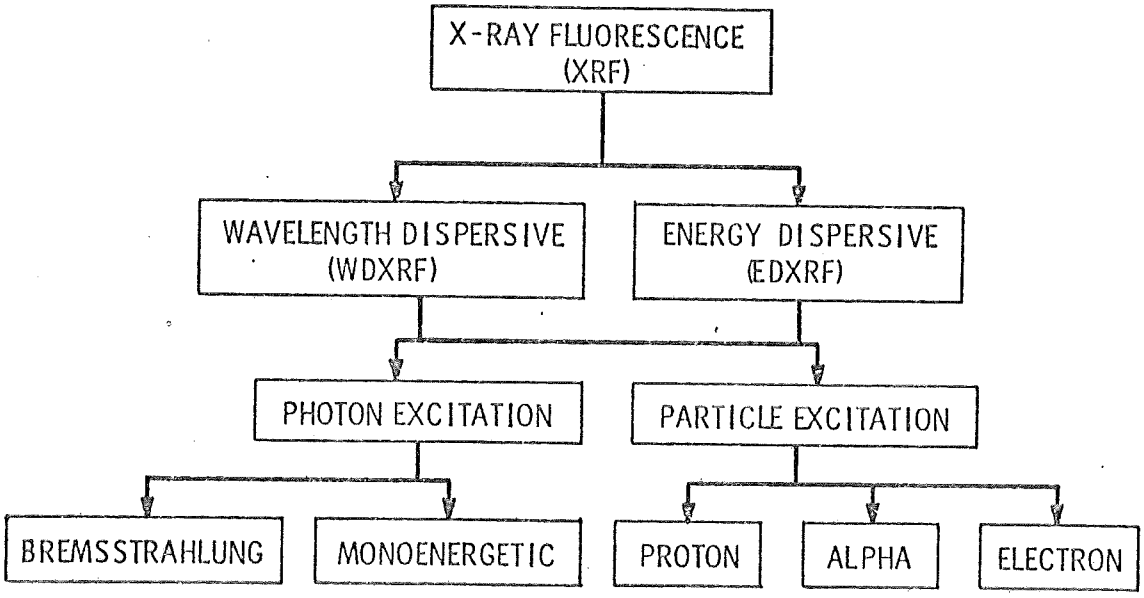
STAGE CONSTANTS
FLOW RATES
BOUNCE OFF
BRAKE UP
SHAPE AND DENSITY
LAST STAGE CUTOFF

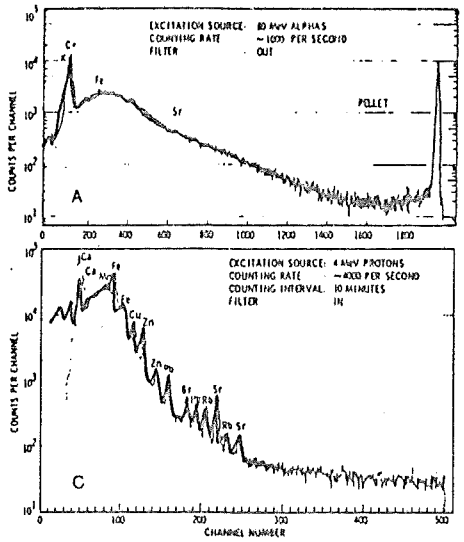
URBAN SOURCE — RURAL — STACK — REMOTE

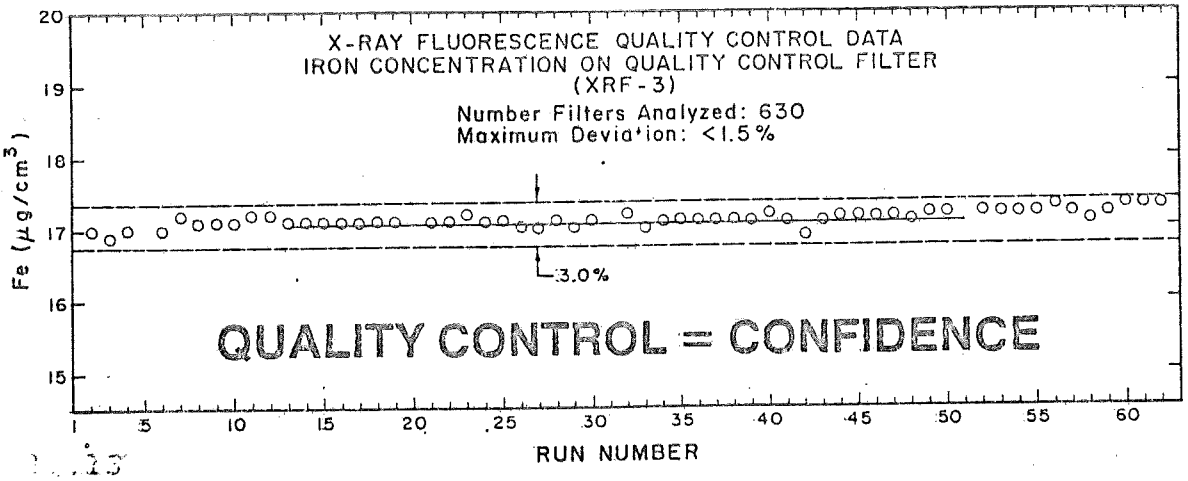




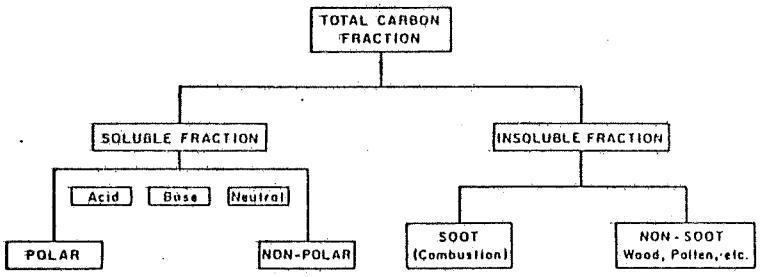

NUMBER OF SAMPLES ANALYZED
MASS
X-RAY FLUORESCENCE
XRD
SEM
NAA
OM


X-RAY FLUORESCENCE (XRF)
WAVELENGTH DISPERSIVE (WDXRF)
ENERGY DISPERSIVE (EDXRF)
PHOTON EXCITATION
PARTICLE EXCITATION
BREMSSTRAHLUNG
MONOENERGETIC
PROTON
ALPHA
ELECTRON





MAJOR FRACTIONS OF CARBONACEOUS AEROSOLS



FOSSIL/CONTEMPORARY
THERMAL GRADIENT COMBUSTION FRACTIONS
SPECIFIC CHEMICAL SPECIES

RECEPTOR MODEL APPROACH TO LONG RANGE TRANSPORT

The basic receptor model equation

$$m_i = \sum_{j=1}^{p} F_{ij} M_j \qquad (7)$$

assumes conservation of mass, i.e., the components making up the M_j are non-reactive and their relative composition doesn't change with deposition. (See Appendix A for detail.) A variety of receptor approaches, including both mass regression and variability analysis, can be used to solve equation (7) for M_j and develop insight into its character. The accuracy and precision with which M_j can be determined with the receptor model can approach 5% relative to the impact. This is particularly the case if size-resolved samples of source emissions are obtained using dilution sampling techniques to determine the F_{ij} values.

The use of receptor models to apportion reactive species was first discussed by Miller, et al., (27) and later by Friedlander and others. (28-30) Miller modified the basic equation by adding a coefficient of fractionation, α_{ij},

$$m_i = \sum_{j=1}^{p} \alpha_{ij} F_{ij} M_j \qquad (8)$$

which is equal to one for nonreactive species. This general equation will be valid even for gaseous species if the impact mass, M_j, includes the mass of all species measured at the source and used in the F_{ij} calculation. Friedlander (31) modified equation (8) by assuming that a reference or tracer species existed for each source and the ratio of reactive species to reference (tracer) species at the source were known. In this case, equation (8) becomes

$$m_i = \sum_{j=1}^{p} \alpha_{ij} r_{ij} M_j^r \qquad (9)$$

where

r_{ij} = ratio of species i to reference species as measured at source j.

M_j^r = mass concentration of reference species for jth source as calculated by the receptor model.

The terms in equation (8) can be grouped and compared to the equation developed from the dispersion model approach, equation (6)

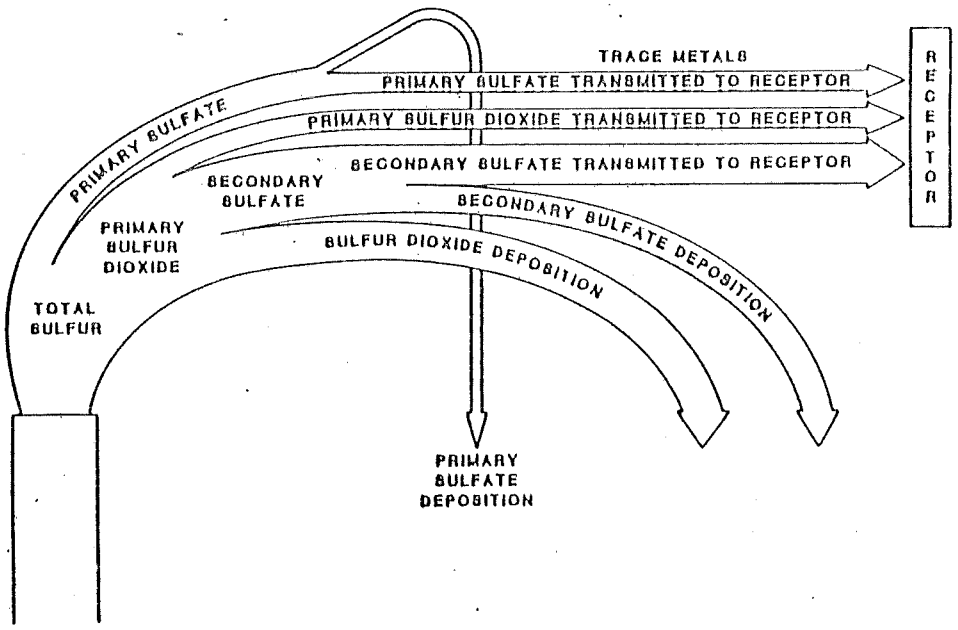
$$m_i = \sum_{j=1}^{p} \alpha_{ij} (r_{ij} M_j^r) \qquad (8)$$

$$m^* = \sum_{j=1}^{p} M_j^* = \sum_{j=1}^{p} (T_j^* d_j^*) M_j' \qquad (6)$$

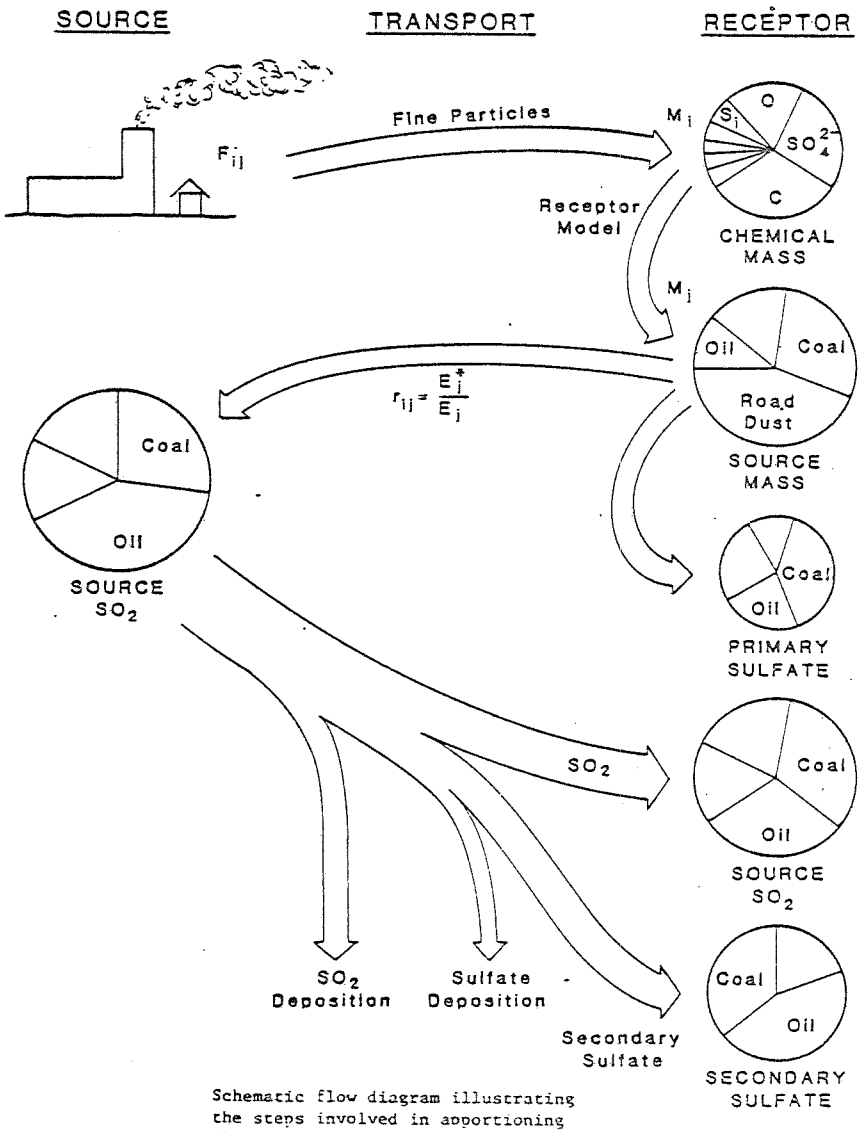
The similarities in these two equations are obvious if the ith component is assumed to be the same reactive species as considered in the dispersion model equation. Then, Miller's coefficient of fractionation is clearly the same as the product of the transformation and deposition attenuation factors and the $r_{ij} M_j^r$ term is equivalent to the M'_j term. Thus, a more general form of the equation for a reactive species is

$$m_i = \sum_{j=1}^{p} \alpha_{ij} M'_{ij} = \sum_{j=1}^{p} \alpha_{ij} r_{ij} M_j \qquad (9)$$

where M'_{ij} is the unattenuated contribution of the jth source to the ith reactive species as determined by any method and α_{ij} is the attenuation coefficient for the ith species from the jth source and is equal to the product of the transformation and deposition term. The α_{ij} term, however, is a complex function of transformation and deposition rates plus many other factors which should be included before any regression analysis.

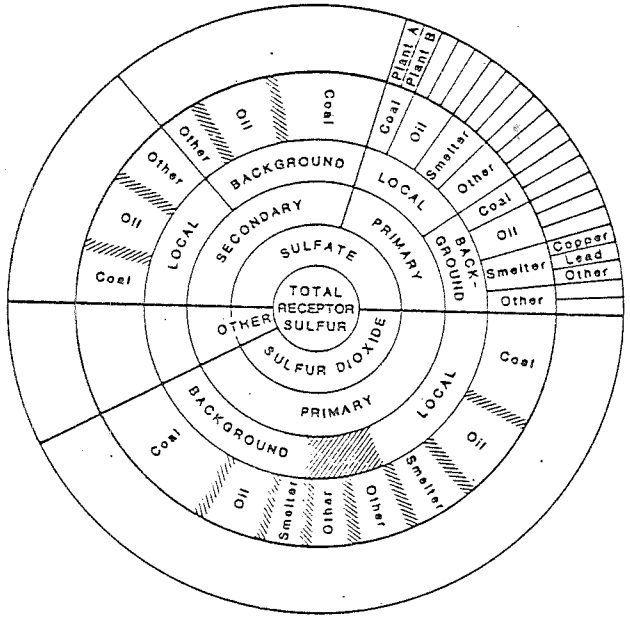


Schematic illustration of the major emission components and their impact on a receptor.



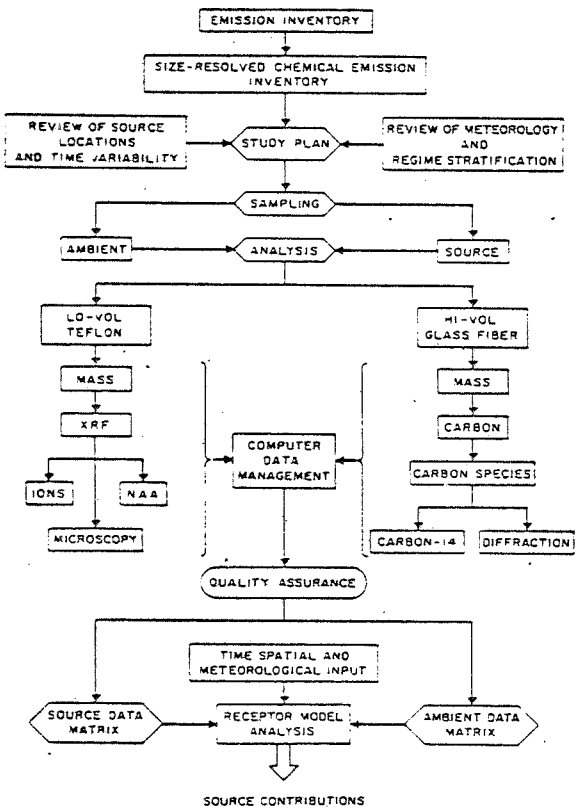
Schematic flow diagram illustrating the steps involved in apportioning the major aerosol and sulfur components.

RECEPTOR MODEL URBAN SULFUR APPORTIONMENT

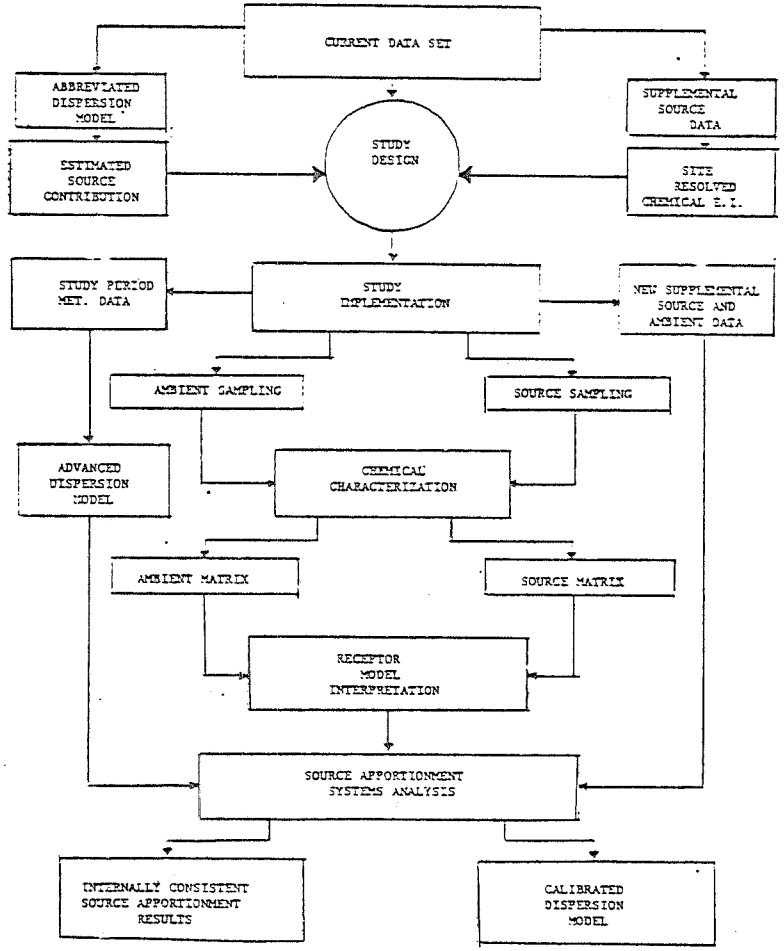


Source apportionment of the total sulfur measured at a receptor in an urban center assuming monitoring is also conducted at a background site.

SOURCE APPORTIONMENT FLOW DIAGRAM



UNIFIED SOURCE APPORTIONMENT AND MODEL CALIBRATION STUDY



CMB APPLICATIONS

RESEARCH STUDIES

- LOS ANGELES
- CHICAGO
- ST. LOUIS
- WASHINGTON, D. C.
- DENVER

CONTROL STRATEGY APPLICATIONS

- OREGON–PORTLAND, MEDFORD, WILLAMETTE VALLEY
- MONTANA–MISSOULA
- IDAHO–KELLOGG, LEWISTON

DISPERSION MODEL VALIDATION

CONTROL STRATEGY TRACKING

EMERGENCY ACTION PLAN DEVELOPMENT

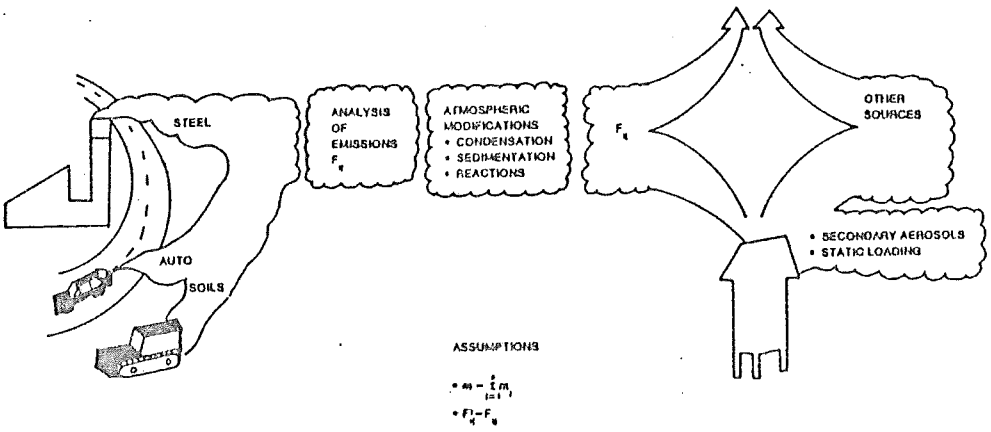
SOURCE CLASSES IDENTIFIED BY CMB

SOURCE GROUP		UNCERTAINTY
• CRUSTAL		+6%
– SOIL DUST	– ROCK CRUSHING	
– ROAD DUST	– COAL FLYASH	
• TRANSPORTATION		
– LEADED AUTO EXHAUST	– DIESEL EXHAUST	+10%
– UNLEADED AUTO EXHAUST		
• VEGETATIVE BURNING		+17%
– RESIDENTIAL	– SLASH BURNING	
– LAND CLEARING	– FOREST FIRES	
• CALCIUM SOURCES		–
– CEMENT DUST	– SLAG DUST	
– LIMESTONE	– DEMOLITION DUST	

SOURCES IDENTIFIED

SOURCE	UNCERTAINTY
MARINE AEROSOL	+13%
RESIDUAL OIL COMBUSTION	+10%
FERROMANGANESE FURNACE	+30%
IRON AND STEEL	+14%
HOG FUEL BOILERS	–
KRAFT RECOVERY FURNACE	+6%
ALUMINUM PRODUCTION	+22%
PAINT PIGMENTS	–
SMELTERS (COPPER, LEAD, ZINC)	–
MUNICIPAL INCINERATORS	–
SECONDARY AEROSOLS	–

CHEMICAL MASS BALANCE PRINCIPLES



CHEMICAL MASS BALANCE THEORY

$m = \sum_{i=1}^{p} m_i$	Steel Impact ($\mu g/m^3$) + Auto + Soils + Other Aerosol mass ($\mu g/m^3$)
$m_i = \sum_{i=1}^{p} m_{ij}$	Si (Steel) $\mu g/m^3$ + Si (Auto) + Si (Soil) + Si (Other) Si concentration, $\mu g/m^3$
$m_{ij} = F_{ij}\ m_j$	If: F_{ij} = 10% of Steel is Si m_j = 20 $\mu g/m^3$ Steel Impact Then: m_{ij} = 2 $\mu g/m^3$ Si

Assume $F_{ij}^{1} = F_{ij}$	Emission Composition is Unchanged
$m_i = \sum_{j=1}^{p} F_{ij}\ m_j$	Substitute $F_{ij}\ m_j$ for m_{ij}
$\frac{m_i}{m} = \sum_{j=1}^{p} F_{ij}\ \frac{m_j}{m}$	Divide by mass
$C_i = \sum_{j=1}^{p} F_{ij} S_j$	Redefine: $\frac{m_i}{m} = C_i$; $\frac{m_j}{m} = S_j$
Solve for S_j	Set of Simultaneous Equations

$$C_{Fe} = \sum_{i=1}^{p} F_{Fe,\,Soil}\,S_{Soil} + F_{Fe,\,Steel}\,S_{Steel} + F_{Fe,\,Auto}\,S_{Auto}$$

$$C_{Al} = \sum_{i=1}^{p} F_{Al,\,Soil}\,S_{Soil} + F_{Al,\,Steel}\,S_{Steel} + F_{Al,\,Auto}\,S_{Auto}$$

$$C_{Si} = \sum_{i=1}^{p} F_{Si,\,Soil}\,S_{Soil} + F_{Si,\,Steel}\,S_{Steel} + F_{Si,\,Auto}\,S_{Auto}$$

$$C_{Pb} = \sum_{i=1}^{p} F_{Pb,\,Soil}\,S_{Soil} + F_{Pb,\,Steel}\,S_{Steel} + F_{Pb,\,Auto}\,S_{Auto}$$

SOLUTIONS TO CMB EQUATIONS

TRACER PROPERTY SOLUTION

- SIMPLE
- TRACER REQUIRES
  - UNIQUE EMISSION TRACER
  - CONSTANT FRACTION OF MASS
  - EASILY AND ACCURATELY MEASURED

LINEAR LEAST SQUARES FITTING

- MINIMIZES DIFFERENCE BETWEEN MEASURED AND PREDICTED SPECIES
- SPECIES WEIGHTING (σC_i)

EFFECTIVE VARIANCE FITTING

- SPECIES WEIGHTED BY σC_i AND σF_{ij}
- PROVIDES "QUALITY OF FIT" INDICATOR
- CALCULATES SOURCE IMPACT UNCERTAINTY

WEIGHTING OF VARIABLES

$$\hat{Y}_i = a_o + a_i X_{1i} + \cdots a_n X_{ni}$$

PREDICTED Y EQUALS LINEAR COMBINATION OF OTHER VARIABLES, X. FIND THE A's.

No weight

$$\chi^2 = \sum_{i=1}^{n} (Y_i - \hat{Y})^2$$

MINIMIZE SUM OF SQUARES OF MEASURED MINUS PREDICTED.

Ordinary Weight

$$\chi^2 = \sum_{i=1}^{n} \frac{(Y_i - \hat{Y})^2}{\sigma_Y^2}$$

MINIMIZE SUM OF SQUARES OF MEASURED MINUS PREDICTED *DIVIDED* BY VARIANCE OF DEPENDENT VARIABLE Y.

Effective Variance Weight

$$\chi^2 = \sum_{i=1}^{n} \frac{(Y_i - \hat{Y})^2}{\sigma_Y^2 + \sum_{i=1}^{p} \sigma_{x_i}^2 a_i^2}$$

MINIMIZE SUM OF SQUARES OF MEASURED MINUS PREDICTED *DIVIDED* BY VARIANCE OF DEPENDENT *AND* INDEPENDENT VARIABLES.

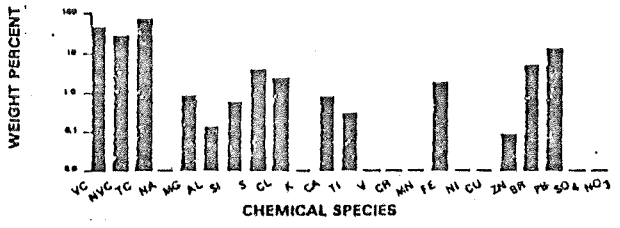
CHEMICAL MASS BALANCE REPORT FORMAT

SOURCE	$\mu g/m^3$	% OF MASS
MARINE AIR	.31 ± .19	0.82 ± 0.5
URBAN DUST	.69 ± .28	1.81 ± 0.7
AUTO EXHAUST	1.17 ± .19	3.0 ± 0.5
RESIDUAL OIL COMB.	1.65 ± .27	4.3 ± 0.7
VEGETATIVE BURNING	7.54 ±3.2	19.7 ± 8.5
FERROMANGANESE FURNACE	6.46 ± .57	16.9 ± 1.6
NITRATE	.65 ± .32	1.7 ± 0.8
SULFATE	8.31 ±1.41	21.8 ± 3.8
TOTAL	26.80 ±3.60	70.0 ±10.4

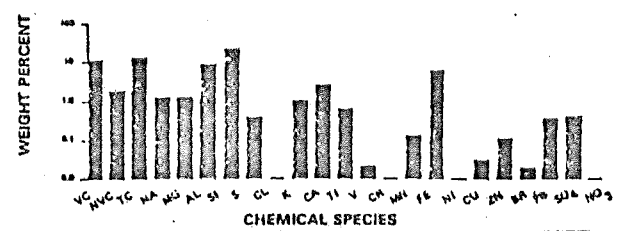
CHEMICAL MASS BALANCE REPORT FORMAT

SPECIES	MEASURED ($\mu g/m^3$)	CALCULATED ($\mu g/m^3$)	RATIO (calc/meas)
NO_3	1.197	1.197	1.00
SO_4	9.805	9.805	1.00
Na	0.416	0.417	1.002
Al	0.149	0.158	1.062
Si	0.277	0.281	1.014
Zn	0.371	0.049	0.132
Br	0.064	0.074	1.158
Pb	0.247	0.243	0.982

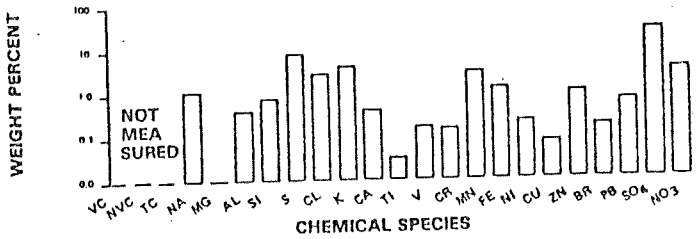
TRANSPORTATION - MEDFORD, OR. 1980



URBAN DUST COMPOSITION

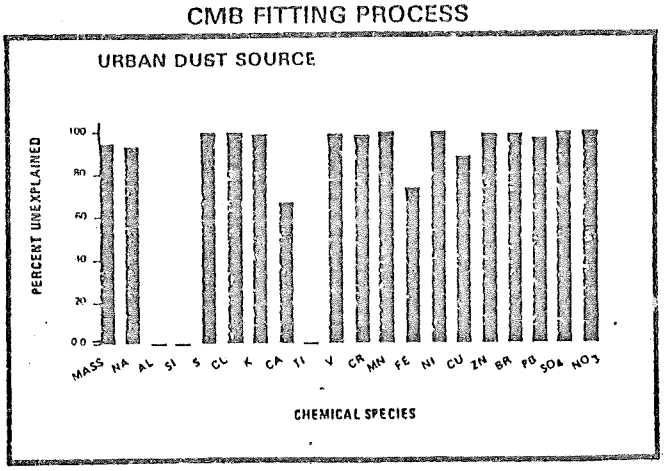


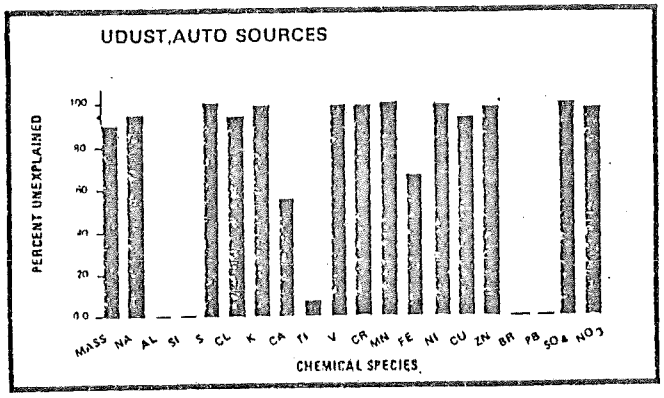
FINE PARTICLE COMPOSITION-1/27/78-PORTLAND

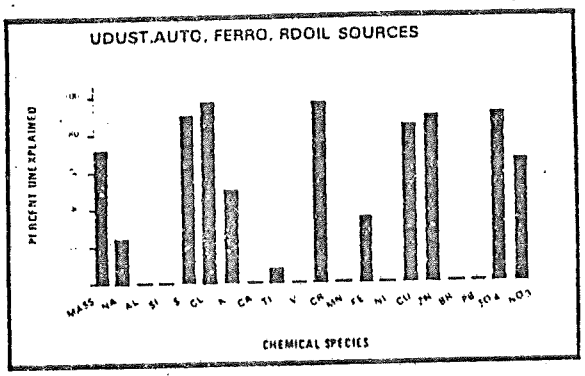


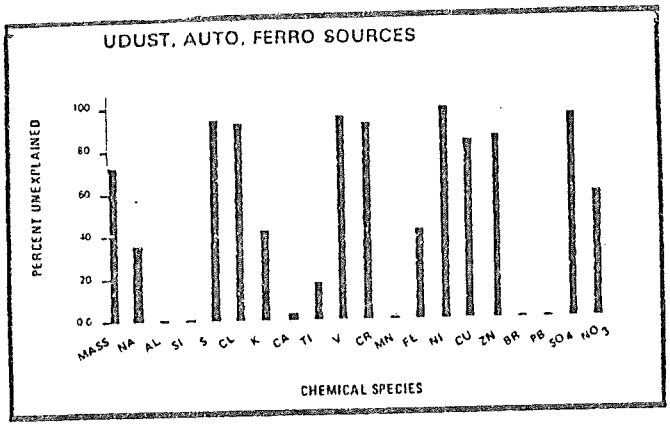
MIDNITE 4AM, DOWNTOWN SITE (LESS THAN 2UMI

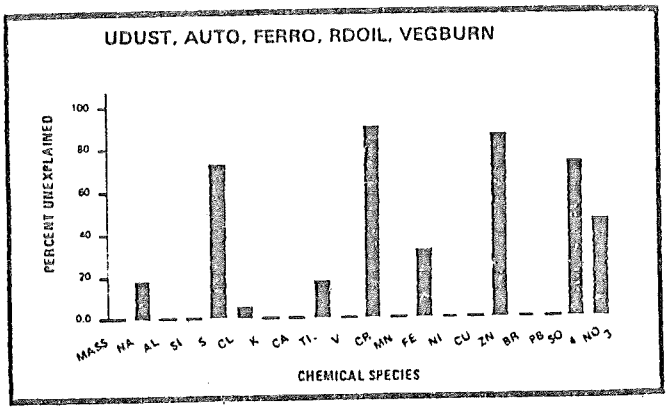
CMB FITTING PROCESS

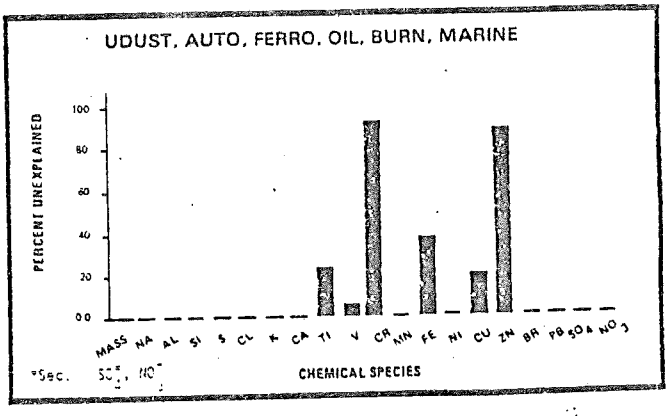












CMB MODEL INPUT REQUIREMENTS

SOURCE COMPOSITION DATA

- PREFER SIZE-RESOLVED
- LOCAL SOURCE TESTS PREFERRED
- DATA FROM LITERATURE
- UNCERTAINTIES

ANALYTICAL METHODS

- XRF
- INAA
- AAS
- IC
- CARBON

CMB MODEL INPUT REQUIREMENTS

AMBIENT AEROSOL COMPOSITION

- SIZE-RESOLVED
- MASS BALANCE
- ANALYSIS REQUIREMENTS (AMBIENT AND SOURCE)

Mass	Cl	Fe	SO_4^{-2}
Na	K	Ni	NO_3^{-1}
Mg	Ca	Cu	ORGANIC CARBON
Al	V	Se	ELEMENTAL CARBON
Si	Cr	Br	
S	Mn	Ba	
Aa	Sr	Cd	
Sn	Sb	Pb	

- UNCERTAINTIES

VALIDATION OF CMB RESULTS

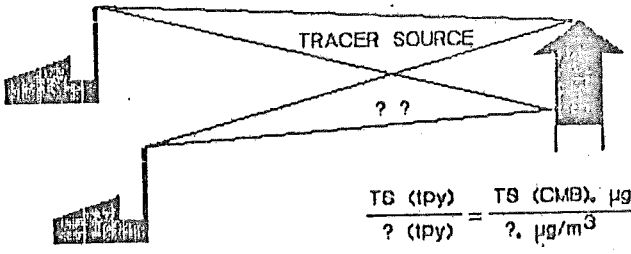
INTERNAL VALIDATION

- CALCULATED/MEASURED SPECIES AND MASS RATIOS
- REPRODUCIBILITY
- PREDICTED/MEASURED SIZE DISTRIBUTORS

EXTERNAL VALIDATION

- SOURCE ACTIVITY
- SPATIAL & TEMPORAL PATTERNS
- RECEPTOR & SOURCE MODELS

COMPLEMENTARY TECHNIQUES EMISSION INVENTORY SCALING



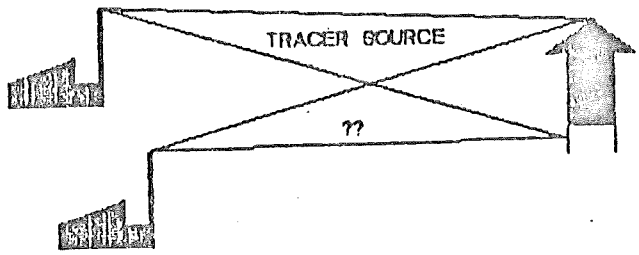
$$\frac{\text{TS (tpy)}}{\text{? (tpy)}} = \frac{\text{TS (CMB), } \mu g/m^3}{\text{?, } \mu g/m^3}$$

REQUIRES SIMILAR:

- DISPERSION
- SOURCE ACTIVITY
- PARTICLE DEPOSITION
- SPATIAL/TEMPORAL

ACCURATE EI DATA

COMPLEMENTARY METHODS EMISSION INVENTORY SCALING



APPLICATIONS:

UNKNOWN SOURCE	"TRACER" SOURCE
UNLEADED AUTO EXHAUST	LEADED AUTO EXHAUST
DIESEL EXHAUST	
DISTILLATE OIL-FIRED BOILERS	RESIDUAL OIL-FIRED BOILERS*

COMPLEMENTARY TECHNIQUES

SOURCE MODELS

- NONDISTINCT SOURCES
- APPORTION CHEMICALLY SIMILAR SOURCES
- PROGRAM DESIGN

RECEPTOR MODELS

- 12C/14C
- XRD
- SOURCE ACTIVITY-TRANSPORT
- MICROINVENTORY
- FACTOR ANALYSIS
- MICROSCOPY

EMISSION INVENTORY

- MICROINVENTORY

CHEMICAL MASS BALANCE ADVANTAGES AND DISADVANTAGES

ADVANTAGES

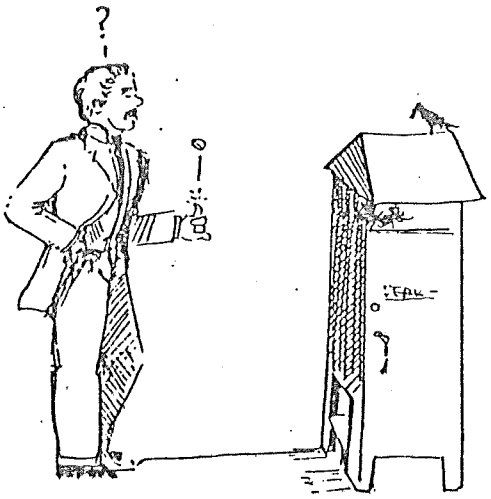
- QUANTITATIVE METHOD
- CAN BE APPLIED TO DATA FROM A SINGLE SAMPLE. REQUIRES SMALL DATA SETS
- CAN BE APPLIED TO DATA COLLECTED FROM SHORT TERM SAMPLE (<24 HOURS)
- PROVIDES AN ESTIMATE OF SOURCE IMPACT UNCERTAINTY
- INTERNAL CONSISTENCY CHECKS OF ANALYSIS QUALITY CAN BE MADE
- IDENTIFIES SOURCES/SOURCE CLASSES BY COMMON NAME

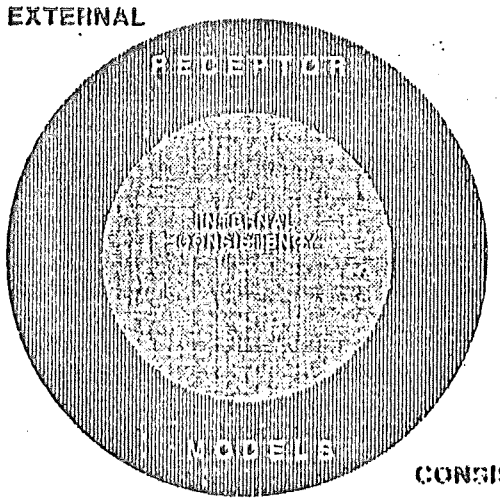
CHEMICAL MASS BALANCE ADVANTAGES AND DISADVANTAGES

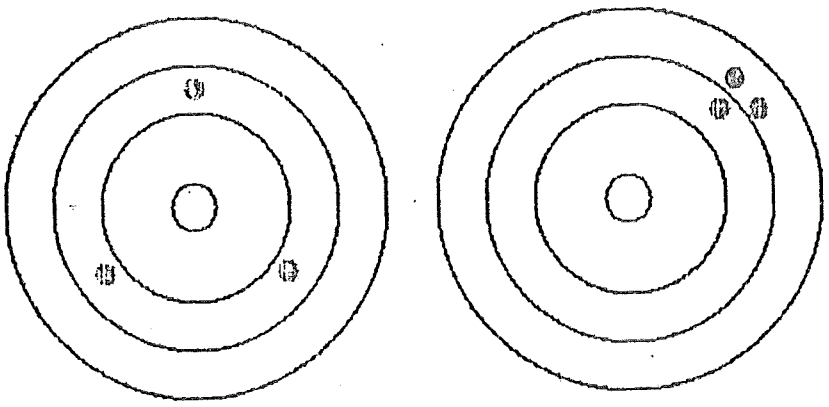
DISADVANTAGES

- REQUIRES SOURCE COMPOSITION DATA
- CANNOT RESOLVE SOURCES OF SECONDARY AEROSOLS
- TYPICALLY UNABLE TO ACCOUNT FOR ALL MEASURED Ca, Cu, Zn, and carbon
- ASSUMES THAT ALL SPECIES EMITTED BY A SOURCE, WITHIN A GIVEN SIZE RANGE, HAVE THE SAME RESIDENCE TIME
- CANNOT DISTINGUISH SOURCES OF SIMILAR CHEMICAL COMPOSITION

MODEL VALIDATION







IMPRECISE BUT ACCURATE PRECISE BUT INACCURATE

INTERNAL CONSISTENCY

QUALITY ASSURANCE (FIELD & LAB)

- SPIKED SAMPLES–ACCURACY
- REPLICATE ANALYSIS–PRECISION
- FLOW AUDITS–ACCURACY
- COLLOCATED SAMPLERS–PRECISION
- CONTAMINATION/HANDLING PROCEDURES

STATISTICAL MEASURES (DATA)

- MASS BALANCE (PREDICTED VS OBSERVED)
- SYNTHETIC DATA SETS
- SENSITIVITY ANALYSIS
- CONFIDENCE INTERVALS
- VARIANCE EXPLAINED

CMB MODEL REPRODUCIBILITY (20% UNCERTAINTIES)

SOURCE	TRUE SOURCE CONTRIBUTION $\mu g/m^3$	AVERAGE RESULTS N = 8	N = 23
MARINE AIR	20	16.6±3.8	15.9±2.2
URBAN DUST	35	29.2±6.1	32.9±4.9
AUTO EXHAUST	30	29.6±8.0	27.0±3.8
RESIDUAL OIL	15	13.9±2.0	14.5±1.6
TOTAL	100	89±11	90±7

N = NUMBER OF SPECIES INCLUDED IN THE FIT

EXTERNAL CONSISTENCY

- ACTIVITY OF SOURCES
- SPATIAL PATTERNS / TRANSPORT
- DISPERSION MODELS
- EMISSION INVENTORIES
- OTHER RECEPTOR MODELS
- COMMON SENSE

COMPARISON OF CMB RESULT TEMPORAL CHANGES VS. SOURCE ACTIVITY

CMB-SOURCE CLASS	SOURCE ACTIVITY INDICATOR
MOTOR VEHICLE	DIURNAL, WEEKDAY-WEEKEND TRAFFIC VOLUME CHANGES
MARINE AIR	MARINE AIR FRONTAL PASSAGES
VEGETATIVE BURNING	SMOKE INTRUSION REPORTS BY FORESTRY AGENCIES, HEATING DEGREE DAYS
INDUSTRIAL PROCESSING	LABOR STRIKES, MAINTENANCE SHUTDOWNS CHANGES IN CONTROL SYSTEM EFFICIENCY

FREQUENCY ROSE

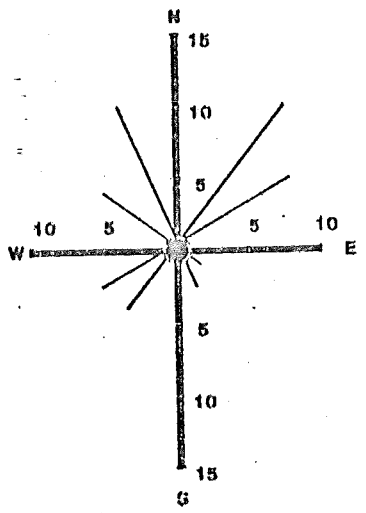


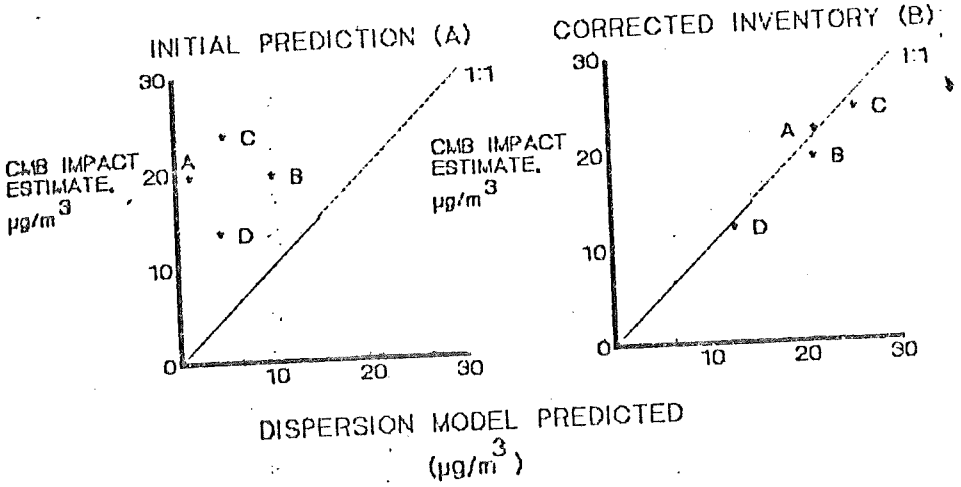
Table 5. Source Composition Data, Portland, Oregon (weight percent of mass) (Continued)*

Source	Ca	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Br	Pb	Fine
1. Marine	1.04	---	---	---	---	---	---	---	---	.20	---	---
2. Continental Dust	.93	.76	.025	.03	.20	6.8	.0092	.02	.041	0.0	.006	---
3. Urban Dust	2.44	.64	.023	.045	.123	6.0	.0093	.030	.11	.020	.37	~10
4. Leaded Auto Exhaust	1.25	0.0	0.0	0.0	0.0	2.1	.018	.073	.35	5.0	20.0	~80
5. Residual Oil Comb.	1.58	.11	3.44	.047	.046	2.97	5.36	.075	.40	0.13	.11	90
6. Vegetative Burn 1	1.07	0.0	0.0	0.0	.12	.19	0.0	.09	0.0	.053	0.0	~99
7. Vegetative Burn 2	.92	.07	0.0	.012	.047	.054	0.0	.054	0.0	.045	0.0	~99
8. Kraft Recovery Boiler	0.0	.006	.001	.28	.03	1.2	.13	.021	0.69	.13	.013	87
9. Sulfite Recovery Boiler	2.0	.01	0.0	0.0	.054	.066	0.0	.016	.017	0.0	0.0	~90
10. Hog Fuel Boiler	5.6	0.0	0.0	.015	.51	1.26	.0067	.12	.73	.055	.42	78
11. Aluminum Processing	.33	.04	.064	0.0	.011	.45	.19	.044	.015	.037	.012	56
12. Steel Electric Furnace	6.2	.20	.06	2.1	8.7	32.0	.07	.28	1.2	0.0	.76	92
13. Ferromanganese	1.3	.046	.024	.42	17.3	2.1	0.0	.036	.58	.16	.045	92
14. Carborundum	.14	.014	.007	.009	.035	.33	.004	.019	.004	.017	0.0	82
15. Glass Furnace	.30	0.0	.0047	.19	.0021	.02	0.0	.0047	.011	.0063	.38	93
16. Carbide Furnace	30.0	0.0	.006	0.0	.042	.54	.022	.020	.015	0.0	.008	55

Source	Ca	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Br	Pb	Coarse
1. Marine	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.20	0.0	---
2. Continental Dust	1.4	0.82	.017	.01	.085	4.78	.009	.02	.031	0.0	.042	---
3. Urban Dust	3.0	1.01	.027	.045	.10	5.73	.004	.03	.11	.008	.37	~90
4. Leaded Auto Exhaust	1.25	0.0	0.0	0.0	0.0	2.1	.018	.073	.35	5.0	20.0	~20
5. Residual Oil Comb.	1.58	.11	3.44	.047	.046	2.97	5.36	.75	.40	.013	.11	10
6. Vegetative Burn 1	1.07	0.0	0.0	0.0	.12	.19	0.0	.09	0.0	.053	0.0	~ 1
7. Vegetative Burn 2	.92	.07	0.0	.012	.047	.054	0.0	.054	0.0	.45	0.0	~ 1
8. Kraft Recovery Boiler	.36	0.0	0.0	.48	.52	1.54	.22	.06	0.0	.56	0.0	13
9. Sulfite Recovery Boiler	2.0	.01	0.0	0.0	.054	.066	0.0	.016	.017	0.0	0.0	~10
10. Hog Fuel Boiler	5.2	.097	.0055	.0073	.29	.92	0.0	.23	.039	.0013	.020	~20
11. Aluminum Processing	.81	.076	.040	.016	0.0	.38	.21	.14	.009	.12	0.0	42
12. Steel Electric Furnace	6.2	.20	.06	2.1	8.7	32.0	.7	.28	1.2	0.0	.76	8
13. Ferromanganese	1.3	.046	.024	.042	17.3	2.1	0.0	.036	.58	.16	.045	8
14. Carborundum	.57	.033	.012	.004	.029	.27	.017	.055	0.0	0.11	0.0	19
15. Glass Furnace	.30	0.0	.0047	.19	.0031	.02	0.0	.0047	.011	.0063	.38	7
16. Carbide Furnace	25.8	0.0	.009	0.0	.036	.33	.021	.04	0.0	0.0	0.0	45

* See Appendix I

PORTLAND, OR DISPERSION MODEL– PREDICTED ROAD DUST IMPACT



MICROINVENTORY

POINT SOURCES WITHIN 5 MILES

- DISTANCE
- DIRECTION
- EMISSIONS
- SOURCE CHARACTERISTICS

AREA SOURCES WITHIN 1 MILE

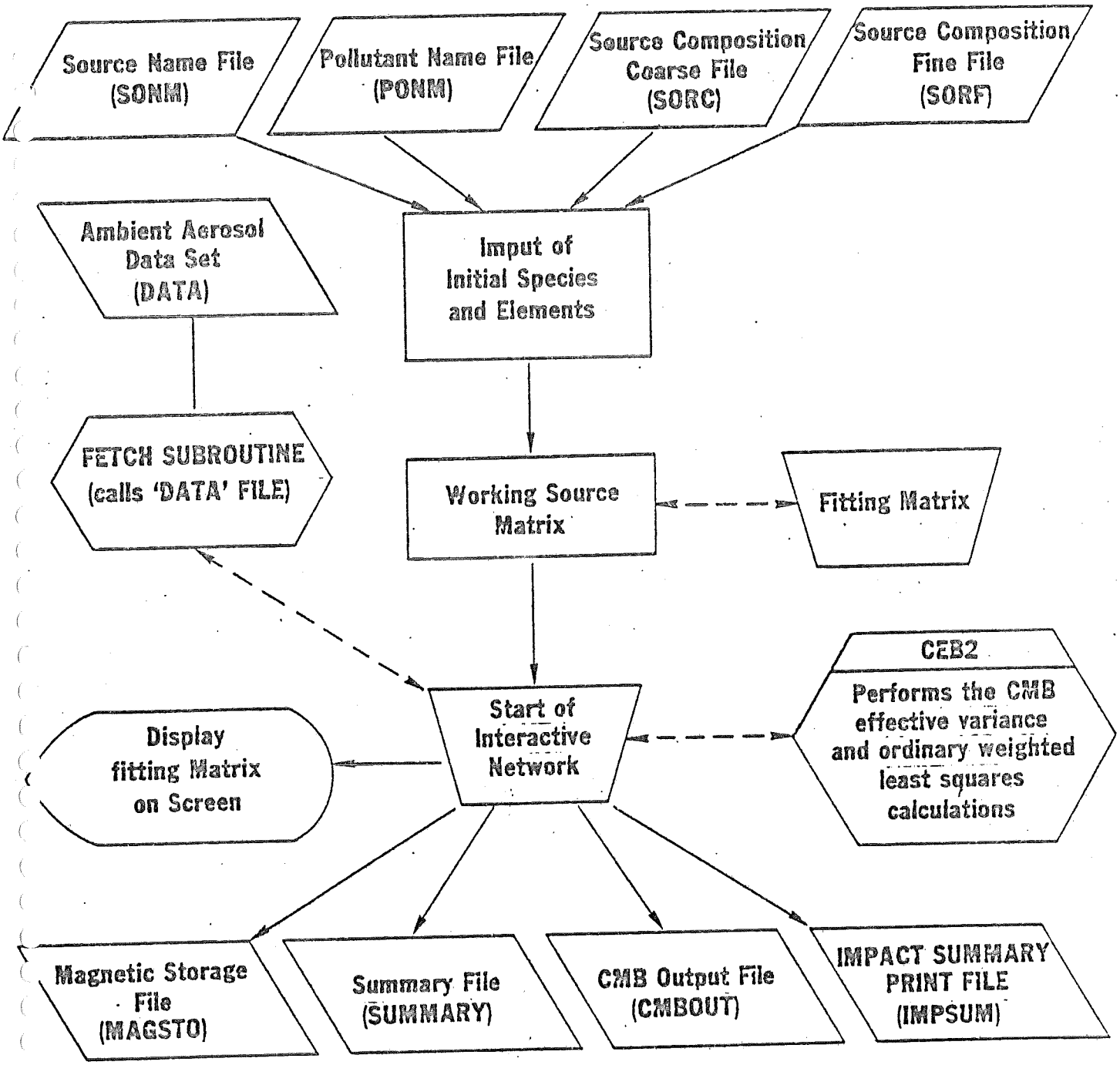
- EMISSIONS
- DIRECTION
- SOURCE CHARACTERISTICS

COMPARISON OF TTFA AND CMB ANALYSIS ON ST LOUIS RAPS DATA

SOURCE CLASS	TTFA	CMB
FINE		
SULFATE	64%	60%
CRUSTAL	7%	10%
MOTOR VEHICLES	6%	8%
OTHER	3%	22%
COARSE		
SULFATE	11%	7%
CRUSTAL	70%	77%
SOIL/FLYASH	10%	–
OTHER	9%	10%
MOTOR VEHICLES	–	6%

CHEMICAL MASS BALANCE PROGRAM

Block Flow Diagram



Note: The dash lines (-----) represents the constant interaction between the two blocks.

The solid lines (——) represents the flow of one block to another.

SONM

```
DATA,L REY-SONM.
DATA [illegible] 07/24/81 13:[illegible] (1)
   1.        01 [illegible]1  MARINE    MARINE AIR
   2.        01 [illegible]03 CDUST     URBAN DUST-PORTLAND
   3.        01 [illegible]4  TRANSF    TRANSPORTATION-PORTLAND
   4.        01 [illegible]23 TRANS     TRANSPORTATION-MACS
   5.        01 [illegible]5  RESOIL    RESIDUAL OIL-PORTLAND
   6.        01 [illegible]31 CASORC    CONSTRUCTION DUST-MACS
   7.        01 [illegible]2[illegible] VBURN1 RESIDENTIAL WOOD BURNING-MACS
   8.        01 [illegible]7  VBURN2    VEGETATIVE BURNING-GRASS-PORTLAND
   9.        01 [illegible]12 STEEL     STEEL ELECTRIC ARC FURNACE-PORTLAND
  10.        01 [illegible]13 FERRO     FERROMANGANESE FURNACE-PORTLAND
  11.        01 [illegible]95 RSDNVC    RESIDUAL NONVOL. CARBON
  12.        01 [illegible]96 SECNO3    SECONDARY NITRATE
  13.        01 [illegible]97 SECSO4    SECONDARY SULFATE
  14.        01 [illegible]98 SECCAR    SECONDARY CARBON
  15.        01 [illegible]99 SECVC     SECONDARY VOLATILE CARBON
  16.        01 [illegible]   DUMMY     FILE READ TO PREVENT ERROR
END DATA. ERRORS: NONE  TIME:  1.177 SEC.  IMAGE COUNT: 16
```

Source code Number — Source Mneumonic

PONM

@DATA,L PRY-PONM.

[illegible] 7/24/81 [illegible]

1.	02	01	TSP	MASS
2.	02	2	VC	VOL.CARBON
3.	02	03	NA	SODIUM
4.	02	4	TC	TOTAL CARBON
5.	02	15	K	POTASSIUM
6.	02	07	MG	MAGNESIUM
7.	02	19	S	SULFUR
8.	02	1[illegible]	SO4	SULFATE ION
9.	02	11	NO3	NITRATE ION
10.	02	12	NVC	NON-VOL.CARBON
11.	02	13	NH4	AMMONIUM ION
12.	02	14	CL	CHLORIDE
13.	02	15	F	FLUORIDE ION
14.	02	16	AL	ALUMINUM
15.	02	17	SI	SILICON
16.	02	1[illegible]	CA	CALCIUM
17.	02	19	TI	TITANIUM
18.	02	20	V	VANADIUM
19.	02	21	CR	CHROMIUM
20.	02	22	MN	MANGANESE
21.	02	23	FE	IRON
22.	02	24	NI	NICKEL
23.	02	25	CU	COPPER
24.	02	26	ZN	ZINC
25.	02	27	BR	BROMINE
26.	02	28	PB	LEAD

END DATA. ERRORS: NONE. TIME: 1.179 SEC. IMAGE COUNT: 26

Pollutant Number — Pollutant Name

Source Number

SORC

Particle Fraction Code (2=Fine, 3=Coarse)

Pollutant Number

$DATA,L PRY-SORC.
DATA (SRC(I),SI,... (I) [illegible]

	Source Number	Particle Fraction Code	Pollutant Number	Fractional Composition		Uncertainty		Description
1.	0001	3	03	.400000	+-	.040000	NA	CR FRACT OF MARINE AIR
2.	0001	3	05	.0140	+-	.00200	K	CR FRACT OF MARINE AIR
3.	0001	3	07	.048000	+-	.009100	MG	CR FRACT OF MARINE AIR
4.	0001	3	09	.0330	+-	.01300	S	CR FRACT OF MARINE AIR
5.	0001	3	10	.100000	+-	.040000	SO4	CR FRACT OF MARINE AIR
6.	0001	3	14	.4 [illegible]	+-	.1 [illegible]	CL	CR FRACT OF MARINE AIR
7.	0001	3	18	.014000	+-	.002000	CA	CR FRACT OF MARINE AIR
8.	0001	3	27	.0020 [illegible]	+-	.0005 [illegible]	BR	CR FRACT OF MARINE AIR
9.	0003	3	03	.017500	+-	.000910	NA	CR FRACT OF URBAN DUST
10.	0003	3	05	.013 [illegible]	+-	.00580	K	CR FRACT OF URBAN DUST
11.	0003	3	07	.015400	+-	.001400	MG	CR FRACT OF URBAN DUST
12.	0003	3	09	[illegible]	+-	.00020	S	CR FRACT OF URBAN DUST
13.	0003	3	10	.00072	+-	.00045	SO4	CR FRACT OF URBAN DUST
14.	0003	3	11	.002 [illegible]	+-	.0010	NO3	CR FRACT OF URBAN DUST
15.	0003	3	14	.000000	+-	.000200	CL	CR FRACT OF URBAN DUST
16.	0003	3	15	[illegible]	+-	[illegible]	F	CR FRACT OF URBAN DUST
17.	0003	3	16	.066000	+-	.007300	AL	CR FRACT OF URBAN DUST
18.	0003	3	17	.28 [illegible]	+-	.013 [illegible]	SI	CR FRACT OF URBAN DUST
19.	0003	3	18	.030000	+-	.002200	CA	CR FRACT OF URBAN DUST
20.	0003	3	19	.001 [illegible]	+-	.0018 [illegible]	TI	CR FRACT OF URBAN DUST
21.	0003	3	20	.000270	+-	.000150	V	CR FRACT OF URBAN DUST
22.	0003	3	21	[illegible] 4 [illegible]	+-	.000170	CR	CR FRACT OF URBAN DUST
23.	0003	3	22	.001000	+-	.000110	MN	CR FRACT OF URBAN DUST
24.	0003	3	23	.0573 [illegible]	+-	.0029 [illegible]	FE	CR FRACT OF URBAN DUST
25.	0003	3	24	.000040	+-	.000030	NI	CR FRACT OF URBAN DUST
26.	0003	3	25	.0003 [illegible]	+-	.000120	CU	CR FRACT OF URBAN DUST
27.	0003	3	26	.001100	+-	.000370	ZN	CR FRACT OF URBAN DUST
28.	0003	3	27	.00005 [illegible]	+-	.000090	BR	CR FRACT OF URBAN DUST
29.	0003	3	28	.003700	+-	.001500	PB	CR FRACT OF URBAN DUST
30.	0003	3	4	.1489 [illegible]	+-	.0156 [illegible]	TC	CR FRACT OF URBAN DUST
31.	0003	3	12	.133400	+-	.019800	VC	CR FRACT OF URBAN DUST
32.	0003	3	12	.0155 [illegible]	+-	.0068 [illegible]	NVC	CR FRACT OF URBAN DUST
33.	0004	3	03	.000000	+-	.000500	NA	CR FRACT AUTO EXHAUST
34.	0004	3	05	.00072	+-	.00029	K	CR FRACT AUTO EXHAUST
35.	0004	3	07	.000000	+-	.000500	MG	CR FRACT AUTO EXHAUST
36.	0004	3	09	[illegible]	+-	.0013 [illegible]	S	CR FRACT AUTO EXHAUST
37.	0004	3	10	.013000	+-	.004000	SO4	CR FRACT AUTO EXHAUST
38.	0004	3	11	.0001 [illegible]	+-	[illegible]	NO3	CR FRACT AUTO EXHAUST
39.	0004	3	14	.030000	+-	.010000	CL	CR FRACT AUTO EXHAUST
40.	0004	3	15	[illegible]	+-	.0001 [illegible]	F	CR FRACT AUTO EXHAUST
41.	0004	3	16	.011000	+-	.005000	AL	CR FRACT AUTO EXHAUST
42.	0004	3	17	.0072 [illegible]	+-	.003 [illegible]	SI	CR FRACT AUTO EXHAUST
43.	0004	3	18	.012500	+-	.005000	CA	CR FRACT AUTO EXHAUST
44.	0004	3	19	[illegible]	+-	[illegible]	TI	CR FRACT AUTO EXHAUST
45.	0004	3	20	.000000	+-	.000150	V	CR FRACT AUTO EXHAUST
46.	0004	3	21	[illegible]	+-	[illegible]	CR	CR FRACT AUTO EXHAUST
47.	0004	3	22	.000000	+-	.000160	MN	CR FRACT AUTO EXHAUST
48.	0004	3	23	.021 [illegible]	+-	[illegible]	FE	CR FRACT AUTO EXHAUST
49.	0004	3	24	.000190	+-	.000080	NI	CR FRACT AUTO EXHAUST
50.	0004	3	25	.0007 [illegible]	+-	[illegible]	CU	CR FRACT AUTO EXHAUST
51.	0004	3	26	.003500	+-	.001300	ZN	CR FRACT AUTO EXHAUST
52.	0004	3	27	.05 [illegible]	+-	.0170 [illegible]	BR	CR FRACT AUTO EXHAUST
53.	0004	3	28	.200000	+-	.030000	PB	CR FRACT AUTO EXHAUST
54.	0004	3	4	.55 [illegible]	+-	.114 [illegible]	TC	CR FRACT AUTO EXHAUST
55.	0004	3	12	.500000	+-	.084000	VC	CR FRACT AUTO EXHAUST

Uncertainty

Fractional Composition

DATA

@DATA,L PDX-TEMP12.
DATA SP101 [illegible] 7/24/81 [illegible] (1)

1.	03 2614176	CAMS			00020 TRTAL				
2.	3 2614176	790626	24	[illegible]	1	37.0010	4.4400	105.0010	9.4530
3.	3 2614176	790626	24	[illegible]	3	0.1110	0.1119	0.0010	0.0019
4.	3 2614176	790626	24	[illegible]	4	16.4[illegible]	0.5576	25.9[illegible]	0.0436
5.	3 2614176	790626	24	[illegible]	5	0.1930	0.0271	0.7710	0.0771
6.	3 2614176	790626	24	[illegible]	9	0.8840	0.0973	5.2630	0.5263
7.	3 2614176	790626	24	[illegible]	10	1.6110	0.1771	5.7100	0.5997
8.	3 2614176	790626	24	[illegible]	11	0.2000	0.1200	4.3900	0.5073
9.	3 2614176	790626	24	[illegible]	14	0.0790	0.0198	0.3250	0.0455
10.	3 2614176	790626	24	[illegible]	16	0.1490	0.0147	2.8220	0.2822
11.	3 2614176	790626	24	[illegible]	17	0.5430	0.0656	6.7760	0.6776
12.	3 2614176	790626	24	[illegible]	18	0.1610	0.0226	2.9840	0.2984
13.	3 2614176	790626	24	[illegible]	19	0.1220	0.0155	0.5000	0.0550
14.	3 2614176	790626	24	[illegible]	20	0.0040	0.0016	0.0610	0.0110
15.	3 2614176	790626	24	[illegible]	22	0.0510	0.0125	1.3440	0.0413
16.	3 2614176	790626	24	[illegible]	23	0.2590	0.0311	4.2290	0.4229
17.	3 2614176	790626	24	[illegible]	24	0.1010	0.0113	0.0010	0.0010
18.	3 2614176	790626	24	[illegible]	25	0.0040	0.0020	0.0590	0.0150
19.	3 2614176	790626	24	[illegible]	26	0.0430	0.0144	0.2330	0.0466
20.	3 2614176	790626	24	[illegible]	27	0.0590	0.0148	0.0590	0.0148
21.	3 2614176	790626	24	[illegible]	28	0.1990	0.0248	1.3120	0.0423

END DATA. ERRORS: [illegible] IMAGE COUNT: [illegible]

Site Name
Data set No.
Descriptor
Site Number
Sample date
Sample duration
Sample start time
Pollutant No.
Fine Concentration
Fine Uncertainty
Coarse/total Concentration
Coarse/total Uncertainty

```
 FINE   SITE: CAMS   DATE: 780127  SAMPLE DURATION: 24 W/ START HOUR:   0
REDUCED CHI:    .516  DF:  1
 2 CRUST     *    1.230+-   .141 UG/M3
 3 TRANSP    *    1.218+-   .213 UG/M3
TOTAL:    2.448
**********************MEAS**************CALC**********RATIO****************
 1 VC        M          <   .001      .754+-  .115   .00+- .00  VC
 2 NA              .416+-   .058      .015+-  .004   .04+- .01  NA
 3 TC        M          <   .001      .823+-  .153   .00+- .00  TC
 4 K           1.520+-   .120      .014+-  .001   .01+- .00  K
 5 MG               <    .540      .016+-  .007 15.98+-****  MG
 6 S           2.937+-   .240      .009+-  .002   .00+- .00  S
 7 SO4         9.805+- 1.037      .021+-  .006   .00+- .00  SO4
 8 NO3         1.197+-   .166      .011+-  .004   .01+- .00  NO3
 9 NVC       M          <   .001      .069+-  .038   .00+- .00  NVC
10 NH4       M          <   .001      .000+-  .000   .00+- .00  NH4
11 CL         1.024+-   .103      .037+-  .012   .04+- .01  CL
12 F        M          <   .001      .000+-  .000   .00+- .00  F
13 AL    *         .149+-   .020      .122+-  .034   .82+- .25  AL
14 SI    *         .277+-   .030      .284+-  .014  1.03+- .12  SI
15 CA             .151+-   .014      .045+-  .008   .30+- .06  CA
16 TI             .012+-   .003      .008+-  .002   .66+- .23  TI
17 V              .063+-   .004      .000+-  .000   .00+- .00  V
18 CR             .054+-   .005      .001+-  .000   .01+- .00  CR
19 MN            1.101+-   .078      .002+-  .000   .00+- .00  MN
20 FE             .449+-   .034      .099+-  .012   .22+- .03  FE
21 NI             .080+-   .007      .000+-  .000   .00+- .00  NI
22 CU             .028+-   .004      .001+-  .000   .04+- .02  CU
23 ZN             .371+-   .038      .006+-  .002   .02+- .00  ZN
24 BR             .064+-   .006      .061+-  .021   .96+- .34  BR
25 PB    *        .247+-   .022      .248+-  .037  1.00+- .17  PB
MASS FINE/COARSE/TOTAL:
 39.100+- 1.500/ 48.300+- 3.176/ 96.400+- 2.800
ENTER COMMAND
```

CMBEPA COMMANDS

DATA ACCESS	SELECT-SELECTS THE DATA SET TO BE USED
	EXIT-TERMINATES THE SESSION
CMB OPERATIONS	AE-ADD AN ELEMENT TO THE FIT
	DE-DELETE AN ELEMENT FROM THE FIT
	AS-ADD A SOURCE TO THE FIT
	DS-DELETE A SOURCE FROM THE FIT
	CMB-PERFORM A CMB CALCULATION USING SOURCES & SPECIE SPECIFIED
PRINTOUTS	PINFO-PRINTS CURRENT STATUS
	PDATA-PRINTS CURRENT SAMPLE DATA
	PCONC-PRINTS MEASURED FINE AND COARSE CONCENTRATIONS
DATA STORAGE	WRITE-WRITES CMB CALCULATION OUT TO SUMMRY AND CMBOUT FILES

CRITERIA FOR CMB FITTING

REDUCED CHI	LESS THAN 2.0
RATIO	BETWEEN 0.5 AND 2.0
MASS	SHOULD BE WITHIN 30% OF MEASURED
FITTING ELEMENTS	INCLUDE IF: MEASURED VALUE IS GT ITS UNCERTAINTY SO4,NO3 MUST BE SPECIFIED IF SECSO4 OR SECNO3 ARE INCLUDED AS SOURCES DATA QUALITY IS ASSURED
FITTING SOURCES	INCLUDE IF: IMPACT ESTIMATE IS GT ITS UNCERTAINTY INCLUDE SO4 AND NO3 AS LAST RESORT EXCLUDE SOURCES OF SIMILAR COMPOSITION

```
   ***  CHEMICAL MASS BALANCE MODEL(CMB) - WORKSHOP EXAMPLE  ***                    DATE 091881      PA

  TYPE YES OR NO.
 >YES
  ORKING SOURCE MATRICES HAVE BEEN CODED
 SOURCES:
  URCE #       SOURCE NAME

    1           MARINE
    2           CRUST
    3           TRANSP
    4           TRANS
    5           RESOIL
    6           CASORC
    7           VBURN1
    8           VBURN2
    9           STEEL
   10           FERRO
   11           RSDNVC
   12           SECNO3
   13           SECSO4
   14           SECCAR
   15           SECVC
   16           DUMMY

 ELEMENTS:
 ELEMENT #     ELEMENT NAME
    1           VC
    2           NA
    3           TC
    4           K
    5           MG
    6           S
    7           S04
    8           N03
    9           NVC
   10           NH4
   11           CL
   12           F
   13           AL
   14           SI
   15           CA
   16           TI
   17           V
   18           CR
   19           MN
   20           FE
   21           NI
   22           CU
   23           ZN
   24           BR
   25           PB
 PLEASE INPUT INITIAL AUTOFIT INFORMATION
INITIAL SOURCE  1: XX
:
INITIAL SOURCE  2: XX
:
INITIAL SOURCE  3: XX
:
INITIAL SOURCE  4: XX
:
INITIAL SOURCE  1: MARINE
INITIAL SOURCE  2: CRUST
INITIAL SOURCE  3: TRANSP

PLEASE INPUT SPECIES
INITIAL SPECIE  1: XX
> 1
INITIAL SPECIE  2: XX
> 2
INITIAL SPECIE  3: XX
> 3
INITIAL SPECIE  4: XX
> 4
INITIAL SPECIE  5: XX
:
INITIAL SPECIE  6: XX
:
INITIAL SPECIE  7: XX
```

```
   ***  CHEMICAL MASS BALANCE MODEL(CMB) - WORKSHOP EXAMPLE  ***                    DATE 091881

 >13
 INITIAL SPECIE  8: XX
 >14
 INITIAL SPECIE  9: XX
 >15
 INITIAL SPECIE 10: XX
 >16
 INITIAL SPECIE 11: XX
  20
 INITIAL SPECIE 12: XX
  24
 INITIAL SPECIE 13: XX
  25
 INITIAL SPECIE 14: XX
   0
 INITIAL SPECIE  1 : VC
  NITIAL SPECIE  2 : NA
 NITIAL SPECIE  3 : K
  NITIAL SPECIE  4 : S04
 NITIAL SPECIE  5 : CL
  NITIAL SPECIE  6 : F
 NITIAL SPECIE  7 : AL
 NITIAL SPECIE  8 : SI
 NITIAL SPECIE  9 : CA
 NITIAL SPECIE 10 : TI
 NITIAL SPECIE 11 : FE
 NITIAL SPECIE 12 : BR
 NITIAL SPECIE 13 : PB

  INITIAL AUTOFIT SOURCES AND SPECIES
ARE CORRECT, TYPE YES , IF NOT TYPE NO
 YES
ENTER COMMAND
 HELP
HELP-LISTS THESE COMMANDS

---- DATA ACCESS AND SEQUENCING ----
 UTOFIT-SEQUENCES AUTOMATICALLY TO NEXT DATA SET
RESUM-RESUME AUTOFIT
 ELECT-SELECT DATA SET FOR CMB
EXIT-CLOSE FILES AND LEAVE

 --- CMB OPERATIONS ----
 A-ADD AN ELEMENT TO THE FIT
DE-DELETE AN ELEMENT FROM THE FIT
AS-ADD A SOURCE TO THE FIT
DS-DELETE A SOURCE FROM THE FIT
CMB-PERFORM CMB, EFFECTIVE VARIANCE
CMBOWL-PERFORM CMB, OWLS

  -- SCREEN DISPLAY ----
PINFO-PRINT CURRENT STATUS ON SCREEN
  ATA-PRINT CURRENT CMB RESULTS ON SCREEN
PCONCS-PRINT MEASURED FINE AND COARSE CONCENTRATIONS TO SCREEN

---- DATA STORAGE ----
  ITE-WRITE PRESENT CMB RESULTS TO FULL PRINTOUT,
       SUMMARY,AND MAG TAPE STORAGE FILES

---- BACKGROUND SITE OPERATIONS ----
  CKOUT-SELECT AND SUBTRACT A BACKGROUND DATA SET
BACKIN-ELIMINATE CURRENT BACKGROUND SUBTRACT

---- VARIOUS AND SUNDRY ----
 ITI-INITIALIZE FITTING ELEMENTS AND SOURCES
CALCON-GET CALCULATED CONCENTRATIONS
 TER COMMAND
>SELECT
 PUT DESIRED CMB ID #: XXXXXX
>000001
 TER TYPE OF DATA SET
 FOR FINE-TOTAL OR FC FOR FINE-COARSE
>T
 PUT DESIRED SIZE FRACTION:(1 OR 2)
>1
 TA SEARCH FOR 000001 BEGUN
        CAMS       000200
```

```
 ***  CHEMICAL MASS BALANCE MODEL(CMB) - WORKSHOP EXAMPLE  ***                    DATE 091881

          TRIAL       000207
          CAMS        000001
 FINE   SITE: CAMS   DATE: 780127  SAMPLE DURATION: 24 W/ START HOUR:  0
REDUCED CHI: 41.466  DF: 10
 1 MARINE    *   1.501+-  .188 UG/M3
 2 CRUST     *   1.637+-  .139 UG/M3
 3 TRANSP    *    .766+-  .114 UG/M3
TOTAL:   3.904
MEASURED MASS FINE/COARSE/TOTAL:
 38.100+- 1.500/ 48.300+- 3.176/ 86.400+- 2.800
PRESS TRANSMIT TO CONTINUE OR ENTER C FOR NEXT COMMAND
>0
INPUT ERROR.
PRESS TRANSMIT TO CONTINUE OR ENTER C FOR NEXT COMMAND
>
**********************MEAS************CALC**********RATIO***************
 1 VC    *  M        <   .001      .576+-  .095    .00+- .00  VC
 2 NA    *       .416+-  .058      .621+-  .060   1.49+- .25  NA
 3 TC       M        <   .001      .635+-  .122    .00+- .00  TC
 4 K     *      1.520+-  .120      .038+-  .003    .03+- .00  K
 5 MG             <   .540      .093+-  .015  93.32+-**** MG
 6 S             2.937+-  .240      .059+-  .020    .02+- .01  S
 7 SO4   *       9.805+- 1.037      .167+-  .060    .02+- .01  SO4
 8 NO3           1.197+-  .166      .007+-  .003    .01+- .00  NO3
 9 NVC      M        <   .001      .059+-  .027    .00+- .00  NVC
10 NH4      M        <   .001      .000+-  .000    .00+- .00  NH4
11 CL    *      1.024+-  .103      .623+-  .150    .61+- .16  CL
12 F     *  M        <   .001      .000+-  .000    .00+- .00  F
13 AL    *       .149+-  .020      .153+-  .045   1.03+- .33  AL
14 SI    *       .277+-  .030      .371+-  .018   1.34+- .16  SI
15 CA    *       .151+-  .014      .071+-  .008    .47+- .07  CA
16 TI    *       .012+-  .003      .010+-  .002    .87+- .28  TI
17 V             .063+-  .004      .000+-  .000    .01+- .00  V
18 CR            .054+-  .005      .001+-  .000    .01+- .01  CR
19 MN           1.101+-  .078      .002+-  .000    .00+- .00  MN
20 FE    *       .449+-  .034      .114+-  .012    .25+- .03  FE
21 NI            .080+-  .007      .000+-  .000    .00+- .00  NI
22 CU            .028+-  .004      .001+-  .000    .04+- .01  CU
23 ZN            .371+-  .038      .004+-  .001    .01+- .00  ZN
24 BR    *       .064+-  .006      .042+-  .013    .65+- .21  BR
25 PB    *       .247+-  .022      .159+-  .023    .64+- .11  PB
ENTER COMMAND
>DE
INPUT CODE OF DELETED ELEMENT
> 1
INPUT CODE OF DELETED ELEMENT
>12
INPUT CODE OF DELETED ELEMENT
> 0
ENTER COMMAND
>AE
INPUT CODE OF ADDED ELEMENT
>19
INPUT CODE OF ADDED ELEMENT
>17
INPUT CODE OF ADDED ELEMENT
>21
INPUT CODE OF ADDED ELEMENT
> 0
ENTER COMMAND
>AS
INPUT CODE OF ADDED SOURCE
> 5
INPUT CODE OF ADDED SOURCE
>10
INPUT CODE OF ADDED SOURCE
> 0
ENTER COMMAND
>PINFO
          ***CURRENT STATUS***
SAMPLE DATE: 780127  SITE CODE: 2614176
DURATION: 24  START HOUR:  0
HAS BACKGROUND BEEN SUBTRACTED: NO
FITTING ELEMENTS
NA
K
SO4
```

```
   ***  CHEMICAL MASS BALANCE MODEL(CMB) - WORKSHOP EXAMPLE  ***                    DATE 091881

 CL
 AL
 SI
 CA
 TI
 FE
 BR
 PB
 MN
 V
 NI
 FITTING SOURCES
 MARINE
 CRUST
 TRANSP
 RESOIL
 FERRO
 ENTER COMMAND
 >CMB
  FINE   SITE: CAMS   DATE: 780127  SAMPLE DURATION: 24 W/ START HOUR:  0
 REDUCED CHI: 11.727  DF:  9
  1 MARINE   *     .856+-  .172 UG/M3
  2 CRUST    *     .869+-  .154 UG/M3
  3 TRANSP   *    1.216+-  .196 UG/M3
  5 RESOIL   *    1.885+-  .299 UG/M3
 10 FERRO    *    6.534+-  .548 UG/M3
 TOTAL:  11.360
 MEASURED MASS FINE/COARSE/TOTAL:
  38.100+- 1.500/ 48.300+- 3.176/ 86.400+- 2.800
 PRESS TRANSMIT TO CONTINUE OR ENTER C FOR NEXT COMMAND
 >
 ********************MEAS************CALC**********RATIO**************
  1 VC       M         <    .001     1.430+-  .170    .00+- .00  VC
  2 NA    *          .416+-  .058      .622+-  .051   1.49+- .24  NA
  3 TC       M         <    .001     1.061+-  .220    .00+- .00  TC
  4 K     *       1.520+-  .120      .713+-  .255    .47+- .17  K
  5 MG                 <    .540      .052+-  .268  52.39+-**** MG
  6 S              2.937+-  .240      .398+-  .052    .14+- .02  S
  7 SO4   *        9.805+- 1.037     1.286+-  .228    .13+- .03  SO4
  8 NO3            1.197+-  .166      .396+-  .183    .33+- .16  NO3
  9 NVC      M         <    .001      .121+-  .060    .00+- .00  NVC
 10 NH4      M         <    .001      .000+-  .000    .00+- .00  NH4
 11 CL    *       1.024+-  .103      .406+-  .087    .40+- .09  CL
 12 F        M         <    .001      .020+-  .005    .00+- .00  F
 13 AL    *          .149+-  .020      .142+-  .026    .95+- .22  AL
 14 SI    *          .277+-  .030      .286+-  .024   1.03+- .14  SI
 15 CA    *          .151+-  .014      .163+-  .017   1.08+- .15  CA
 16 TI    *          .012+-  .003      .011+-  .002    .89+- .27  TI
 17 V     *          .063+-  .004      .067+-  .014   1.06+- .24  V
 18 CR               .054+-  .005      .004+-  .000    .07+- .01  CR
 19 MN    *       1.101+-  .078     1.132+-  .065   1.03+- .09  MN
 20 FE    *          .449+-  .034      .271+-  .093    .60+- .21  FE
 21 NI    *          .080+-  .007      .101+-  .023   1.27+- .31  NI
 22 CU               .028+-  .004      .005+-  .001    .18+- .03  CU
 23 ZN               .371+-  .038      .051+-  .017    .14+- .05  ZN
 24 BR    *          .064+-  .006      .073+-  .025   1.15+- .41  BR
 25 PB    *          .247+-  .022      .251+-  .037   1.02+- .17  PB
 ENTER COMMAND
 >AS
 INPUT CODE OF ADDED SOURCE
 > 8
 INPUT CODE OF ADDED SOURCE
 > 9
 INPUT CODE OF ADDED SOURCE
 > 0
 ENTER COMMAND
 >CMB
  FINE   SITE: CAMS   DATE: 780127  SAMPLE DURATION: 24 W/ START HOUR:  0
 REDUCED CHI:  4.541  DF:  7
  1 MARINE   *     .264+-  .269 UG/M3
  2 CRUST    *     .535+-  .275 UG/M3
  3 TRANSP   *    1.096+-  .194 UG/M3
  5 RESOIL   *    1.766+-  .293 UG/M3
  8 VBURN2   *   23.048+- 7.624 UG/M3
  9 STEEL    *     .287+-  .529 UG/M3
 10 FERRO    *    6.145+-  .644 UG/M3
 TOTAL:  33.142
```

*** CHEMICAL MASS BALANCE MODEL(CMB) - WORKSHOP EXAMPLE *** DATE 091881

```
MEASURED MASS FINE/COARSE/TOTAL:
 38.100+- 1.500/ 48.300+- 3.176/ 86.400+- 2.800
PRESS TRANSMIT TO CONTINUE OR ENTER C FOR NEXT COMMAND
>0
INPUT ERROR.
PRESS TRANSMIT TO CONTINUE OR ENTER C FOR NEXT COMMAND
>
**********MEAS**********CALC**********RATIO**********
 1 VC      M        <   .001   12.121+- 2.195   .00+- .00  VC
 2 NA   *       .416+-  .058     .424+-  .087  1.02+- .25  NA
 3 TC      M        <   .001   12.780+- 2.888   .00+- .00  TC
 4 K    *      1.520+-  .120    2.023+-  .624  1.33+- .42  K
 5 MG             <   .540     .038+-  .252 38.26+-**** MG
 6 S           2.937+-  .240     .706+-  .168   .24+- .06  S
 7 SO4  *      9.805+- 1.037    2.310+- 1.014   .24+- .11  SO4
 8 NO3         1.197+-  .166     .577+-  .270   .48+- .23  NO3
 9 NVC     M        <   .001    1.120+-  .694   .00+- .00  NVC
10 NH4     M        <   .001     .000+-  .000   .00+- .00  NH4
11 CL   *      1.024+-  .103     .884+-  .462   .86+- .46  CL
12 F       M        <   .001     .019+-  .005   .00+- .00  F
13 AL   *       .149+-  .020     .188+-  .071  1.26+- .51  AL
14 SI   *       .277+-  .030     .290+-  .051  1.05+- .22  SI
15 CA   *       .151+-  .014     .248+-  .071  1.64+- .49  CA
16 TI   *       .012+-  .003     .009+-  .002   .74+- .22  TI
17 V    *       .063+-  .004     .063+-  .013   .99+- .22  V
18 CR           .054+-  .005     .011+-  .004   .20+- .08  CR
19 MN   *      1.101+-  .078    1.090+-  .061   .99+- .09  MN
20 FE   *       .449+-  .034     .374+-  .164   .83+- .37  FE
21 NI   *       .080+-  .007     .097+-  .021  1.21+- .29  NI
22 CU           .028+-  .004     .031+-  .092  1.09+-3.30  CU
23 ZN           .371+-  .038     .051+-  .016   .14+- .04  ZN
24 BR   *       .064+-  .006     .084+-  .028  1.31+- .46  BR
25 PB   *       .247+-  .022     .235+-  .034   .95+- .16  PB
ENTER COMMAND
>DS
INPUT CODE OF DELETED SOURCE
> 9
INPUT CODE OF DELETED SOURCE
> 0
ENTER COMMAND
>AE
INPUT CODE OF ADDED ELEMENT
> 8
INPUT CODE OF ADDED ELEMENT
> 0
ENTER COMMAND
>AS
INPUT CODE OF ADDED SOURCE
>12
INPUT CODE OF ADDED SOURCE
>13
INPUT CODE OF ADDED SOURCE
> 0
ENTER COMMAND
>CMB
 FINE   SITE: CAMS   DATE: 780127  SAMPLE DURATION: 24 W/ START HOUR:  0
REDUCED CHI:  .887  DF:  7
 1 MARINE   *    .361+-  .215 UG/M3
 2 CRUST    *    .700+-  .204 UG/M3
 3 TRANSP   *   1.132+-  .192 UG/M3
 5 RESOIL   *   1.642+-  .271 UG/M3
 8 VBURN2   *  14.056+- 5.461 UG/M3
10 FERRO    *   6.301+-  .570 UG/M3
12 SECNO3   *    .692+-  .281 UG/M3
13 SECSO4   *  7.994+- 1.314 UG/M3
TOTAL:  32.877
MEASURED MASS FINE/COARSE/TOTAL:
 38.100+- 1.500/ 48.300+- 3.176/ 86.400+- 2.800
PRESS TRANSMIT TO CONTINUE OR ENTER C FOR NEXT COMMAND
>
**********MEAS**********CALC**********RATIO**********
 1 VC      M        <   .001    7.937+- 1.344   .00+- .00  VC
 2 NA   *       .416+-  .058     .439+-  .060  1.06+- .21  NA
 3 TC      M        <   .001    8.189+- 1.768   .00+- .00  TC
 4 K    *      1.520+-  .120    1.509+-  .429   .99+- .29  K
 5 MG             <   .540     .026+-  .257 26.40+-**** MG
 6 S           2.937+-  .240     .555+-  .108   .19+- .04  S
```

```
  ***  CHEMICAL MASS BALANCE MODEL(CMB) - WORKSHOP EXAMPLE  ***                DATE 091881

 7 SO4   *       9.805+- 1.037    9.805+-  .751  1.00+- .13  SO4
 8 NO3   *       1.197+-  .166    1.197+-  .220  1.00+- .23  NO3
 9 NVC       M       <    .001     .725+-  .425   .00+- .00  NVC
10 NH4       M       <    .001     .000+-  .000   .00+- .00  NH4
11 CL    *      1.024+-  .103     .640+-  .284   .63+- .28  CL
12 F         M       <    .001     .019+-  .005   .00+- .00  F
13 AL    *       .149+-  .020     .171+-  .047  1.15+- .35  AL
14 SI    *       .277+-  .030     .286+-  .036  1.03+- .17  SI
15 CA    *       .151+-  .014     .200+-  .045  1.33+- .32  CA
16 TI    *       .012+-  .003     .009+-  .002   .77+- .23  TI
17 V     *       .063+-  .004     .058+-  .012   .92+- .21  V
18 CR            .054+-  .005     .004+-  .001   .08+- .02  CR
19 MN    *      1.101+-  .078    1.092+-  .062   .99+- .09  MN
20 FE    *       .449+-  .034     .275+-  .123   .61+- .28  FE
21 NI    *       .080+-  .007     .088+-  .020  1.10+- .27  NI
22 CU            .028+-  .004     .020+-  .056   .71+-2.01  CU
23 ZN            .371+-  .038     .048+-  .016   .13+- .05  ZN
24 BR    *       .064+-  .006     .079+-  .026  1.23+- .42  BR
25 PB    *       .247+-  .022     .238+-  .034   .96+- .16  PB
ENTER COMMAND
>WRITE
ENTER COMMAND
>EXIT

)XQT PAGE
```

*** CMB MODEL : OUTPUT FORMAT OF 'CMBOUT' DATA FILE *** DATE 091881

```
@ED,R CMBOUT.
READ-ONLY MODE
ED 16R1-FRI-09/18/81-14:55:19-(0,)
EDIT
```

CMBDEQ RESULTS FOR CMB # 000001
FINE PARTICULATE FRACTION
SAMPLING DATE: 780127 SITE: CAMS SITE CODE: 2614176
SAMPLING DURATION: 24 HRS. WITH START HOUR: 0
BACKGROUND SITE SUBTRACTED: NO
EFFECTIVE VARIANCE FITTING. REDUCED CHI SQUARE: .887 DEGREES OF FREEDOM: 7

CODE	SOURCE	FLG	UG/M3	%
1	MARIN	*	.361+- .215	.946+- .565
2	CRUST	*	.700+- .204	1.837+- .540
3	TRANS	*	1.132+- .192	2.970+- .517
5	RESOI	*	1.642+- .271	4.310+- .731
8	VBURN	*	14.056+- 5.461	36.892+-14.407
10	FERRO	*	6.301+- .570	16.538+- 1.631
12	SECNO	*	.692+- .281	1.816+- .741
13	SECSO	*	7.994+- 1.314	20.981+- 3.545
	TOTAL:		32.877+- 5.670	86.290+-15.265

SPECIE CODE		FIT FLG	MISS FLG	FINE SUSPENDED PARTICULATE MEAS. UG/M3	PERCENT	CALC. UG/M3	RATIO	
1	VC		M	< .000	< .003	7.937+- 1.344	.000+- .000	VC
2	NA	*		.416+- .058	1.092+- .158	.439+- .060	1.056+- .211	NA
3	TC		M	< .000	< .003	8.189+- 1.768	.000+- .000	TC
4	K	*		1.520+- .120	3.990+- .352	1.509+- .429	.992+- .397	K
5	MG			< .001	< 1.417	.026+- .257	26.401+-*****	MG
6	S			2.937+- .240	7.709+- .699	.555+- .108	.189+- .038	S
7	SO4	*		9.805+- 1.037	25.735+- 2.904	9.805+- .751	1.000+- .108	SO4
8	NO3	*		1.197+- .166	3.142+- .453	1.197+- .220	1.000+- .260	NO3
9	NVC		M	< .000	< .003	.725+- .425	.000+- .000	NVC
10	NH4		M	< .000	< .003	.000+- .000	.000+- .000	NH4
11	CL	*		1.024+- .103	2.688+- .290	.640+- .284	.625+- .327	CL
12	F		M	< .000	< .003	.019+- .005	.000+- .000	F
13	AL	*		.149+- .020	.391+- .055	.171+- .047	1.148+- .485	AL
14	SI	*		.277+- .030	.727+- .084	.286+- .036	1.031+- .186	SI
15	CA	*		.151+- .014	.396+- .040	.200+- .045	1.327+- .493	CA
16	TI	*		.012+- .003	.031+- .008	.009+- .002	.771+- .169	TI
17	V	*		.063+- .004	.165+- .012	.058+- .012	.924+- .268	V
18	CR			.054+- .005	.142+- .014	.004+- .001	.082+- .019	CR
19	MN	*		1.101+- .078	2.890+- .234	1.092+- .062	.992+- .080	MN
20	FE	*		.449+- .034	1.178+- .101	.275+- .123	.612+- .321	FE
21	NI	*		.080+- .007	.210+- .020	.086+- .020	1.105+- .370	NI
22	CU			.028+- .004	.073+- .011	.020+- .056	.714+-2.468	CU
23	ZN			.371+- .038	.974+- .107	.048+- .016	.130+- .044	ZN
24	BR	*		.064+- .006	.168+- .017	.079+- .026	1.234+- .637	BR
25	PB	*		.247+- .022	.648+- .063	.238+- .034	.963+- .194	PB

MEASURED AMBIENT MASS (UG/M3): FINE: 38.1+- 1.5 COARSE: 48.3+- 3.2 TOTAL: 86.4+- 2.8

```
EOF:56
NO CORRECTIONS APPLIED.

@XQT PAGE
```

*** CMB MODEL : OUTPUT FORMAT OF 'CMBOUT' DATA FILE ***

```
@ED,R CMBOUT.
READ-ONLY MODE
ED 16R1-THU-09/Q3/81-08:51:29-(0,)
EDIT
```

CMBDEQ RESULTS FOR CMB # 000001
FINE PARTICULATE FRACTION
SAMPLING DATE: 780127 SITE: CAMS SITE CODE: 2614176
SAMPLING DURATION: 24 HRS. WITH START HOUR: 0
BACKGROUND SITE SUBTRACTED: NO
EFFECTIVE VARIANCE FITTING. REDUCED CHI SQUARE: .887 DEGREES OF FREEDOM: 7

CODE	SOURCE	FLG	UG/M3	%
1	MARIN	*	.361+- .215	.946+- .565
2	CRUST	*	.700+- .204	1.837+- .540
3	TRANS	*	1.132+- .192	2.970+- .517
5	RESOI	*	1.642+- .271	4.310+- .731
8	VBURN	*	14.056+- 5.461	36.892+-14.407
10	FERRO	*	6.301+- .570	16.538+- 1.631
12	SECNO	*	.692+- .281	1.816+- .741
13	SECSO	*	7.996+- 1.314	20.981+- 3.545
	TOTAL:		72.877+- 5.670	86.290+-15.265

CODE	SPECIE	FIT FLG	MISS FLG	FINE MEAS. UG/M3	SUSPENDED PARTICULATE PERCENT	CALC. UG/M3	RATIO	
1	VC		M	< .000	< .003	7.937+- 1.344	.000+- .000	VC
2	NA	*		.416+- .058	1.092+- .158	.439+- .060	1.056+- .211	NA
3	TC		M	< .000	< .003	8.189+- 1.768	.000+- .000	TC
4	K	*		1.520+- .120	3.990+- .352	1.509+- .429	.992+- .397	K
5	MG			< .001	< 1.417	.026+- .257	26.401+-*****	MG
6	S			2.937+- .240	7.709+- .699	.555+- .108	.189+- .038	S
7	SO4	*		9.805+- 1.037	25.735+- 2.904	9.805+- .751	1.000+- .108	SO4
8	NO3	*		1.197+- .166	3.142+- .453	1.197+- .220	1.000+- .260	NO3
9	NVC		M	< .000	< .003	.725+- .425	.000+- .000	NVC
10	NH4		M	< .000	< .003	.000+- .000	.000+- .000	NH4
11	CL	*		1.024+- .103	2.688+- .290	.640+- .284	.625+- .327	CL
12	F		M	< .000	< .003	.019+- .005	.000+- .000	F
13	AL	*		.149+- .020	.391+- .055	.171+- .047	1.148+- .465	AL
14	SI	*		.277+- .030	.727+- .084	.286+- .036	1.031+- .186	SI
15	CA	*		.151+- .014	.396+- .040	.200+- .045	1.327+- .493	CA
16	TI	*		.012+- .003	.031+- .008	.009+- .002	.771+- .169	TI
17	V	*		.063+- .004	.165+- .012	.058+- .012	.924+- .268	V
18	CR			.054+- .005	.142+- .014	.004+- .001	.082+- .019	CR
19	MN	*		1.101+- .078	2.890+- .234	1.092+- .062	.992+- .080	MN
20	FE	*		.449+- .034	1.178+- .101	.275+- .123	.612+- .321	FE
21	NI	*		.080+- .007	.210+- .020	.088+- .020	1.105+- .370	NI
22	CU			.028+- .004	.073+- .011	.020+- .056	.714+-2.468	CU
23	ZN			.371+- .038	.974+- .107	.048+- .016	.130+- .044	ZN
24	BR	*		.064+- .006	.168+- .017	.079+- .026	1.234+- .637	BR
25	PB	*		.247+- .022	.648+- .063	.238+- .034	.963+- .194	PB

MEASURED AMBIENT MASS (UG/M3): FINE: 38.1+- 1.5 COARSE: 48.3+- 3.2 TOTAL: 86.4+- 2.8

CMBDEQ RESULTS FOR CMB # 000001
COARSE PARTICULATE FRACTION
SAMPLING DATE: 780127 SITE: CAMS SITE CODE: 2614176
SAMPLING DURATION: 24 HRS. WITH START HOUR: 0
BACKGROUND SITE SUBTRACTED: NO
EFFECTIVE VARIANCE FITTING. REDUCED CHI SQUARE: 4.460 DEGREES OF FREEDOM: 7

CODE	SOURCE	FLG	UG/M3	%
1	MARIN	*	-.107+- .478	.495+- .990
2	CRUST	*	19.501+- 1.369	40.374+- 3.884
3	TRANS	*	.407+- .257	.843+- .535
5	RESOI	*	1.130+- .262	2.340+- .563
8	VBURN	*	31.345+-12.356	64.897+-25.935
10	FERRO	*	10.451+- 1.371	21.638+- 3.176
12	SECNO	*	.350+- .539	.559+- 1.117
13	SECSO	*	11.146+- 3.117	23.077+- 6.629

*** CMB MODEL : OUTPUT FORMAT OF 'CMBOUT' DATA FILE *** DATE 0

	TOTAL:			74.223+-12.915		153.671+-28.584				
SPECIE CODE		FIT FLG	MISS FLG	COARSE SUSPENDED PARTICULATE MEAS. UG/M3		PERCENT		CALC. UG/M3	RATIO	
1	VC		M	<	.000	<	.002	16.607+- 2.986	.000+- .000	VC
2	NA	*		.718+-	.147	1.487+-	.320	.737+- .114	1.027+- .228	NA
3	TC		M	<	.000	<	.002	18.495+- 3.933	.000+- .000	TC
4	K	*		2.124+-	.311	4.398+-	.706	3.150+- .883	1.483+- .744	K
5	MG			<	.647	<	2.683	.295+- .420	.456+- .713	MG
6	S			3.386+-	.565	7.010+-	1.258	.796+- .224	.235+- .068	S
7	SO4	*		13.705+-	2.682	28.375+-	5.857	13.705+- 1.465	1.000+- .151	SO4
8	NO3	*		1.240+-	.331	2.567+-	.705	1.240+- .407	1.000+- .464	NO3
9	NVC		M	<	.000	<	.002	1.889+- .950	.000+- .000	NVC
10	NH4		M	<	.000	<	.002	.000+- .000	.000+- .000	NH4
11	CL	*		1.103+-	.239	2.284+-	.518	.985+- .627	.893+- .762	CL
12	F		M	<	.000	<	.002	.032+- .008	.000+- .000	F
13	AL	*		1.728+-	.140	3.578+-	.374	1.471+- .166	.851+- .126	AL
14	SI	*		4.627+-	.378	9.580+-	1.005	5.672+- .301	1.226+- .103	SI
15	CA	*		1.107+-	.094	2.292+-	.246	.868+- .105	.784+- .120	CA
16	TI	*		.178+-	.017	.369+-	.043	.203+- .035	1.141+- .299	TI
17	V	*		.037+-	.009	.077+-	.019	.047+- .009	1.265+- .382	V
18	CR			.082+-	.013	.170+-	.029	.015+- .004	.186+- .050	CR
19	MN	*		1.757+-	.217	3.638+-	.508	1.829+- .104	1.041+- .085	MN
20	FE	*		2.979+-	.253	6.168+-	.663	1.442+- .245	.484+- .091	FE
21	NI	*		.074+-	.015	.153+-	.032	.062+- .014	.832+- .241	NI
22	CU			.166+-	.016	.344+-	.041	.045+- .125	.273+- .783	CU
23	ZN			.481+-	.079	.996+-	.176	.089+- .027	.186+- .058	ZN
24	BR	*		.040+-	.012	.083+-	.025	.064+- .033	1.591+-1.530	BR
25	PB	*		.177+-	.042	.366+-	.091	.169+- .034	.954+- .267	PB

MEASURED AMBIENT MASS (UG/M3): FINE: 38.1+- 1.5 COARSE: 48.3+- 3.2 TOTAL: 86.4+- 2.8

CMBDEQ RESULTS FOR CMB # 000001
TOTAL PARTICULATE FRACTION
SAMPLING DATE: 780127 SITE: CAMS SITE CODE: 2614176
SAMPLING DURATION: 24 HRS. WITH START HOUR: 0
BACKGROUND SITE SUBTRACTED: NO
RESULTS DERIVED FROM FINE AND COARSE FITTINGS

CODE	SOURCE	FLG	UG/M3	%
1	MARIN	*	.253+- .524	.303+- .607
2	CRUST	*	20.200+- 1.684	23.380+- 1.772
3	TRANS	*	1.509+- .721	1.761+- .376
5	RESOI	*	2.772+- .377	3.209+- .448
8	VBURN	*	45.401+-13.309	52.547+-15.728
10	FERRO	*	16.756+- 1.485	19.389+- 1.830
12	SECNO	*	1.042+- .608	1.206+- .705
13	SECSO	*	19.140+- 3.382	22.153+- 3.980
	TOTAL:		107.100+-14.104	123.958+-16.812

SPECIE CODE		FIT FLG	MISS FLG	TOTAL SUSPENDED PARTICULATE MEAS. UG/M3		PERCENT		CALC. UG/M3	RATIO	
1	VC		M	<	.000	<	.001	24.543+- 3.275	.000+- .000	VC
2	NA	*		1.134+-	.135	1.312+-	.162	1.177+- .129	1.038+- .164	NA
3	TC		M	<	.000	<	.001	26.685+- 4.312	.000+- .000	TC
4	K	*		3.644+-	.287	4.218+-	.359	4.658+- .982	1.278+- .437	K
5	MG			<	.001	<	1.362	.322+- .493	******+-*****	MG
6	S			6.323+-	.512	7.318+-	.638	1.352+- .249	.214+- .040	S
7	SO4	*		23.510+-	2.473	27.211+-	2.995	23.510+- 1.647	1.000+- .099	SO4
8	NO3	*		2.437+-	.286	2.821+-	.343	2.437+- .463	1.000+- .268	NO3
9	NVC		M	<	.000	<	.001	2.614+- 1.041	.000+- .000	NVC
10	NH4		M	<	.000	<	.001	.000+- .000	.000+- .000	NH4
11	CL	*		2.127+-	.216	2.462+-	.262	1.625+- .688	.764+- .407	CL
12	F		M	<	.000	<	.001	.052+- .010	.000+- .000	F
13	AL	*		1.877+-	.139	2.172+-	.176	1.642+- .173	.875+- .122	AL
14	SI	*		4.904+-	.377	5.676+-	.474	5.957+- .303	1.215+- .097	SI
15	CA	*		1.258+-	.093	1.456+-	.118	1.068+- .114	.849+- .119	CA

*** CMB MODEL : OUTPUT FORMAT OF 'CMBOUT' DATA FILE *** DATE 090381

16	TI	*	.190+-	.017	.220+-	.021	.212+-	.035	1.118+-	.277	TI
17	V	*	.100+-	.008	.116+-	.010	.105+-	.015	1.050+-	.220	V
18	CR		.136+-	.012	.157+-	.015	.020+-	.004	.145+-	.031	CR
19	MN	*	2.658+-	.202	3.308+-	.257	2.922+-	.121	1.022+-	.060	MN
20	FE	*	3.428+-	.251	3.968+-	.318	1.717+-	.274	.501+-	.089	FE
21	NI	*	.154+-	.013	.178+-	.016	.150+-	.024	.974+-	.219	NI
22	CU		.194+-	.016	.225+-	.020	.065+-	.137	.336+-	.747	CU
23	ZN		.852+-	.069	.986+-	.086	.138+-	.032	.162+-	.038	ZN
24	BR	*	.104+-	.010	.120+-	.012	.143+-	.041	1.371+-	.677	BR
25	PB	*	.424+-	.036	.491+-	.045	.407+-	.049	.959+-	.159	PB

MEASURED AMBIENT MASS (UG/M3): FINE: 38.1+- 1.5 COARSE: 48.3+- 3.2 TOTAL: 86.4+- 2.8

EOF:168
NO CORRECTIONS APPLIED.

@XQT PAGE

CMB MODEL : OUTPUT FORMAT OF 'SUMMRY' DATA FILE ***

),P SUMMRY.
40 ONLY MODE
)/01-THU-09/03/81-06:51:28-(0,)
IT

*** CMBDEQ SOURCE CONTRIBUTION SUMMARY ***

CMBDEQ RESULTS FOR CMB # 000001
SAMPLING DATE: 780127 SITE: CAMS SITE CODE: 2614176
SAMPLING DURATION: 24 HRS. WITH START HOUR: 0
BACKGROUND SITE SUBTRACTED: NO

SOURCE	FINE		COARSE		TOTAL	
	UG/M3	%	UG/M3	%	UG/M3	%
MARIN	.361 +- .215	.946 +- .565	-.107 +- .478	.495 +- .990	.253 +- .524	.303 +- .607
DUST	.700 +- .204	1.837 +- .540	19.501 +- 1.369	40.374 +- 3.884	20.200 +- 1.384	23.380 +- 1.772
TRANS	1.132 +- .192	2.970 +- .517	.407 +- .257	.843 +- .535	1.539 +- .321	1.781 +- .376
ESOI	1.642 +- .271	4.310 +- .731	1.130 +- .262	2.340 +- .563	2.772 +- .377	3.209 +- .448
VBURN	14.056 +- 5.461	36.892 +- 14.407	31.345 +- 12.356	64.897 +- 25.935	45.401 +- 13.509	52.547 +- 15.728
ERRO	6.301 +- .570	16.538 +- 1.631	10.451 +- 1.371	21.638 +- 3.176	16.752 +- 1.485	19.389 +- 1.830
SECNO	.692 +- .281	1.816 +- .741	.350 +- .539	.559 +- 1.117	1.042 +- .608	1.206 +- .705
ECSO	7.994 +- 1.314	20.981 +- 3.545	11.146 +- 3.117	23.077 +- 6.629	19.140 +- 3.382	22.153 +- 3.980
CALC.MASS	32.877 +- 5.670	86.290 +- 15.265	74.223 +- 12.915	153.671 +- 28.584	107.100 +- 14.104	123.958 +- .045
MEAS.MASS	38.100 +- 1.500		48.300 +- 3.176		86.400 +- 2.800	

OF 7
O CORRECTIONS APPLIED.

XQ PAGE

*** CMB MODEL : OUTPUT FORMAT OF 'MAGSTO' DATA FILE ***

```
@ED,R MAGSTO.
READ-ONLY MODE
ED 16R1-THU-09/03/81-08:51:27-(0,)
EDIT
03 2614176  CAMS        000001 PACS
30 2614176 780127 24 00      1          38.1000      1.5000     86.4000      2.8000
30 2614176 780127 24 00      3           0.4160      0.0580      1.1340      0.1350
30 2614176 780127 24 00      5           1.5200      0.1200      3.6440      0.287
30 2614176 780127 24 00      7           0.0010      0.5400      0.0010      1.1770
30 2614176 780127 24 00      9           2.9370      0.2400      6.3230      0.5120
30 2614176 780127 24 00     10           9.8050      1.0370     23.5100      2.4730
30 2614176 780127 24 00     11           1.1970      0.1660      2.437       0.2860
30 2614176 780127 24 00     14           1.0240      0.1030      2.1270      0.2160
30 2614176 780127 24 00     16           0.1490      0.0200      1.8770      0.1390
30 2614176 780127 24 00     17           0.2770      0.0300      4.9040      0.3770
30 2614176 780127 24 00     18           0.1510      0.0140      1.2580      0.0930
30 2614176 780127 24 00     19           0.0120      0.0030      0.1900      0.0170
30 2614176 780127 24 00     20           0.0630      0.0040      0.1000      0.0080
30 2614176 780127 24 00     21           0.0540      0.0050      0.1360      0.0120
30 2614176 780127 24 00     22           1.1010      0.0780      2.8580      0.2020
30 2614176 780127 24 00     23           0.4490      0.0340      3.4280      0.2510
30 2614176 780127 24 00     24           0.0800      0.0070      0.1540      0.0130
30 2614176 780127 24 00     25           0.0280      0.0040      0.1940      0.0160
30 2614176 780127 24 00     26           0.3710      0.0380      0.8520      0.0690
30 2614176 780127 24 00     27           0.0640      0.0060      0.1040      0.0100
30 2614176 780127 24 00     28           0.2470      0.0220      0.4240      0.0360
40 2614176 78 127 24  0                          1   1       .3605       .2148      -.1074       .4779
40 2614176 78 127 24  0                          1   3       .1442       .0871      -.0429      -.1912
40 2614176 78 127 24  0                          1   5       .0050       .0031      -.0015      -.0067
40 2614176 78 127 24  0                          1   7       .0173       .0108      -.0052      -.0230
40 2614176 78 127 24  0                          1   9       .0119       .0085      -.0035      -.0158
40 2614176 78 127 24  0                          1  10       .0361       .0259      -.0107      -.0480
40 2614176 78 127 24  0                          1  14       .1442       .0932      -.0429      -.1915
40 2614176 78 127 24  0                          1  18       .0050       .0031      -.0015      -.0067
40 2614176 78 127 24  0                          1  27       .0007       .0005      -.0002      -.0010
40 2614176 78 127 24  0                          3   1       .6997       .2040     19.5005      1.3691
40 2614176 78 127 24  0                          3   2       .0826       .0385       .6513       .1965
40 2614176 78 127 24  0                          3   3       .0087       .0035       .3413       .0298
40 2614176 78 127 24  0                          3   4       .0955       .0459       .9536       .3115
40 2614176 78 127 24  0                          3   5       .0072       .0021       .2009       .0181
40 2614176 78 127 24  0                          3   7       .0091       .0033       .3003       .0345
40 2614176 78 127 24  0                          3   9       .0026       .0012       .0000       .0000
40 2614176 78 127 24  0                          3  10       .0029       .0023       .0144       .0088
40 2614176 78 127 24  0                          3  11       .0000       .0000       .0039       .0020
40 2614176 78 127 24  0                          3  12       .0129       .0074       .3023       .1343
40 2614176 78 127 24  0                          3  15       .0000       .0000       .0016       .0014
40 2614176 78 127 24  0                          3  16       .0619       .0262      1.2870       .1637
40 2614176 78 127 24  0                          3  17       .1560       .0461      5.4601       .4822
40 2614176 78 127 24  0                          3  18       .0171       .0057       .5850       .0594
40 2614176 78 127 24  0                          3  19       .0045       .0016       .1970       .0377
40 2614176 78 127 24  0                          3  20       .0002       .0001       .0053       .0010
40 2614176 78 127 24  0                          3  21       .0003       .0002       .0088       .0034
40 2614176 78 127 24  0                          3  22       .0009       .0003       .0195       .0025
40 2614176 78 127 24  0                          3  23       .0420       .0129      1.1174       .0967
40 2614176 78 127 24  0                          3  24       .0001       .0000       .0008       .0006
```

CMB Laboratory Model Instructions
-Preliminary Inputs-

1. Initial Sources

   Crustal 2
   Transp 3

2. Initial Species

VC	1	F	12	Fe	20
Na	2	Al	13	Ni	21
K	4	Si	14	Br	24
SO_4	7	Ca	15	Pb	25
Cl	11	Ti	16		

3. Enter Command: SELECT

4. CMB ID #: 000001

5. Data Set: FT

6. Size Fraction: 1

7. Select Fitting Elements

8. Add and Delete Sources

Commands

AE	Add element	Mistaken Entry	Control X
DE	Delete element	EXIT	Terminates program
AS	Add source	CMB	Effective variance CMB
DS	Delete source		
Pinfo	Prints Information		
Pdata	Prints last CMB		

Sources

No.	Name	
1	MARINE	Marine aerosol
2	CRUST	Crustal components (soil dust)
3	TRANSP	Transportation sources (Portland, 1978)
4	TRANS	Transportation sources (Medford, OR 1980)
5	RESOIL	Residual Oil Combustion
6	CASORC	Calcium source (cement dust)
7	$VBURN_1$	Agricultural grass burning
8	$VBURN_2$	Wood burning
9	STEEL	Electric arc furnace
10	FERRO	Ferromanganese furnace
11	RSDNVC	Residual non-volatile carbon
12	$SECNO_3$	Secondary nitrate
13	$SECSO_4$	Secondary sulfate
14	SECCAR	Secondary carbon
15	SECVC	Secondary volatile carbon
16	DUMMY	Disregard

Table 5. Source Composition Data, Portland, Oregon (weight percent of mass)*

Fine Particulate Composition (<2.0μ)

Source	OC	EC	NO_3	SO_4	F	Na	Mg	Al	Si	S	Cl	K
1. Marine	--	---	---	10	---	40.0	4.8	---	0.0	3.3	40.0	1.0
2. Continental Dust	4.32	0.59	---	0.0	0.0	0.69	1.76	11.7	25.4	.07	0.0	1.0
3. Urban Dust	11.8	1.85	0.0	0.42	0.0	1.25	1.30	8.84	22.3	.37	0.0	1.03
4. Leaded Auto Exhaust	50.0	3.8	0.91	1.3	0.0	0.0	---	1.1	.82	.4	3.0	.072
5. Residual Oil Comb.	7.0	3.1	0.65	48.1	0.05	3.5	0.0	0.53	.96	13.3	0.0	.28
6. Vegetative Burn 1	59.0	3.5	5.1	1.6	0.0	0.65	0.0	1.44	.89	.48	5.55	.60
7. Vegetative Burn 2	47.0	4.4	2.0	5.0	0.32	0.33	0.0	0.45	.49	1.6	9.9	6.5
8. Kraft Recovery Boiler	1.7	0.22	0.0	40	0.0	12.7	0.63	0.25	.15	11.7	1.8	1.5
9. Sulfite Recovery Boiler	0.0	0.0	0.3	56	0.0	2.5	0.73	0.0	.40	12	.58	30.0
10. Hog Fuel Boiler	0.0	0.0	0.51	33.8	0.15	3.4	0.0	0.24	.76	8.8	9.5	22.4
11. Aluminum Processing	3.9	2.3	0.41	4.4	6.0	4.1	2.8	27.0	.34	1.4	1.33	.22
12. Steel Electric Furnace	0.0	0.0	0.0	2.5	0.0	1.26	6.5	0.65	5.0	1.9	1.85	.92
13. Ferromanganese	9.0	1.5	5.7	4.2	0.29	3.1	0.0	0.64	.99	1.7	.42	10.5
14. Carborundum	13.6	55.0	1.6	16.0	0.05	0.12	0.78	0.35	3.5	4.8	1.7	.79
15. Glass Furnace	0.0	0.0	0.62	65.0	0.54	9.2	0.0	0.19	.25	11.3	.06	1.37
16. Carbide Furnace	7.3	1.2	0.57	3.2	0.0	0.92	2.4	0.58	2.5	1.6	1.05	1.25

Coarse Particulate Composition (2.0-20 μm)

Source	OC	EC	NO_3	SO_4	F	Na	Mg	Al	Si	S	Cl	K
1. Marine	0.0	0.0	0.0	10	0.0	40	4.8	0.0	0.0	3.3	40.0	1.4
2. Continental Dust	4.32	.59	.01	.004	.002	1.3	1.2	7.2	29.7	0.0	0.0	2.2
3. Urban Dust	3.34	1.55	.02	.074	.008	1.75	1.54	6.6	28.0	0.0	0.0	1.03
4. Leaded Auto Exhaust	50.0	3.8	.91	1.3	0.0	0.0	0.0	1.1	.82	.4	3.0	0.72
5. Residual Oil Comb.	7.0	3.1	.65	48.1	.052	3.5	0.0	.53	.96	13.3	0.0	.28
6. Vegetative Burn 1	59.0	3.5	5.1	1.6	0.0	.65	0.0	1.44	.89	.43	5.55	.60
7. Vegetative Burn 2	47.0	4.4	20.0	5.0	.32	.33	0.0	.45	.49	1.6	9.9	6.5
8. Kraft Recovery Boiler	15.8	1.8	0.0	11.8	0.0	5.3	0.0	.28	.13	3.3	2.9	.40
9. Sulfite Recovery Boiler	0.0	0.0	.3	56.0	0.0	2.5	.73	0.0	.40	12.0	.58	30.0
10. Hog fuel Boiler	11.1	4.3	.2	1.5	.11	.69	.46	.28	.96	.59	.83	1.3
11. Aluminum Processing	0.0	1.6	0.0	1.7	4.2	2.4	2.7	31.3	.097	0.0	1.2	0.0
12. Steel Electric Furnace	0.0	0.0	0.0	2.5	0.0	1.26	6.5	.65	5.0	1.95	1.85	.92
13. Ferromanganese	9.0	1.5	5.7	4.2	.29	3.1	0.0	.65	.99	1.7	.42	10.5
14. Carborundum	4.6	24.0	.83	1.6	0.0	.26	0.0	2.8	12.0	.41	.99	.72
15. Glass Furnace	0.0	0.0	.62	65.0	.054	9.2	0.0	.19	.25	11.3	.06	1.37
16. Carbide Furnace	4.5	3.6	0.0	.93	0.0	.43	1.25	.86	2.9	.54	.96	.48

SOURCE: Cooper (Reference 20)

* See Appendix I