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Fine Particle Emissions from Stationary and Miscellaneous Sources in the South Coast Air Basin. Final Report

KVB, Inc, Tustin, CA

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Prepared for

California State Air Resources Board, Sacramento

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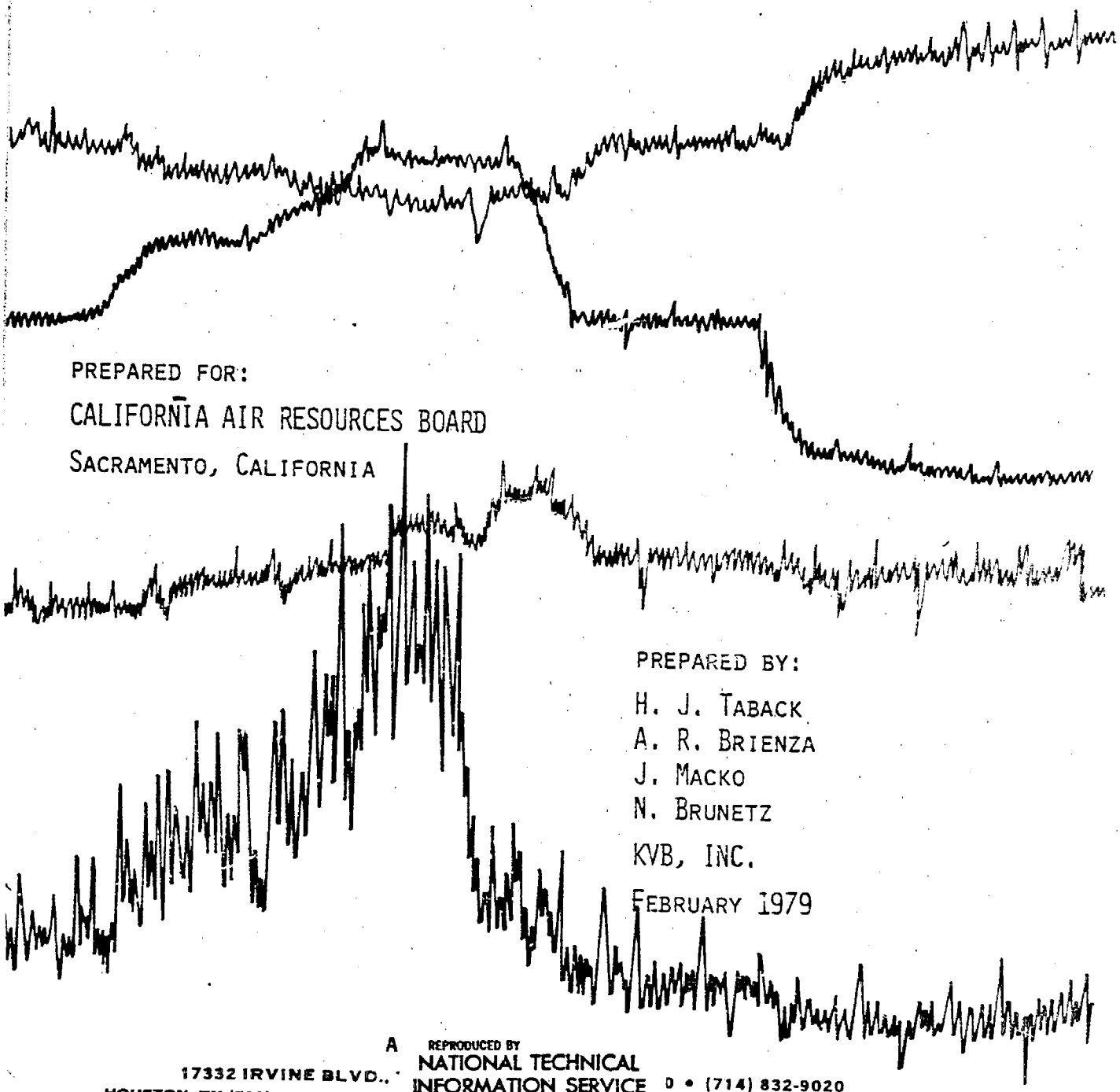
FINE PARTICLE EMISSIONS FROM STATIONARY AND MISCELLANEOUS SOURCES IN THE SOUTH COAST AIR BASIN

FINAL REPORT

KVB 5806-783



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ABSTRACT

An investigation of fine particulate emissions from stationary and miscellaneous sources in the greater Los Angeles area was conducted. The objectives were to help provide information on the origin of the ambient aerosol (haze) and to develop a basis from which to plan control strategy. The program results included extensive field test data, an inventory of total suspended particulate (TSP) emissions, a comprehensive profile on these emissions (i.e., by size distribution and chemical composition) and recommendations of alternative methods of emission control. The particulate inventory was delivered to the ARB in the form of computer print-outs and magnetic tapes. The emission profiles developed on the program were presented as an appendix to this report. These profiles divide the TSP emissions by weight percent into four categories, >10μm, 3-10μm, 1-3μm, and <1μm. Within each category, the chemical composition is tabulated in weight percent. These data include: elemental composition (by X-ray fluorescence); sulfate and nitrate composition (by wet chemistry); and carbon content (by carbon analyzer) in the forms of volatile, carbonate, and total carbon.

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SECTION 1.0
OVERVIEW

1.1 INTRODUCTION

In order to characterize air quality in the California South Coast Air Basin (SCAB) and to provide information on which to base control strategy decisions, the ARB has sponsored a series of programs to inventory emissions from stationary sources and investigate the systems in place for their control. The NOx, SOx and VOC* programs have already been completed and the present program documents the work performed to provide the same information for fine particulates.

Air-suspended matter having particle diameters of less than 10μm is defined as fine particulates. Emitted from stationary sources, fine particulates contribute to the ambient aerosol, causing haze or reduced visibility, and constitute a human health hazard. Because of their visibility, some of the earliest efforts to control air pollution were directed at particulate emissions. As a result, the mass flow of particle emissions has been reduced by 95% or more from what prevailed under previously uncontrolled conditions. Because of the classifying nature of the control processes applied, however, the remaining particulate emissions are in the fine particle range. This material tends to remain suspended in the ambient air and, compared with coarser particle ranges, constitutes the greatest health hazard.

Fennelly (Ref. 1-1) indicates that for very fine (<1μm) particles that enter the pulmonary system, more than 30% will remain there. In considering a fine particulate standard recently, the U.S. EPA decided that particles <15μm are in the respirable range. In combustion sources, KVB (Ref. 1-2) and others (Ref. 1-3) have found that the smaller particles often have higher concentrations of toxic metals than do larger particles. This effect is due

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*Volatile Organic Compounds

to selective condensation in the cooling gas. Friedlander (Ref. 1-4) identified fuel-oil fly ash as a significant constituent in the ambient aerosol of the Basin.

Particles having diameters of 0.3 to 1.0μm are considered to be most effective in light scattering and, therefore, haze production. This is because this size range corresponds to the wavelength range of visible light. Thus, while emissions of (coarser) particulates in the Basin have been greatly reduced as a result of applied controls, fine particle that are still emitted by stationary sources contribute significantly to reduced visibility and increased health hazards. In view of these considerations, a study of the persistent fine fraction of particulate emissions was considered justified. A contract was accordingly awarded by the ARB, resulting in the work described here.

The objectives of this program were to:

a. Characterize the emissions of fine particulates from stationary sources in the South Coast Air Basin and Ventura County in terms of:
   - identification and location of point and area sources
   - individual source annual emission rates
   - seasonal and temporal operational variations
   - particle size distributions
   - predominant chemical compositions

b. Report the above data (excluding chemical compositions) in the EPA's Emission Sub-system format on IBM-compatible magnetic tape.

c. Generate the following computer print-outs or typed reports:
   - Application Category Report
   - Geographic Location Listing (10 km grid)
   - Emission profile listing by SCC Code

d. Provide particle size distribution and chemical composition data in the form of emission profiles

e. Assess the cost effectiveness of potential methods of reducing the emissions identified.

1.2 SUMMARY AND CONCLUSIONS

In order to accomplish the above objectives, the first steps undertaken were: to prepare a preliminary inventory of total suspended particulates (TSP) without consideration of particle size or composition; to identify the major emission sources; and to determine the distribution of emissions among the various source types.

On the basis of this preliminary inventory, a field test program was next conducted to characterize emissions from the sources selected, emphasizing those source types producing the greater amounts of emissions. Seventy-eight particulate sampling runs were then made, 40 using the EPA Source Assessment Sampling System (SASS) and 37 employing a modified EPA Method 5 train. In each run particles were collected in three cyclones with particle size cuts of 10, 3 and 1 μm followed by a backup filter and water impinger. Whenever catches in excess of 100 milligrams were acquired, they were analyzed for chemical composition. A summary of the sources tested is as follows:

Source Type	No. of Runs
Utility Boiler	18
Industrial Boiler	10
IC Engine	3
Hog Fuel (Woodchip) Boiler	1
Gypsum Plant	1
Brick Plant	2
Cement Plant	2
Glass Furnace	6
Fiberglass Plant	2
Asphalt Roofing Plant	2
Asphalt Paving Plant	2
Rice Dryer	2
Carob Plant	2
Heat Treating Process	2
Sand Blasting Process	2

Open Hearth Plant	2
Spray Booth	4
Boric Acid Plant	2
Fertilizer Plant	2
Wood Processing	5
Process Heater	1
Fluidized Bed Catalytic Cracking (FCC Unit)	1

In preparing for the field test program a commercial SASS unit without the standard organic module was acquired along with a commercial Method 5 unit. With the assistance of the Southern Research Institute a set of three cyclones having the same cut sizes as the SASS train were designed and fabricated for the Method 5 train. Subsequently, both the SASS and the Method 5 cyclone sets were calibrated at 400 °F using sperical aluminum powder. At flow rates of 4 and 1 SCFM, respectively, the results were as follows:

Nominal Cut Size, μm	SASS D_{50}*, μm	Method 5 D_{50}*, μm
10	9.2	8.3 (9.1)†
3	3.8	1.9 (4.1)†
1	1.3	0.6 (1.2)§

*D_{50} is the aerodynamic diameter at which 50% of the particles would be retained in the cyclone and 50% would pass through.

†The numbers in parenthesis are the D_{50}'s obtained by Southern Research on identical cyclones using a vibrating orifice aerosol generator calibration technique (See Section 3.2.1).

§The value of (1.2) shown was not measured directly by Southern Research but was derived from measurements at a lower temperature.

Particle size distributions were calculated for each particulate sampling run. Chemical analysis of the particulate catches consisted of X-ray fluorescence analysis for elemental composition, wet chemistry for nitrate and sulfate content, and carbon analysis for volatile, carbonate, and total carbon values.

From these data--plus data found in the literature--emission profiles were prepared for 81 of the 135 Source Classification Codes which are found in the Basin. The profiles divide the TSP emissions by weight percent into

four categories: >10μm, 3-10μm, 1-3μm and <1μm. The XRF analysis, sulfates, nitrate and carbon composition are listed in weight percent for each size category.

The next step in the program was to generate a final inventory. The ARB provided Emission Information Subsystem (EIS) data files for the South Coast Air Quality Management District (SCAQMD), which includes Los Angeles, Orange, Riverside, and San Bernardino Counties, and the Ventura Air Pollution Control District (VAPCD), along with a breakdown of human population data for the Basin on a 1 Km grid map. The EIS data were the basis for the KVB final inventory. The emission factors in the EIS files were reviewed by KVB and adjusted where necessary by applying correction factors determined from data obtained in tests of specific sources or from data for a group of sources identified with a certain Source Classification Code (SCC) number. The emission profiles were keyed to the specific sources. Additionally, source types not contained in the EIS files, primarily area sources, were added to the data base.

The final inventory was delivered to the ARB under separate cover as computer print-outs and magnetic tape files. The primary elements delivered are as follows:

- a total suspended particulates report with 10 km-grid mapping
- a total suspended particulates report by ARB application category
- a plant index
- an emission profile listing (Appendix A of final report)
- an SCC report
- a point source emission file in EIS format (tape)
- an area source file (tape)
- an SCC report file (tape)

The inventory, which has the time frame of 1975-1976, shows total suspended particulate emissions of 510 tons/day. Of this, 385 tons/day derived from miscellaneous area sources, such as fugitive dust (290 tons/day) sea salt (55 tons/day), automotive tires and brakes (30 tons/day), and various forms of open burning (12 tons/day). Of the 125 tons/day emitted by point

sources, 28 percent came from mineral sources, notably one sand and gravel and one brick manufacturing plant (both in Ventura County). Utility boilers accounted for 27% of the point source emission, while the entire category of "Combustion of Fuel" accounted for 30% of the point source emissions.

Over 90% of the total emissions (point and area source) have a particle size of less than ten μm. This assessment was based on an analysis of available emission profiles for the various application categories. It should be pointed out, however, that the major category, "Miscellaneous Area Sources," here includes only particulate contributions of 10μm and smaller. A summary of the overall TSP and fine particulate emissions for the period covered is as follows:

Application Category	TSP Tons/Day	Fine Particle (<10μm) Tons/Day
Petroleum	2.1	1.2
Solvent use	3.2	2.1
Chemical	1.5	1.4
Metallurgical	11.5	10.4
Mineral	35	6.8
Combustion of fuel	38	35
Food and agriculture	30	24
Wood processing	0.4	0.2
Waste burning	1.6	1.1
Misc. industrial	1.2	0.5
Misc. area sources	385	385
Total	510	468

From these totals, it can be seen that 66% of the particulates emitted from point sources in the Basin were in the fine (<10μm) particle size range.

Table 1-1 summarizes the TSP particulate emissions of both point and area sources by application category. As given, area sources account for 80% of the TSP. In this connection, it should be pointed out that the Table 1-1 data and that tabulated just above do not reflect fugitive dust emissions attributable to "paved road travel." This major classification comprises materials released from roadbeds, including deposited dusts but not automotive exhaust particulates or matter released from tires or brakes. Paved road travel emissions and the rationale for their omission in these totals are explained in Section 2.3.3.

TABLE 1-1. EIS/KVB TSP PARTICULATE EMISSION INVENTORIES
Tons/Year

Application Category	No. Point Sources	1975-76 EIS/KVB File		
		Point Sources	Area Sources	Total
Petroleum		750		750
Production	34	50	0	50
Refining	25	600	0	600
Marketing	8	100	0	100
Organic Solvent Use		1160		1160
Surface coating	546	1150	5	1150
Degreasing	5	10	0	10
Other	4	5	0	5
Chemical	157	540	0	540
Metallurgical	547	4200	0	4200
Mineral	480	12600	0	12600
Waste Burning	48	75	500	600
Combustion of Fuel		13900		13900
Utility boilers	187	9100	0	9100
Industrial devices	1084	2700	0	2700
Commercial/institut'l	199	600	0	600
Petroleum	316	1500	0	1500
Wood Processing	25	130	0	130
Food and Agriculture	163	460	11000	11000
Miscell. Industrial	72	440	10	450
Unclassified (Misc. Area)	0	0	140,500	140,500
Fugitive dust			105,000	105,000
Forest & structural fires			4,500	4,500
Tires and brakes			11,000	11,000
Sea salt			20,000	20,000
	3900 Sources			
Total, Tons/Year,		34000	152,000	185,830
(Total), Tons/Day		(93)	(416)	(510)

Table 1-2 is a detailed breakdown, with estimated accuracies, of the miscellaneous area sources by county in the SCAB. These estimates involve an overall uncertainty of +65,000 tons/year (180 tons/day) and -36,000 tons/year (-99 tons/day). Unlike the previous two tables, paved road travel emissions are included in Table 1-2.

Figure 1-1 furnishes a spatial distribution of point and area TSP sources based on a 10-km grid map of the SCAB. Each grid element shows the daily emission rate, while Table 1-3 itemizes those grid elements with TSP emission rates greater than 5 tons/day.

Finally, an investigation of control techniques was made. Control techniques reviewed in the report include:

- Mechanical collectors (cyclones, settling chambers, etc.)
- Wet scrubbers
- Electrostatic precipitators
- Fabric filters (baghouses)

Cost data for control systems were obtained from Research-Cottrell and are presented. These data present installed cost as a function of: mean particle size; volumetric flow rate; and particulate loading.

This report consists of five sections, the present discussion comprising Section 1.0. Section 2.0 deals with the emission inventory; it describes the data sources and presents the detailed data used in the inventory compilations. Various summary tables and plots are also presented. Section 3.0 presents the sampling and analysis methodology as well as an assessment of the data quality. Section 4.0 is a detailed discussion of results obtained from each of the tests conducted. Finally, Section 5.0 is a treatment of control techniques and their associated costs of application.

1.3 RECOMMENDATIONS FOR FURTHER RESEARCH

On this program, a maximum effort has been made to perform as many tests as possible within budgetary constraints. There are many additional sources that could not be tested due to lack of time or the availability of

TABLE 1-2. ESTIMATED 1976 AREA SOURCE FINE PARTICLE EMISSIONS SUMMARY[a]

	South Coast Air Basin Counties[b]						(c)	Percent	
	Orange	Los Angeles	River-side	San Bernardino	Ventura	Santa Barbara	Emissions Tons/yr	of Grand Total	Estimated Percent Accuracy
Road & Building Construction	21,000	24,000	7,100	11,000	6,400	1,000	71,000	20.9	+50,-20
Agricultural Tilling	1,300	1,200	3,100	800	3,100	40	9,500	2.8	±25
Refuse Disposal Sites	60	200	20	20	20	6	300	<0.1	±25,-20
Livestock Feedlots	150	3	150	950	5	5	1,300	0.4	±50
Unpaved Road Travel	2,000	14,000	2,000	1,800	2,600	230	23,000	6.8	±40
Paved Road Travel (d)	33,000	140,000	7,600	12,000	8,800	3,100	200,000(d)	58.8	±50
Fugitive Dust--Subtotal							305,000	89.7	
Forest Fires	120	700	600	430	530	50	2,400	0.7	+50,-20
Structural Fires (e)	40	160	10	15	10	5	200	<0.1	+100,-20
Fireplaces	70	280	30	60	20	10	500	0.1	+100,-10
Residential Natural Gas	20	90	5	10	10	5	100	<0.1	±25
Cigarettes	130	520	30	50	30	10	800	0.2	+20,-50
Agricultural Burning	20	50	30	--	400	10	500	0.1	±25
Combustion--Subtotal							4,500	1.3	
Tire Attrition	1,400	5,700	320	490	370	130	8,400	2.5	±20
Brake Lining Attrition	530	2,100	120	180	140	50	3,100	0.9	±20
Automotive--Subtotal							11,000	3.2	
Sea Salt--	4,000	6,700	---	---	3,500	5,800	20,000	5.9	+50,-20
Grand Total							340,000	100%	

a) Emission estimates are based on particles ≤ 10 μm
b) Includes only that portion of County within SCAB
c) Rounded to three significant figures
d) A large (but unknown) percentage of the 200,000 tons/year is assignable to other area source categories only some of which were studied on this program. For this reason (see Section 2.3.3 A-6) it was not included in the final inventory count as indicated in Table 2-18.
e) Includes property, contents and vehicle loss.

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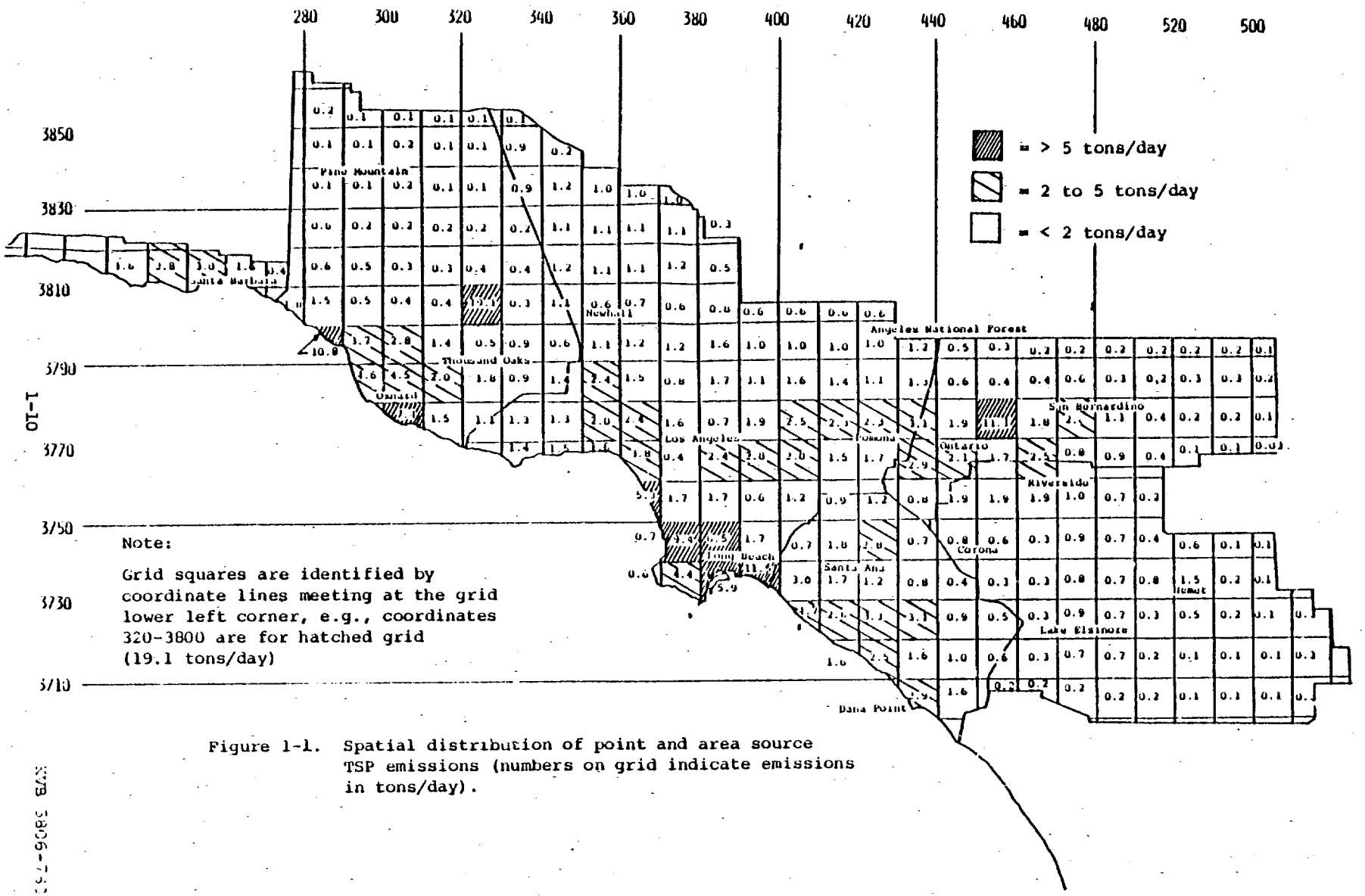

Figure 1-1. Spatial distribution of point and area source TSP emissions (numbers on grid indicate emissions in tons/day).

TABLE 1-3. GRID-ZONES HAVING ESTIMATED EMISSION RATES IN EXCESS OF 5 TONS/DAY

UTM Coor. E/W	UTM Coor. N/S	Nearest City	Emissions (Ton/Day)	Principal Source Type
280	3790	W. Ventura	10.8	Ceramic manufacturing
300	3770	Pt. Mugu	7.4	Elect. gen. & area.
320	3800	Fillmore	19.1	Sand and gravel
360	3750	LA Airport	5.3	Area
370	3740	Torrance	9.4	Elect. gen. & area
380	3740	Paramount	6.4	280 Pt. sources & area sources
380	3730	LA Harbor	5.9	250 Pt. sources & area sources
390	3730	Long Beach	11.5	Elect. gen. & area
450	3770	Fontana	11.1	Steel manufacturing

the test unit. As mentioned earlier, only 70% of the SCC's found in the Basin had emission profiles developed for them. In most cases a source type has had to be characterized by the emission from only a single plant tested.

To give a greater universality to the emission profiles developed in this program and to develop additional new profiles, it is recommended that further testing be considered. Particulate testing with the full characterizations achieved on this program is expensive, particularly if compared to any other type of pollution testing. The trains used in this program performed adequately, but it is questionable if this would have been true had more economical approaches been applied. Therefore, to insure that these presently developed data are to be meaningfully used with any future new data that are generated, it is recommended that the same general procedures used on this program be employed in any subsequent efforts.

REFERENCES

SECTION 1.0

1-1 Fennelly, P. E., "Primary and Secondary Particulates as Air Pollutants," JAPCA, July 1975.

1-2 Cato, G. A., "Field Testing: Trace Elements and Organic Emissions from Industrial Boilers," EPA 600/2-76-086b, KVB, Inc., October 1976.

1-3 Goldstein, H. L. and Siegmund, C. W., "Influence of Heavy Fuel Oil Composition and Boiler Combustion Conditions on Particulate Emissions," Env. Science & Tech., November 1976.

1-4 Friedlander, S. K., "Chemical Element Balances and Identification of Air Pollution Sources," Env. Science & Tech., 7:235, 1973.

SECTION 2.0

INVENTORY

2.1 DATA SOURCES

The data used in this particulate emission inventory were obtained from the following sources:

1. Various government agency files
2. Field testing
3. Literature
4. Engineering analyses
5. Personal contacts with government and industry personnel.

The final inventory was compiled using the South Coast AQMD and Ventura County APCD EIS* (Ref. 2-1) data bases for the major point sources, and a KVB-developed area source file. The EIS files were checked for completeness and emission data credibility. Adjustments in emission factors were made as required based on information acquired from the field test program and other studies performed during the program. The following key data were contained in the EIS data base:

1. Plant name, address, ID No., etc.
2. Standard Industrial Code (SIC)
3. Source Classification Codes (SCC)
4. UTM Coordinates
5. Stack height
6. Pollutant identification
7. Emission factor
8. Throughput rates
9. Estimated emissions
10. Seasonal variations
11. Operating period (hr/day, day/week, week/yr)

*Emission Inventory Subsystem/Permit and Registration

Field test data were used to formulate emission profiles and to develop emission factors for new sources or check those factors on sources already characterized by the Districts or the EPA in AP-42 (Ref. 2-3).

Other sources of information included personal contacts with various industry associations and government agencies (especially the ARB, EPA Office of Air Quality Planning and Standards in Durham, EPA Region 9, local air pollution districts, and the Southern California Association of Governments (SCAG). The data received from these sources were used to derive additional emission profiles in a form compatible with the inventory format.

From summaries of the EIS files, a breakdown of total particulate emissions into industrial source categories (referred to hereafter as ARB Application Categories) for each country was tabulated as shown in Figure 2-1. A summary of emissions by application categories for the entire SCAB is given in Figure 2-2a. The fraction of the total particulate emissions from each county is given in Figure 2-2b. From these breakdowns of emissions into application categories, the Phase II field test program was developed. The distribution of the field tests among the various application categories is shown in Figure 2-2c.

2.2 DATA MANAGEMENT

The data to be processed as part of the final particulate emission inventory included:

1. EIS data for major and minor point sources of SCAQMD
2. EIS data for major and minor sources of Ventura County
3. Additional area data for sources such as forest fires, fugitive dust, tire attrition, and agricultural burning
4. Emission profile number vs SCC number
5. Population distribution by one kilometer grid
6. Emission factor adjustments to EIS data

The available EIS data processing software was incorporated for processing the EIS data. In this system, individual sources could be modified,

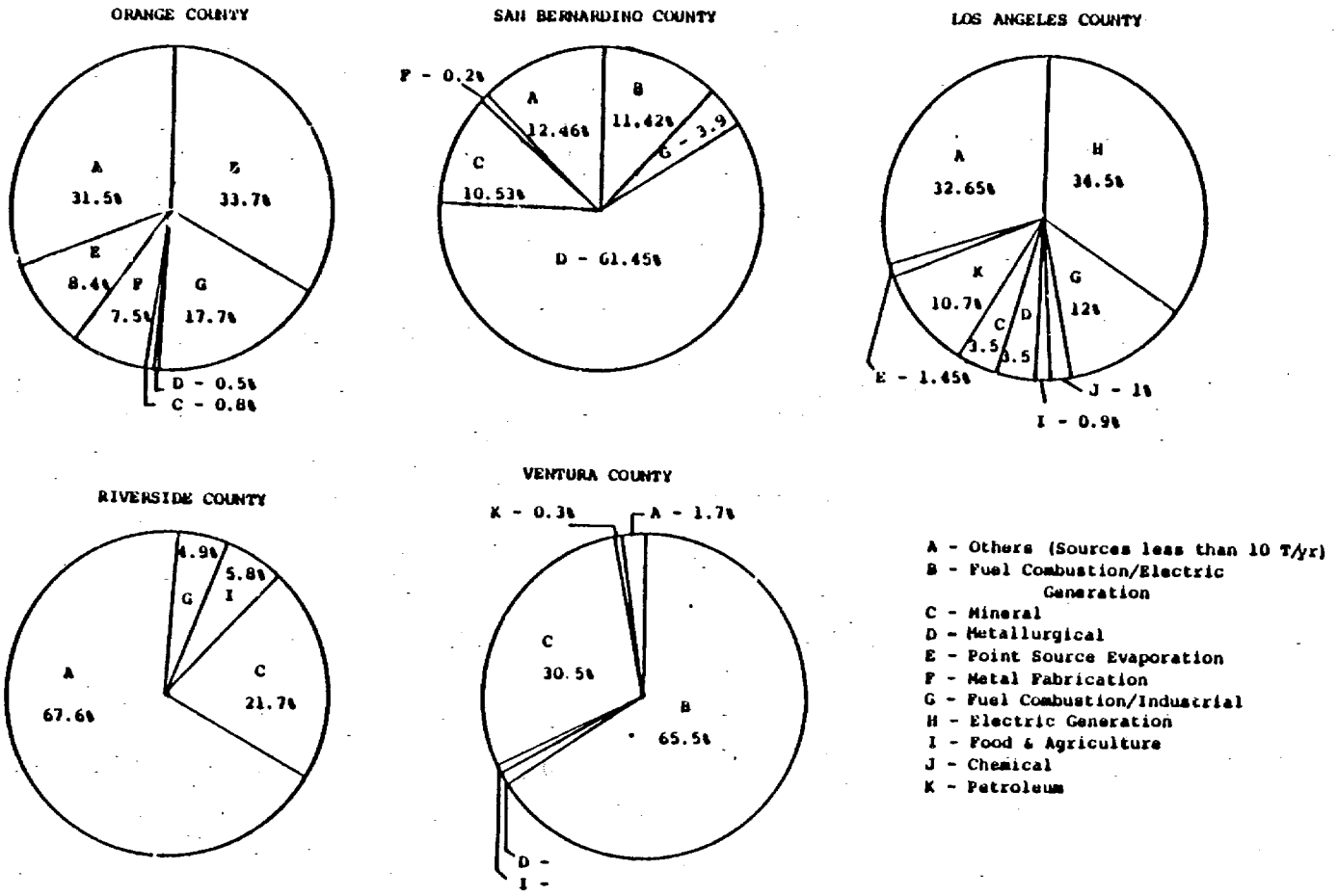

Figure 2-1. Breakdown of particulate point sources into ARB application category for each county in the SCAB.

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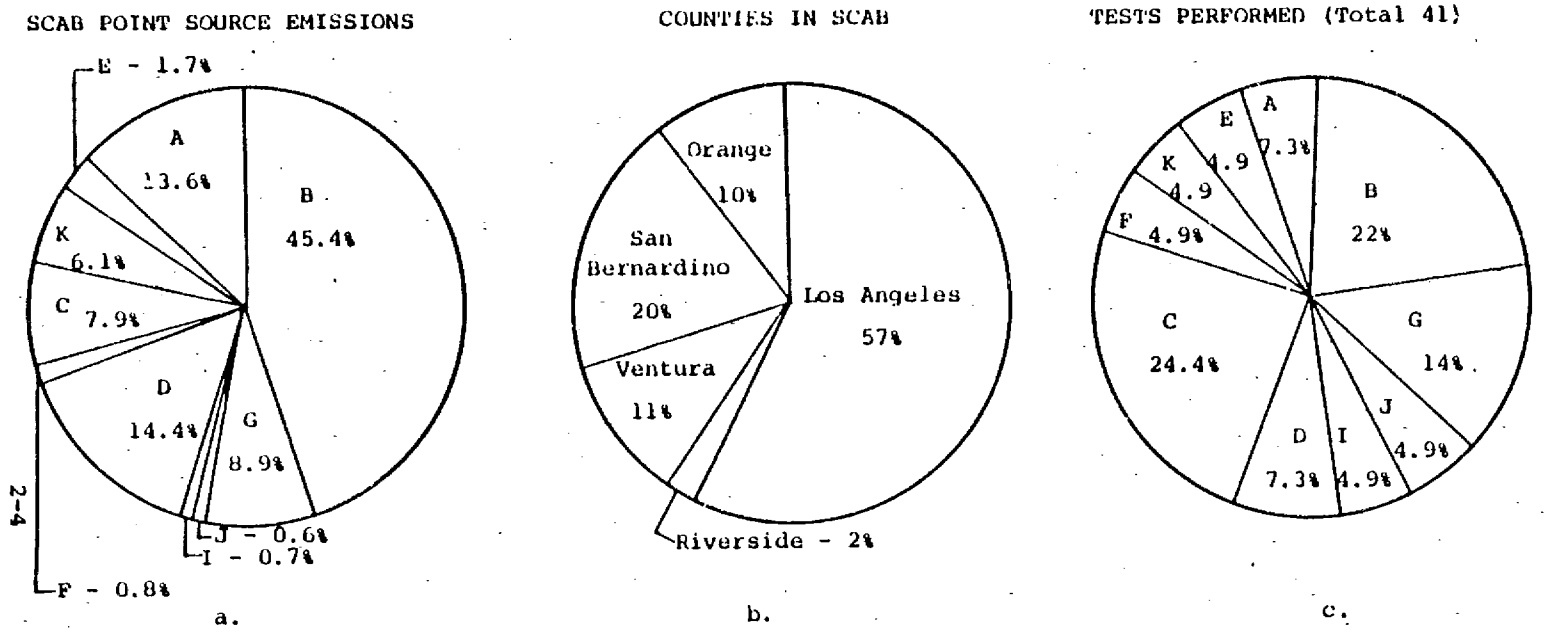

A - Others (Sources less than 10 T/yr)
B - Fuel Combustion/Electric Generation
C - Mineral
D - Metallurgical
E - Point Source Evapoaration
F - Metal Fabrication
G - Fuel Combustion/Industrial
H - Electric Generation
I - Food & Agriculture
J - Chemical
K - Petroleum

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2-4

Figure 2-2. a. Composite of point source emissions into source classification for SCAB.
b. Fraction of point source emissions from each county.
c. Fraction of field tests done for each source classification.

added, or deleted. KVB added a feature which also permitted the data to be modified by SCC number. For example, the emissions in the EIS data base from certain utility boilers (identified by a specific SCC number) appeared to be too high based on recent test data. The emissions from those units were modified by one correction factor applied to all the emissions of that specific SCC number.

For each SCC number an emissions profile key was assigned, if available. Each emission profile provides a breakdown of the total suspended particulate (TSP) emissions into four size ranges (% by weight) and for each size range a chemical compositional breakdown is provided (% by weight). Storage and Retrieval of Aerometric Data (SAROAD) codes were assigned to each chemical species identified. Each profile also contains information concerning the method of determining the profile and rating number indicating the relative velocity of the profile. The 49 profiles developed during the program are presented in the Appendix, Volume II. SCC's for which no profiles are available were assigned a "not classified" key number.

Area source emission rates were added to the EIS data file using the emission factors and throughput data presented in Section 2.3.4. These sources, including natural emissions, fugitive dust, and tire attrition, constituted a large portion of the total emissions in the Basin. Since a standard format was not yet available for describing emissions not meeting the EIS point source criteria, KVB chose to develop an area source data base for this purpose based on general guidelines proposed by the ARB (Ref. 2-4). The format was designed to allow description of emissions by their one kilometer grid location and process (or activity).

Each source in the inventory was categorized by a Source Classification Code (SCC) number which was occasionally qualified by the SIC number. (SCC numbers for area sources were created together with ARB personnel.) A file was created with all information relative to these SCC numbers, the emission correction factors to be applied to all sources with the given SCC/SIC number, the profile key to identify the profile for this source type, the relevant ARB application category, and summer or winter differentials to be used to alter emissions seasonally if warranted by the source type. This SCC file was used as the major system link between sources and their profiles. From these data files a final inventory was produced in the form of various

computer reports and magnetic tapes which were delivered to the ARB under separate cover. A description of the final inventory reports and a discussion of the results are presented in Section 2.4. First, however, is a discussion of the various technical considerations (i.e., emission factors, emission profiles, etc.) that were used in preparing the inventory.

2.3 ENGINEERING ANALYSIS

2.3.1 Point Source Emission Factors

There has been considerable interest in the development of emission factors that can be employed to estimate emissions from specific sources based upon a knowledge of the pertinent operating characteristics of the source. Such procedures are in common use throughout the country by local control agencies to estimate air pollution emission rates for point and area sources. One of the primary objectives of the ARB fine particulate emission study was to critically evaluate the emission factors for fine particulate emissions used by the SCAQMD and local APCD's and to develop new emission factors for sources not contained in the EIS data system that were applicable to the South Coast Air Basin. The following discussion outlines the methodology employed during the analysis for point sources. Emission factors for area sources are discussed in Section 2.3.3 since they required a significantly different approach.

Point source emission factors for industrial point sources in the Basin were divided into nine application categories: (1) the combustion of fuels, (2) evaporative emissions, (3) mineral products, (4) metallurgical, (5) petroleum, (6) wood operations, (7) food and agriculture, (8) metal fabrication, and (9) chemical uses. In general, emission rates from these sources had been calculated by the local control agencies using emission factors and the appropriate information on fuel usage, product throughput, etc. The combustion of fuel categories represented a large part of the total particulate emissions in the Basin and therefore was given primary emphasis in the analysis of point source emission factors.

A. Approach--

A comprehensive listing of point source emission factors may be found in the EPA publication, "Compilation of Air Pollution Emission Factors" (Ref. 2-3), hereafter referred to as "AP-42." The SCAQMD has its own emission factors which have been employed in the process estimating emission rates for industrial point sources contained in the EIS data file. To a certain extent, these emission factors were the same, because frequently SCAQMD data were used as the basis for the development of AP-42 emission factors. In other instances the emission factors differed because the SCAQMD sometimes based its emission factors on its own test data in preference to using AP-42 values.

A specific objective of this study was to examine the point source emission factors used by the SCAQMD and AP-42. This was done for three reasons. First, much of the data used to generate emission factors for specific source types stem from studies conducted as far back as the 1950's. Second, certain emission factors listed in AP-42 intended for use nationally may not necessarily represent conditions in the Basin. Finally, it was necessary to generate entirely new emission factors where none had existed previously.

Field tests were conducted to provide data to assist in emission factor evaluation and development. In addition, data from several related projects, specifically oriented to improving AP-42 emission factors, have been incorporated into this analysis. In most cases, these studies had been directed at conditions within the Basin making them directly applicable to the current study.

Comparisons have been made between the emission factors used by the SCAQMD, those contained in AP-42, and those generated in this and related studies. Where KVB felt that available data disagreed with the SCAQMD emission factors, correction factors were applied to the emission rates listed in the EIS data system to update these emission estimates. The intent was to have the EIS data file, delivered to the ARB, reflect the best and most recent information available. This was a vital part of the improvements incorporated into the final KVB data base.

B. Results--

In this section the various adjustments made to the SCAQMD emission factors in their EIS file prior to running the final TSP inventory will be discussed. The results are tabulated in Table 2-1 and explained in the following discussion. In the table for each source type and applicable SCC number, the AP-42 (Ref. 2-3) emission factor is listed along with emission factors obtained from the SCAQMD EIS file and derived from KVB test data. Each emission factor column provides both control ("con") and uncontrolled ("unc") emissions data where available. For the SCAQMD the data are presented as "specific" or "overall" from the standpoint of whether the data applied to one particular source or whether it represented a composite of data from multiple sources. The SCAQMD value shown in the table is the emission factor that was in the AQMD's EIS data base used for the final ARB inventory run. At the right side of the table are two columns indicating whether or not a change was made to the AQMD value. If no change was made, the "EIS Correction Factor" column has a 1.0 and the next column "Final Inventory Emission Factor" contains a value identical to the AQMD column.

1. Combustion of fuel -- Residual oil combustion from power plants represents the largest point source type for TSP emissions in the Basin accounting for over 45%. This source type was given a great deal of investigation and analysis considering not only the AP-42 emission factor, the field test data (18 tests) from this program, but other oil-fired utility boiler test data from the KVB confidential file of client data. Figure 2-3 summarizes these data.

Note that the data points in Figure 2-3 are filled or open, with the filled points indicating the total particulate catch including impinger and the open points indicating the EPA Method 5 data which do not include the impinger catch. For the tests conducted on this program, points were plotted both with and without the impinger catch.

It was the decision of the ARB that for this inventory the TSP should include the impinger catch. But most of the comparison data were for the EPA Method 5. Therefore, the data were analyzed on the no-impinger basis first and then on the total catch basis.

TABLE 2-1. TSP EMISSION FACTOR SUMMARY AND ANALYSIS

Description	Applicable SCC Code	Units	AP-42 Aug. '77 Unc	AP-42 Aug. '77 Con	SCAQMD Specific Unc	SCAQMD Specific Con	SCAQMD Overall Unc	SCAQMD Overall Con	KVB Unc	KVB Con	Other Unc	Other Con	EIS Proposed Correction Factor	Final Invento. Emission Factor	Comments
a. COMBUSTION OF FUELS															
Residual Oil Combustion-- Power Plants	1-01-004-XX	lb TSP/ 10^3 gal	5.5 (front 1/2) 0.25%S				7.14 (total)		3 (total)		(a)		0.42	3.0	
Distillate Oil Combustion-- Industrial	1-02-005-XX	lb TSP/ 10^3 gal	7.0 (front 1/2) 0.4%S				"		7.2 (total)		1.4-4.7 (front 1/2)	[b]	1.0	7.14	
Refinery Gas Process Heaters	3-06-001-04	lb TSP/ $10^6 ft^3$	20 (total)		22.1		27 (total)		9 (total)		---		1.0	27	
CO Boiler FCC Unit	3-06-002-01	lb TSP/ 10^3 bbl through-put	45 (range 7-150)			4.3 [d]		14 (total)		32 [e] (total)		25 [c] 32 [c]	1.0	14	Corrected specific emissions
Hog Fuel Boiler	1-03-009-02	lb TSP/ ton burned	38 (total)	3.8						3.6		2.5 [f]	1.0	3.8	None in the Basin

(a) See Figure 2-3

(b) Cato, G. A., et al., "Application of Combustion Modifications to Control Pollutant Emissions from Industrial Boilers," EPA 600/2-76-086a.

(c) EPA Source Test Data, September 1977.

(d) Value in EIS for source tested by KVB.

(e) ESP working poorly during test

(f) BWR Assoc. TSP test June 27, 1977 - throughput not specified; assumed to be 2500 lb/dry wood/hr

(Front 1/2) refers to the EPA Method 5 which requires the impinger catch in the TSP determination

(Total) refers to the ARB method which includes the impinger catch in the TSP determination.

Control Device Code

001 - Scrubber
007 - Mech. collector (cyclone)
012 - Elect. st. precip.
015 -
016 -
018 - Baghouse

TABLE 2-1.[a] Continued

Description	Applicable SCC Code	Units	AP42 unc	AP42 con	SCAPCD Specific EIS Listing unc	SCAPCD Specific EIS Listing con	SCAPCD Overall unc	SCAPCD Overall con	KVB unc	KVB con	Other unc	Other con	Control No.[a]	Control % Eff.	EIS Proposed Con. Fac.	Final Inv. Emis. Fac.
b. MINERAL PRODUCTS																
Gypsum-Calciner	3-05-015-03	lbs TSP/ton prod	90	0.1		0.1				0.2	---		016	99	1.0	0.1
Clay grinding & pulverising	3-05-003-02	lbs TSP/ton prod	96			0.48			0.7	0.1[b]	---		018	99.5	1.0	0.48
Cement Kiln	3-05-006-01 3-90-002-01	lbs TSP/bbl	46	0.05		0.1				0.05[d]	49 ~0.05[e] calc. 0.09[g]		016	99.9	1.0	0.1
Glass Furnace-- gen'l--	3-05-014-01	lbs TSP/ton prod	2		~1.5[c]				1.41		2.25[j]				1.0	1.5
soda lime	3-90-006-08	lbs TSP/mscf	378[f]		250				265.3				none		1.0	250
Fiberglass forming	3-05-012-04	lbs TSP/ton	50			4.8				29	4.37[h] 5.01		wet scrubber 001	99	1.0	4.8
Asphalt Roofing Felt saturators	3-05-001-04	lbs TSP/ton felt	2.0	0.1 calc		0.6				0.3	see foot-note[k]		015	98		0.6
Asphaltic Concrete Batch Plant	3-05-002-01	lbs TSP/ton prod	45	0.1		0.01			34	0.02	12[i] (range) 1-46		018	99.9		0.01
c. FOOD AND AGRICULTURE																
Carob Roaster Direct fired	3-02-002-01 3-90-006-99	lbs TSP/ton pods lbs TSP/mscf	7.6			23			6.1 1333						1.0	23
Rice-Dryer	3-02-999-98	lb TSP/ton thru.		0.3						0.1			screens			

a) Aeros Code Designation

b) Emissions include screening & grinding operations

c) EPA/KVB Test--downstream from cyclone and upstream from baghouse

d) One tenth of a percent change in efficiency accounts for 0.05 lbs/bbl emissions; 99.1% eff. accounts for 0.1 lbs/bbl; 99.9% eff. accounts for 0.05 lbs/bbl.

e) Derived from KVB source test 5300cf Natural Gas/ton glass produced correlation factor

f) Derived from EIS file LA plant 5095, permit #P06882

g) Derived from EIS file Riv. plant 0034, Neds 14 and 15 Oil & Gas fired

h) Derived from EIS file Riv. plant 0020, Neds 31 and 37

i) AP40 May '73, range of thirteen Los Angeles Source Test

j) AP40 May '73, Statistical Analysis of 25 Los Angeles Soutce Tests, p. 775, Particulate Emission Calculated Value 4

k) AP40 May'73, Emissions from Two Installations Venting Asphalt Saturators, Table 110-12, p. 382-3,
0.416 gr/scf, 0.590 gr/scf, 0.535 gr/scf
KVB reported 0.0075 gr/scf and 0.0070 gr/scf downstream fiber filter plus mist eliminator control devices reported 98% overall eff.

$(1 - \frac{0.0077}{0.416}) \times 100 = 98.2\%$; $(1 - \frac{0.0077}{0.590}) \times 100 = 98.7\%$

$(1 - \frac{0.0077}{0.535}) \times 100 = 98.6\%$

TABLE 2-1. Continued

Description	Applicable SCC Code	Units	AP-42 Emission Factor		Emission Factor Rating				EVB		Other		Control		Ely Proposed Correction Factor	Final Inv. Proposed Emission Factor	Comments
					Specific		Overall										
			Emis.	Con	Emis.	Con	Emis.	Con	Emis.	Con	Emis.	Con	Dev.	% Eff.			
d. EVAPORATIVE SOURCES																	
Spray Booth Water base enamel	4-02-005-01	lbs TSP/ ton coating	Not listed		Not listed					10			Water curtain				
Spray Booth Acrylic solvent	4-02-005-99	lbs TSP/ ton solvent coating	Not listed			70				30			002	90			
e. CHEMICAL USERS																	
Boric Acid	3-01-999-99	lbs TSP/ ton prod.	Not listed		3.15				8.33	(a) 0.21			016	98		3.15	Only one in Basin
Fertilizer-Rotary Dryer	3-01-030-01	lbs TSP/ ton processed	80						(b) 1.00				018		1.0		
f. WOOD OPERATION																	
Plywood Sanding		(c) lbs TSP/ hr	5 lbs out of cyclone range (0.2 - 30)		Not listed Rule 219				35	0.6			007	98			
										0.1			018	96			
Plywood Sanding	3-07-007-02	lbs TSP/ ton	Not listed						70	1.2			007	98			
										0.2			018	96			
Wood Resawing		(c) lbs TSP/ hr	2 lbs/hr out of cyclone range (0.03-24)						20	0.2			007	99	0.2 lbs/ hr lumber yard		

(a) Unit upset during test

(b) Raining during test

(c) AP-42 lists sander dust emissions as a control device related lbs/hr emissions and not device related

(d) Based on reported 90% wet scrubber efficiency

TABLE 2-1. Continued

Description	Applicable SCC Code	Units	AP-42 Aug. '77 lbs/ton	SCAQMD Specific lbs/ton	SCAQMD Specific tons/yr	SCAQMD Overall lbs/ton	SCAQMD Overall tons/yr	KVB lbs/ton	KVB tons/yr	Other lbs/ton	Other tons/yr	Control No.	Control % Eff.	EIS Proposed Correction Factor	Final Rev. Proposed Emission Factor	Comments
9. METALLURGICAL OPERATIONS																
Steel heat treating--salt bath	3-09-001-99	lbs TSP/ton process	Not listed	2.0 (d)				3.0	0.31	--	--	018	94.9	1.0		Controlled emissions not listed
Steel sand blasting[c]	3-09-999-99	lbs TSP/ton	Not listed	2105	(a) 1.43 calc	(b) 4%		1530	1.04	--	--	018	99.9	1.0		Controlled emissions not listed
Aluminum smelting--reverb. furnace	3-04-001-03	lbs TSP/ton Al	4.3	New furnace not yet tested		1.1	(c) 0.04	0.01		--	--		--	N/A	0.01	Revised specific source
Iron sintering	3-03-008-03	lbs TSP/ton prod	0.67 22 calc	41	0.73	NA		8.4	1.6	--	--	016	98.2	1.0	0.73	
Steel open hearth or lance	3-03-009-01	lbs TSP/ton	0.35 17.4 98%		0.43	9.3	(c) 0.17	4.2	0.67		(e) 0.11 ±50%	012	98	1.0	0.17	

(a) Columbia Steel Co. 1951 test on new ES", tons of steel not reported.

(b) SCAQMD Memo to all engineers Aug. 5, 1977 from William Hamsond; 4% of the amount of sand used.

(c) SCAQMD Memo to all engineers, Aug. 5, 1977 from William Hamsond.

(d) Control device not listed in EIS printout.

(e) Controlled emissions based on 99.9% control efficiency measured by KVB test crew.

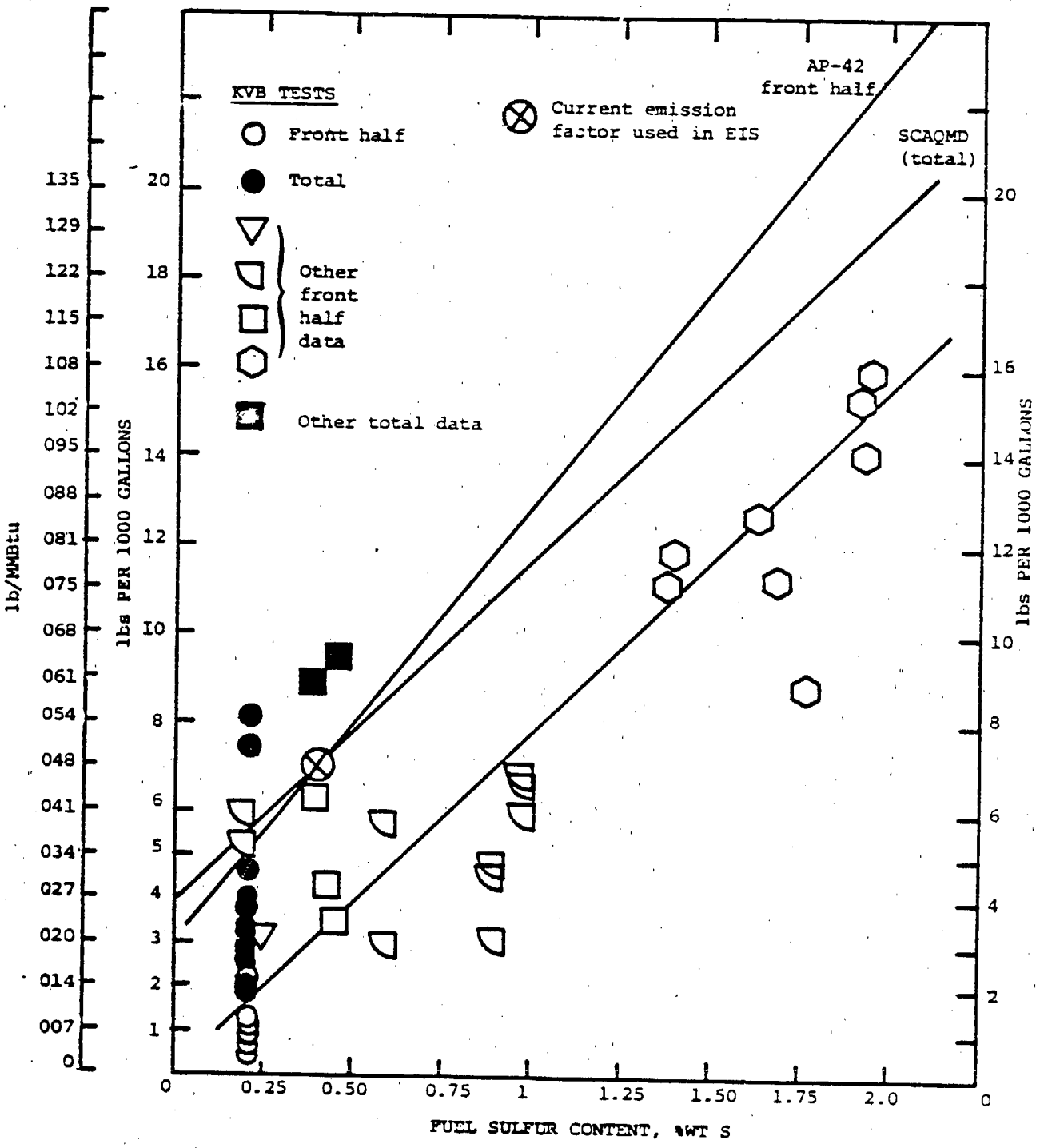

Figure 2-3. Emission factors as a function of fuel sulfur content for utility boilers.

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The AP-42 emission factor curves plotted in Figure 2-3 are substantially higher than any of the KVB test data. The front half data (i.e., without impinger) for the 18 tests conducted for this program (9 SASS and 9 Joy), while there is a significant spread, do agree with the other front half data. The lower curve is the best fit through these data. Since the front data, taken on this program appear to be valid because they are consistent with other data by different crews at different locations, it seems reasonable to assume that the total catch data taken on this program should also be valid. The mean emission factor value for total catch measurements is 3 lb/1000 gal burned which is the value selected for use in the final inventory.

Distillate oil combustion by industrial sources also represents an important industrial source of particulates. Once again it was difficult to make a comparison between AP-42's value for a front half catch and the SCAQMD's value for total particulates. However, there was good agreement between KVB and the SCAQMD. Therefore, no correction factor to the EIS system was felt necessary.

For CO boilers the AQMD did not use a single emission factor but used the test data for each source. A review of the EIS data indicated that the average CO boiler TSP emission was 14.4 lb/1000 bbl throughput. This is on the low end of the AP-42 range but all units in the Basin utilize electrostatic precipitators (ESP). The unit tested by KVB had been listed in the EIS file at the equivalent of 4.3 lb/1000 bbl which was obviously low compared to KVB test data of 32 lb/1000 bbl. It was later learned that the EPA had recently tested the same CO boiler. The EPA used a Method 5 train and a SCAQMD train and measured total emissions (including the impinger) in both cases. The results were 32 and 25 lb/1000 bbl respectively. KVB corrected EIS file for the emissions of the specific CO boiler involved in the tests.

2. Mineral products--Table 2-1b presents a comparison of the emission factors used to estimate the particulate emissions emitted from mineral product operations. Since the SCAQMD used test results from these sources rather than emission factors, the comparison between SCAQMD values and those obtained in this program has been made for a particular unit tested.

The results of the gypsum calciner test conducted by KVB are a factor of 2 greater than that found by the AQMD and that listed in AP-42. The reason for this is believed to be an abnormal baghouse operation on the day of the test as commented on by the operators. No correction was made.

The emission factor for the claygrinding and pulverizing operation for brick manufacturers generated from KVB test data are lower than the values listed in AP-42 (the value in the EIS system). If the fugitive dust from this process could have been included (not tested in this study) the emission factor would be much higher and thus be closer to the AP-42 value. Also the clay was slightly more moist due to rainy weather. This would greatly aid in reducing the emission. Therefore the emission factor used in the current EIS system was left unchanged.

The results of the coal fired cement kiln test indicated that there was good agreement between KVB and AP-42. The SCAQMD's value listed in the EIS however was six times greater than that listed in AP-42 or measured by KVB. A close look at the effects of control device efficiency revealed that a 0.1% change in efficiency results in a 0.05 lb/bbl cement emission increase. Therefore a 99.9% efficiency results in a 0.05 lb/bbl emission factor while a 99.3% efficiency results in 0.3 lb/bbl emission factor. The latter efficiency seemed reasonable for an industrial process. This coupled with the limited number of tests taken was the basis for not initiating an emissions factor change to the EIS file.

The emission factors generated from the results of KVB field testing for the glass furnaces are in good agreement with the values listed in AP-42 and the current EIS system. The emission factors in the EIS system were left unchanged except in the case where there was no listing for a glass furnace. When there was not a listing the controlled emission factor was assigned to the plant. Often other plant data needed to be obtained to make an entry in the EIS system.

In comparing KVB's measured emissions from fiberglass forming operations against those listed in AP-42 and the EIS system it was found that KVB's value was approximately midway between them. A source test conducted by the SCAQMD at a similar plant supports their lower value. Based on the limited number of samples taken and variables in the operation, a point source emission factor change was not felt to be appropriate.

KVB's measured emission factor for an asphalt roofing felt saturator was approximately one-half the value found in the EIS system. It was difficult to use AP-42's value for comparison purposes because it is only given for uncontrolled sources. KVB and the SCAQMD's values are for controlled devices. No correction factor was applied.

In reviewing the EIS computer printout for the asphaltic concrete batch plant tested, a decimal error located in the emission factor was noted and corrected. KVB's measured value supported the now correct SCAQMD value and therefore, no further change was necessary. AP-42's value appeared to be high in this case.

3. Food and agriculture--The carob roaster in Table 2-1c shows agreement between the KVB test results and the AP-42 results but disagreement with the AQMD results. The AQMD emissions were on a million cubic feet basis instead of a ton of product basis as in AP-42. No changes in emissions were made but the AQMD was recommended to change the basis for computing emissions. The KVB results for the rice dryer were in agreement with AP-42. There are no rice dryers in the Basin.

4. Evaporative sources--Table 2-1d presents a comparison of the emission factors used in estimating the emissions from water-based and solvent-based spray paint booths. There is no existing emission factor listing for this category in AP-42. Also. since the SCAQMD used test results from these sources rather than overall emission factors, the comparison between the SCAQMD's values and those obtained in this program has been made for a particular unit tested.

5. Metallurgical operations--Table 2-1g presents a comparison of the emission factors used to estimate the particulate emissions from metallurgical operations. Here again, the SCAQMD used test results from these sources rather than overall emission factors for computing a source's annual emissions.

An absence of emission factors in AP-42 for steel heat treating and steel sand blasting was noted. KVB's measured emissions upstream and downstream of a control device for these operations were difficult to compare against the SCAQMD's uncontrolled values. No corrections were applied.

For the aluminum reverbatory furnaces tested the EIS listing was found to be outdated and in the process of being revised. There was also wide disagreement between the three emission factor sources. The SCAQMD overall emission factor for this operation was found to lie midway between AP42 and KVB. It was therefore felt that the SCAQMD emission factor was best suited.

KVB's measured emission factors for an open hearth steel furnace (oxygen lance) are slightly higher than the SCAQMD's source test emission factor and those listed in AP-42. The reason is that the electrostatic precipitator being used is not as efficient as it had been in the past. This reduced efficiency results in a slightly higher controlled emission factor.

The factor listed in the EIS system was deemed correct and therefore not altered. The SCAQMD's overall emission factor for this category appears to be low. There was not sufficient test information available, however, to critique it with a reasonable degree of accuracy.

2.3.2 Emission Profiles

A. Description--

A unique aspect of the current program was the development of emission profiles -- the identification of the elements in four particle size ranges represented by the TSP emission rates currently given in emission measurements.

A primary objective of this program was to identify the elemental emissions and size distribution for each stationary source type in the Basin. Thus an emission profile was formulated for each Source Classification Code (SCC) emitting particulate material in the Basin. Both point and area sources were included. All plant devices identified by the same SCC and SIC number were given the same emission profile. Conversely, it was important that profiles be truly representative of the device in general. Additional advantages of developing aggregate profiles by SCC number were: (1) estimations based on larger data samples were more statistically reliable than single data samples, (2) profiles were compatible with the EIS concept by describing devices by the SCC number system, and (3) volume of profile data was reduced to a more manageable level.

The initial intent was to provide a profile for each SCC listed in the data base. In many instances, however, an individual profile was found to cover several SCC and SCC/SIC combinations. The profile data base was therefore formulated and indexed by a profile number. Separate profile numbers (with identical specie distributions) were given to SCC/SIC combinations to facilitate data management, specifically the segregation of emissions from devices with similar SCC codes in two different industry classes into the appropriate ARB Application Categories.

In each profile the chemical elements of the particulates were identified by their appropriate SAROAD code for each size range (4 ranges.) A typical profile is shown on the following page. Associated with each emission profile was an estimate of its relative credibility. This estimate of credibility was strictly subjective and has been included to give a relative level of confidence to the specific profile. No statistical significance has been or should be given to these error estimates.

The emission profiles developed in the current study are presented in the Appendix. A profile lists the SAROAD code, elemental name, and percent contribution of each species. The elements are also summed by size distribution. A sample profile is presented on the next page. Two reports are used to relate the profiles to the devices in the inventory. The SCC report (sorted by SCC number and profile number) lists all devices in the inventory and gives the profile number of the profile that describes the emission breakdown for the particular device. The profile file (Appendix) lists the profiles by profile number.

B. Methodology--

Two general approaches were used to formulate the emission profiles: one where only one data point was available to characterize many sources and the other where multiple data points were available. In cases where a profile was available from only one source and that source was believed to be representative of all such source types in the Basin, then that particular source emission profile was used. An appropriate credibility estimate was given to reflect the relative confidence level of these data. It was anticipated early in the program that a significant number of source types would fall into this category due to the limited amount of field tests available. Therefore, test locations were carefully selected on the basis of the representative nature of their emissions to all other devices of that particular type. In this way, data from this source could be assumed to apply to other non-tested sources.

EXAMPLE OF EMISSION PROFILE. OTHER PROFILES LISTED IN APPENDIX.

Title: Utility Boilers (Residual Fuel)

Profile Key: 0006

Source of Data:

X KVB Test

X Literature Data--Ref.*

X Estimate--Basis†

Confidence Level II

Applicable SCC's

1-01-004-01, 1-02-004-01
1-02-004-03, 1-02-005-01
1-02-005-02, 1-02-005-03

Test # 11,12,13,21,22,23,24,32,33

Size Range		>10μm	3-10μm	1-3μm	<1μm	Composite
Wt% TSP in Size Range		3	4	8	85	100
Species	SAROAD Code	Wt% of Species in Indicated Size 0.1% < t < 1.0%				d < 0.1%
Arsenic	12103	d	d	d †	d	d
Barium	12107	t			t	t
Bromine	12109				d	d
Cadmium	12110		d	d	d	
Calcium	12111	t	t	t	10	10
Chromium	12112	t	t	t	t	t
Cobalt	12113	d	d	d	d	d
Copper	12114	d	d	d	d	d
Iron	12126	4	4	4	2	2
Lead	12128	d	d	d	d	d
Manganese	12132	d	d	d	d	d
Molybdenum	12134	d	d		d	d
Nickel	12136	2	2	2	5	5
Potassium	12180	t	t	t	t	t
Selenium	12154	d	d	d	d	d
Strontium	12168	d	d	d	d	d
Titanium	12161	d	d	d	d	d
Vanadium	12164	t	t	t	t	t
Zinc	12167	t	t	t	t	t
Sulfates	12403	20	20	20	30	28
Nitrate (H_2O sol)	12306	d	d	d	d	d
Total Carbon	12116	30	30		20	22
(Volatile Carbon)	15101	(20)	(20)	(20)	(14)	(15)
Subtotal		56	56	56	67	67
Other		44	44	44	33	33
Total		100	100	100	100	100

SAMPLE ONLY

*Ref 2-9

†Estimated to be same as 3-10μm size fraction

( ) included in total carbon

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1. Single data point profiles--The weight percent of each size range was obtained from the particle size distribution plot (which included the impinger catch) given in Section 4 for each industrial type tested. The details of how these curves were generated are discussed in Section 3.2.3 B. Whenever data was taken on a control device, the downstream (outlet) data was used to generate the profile for both chemical composition and size distribution. The chemical composition for each size range was obtained from the analyses for the particulate catches as discussed in Section 3.2.2. The first, second, and third cyclone analysis results were used in conjunction with the >10μm, 10-3μm, and 3-1μm size range respectively. The filter and impinger catch analysis results were used in conjunction with the <1μm size range. For each impinger catch there was an organic fraction which was obtained from methyl chloroform extraction of the impinger condensate as explained in Section 3.3.3-C and an inorganic fraction which was the remaining impinger residue as also explained in Section 3.2.2-C. Because the organic fraction residue could not be removed from the evaporation dish as discussed in Section 3.2.2-D (page 3-52), for chemical analysis purposes only the inorganic fraction of the impinger catch was used with the filter analysis to fully characterize the <1μm size range. The percent of carbon in the organic fraction was incorporated with the carbon concentration of the <1μm size range for each profile.

Whenever there were no data for a size range of a particular profile and there were data for the other size ranges, then an estimate was made. This estimate generally assumed that the concentrations of the chemical constituents were the same for each size range. It is believed that this is a good assumption because most of the profiles where complete data were available indicated that the concentrations of the chemical constituents were similar for the size range, except for sulfate and condensible carbon. Sulfates tend to be about two to three times more concentrated in the smaller sizes (impinger) than in the larger sizes. Condensible carbon usually ends up in the impinger catch (small size) and showed up in the impinger organic fraction.

2. Multiple data point profiles--The second approach used was to develop emission profiles based on data from several sources within a particulate source type. This involved: (1) acquiring the data, (2) determining the relative magnitudes of each source compared to the total emission from the source type, and (3) forming a composite profile by factoring the data from each source by an appropriate weighting factor. In this manner, emission profiles were developed for individual source types that in actuality represented the average emissions from sources of that category (SCC number).

The approach used to assign profile numbers (keys) to each source type (SCC number) was as follows:

1. A current list of all source types (SCC number) that were emitting particulates into the SCAB was generated from the most recent (April 1978) EIS summary.

2. Each item on this list of source types was assigned a four-digit number. These are listed in Table 2-2. The number 0000 indicates that there was no data available to generate the emission profile. The number 0099 indicates that the source type is not classified. All other numbers were assigned to a specific source type.

3. Each of the profile numbers listed in Table 2-2 were matched with the appropriate SCC number from the list generated from the current EIS file (1 above). In many instances, an individual profile was found to cover several SCC and SCC/SIC combinations. The profile data base was therefore formulated and indexed by a profile number. This is listed in Table 2-3.

TABLE 2-2. PROFILE KEY INDEX

Profile Key	Source Classification	Reference
0000	Data not available for profile	
0001	Industrial boilers (crude and residue)	Sec. 4.2.1
0002	Industrial boilers (diesel fuel)	Sec. 4.2.2
0003	Internal combustion engines (diesel fuel)	Sec. 4.2.5
0004	Internal combustion engines (gas fuel)	Sec. 4.2.5
0005	Wood waste boiler	Ref. 2-8, Sec. 4.2.4
0006	Utility boilers (residual fuel)	Ref. 2-9, Sec. 4.2.4
0007	Rice dryer	Sec. 4.2.13
0008	Coffee/Carob roasting	Sec. 4.2.14
0009	Steel heat treating	Sec. 4.2.15
0010	Steel abrasive blasting	Sec. 4.2.16
0011	Aluminum foundry	Sec. 4.2.17
0012	Steel-sinter plant	Sec. 4.2.18
0013	Steel-open hearth furnace	Ref. 2-10, Sec. 4.2.19
0014	Calcination of gypsum	Sec. 4.2.7
0015	Brick grinding and screening	Sec. 4.2.8
0016	Cement production	Sec. 4.2.6
0017	Glass melting furnace	Sec. 4.2.9
0018	Fiberglass forming line	Sec. 4.2.10
0019	Asphalt roofing	Sec. 4.2.11
0020	Asphaltic concrete batch plant	Sec. 4.2.12
0021	Paint spray booth (water solvent)	Sec. 4.2.22
0022	Paint spray booth (oil solvents)	Sec. 4.2.22
0023	Boric acid manufacture	Sec. 4.2.20
0024	Chemical fertilizer (urea)	Sec. 4.2.21
0025	Wood operation (resawing)	Sec. 4.2.23

TABLE 2-2. (Continued)

0026	Wood operation (sanding)	Section 4.2.23
0027	Petroleum heaters (natural gas fuel)	Section 4.2.24
0028	Petroleum--FCC Units/CO Boilers	Ref. 2-11 Section 4.2.25
0029	Feed and grain operations	Ref. 2-12
0030	Limestone kilns	Ref. 2-13
0031	Basic oxygen furnace (steel)	Ref. 2-10
0032	Electric arc furnace (steel)	Ref. 2-14
0033	Rock crushers	Ref. 2-15
0034	Rock screening and conveying	Ref. 2-15
0035	Structural fire	
0036	Residential natural gas burning	
0037	Fireplaces	
0038	Tire attrition	
0039	Cigarette smoke	
0040	Sea salt spray	
0041	Brake lining wear	
0042	Livestock dust	
0043	Unpaved roads	
0044	Construction dust	
0045	Agricultural burning	
0046	Forest fires	
0047	Landfill dust	
0048	Agricultural tilling	
0049	Industrial Boiler (natural gas fuel)	
0099	Not classified	

TABLE 2-3. PROFILE KEY ASSIGNMENT TO SCC NUMBERS

SCC#	Profile Key
1-01-004-01	0006
1-01-005-01	0002
1-01-006-01	0049
1-01-006-02	0049
1-02-004-01	0006
1-02-004-03	0006
1-02-005-01	0006
1-02-005-02	0006
1-02-005-03	0006
1-02-006-01	0049
1-02-006-02	0049
1-02-006-03	0049
1-02-007-01	0049
1-02-007-02	0049
1-02-007-07	0049
1-03-005-02	0002
1-03-006-02	0049
1-03-007-03	0049
1-05-002-06	0049
2-01-001-01	0002
2-01-002-01	0049
2-02-002-02	0049
2-06-013-01	0099
3-01-009-99	0099
3-01-017-01	0000
3-01-999-99	0099
3-02-001-99	0099
3-02-005-01	0029
3-02-006-01	0029
3-02-006-02	0029

TABLE 2-3. (Continued)

3-02-007-30	0029
3-02-008-99	0029
3-02-999-98	0099
3-02-003-02	0000
3-03-003-04	0000
3-03-003-06	0000
3-03-003-99	0099
3-03-008-02	0000
3-03-008-03	0012
3-03-008-99	0099
3-03-009-01	0013
3-03-009-03	0031
3-03-009-05	0032
3-04-001-01	0011
3-04-001-99	0099
3-04-003-01	0000
3-04-003-50	0000
3-04-004-03	0000
3-04-007-01	0032
3-04-007-09	0099
3-04-999-99	0099
3-05-001-04	0019
3-05-001-99	0019
3-05-002-01	0020
3-05-002-99	0020
3-05-003-02	0015
3-05-006-02	0016
3-05-006-99	0099
3-05-007-99	0016
3-05-008-01	0015
3-05-008-02	0015
3-05-008-99	0099
3-05-011-01	0016
3-05-012-04	0018

TABLE 2-3. (Continued)

3-05-011-99	0099
3-05-014-01	0017
3-05-014-11	0017
3-05-015-02	0014
3-05-015-99	0014
3-05-016-99	0030
3-05-017-01	0000
3-05-017-99	0099
3-05-020-01	0033
3-05-020-02	0033
3-05-020-05	0033
3-05-020-06	0034
3-05-020-80	0099
3-05-020-99	0099
3-05-025-01	0033
3-05-025-99	0099
3-05-999-88	0099
3-05-999-99	0099
3-06-001-02	0027
3-06-001-03	0000
3-06-001-04	0027
3-06-001-09	0099
3-06-002-01	0028
3-06-009-99	0099
3-06-011-99	0099
3-06-012-03	0000
3-06-999-97	0099
3-06-999-98	0099
3-07-004-99	0099
3-07-020-99	0099

TABLE 2-3. (Continued)

3-09-001-88	0099
3-09-001-99	0099
3-09-030-04	0000
3-09-030-99	0099
3-09-999-99	0099
3-63-009-01	0099
3-90-005-05	0000
3-90-006-05	0011
3-90-006-08	0000
3-90-006-31	0000
3-90-006-99	0099
3-90-008-99	0099
3-99-999-99	0099
4-02-001-01	0021
4-02-003-01	0022
4-02-004-01	0022
4-02-004-05	0022
4-02-005-99	0099
4-02-007-01	0000
4-02-008-01	0000
4-02-008-03	0000
4-04-001-99	0099
4-90-999-99	0099
5-03-002-01	0045
9-12-071-00	0043
9-13-081-00	0046
9-14-001-07	0036
9-14-034-00	0037
9-24-089-95	0035
9-27-619-50	0039
9-41-009-52	0041

TABLE 2-3 (Continued)

9-47-239-00	0048
9-47-307-42	0044
9-47-549-01	0040
9-49-000-00	0047
9-49-999-01	0038
9-49-999-98	0042
9-49-999-99	0047

C. Critical Profiles--

Due to the magnitude of the sources which they represent, several emission profiles were recognized to have a significant impact on the results of the final inventory. These include: (1) combustion of fuels for utility and industrial boilers, (2) cement production, (3) fugitive dust from unpaved roads and construction, and (4) tire dust from wear. Detailed discussion of the development of these profiles are included in the following section.

1. Combustion of fuels--The combustion of fuels constitutes about 50% of the particulate emissions from point sources in the SCAB. This large source of emission was broken down into two groups: (1) emissions from utility boilers and (2) emissions from industrial boilers.

Nine field tests*, with two sampling trains for a total of 18 tests, were done on utility boilers burning low sulfur residual fuel. These were used to develop the emission profile for utility boilers burning residual fuel. The results from these tests indicated that 85% by weight of the particles were less than 1μm. Thirty-six percent of the total particulates were sulfates, 22% were carbon, 10% were calcium, 5% were nickel and 2% were iron. All other elements that were detected by the analysis were in concentrations less than 1%. This profile (profile key 0001) is listed in the Appendix (Vol. II).

The results of two field tests* on industrial boilers burning diesel fuel were used to develop the emission profile for industrial boilers. The results indicated that 96% by weight of the particulates were less than 1μm of which 65% were sulfates, 15% were carbon, and all other elements detected were in concentrations less than 1%. This profile (profile key 0002) is listed in the Appendix.

2. Cement production--The results of two field tests* and data from Reference 2-16 were used to develop the emission profile for the production of Portland Cement. These results indicated that 34% by weight of the particles

* These field tests are discussed in detail in Section 4.0

were less than 1μm, 34% between 3-1μm, 24% between 10-3μm, and 8% greater than 10μm. Twenty five percent of the composite of the sizes were sulfates, 10% silicon, 20% calcium, 8% carbon, and all other elements detected were in concentrations less than 1%. This profile (profile key 0016) is listed in the Appendix.

3. Fugitive dust--The fugitive dust emission constitutes about 80% of the particulate emission from the accountable area sources. Fugitive dust emissions are broken into five groups: (1) road and building construction, 55%, 2) unpaved roads 18%, 3) agricultural tilling, 7%, 4) livestock feed lots, 1%, and 5) refuse disposal sites, <1%. Only road and building construction and unpaved roads will be discussed here. From the literature, (Ref. 2-17,18), it was determined that 45% by weight of the particles were greater than 10μm, 15% between 10-3μm, 12% between 3-1μm, and 28% less than 1μm, for construction dust. Twenty percent were silicon, 8% aluminum, 2% calcium, 3% iron, and 2% potassium. All other elements listed were in concentrations less than 1%. The profile for construction dust (profile key 0044) is given in Appendix A. The profile for fugitive dust from unpaved roads is similar to that of construction dust. From the literature (Ref. 2-17,18) it was determined that 55% by weight of the particles were greater than 10μm, 15% between 10-3μm, 12% between 3-1μm, and 18% less than 1μm. Twenty percent were silicon, 8% aluminum, 2% calcium, 3% iron, and 2% potassium. All other elements listed were in concentrations less than 1%. The profile for fugitive dust from unpaved roads (profile key 0043) is listed in the Appendix.

4. Tire Dust--Emissions from tire attrition constitutes about 7% of the particulate emissions from the accountable area sources. From the literature (Ref. 2-17,18) it was determined that breakdown of the particle size distribution is as follows:

	>10μm	10-3μm	3-1μm	<1μm
Tire Dust	60%	5%	15%	20%

The dust is composed of about 90% carbon, and 1% zinc. The remaining element is hydrogen. Further information on tire dust is presented in the next section (Section 2.3.3 C.1)

2.3.3 Area Sources

An important aspect of the KVB fine particulates emission inventory was the identification of sources of fine particulate emissions not under permit and generally not included or adequately characterized in previous inventories. These sources were categorized into four main groups: 1) fugitive dust sources, 2) combustion sources, 3) automobile sources, and 4) sea salt spray. Because these are diffuse and not concentrated sources like industrial point sources, they are referred to as area sources. Emission factors for these sources were therefore based on land area, population, land use, or other criteria characteristic of the area source.

Table 2-4 presents a summary of the area source suspended particulate emission estimates for each of the sources considered. Precise emission rates were difficult to estimate due to the complex nature and non-availability of applicable data for each source type.

A second objective of the area source inventory was to identify the particle size and chemical composition of the reported particulate emissions from each source type. Again, precise particle sizing and chemical composition were difficult to obtain for many area source types due to the wide variation in materials associated with each area source. Specific source chemical composition analysis can be found under that section titled "Area Profiles."

A third objective of the study was to locate these area sources geographically in the South Coast Air Basin. To this end, information was secured from various governmental agencies on population distribution, land use, agricultural plantings, construction and road building, etc. Maps corresponding to the approximate location of each source were developed. Area sources based on population were distributed on a per capita basis based on information from the ARB.

TABLE 2-4. ESTIMATED 1976 AREA SOURCE FINE PARTICLE EMISSIONS SUMMARY[a]

	South Coast Air Basin Counties[b]						(c)	Percent	
	Orange	Los Angeles	River-side	San Bernardino	Ventura	Santa Barbara	Emissions Tons/yr	of Grand Total	Estimated Percent Accuracy
Road & Building Construction	21,000	24,000	7,100	11,000	6,400	1,000	71,000	20.9	+50,-20
Agricultural Tilling	1,300	1,200	3,100	800	3,100	40	9,500	2.8	±25
Refuse Disposal Sites	60	200	20	20	20	6	300	<0.1	±25,-20
Livestock Feedlots	150	3	150	950	5	5	1,300	0.4	±50
Unpaved Road Travel	2,000	14,000	2,000	1,800	2,600	230	23,000	6.8	±40
Paved Road Travel (d)	33,000	140,000	7,600	12,000	8,800	3,100	200,000(d)	58.8	±50
Fugitive Dust--Subtotal							305,000	89.7	
Forest Fires	120	700	600	430	530	50	2,400	0.7	+50,-20
Structural Fires (e)	40	160	10	15	10	5	200	<0.1	+100,-20
Fireplaces	70	280	30	60	20	10	500	0.1	+100,-10
Residential Natural Gas	20	90	5	10	10	5	100	<0.1	±25
Cigarettes	130	520	30	50	30	10	800	0.2	+20,-50
Agricultural Burning	20	50	30	--	400	10	500	0.1	±25
Combustion--Subtotal							4,500	1.3	
Tire Attrition	1,400	5,700	320	490	370	130	8,400	2.5	±20
Brake Lining Attrition	530	2,100	120	180	140	50	3,100	0.9	±20
Automotive--Subtotal							11,000	3.2	
Sea Salt--	4,000	6,700	---	---	3,500	5,800	20,000	5.9	+50,-20
Grand Total							340,000	100%	

a) Emission estimates are based on particles ≤ 10 μm

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b) Includes only that portion of County within SCAB

c) Rounded to three significant figures

d) A large (but unknown) percentage of the 200,000 tons/year is assignable to other area source categories studied and not studied in this inventory. For this reason (see Section 2.3.3-A-6) it was not included in the final inventory count as indicated in Table 2-18.

e) Includes property, contents and vehicle loss.

The following sections present a discussion of the methodologies and references used in making these estimates. In general, the procedure involved the establishment of two criteria: 1) an emission factor coupled with 2) an appropriate inventory. Using this format, improvements of either criteria can be readily employed to improve future estimates.

It must be pointed out that many of the emission factors applied to the inventories presented were developed specifically for this study of the South Coast Air Basin and are not necessarily appropriate or applicable to other study areas.

Those emission factors based on studies conducted outside the air basin were carefully reviewed and reevaluated when it was deemed necessary in order to make the raw emission factor more applicable to the study area.

A. Fugitive Dust--

Significant sources of atmospheric dust arise from the mechanical disturbance of granular material exposed to the air. Dust generated from these open sources is termed "fugitive" because it is not discharged to the atmosphere in a confined flow stream.

In the 1976 inventory (Table 2-4), fugitive dust accounted for approximately 75% of the 140,000 tons of suspended particulate matter (<10μm particles) estimated to be emanating from the area sources considered excluding paved road travel. The six fugitive dust areas considered are: (1) road and building construction, (2) agricultural tilling, (3) refuse disposal sites, (4) livestock feedlots, (5) unpaved road travel, and (6) paved road travel. As can be seen in Table 2-4, road and building construction coupled with unpaved road travel account for 66% of the total 1976 area source estimate (excluding paved road travel). The basis for exluding paved road travel is explained in Section 3.2.3-6.

For the above categories of fugitive dust sources, the dust generation process is caused by two basic physical phenomena:

1. Pulverization and abrasion of surface materials by application of mechanical force through implements (wheels, blades, etc.)
2. Entrainment of dust particles by the action of turbulent air currents generated by winds, moving vehicles, etc.

The air pollution impact of a fugitive dust source depends on the quantity and drift of the dust particles emitted into the atmosphere. In addition to large dust particles that settle out near the source (often creating a localized nuisance problem), considerable amounts of fine particles are also emitted and dispersed over much greater distances from the source (Ref. 2-19).

The quantities of dust reported as emissions in this report are defined as being comprised of particles smaller than 10μm and having a particle density of 2.0 - 2.5 g/cm^3. Further particle size breakdown into <10μm, <3μm, and <1μm intervals is included in each sub-category discussion. The correlation between Ambient Hi-Volume Samples and the Pasquile-Gifford Diffusion equation for ground level sources was employed by the referenced studies (Refs. 2-17,18) as the basis for computing the original emission factors.

1. Road and building construction--Recent studies (Refs. 2-20,21) have concluded that road and building construction activities are significant sources of fugitive dust. Such emissions are associated with land clearing, blasting, ground excavations, cut and fill operations, and the construction of the particular facility itself. As can be seen in Table 2-4, construction activities accounted for the single largest source of particulate matter (excluding paved road travel).

Pedco-Environmental Specialists (Ref. 2-17) and Midwest Research Institute (Ref. 2-18) have conducted investigations into the emissions from construction operations. An uncontrolled emission factor of 1.2 tons per acre of construction per month of activity for particles <30um was determined. However, Pedco also concluded that a 50% reduction in emissions is possible if adequate dust control such as watering twice daily is practiced. Review of SCAQMD's Rules 402 and 403 on Fugitive Dust, communication about Rules 402 and 403 with the SCAQMD (Ref. 2-22) and on-site observations of construction sites revealed that a 50% reduction is indeed possible and was therefore used in this study.

Also, approximately 20% by weight of the particles lie in the 30μm to 10um particle size interval. Therefore an emission factor of 0.5 tons per acre-month for building construction was chosen to be applicable to the study area with this factor including the 50% reduction achieved by watering. For highway construction an emission factor of 0.25 tons per acre-month was estimated based on communications with the ARB (Ref. 2-21).

An inventory of the acre-months of building and road construction for 1976 was obtained from the ARB (Ref. 2-21). Table 2-5 lists the acre-months of construction activity and emissions per county. An emission factor of 6.8 tons per 1000 people per year was entered into the final inventory. A population based emission factor was chosen to best reflect the location of their emissions since residential construction, at least, would be in proportion to the neighboring population density.

On the average, dust emissions from construction operations have the following particle size characteristics:

Particle Diameter	Weight Percent
<1um	24
1-3um	16
3-10um	24
>10um	36

A particle size distribution plot is presented in Figure 2-4.

TABLE 2-5. ROAD & BUILDING CONSTRUCTION
PARTICULATE EMISSIONS SUMMARY

County	Acre-months Construction			Emissions tons/yr
	Residential	Non-Residential	Roads	
Orange	29,894	6,004	11,832	21,000
Los Angeles	25,627	13,304	20,184	24,000
Riverside	8,078	1,236	9,860	7,100
San Bernardino	12,501	1,738	14,384	11,000
Ventura	9,787	1,085	3,828	6,400
Santa Barbara	1,172	258	1,144	1,000
Total				71,000 tons/yr

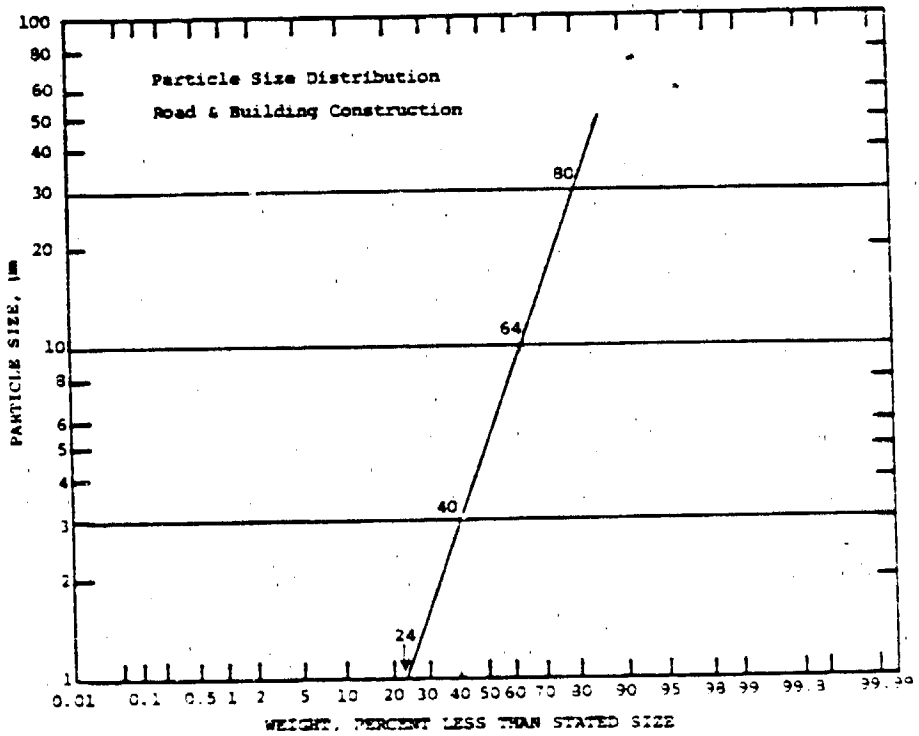

Figure 2-4. Road and building construction dust particle size distribution.

2. Agricultural tillage—Approximately 9500 tons per year of fugitive dust (particles <10um) were estimated to be coming from agricultural tilling operations within the basin as shown in Table 2-4.

The two universal objectives of agricultural tilling are the creation of the desired soil structure to be used as the crop seedbed and the eradication of weeds. Plowing, the most common method of tillage, consists of some form of cutting loose, granulating, and inverting the soil and turning under the organic litter. Implements that loosen the soil and cut off the weeds but leave the surface trash in place, have recently become more popular for tilling in dryland farming areas.

During a tilling operation, dust particles from the loosening and pulverization of the soil are emitted into the atmosphere as the soil is dropped to the surface. Dust emissions are greatest when the soil is dry and during final seedbed preparation (Ref. 2-23).

In developing an emissions estimate, a threefold approach was taken:

1. Establishment of a 1976 inventory of the harvested acreage of field, truck, orchards, outdoor nursery, and improved pasture.
2. Determination of the passes per crop made by a farming implement that disturbs the soil significantly.
3. Development of the proper emission factor to apply to farming operations within the Basin.

An inventory of harvested acreage was compiled with the aid of the 1976 County Agricultural Commission's Crop Reports (Refs. 2-24 through 29). The passes per crop were determined through lengthy communication with numerous University of California Cooperative Extension Service Farm Advisors (Refs. 2-30 through 33). The estimated average number of passes per crop type are presented in Table 2-6.

TABLE 2-6. ESTIMATED AVERAGE FARM IMPLEMENT PASSES PER CROP

Field Crops	Estimated Average passes per crop
Barley	3
Lima beans	3
Hay, alfalfa	0.5
Hay, grain	3
Improved pasture	1
Sugar beets	4
Wheat	3
Corn	3
Grass	3
Safflower	3
Misc. Seed	3
Truck Crops	
Asparagus	3
Beans	3
Beets	4
Berries--Strawberries	6
Berries	3
Broccoli	3
Cabbage	3
Carrots	5
Cauliflower	3
Corn	3
Cucumbers	3
Egg Plant	3
Endive	3
Garlic	3
Lettuce	3
Canteloupe	3
Crenshaws	3
Honeydew	3
Misc. Melons	3
Watermelons	3
Misc. Vegetables	3
Okra	3
Onions	5
Peas	3
Peppers	3
Potatoes	3
Pumpkins	5
Radishes	3
Romaine	3
Rutabaga	3
Squash	3
Tomatoes	3
Turnips	5
Parsley	3
Parsnips	3
Orchard Crops	
Citrus	3
Deciduous	3
Nursery	
Outdoor Field Grown	3
Cut flowers	3

Source: References 2-30 through 2-33.

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Current farming practices in orchards disclosed that only 10-20% of the acreage presently alotted to orchards is actually tilled. An increased use of herbicides is the reason for this practice.

A field study conducted by Midwest Research Institute (Ref. 2-18) concluded that the quantity of dust emitted from agricultural tilling is proportional to the area of land being tilled. In addition, emissions depend on the following variables: soil texture, soil moisture, and tractor speed. Available test data indicate no substantial dependence of emissions on the type of tillage implement being used when operating at a typical speed of 6 mph (Ref. 2-18).

The equation for estimating the total amount of tillage dust emissions is as follows:

$$e\ (\text{tilling}) = \frac{1.4s\ (S/5.5)}{(PE/50)^2}\ (C) \quad \pm 15\%$$

where: e = emission factor (pounds per acre)

s = silt content (particles between 2μm-50μm as defined by the U.S. Dept. of Agriculture) of the surface soil (0-4 inches depth) percent

S = implement speed (miles per hour)

PE = Thornthwaite's precipitation-evaporation index corrected for irrigation

C = particle sizing factor (e.g. 65% wt. <10μm diameter particles, see Figure 2-5)

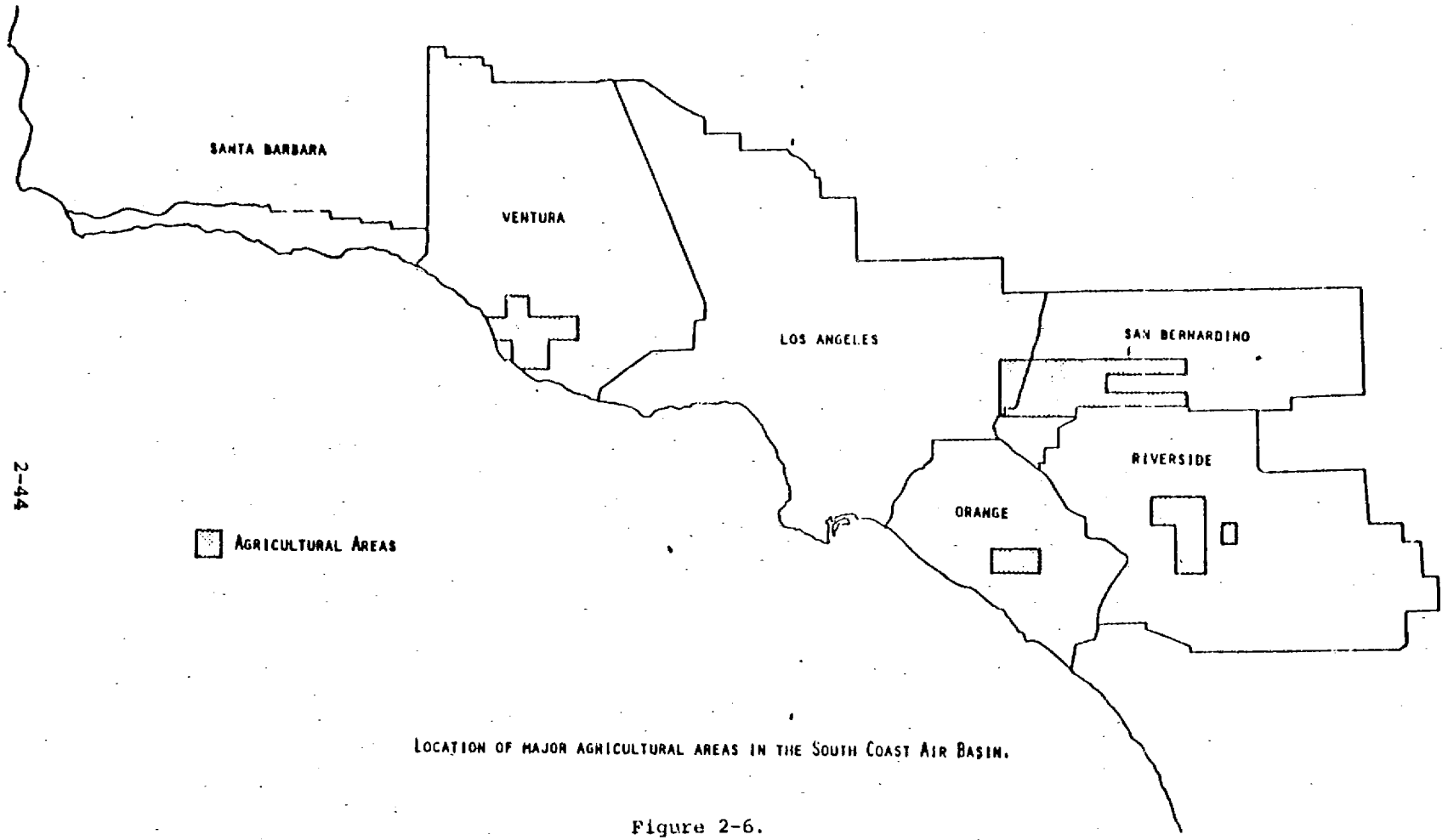
The silt content of SCAB agricultural lands generally range from 10-30%. A mid-range value of 20% was chosen. Also, reports on the moisture content of the top four inches of soil during tilling varied from a PE Index of 17 to 56 (Refs. 2-39,32,34,35). A value of 41 was chosen to be representative. Implement speed varied considerably so a value of 5.5 mph was chosen.

By inserting this information into the forementioned tillage dust equation, an emission factor of 27 lb per acre pass was derived. A particle size distribution plot is shown in Figure 2-5. On the average, dust emissions calculated for agricultural tilling have the following particle size characteristics (Ref. 2-18):

Particle Diameter	Weight Percent
<1μm	25%
1-3μm	17%
3-10μm	22%
>10μm	36%

A summarization of the inventory and emission estimates by crop group and county are presented in Table 2-7. Figure 2-6 depicts the major agricultural areas to which these emission estimates were assigned. The aid of County Agricultural Commissioners' Farm Advisors (Refs. 2-31,36-38) and an ARB memo (Ref. 2-39) were solicited in estimating the percentage of crops contained within the Air Basin when a county such as Riverside extends outside the study area.

3. Refuse Disposal Sites--Over 15 million tons of liquid and solid waste were disposed of annually in the 45 major landfill sites located in the basin. This accounted for approximately 300 tons of fugitive dust. Disposal involves the collection, transportation, unloading, and soil covering of daily refuse. For our purposes, the dust associated with unloading and soil covering will be considered to constitute the major portion of the dust generated from the total disposal cycle.



LOCATION OF MAJOR AGRICULTURAL AREAS IN THE SOUTH COAST AIR BASIN.

Figure 2-6.

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A threefold approach was taken in the establishment of the 300 tons per year estimate:

1. Review of County Solid Waste Management Plans to establish site location and annual refuse disposal
2. Determination of the surface area worked based on the annual quantities of refuse disposed
3. Establishment of an applicable emission factor

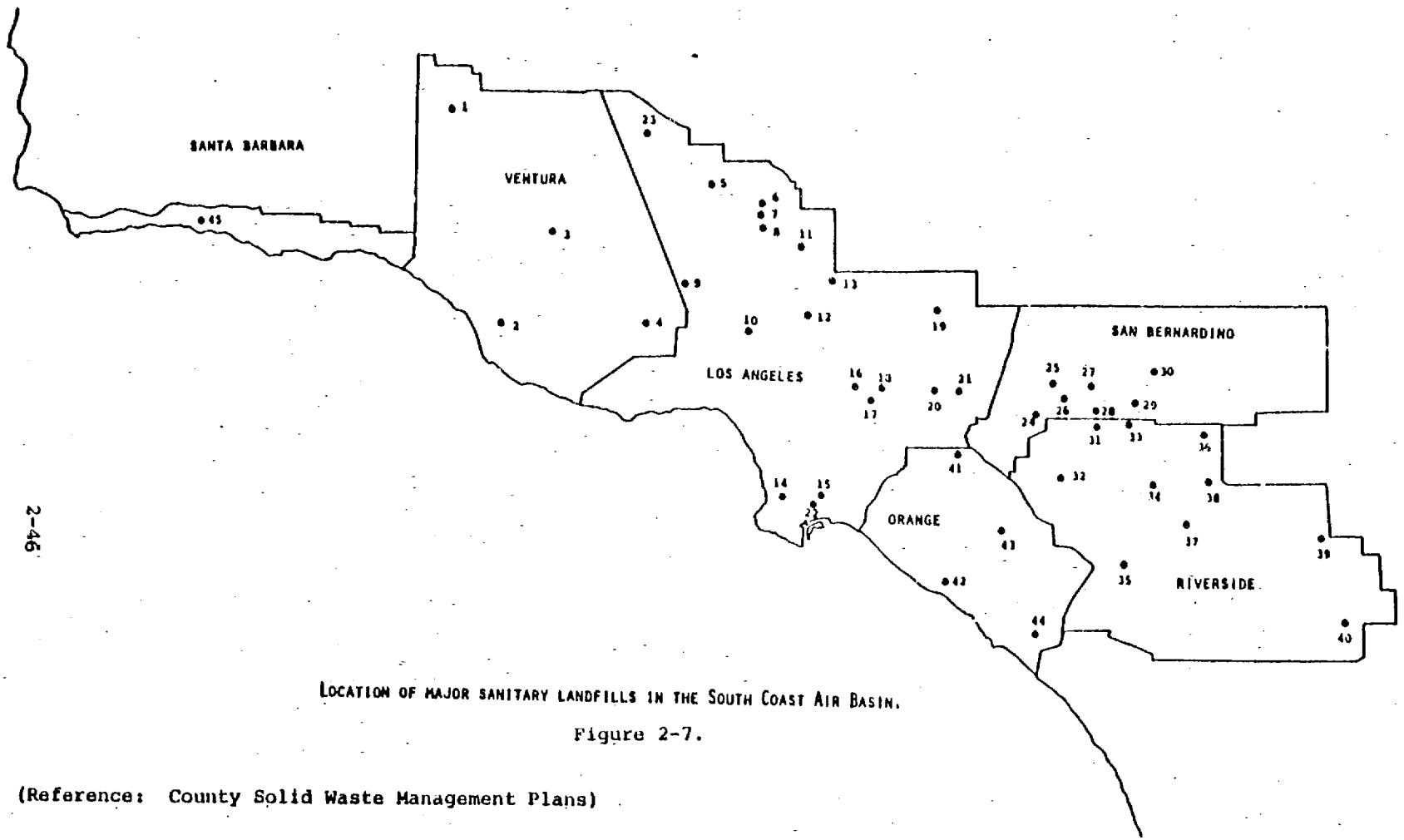
Coyote Canyon landfill site was chosen as a model refuse site. The surface area worked was estimated to be equal to 2/3 power of the volume of the disposed refuse (Ref. 2-40). One cubic yard of compacted refuse was estimated to weigh ~1200 pounds (density of 0.71 g/cm^3) (Ref. 2-41). Review of numerous articles on fugitive dust emissions failed to reveal an emission factor specifically designed for landfill sites.

Since the activities at a landfill site approximate those found at a construction site, the 0.5 ton per acre-month of activity for construction was chosen. Investigation of dust control practices at Orange County landfill sites (Ref. 2-42) disclosed that continuous watering of the dirt roadway and active dump area is common practice. Also, continuous watering is practiced at a majority, if not all, municipal sites in the basin. Therefore, it was felt that the 0.5 ton per acre-month was indeed appropriate.

The specific site locations and annual refuse disposed can be found in Figure 2-7 and Table 2-8. Emissions were entered into the final inventory on the basis of site location.

Particle sizing information on fugitive dust from construction sites was also judged to be applicable to landfill sites.

4. Livestock dust--An EPA sponsored study (Ref. 2-17) has been conducted to quantify the fugitive dust emissions from livestock feedlots. A total of 48 samples were taken at 24 different feedlot locations. Emission factors of 8 tons/1000 hd/year for uncontrolled lots with less than 25,000 head, and 5 tons/1000 hd/year for feedlots with more than 25,000 head (particle <30μm) were derived. Additional particle sizing information was not taken, however.



LOCATION OF MAJOR SANITARY LANDFILLS IN THE SOUTH COAST AIR BASIN.

Figure 2-7.

(Reference: County Solid Waste Management Plans)

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TABLE 2-8. EXISTING MAJOR CLASS I AND II SANITARY LANDFILL SITES IN THE SOUTH COAST AIR BASIN

(Reference - County Solid Waste Management Plans)

Quantity of Waste Received	Class	Reported Acreage	Tons/Year Liquid	Solid	Total
Ventura County, 1975					
1. Omaha	II		- 1,086 -		1,086
2. Santa Clara	II	47	- 434,400 -		434,400
3. Toland Road	II	120	- 36,200 -		36,200
4. Simi	I	230	- 144,800 -		144,800
All Other Class II Sites		460	- 167,400 -		167,400
Total		457			781,886
Los Angeles County, 1974					
5. N. Valley Refuse Center	II	230	-	550,000	550,000
6. Bradley Avenue Dump	II	63	-	332,000	332,000
7. Penrose Pit	II	73	-	398,000	398,000
8. Hewitt Pit	II	117	-	436,000	436,000
9. Calabasas Land Fill	I	416	36,000	320,000	356,000
10. Mission Canyon Land Fill	II	1,491	-	1,394,000	1,394,000
11. Burbank City Land Fill	II	133	-	75,000	75,000
12. Toyon Canyon Land Fill	II	40	-	795,000	795,000
13. Scholl Canyon Land Fill	II	484	-	450,000	450,000
14. Palos Verdes Land Fill	I	295	280,000	1,300,000	1,580,000
15. Ascon	II	65	85,000	422,000	507,000
16. Operating Industries	II	190	177,000	589,000	766,000
17. City of Whittier Land Fill	II	117	-	107,000	107,000
18. Puente Hills Land Fill	II	1,214	17,000	1,165,000	1,182,000
19. Azusa Western	II	307	-	271,000	271,000
20. B.K.K. Land Fill	I	583	254,000	352,000	606,000
21. Spadra Land Fill	II	199	13,000	192,000	205,000
22. Harbor Dump	II	25	-	160,000	160,000
23. Chiquita Canyon Land Fill	II	40	-	33,000	33,000
All Other Minor Class II Sites		N.R.		56,050	56,050
Total		6,082	862,000	9,341,000	10,203,000
San Bernardino County, 1974					
24. Milliken	II	106	-	215,500	215,500
25. Cajon	II-2	106	- 117,500 -		117,500
26. Fontana	II	82	-	64,000	64,000
27. Heaps Peak	II	63	-	16,600	16,600
28. Colton	II	94	-	93,700	93,700
29. Yucaipa	II	560	-	34,600	34,600
30. Big Bear	II	70	-	11,600	11,600
Total		1,081			553,500
Riverside County, June 1975					
31. West Riverside	II-2	63	- - 52,700 -		52,700
32. Corona	II-2	101	- 88,350 -		88,350
33. Highgrove	II-2	280	-	8,100	8,100
34. Mead Valley	II-2	240	-	8,100	8,100
35. Elsinore	II-2	44	-	12,400	12,400
36. Badlands	II-2	904	-	15,500	15,500
37. Double Butte	II-2	580	-	61,380	61,380
38. Lamb Canyon	II-2	788	- 48,050 -		48,050
39. Idyllwild	II-2	30	- - 3,010 -		3,010
40. Anza	II-2	10	-	1,550	1,550
Total		1,940			299,140
Orange County, December 1975					
41. Olinda	II	235	-	758,000	758,000
42. Coyote Canyon	II	593	-	2,130,000	2,130,000
43. Santiago Canyon	II	160	-	374,000	374,000
44. Prima Deschecha	II	945	-	478,000	478,000
Total		1,933		1,740,000	1,740,000
Santa Barbara, 1975					
45. Tajiguas	II	130	-	202,900	202,900
GRAND TOTAL		11,580			15,782,426

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A particle size distribution plot shown in Figure 2-8 was generated based on the assumptions that the silt content of the soil contained within a feedlot pen is higher than that of construction and unpaved roads, and that the moisture content of the soil may be somewhat higher due to livestock excretions.

On the average therefore, it is estimated that dust particles from feedlots would have the following particle size characteristics:

Particle Diameter	Percent by Weight
<1μm	46
1-3μm	16
3-10μm	13
>10μm	25

A recent inventory of particulate emissions from feedlots located within the basin was conducted by the Air Resources Board (Ref. 2-43). Emissions of 1400 tons (particles <30μm) were estimated. Basis for this estimate was the above mentioned study and the California Livestock Statistics Report for 1976. A recent study (Ref. 2-44) on this same subject conducted by the SCAQMD was used as a tool in evaluating the ARB's estimate.

The specific emission factors applied in the ARB estimate are (Ref. 2-39):

Cattle	8 T/1000 hd/yr
Sheep & Hogs	1.25 "
Goats	1.25 "
Turkeys	0.2 "

Emissions totaling 1300 tons (particles <10μm) were entered into the final inventory. Feedlot locations, Figure 2-9, were extracted from the California Livestock Statistics Report.

5. Unpaved road travel--Studies (Refs. 2-17,18,45-48) have shown that significant quantities of fugitive dust are emitted during vehicular travel on unpaved roadways. Dust plumes trailing behind vehicles traveling on unpaved roads are a familiar sight in rural areas. When a vehicle travels over an unpaved road, the force of the wheels on the road surface causes pulverization

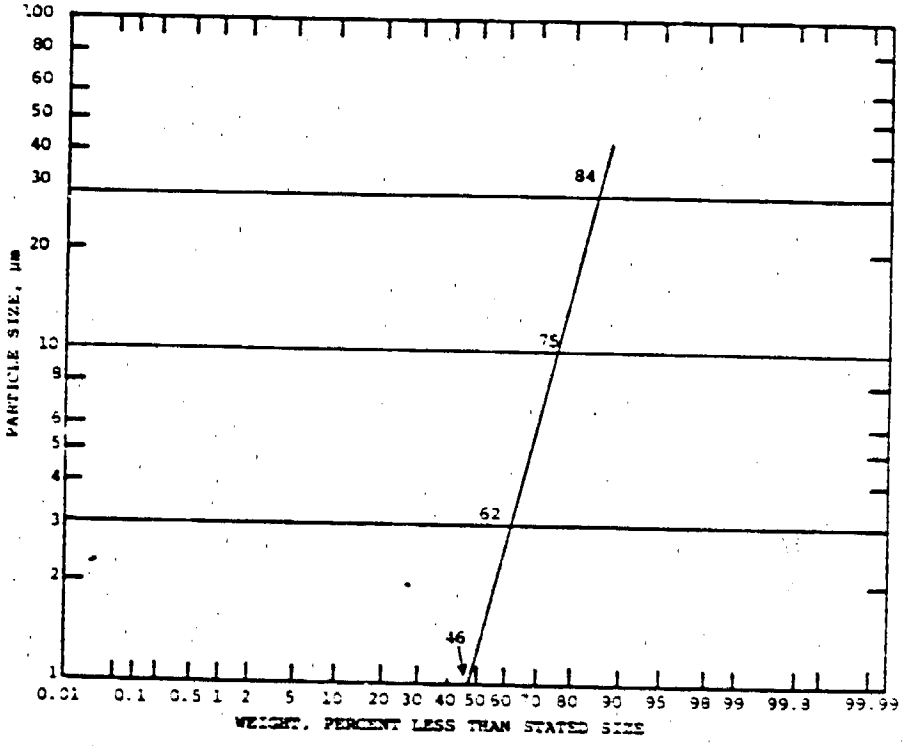

Figure 2-6. Livestock feedlot particle size distribution.

Source: KVB Engineering Analysis of comparable fugitive dust sources.

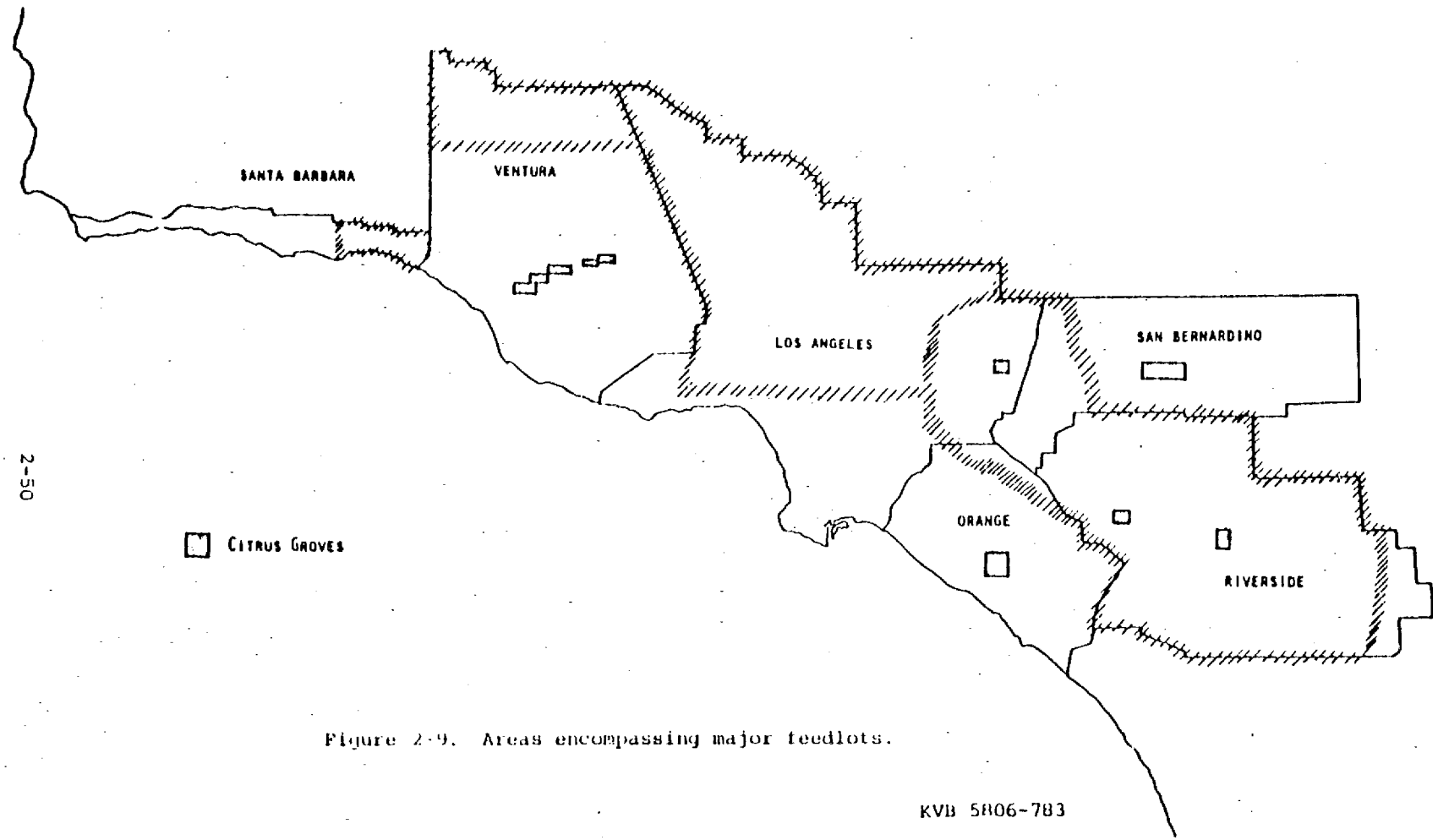

Figure 2-9. Areas encompassing major feedlots.

of the surface material. Particles are lifted and dragged from the rolling wheels while the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The amount of surface fines on an unpaved road is normally close to an equilibrium value. The fines which are injected into the atmosphere by vehicular traffic are replaced in the same process by new fines which are generated by abrasion of surface material. This equilibrium can be upset, however, by a windstorm or other severe phenomenon, and for a time emissions are reduced (Ref. 2-18).

A literature search of existing emission factors for unpaved road travel revealed that no one factor is applicable to all conditions, but that a mathematical expression (Ref. 2-18) encompassing the variables affecting dust generation would give a good approximation within ±20%. The equation for estimating the total amount of road dust emissions with drift potential greater than 25 feet is as follows:

$$e \text{ (unpaved roads)} = 0.18s\ (S/30)\left(\frac{365 - W}{365}\right)(Se)\ (C_p)^{*}$$

where e = emission factor (pounds per vehicle mile)

s = silt content of road surface material (percent)†

S = average vehicle speed (miles per hour)

(continued next page)

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* A recent study of unpaved road emissions, EPA-600/2-78-050, March 1978, recommends an emission factor of:

$$\text{lb/vehicle-mile} = (5.9)\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.8}\left(\frac{d}{365}\right),\ d_p < 30\mu m$$

where d = number of dry days/year, and W = vehicle weight (tons). For particle diameters <30um, C_p above would be 0.61 (Figure 2-10) and the two expressions would be identical, except for the vehicle weight and speed corrections.

† EPA no longer recommends using the silt content of the native top soil unless s ≤15%; if s >15%, use 15%.

Se = vehicle speed correction factor[§] (Ref. 2-20)

30 mph	25% approx. control eff.
20 mph	65% " " "
15 mph	80% " " "

W = mean annual number of days with 0.01 in. or more of rainfall[#]

C_p = particle size range factor, see Figure 2-10 [e.g. to determine the emission factor for particles less than 10μm, C_p is 0.46 (or 46% from Figure 2-10)].

On the average, dust emissions from unpaved road travel have the following particle size characteristics:

Particle Size	Weight Percent
<1μm	18
1-3μm	12
3-10μm	16
>10μm	54

A summary of the individual road types, miles per hour speed restrictions, and emission rates per county are presented in Table 2-9. Per county inventories of the vehicle miles traveled per year (VMT) per road type were obtained from the Air Resources Board (Ref. 2-49). Table 2-10 presents a summary of the estimated VMT for each county within the study area.

Applying the emission factors presented in Table 2-9 to the inventory in Table 2-10 resulted in a total emissions rate from these sources of approximately 23,000 tons per year. This is equal to approximately 16% of all area sources accounted for in Table 2-4.

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§ Based on the assumption that "uncontrolled" speed is typically 40 mph. Between 30-50 mph emissions are linearly proportioned to vehicle speed. Below 30 mph, however, emissions appear to be proportioned to the square of the vehicle speed.

\# The temporary reduction in emissions because of rainfall is accounted for by neglecting emissions on "wet" days, i.e., days with more than 0.01 inches of rainfall.

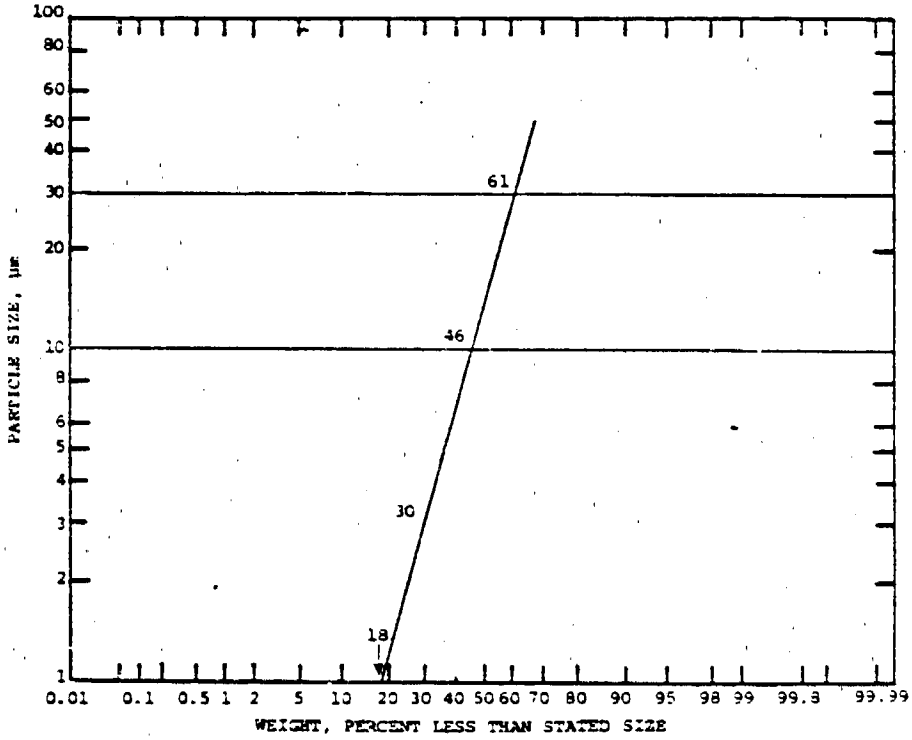

Figure 2-10. Unpaved road dust particle size distribution. Source: Ref. 2-18.

TABLE 2-9. SUMMARY OF UNPAVED ROAD EMISSION FACTORS PER ROAD LOCATION

	ROAD LOCATION TYPES					
County-SCAB	City & County	U.S. Forest & Parks	Timber Prod.	BLM	Agriculture	W (1)
Orange	3.65 lbs/VMT 30 MPH	1.14 lbs/VMT 20 MPH	--	--	2.23 lbs/VMT 25 MPH	40
Los Angeles	3.65 lbs/VMT 30 MPH	1.14 lbs/VMT 20 MPH	--	--	2.23 lbs/VMT 25 MPH	40
Riverside	3.93 lbs/VMT 30 MPH	1.22 lbs/VMT 20 MPH	--	--	2.40 lbs/VMT 25 MPH	15
San Bernardino	3.93 lbs/VMT 30 MPH	1.22 lbs/VMT 20 MPH	--	--	2.40 lbs/VMT 25 MPH	15
Ventura	3.65 lbs/VMT 30 MPH	1.14 lbs/VMT 20 MPH	0.57 lbs/VMT 20 MPH	6.49 lbs/VMT 40 MPH	2.23 lbs/VMT 25 MPH	40
Santa Barbara	3.65 lbs/VMT 30 MPH	1.14 lbs/VMT 20 MPH	--	--	2.23 lbs/VMT 25 MPH	40

(1) Mean annual number of days with 0.01 in. or more of rainfall.

TABLE 2-10. SUMMARY OF VMT PER UNPAVED ROAD LOCATION IN BASIN[1]

County-SCAB	VMT x 10^3					Totals	
	City & County	U.S. Forest & Parks	Timber Production	BLM	Agriculture	VMTx10^3	Emissions T/yr
Orange	807	651	---	---	159	1600	2,000
Los Angeles	5647	6135	---	---	240	--	14,000
Riverside	555	813	---	---	309	--	2,000
San Bernardino	504	1236	---	---	66	--	1,800
Ventura	142	1983	467	174	497	--	2,600
Santa Barbara[2]	60	160	---	---	20	240	230
Total[3]							23,000

[1] Source (Ref. 2-49)

[2] Original VMT estimates for entire county
Assume 5% in SCAB area

[3] Carried to two significant figures

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6. Particulate emissions from paved roadways--The action of vehicular traffic on a dust laden paved roadway causes some of the material to be emitted into the atmosphere. The larger particles (>100μm) emitted will normally settle out within 20 to 30 feet from the edge of the roadway and, therefore, are not included in the area source emission profile. Particles of less than 100μm diameter will be dispersed depending upon their diameter and extent of atmospheric turbulence.

An equilibrium roadway dust loading will result when a balance is achieved between the material deposition and removal rates. The former rate includes: tire and brake lining wear; pavement wear; atmospheric dust fallout; mud and dust carryout from unpaved areas; vehicle engine particulate emissions; etc. Material is removed from the roadway under the action of: entrainment by tire motion and vehicle-generated turbulence; wind erosion (for wind speeds exceeding 13 mi/hr); rainfall washing; street sweeping; etc.

Measurements of airborne particulates emanating from paved roadways were reported in References 2-113 and 2-114. Both studies addressed dust entrainment from dry streets in the Kansas City area. These data were the basis of the AP-42 recommended emission factor of 0.012 lb/vehicle-mile. However, this single value must be modified to account for dust removal by rain, tire and brake lining emissions, and high-speed, high-volume traffic patterns.

Dust removal by rain was accounted for by assuming that rainfall in excess of 0.01 in./day would completely inhibit particulate emissions of any kind from the roadway. This is the same criterion utilized in the analysis of unpaved roads. Thus, the basic emission factor was modified by a term:

$$\left(\frac{365 - W}{365}\right)$$

where W is the number of days/year with rainfalls exceeding 0.01 in./day.

Reference 2-114 performed microscopic analyses of collected particulate samples and found traces of rubber tire particles. Other sections in this report estimated particulate emissions from tire and brake wear, therefore, these totals were subtracted from the paved road emissions in order to prevent double counting.

The equilibrium dust content on high-speed, high-volume roadways was expected to be less than on residential, commercial or industrial surfaces. This is due to the high traffic volume producing a high removal rate, i.e:

$$\text{Mass rate of removal} = \frac{\text{lb}}{\text{vehicle/mile}} \times \frac{\text{vehicle}}{\text{hour}} = \frac{\text{lb}}{\text{hour-mile}}$$

This removal rate would be partially offset by engine-generated particulates, pavement wear and dirt carryout (directly proportional to traffic volume). However, other deposition sources (background dust fallout, etc.) would be, to a first approximation, independent of traffic volume.

No quantified data was found describing particulate emissions from high-speed, high-volume paved roadways and it was assumed that these conditions would produce one-half the emission factor recommended in AP-42, i.e. 0.006 lb/vehicle-mile, based on the considerations previously discussed.

The particle size distribution from paved roads was taken as the mean of the appropriate tests reported in Ref. 2-113 and is shown in Figure 2-11. This distribution has the following characteristics:

Particle Size	Weight Percent
<1μm	13
1-3μm	25
3-10μm	34
>10μm	28

Freeway and highway travel represents 50% of the total vehicle-miles traveled (VMT) in the South Coast Air Basin, according to Ref. 2-115. Total vehicular travel on paved roads in the SCAB, excluding towed trailers, amounts to an estimated 7.2×10^{10} VMT/year (cf. Table 2-15) and, with the emission factors developed, represents a gross particulate emission rate of 330,000 tons/year.

This amount was reduced by those corresponding to tire wear (8400 tons/year) and brake wear (3100 tons/year) in order not to double count these sources. The resultants were further reduced by the average number of rainy days (>0.010 in./day) in the SCAB (32 days/year) to achieve an estimated total particulate emission rate of 290,000 tons/year.

Reference 2-113 produced the particle size distribution shown above which allowed the specification of the total emission rate associated with particles <10μm in diameter, i.e. 72% by weight. Thus, the total emissions in

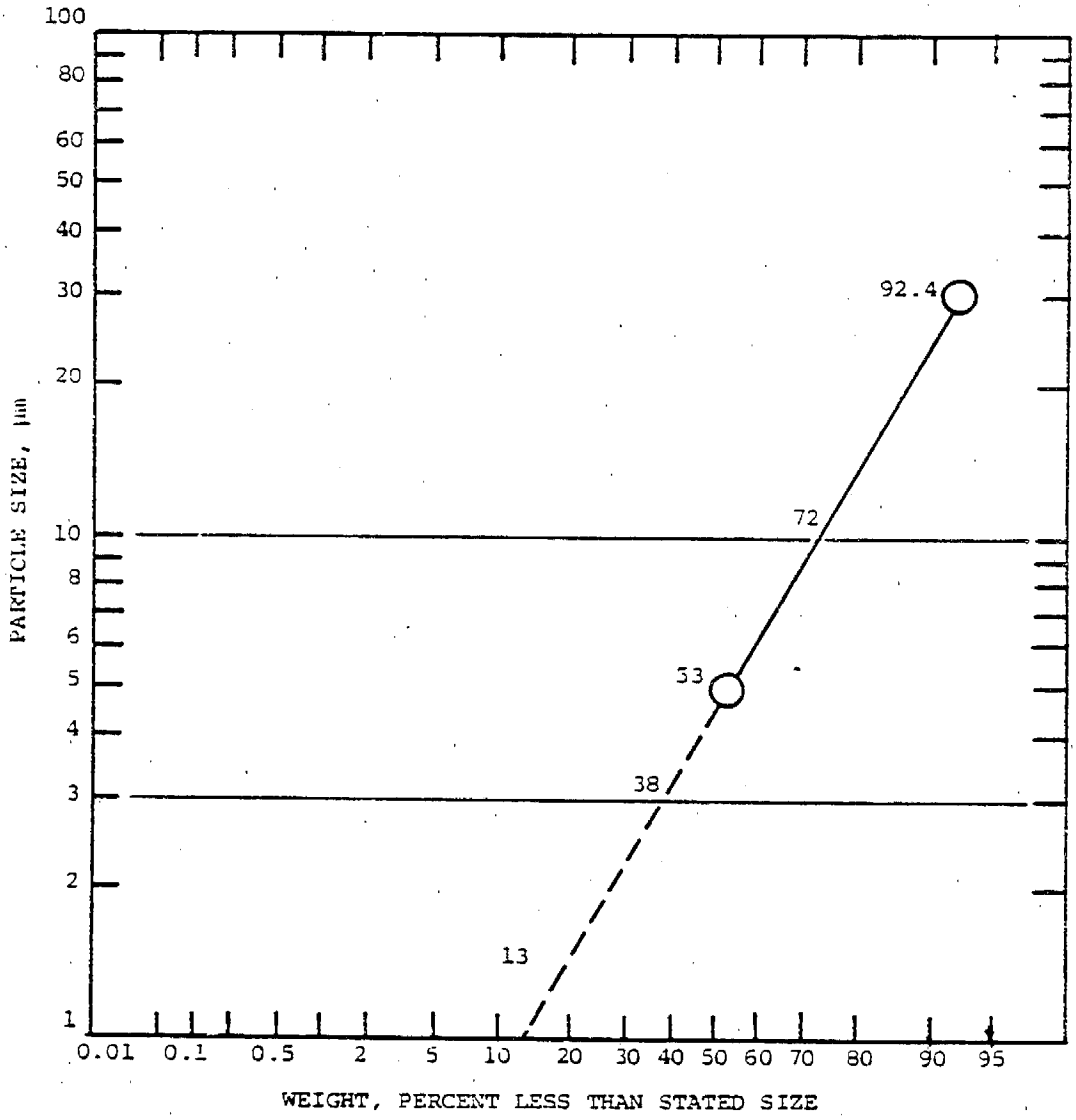

Figure 2-11. Paved road particle size distribution (Source: Ref. 2-113).

this size range was 210,000 ton/year (70,000 ton/year from freeways/highways and 140,000 tons/year from surface streets).

Table 2-11 presents the emissions from paved roadways in the SCAB (for d<10μm), by roadway category and particulate type. These figures must be viewed with caution since, according to AP-42, 40% by weight of samples collected were analyzed to be engine combustion generated particulates. These particles would have been included in a mobile source inventory and it would be incorrect to include them again in a new category--paved road travel.

Vehicular travel on paved roads produces particulate emissions categorized as (AP-42): engine exhaust particles (40% by weight); mineral matter (59% by weight); and biological and tire dust (1% by weight). However, the engine exhaust particles have already been included as a mobile source contribution and, therefore, should not be counted again by this study. Mineral matter emissions result from re-entrainment of background dust depositing on the roadway and from dirt and mud carried out from unpaved areas. Thus, a large percentage of the roadway dust emissions actually originated from an area source not considered in the present work, e.g., wind erosion of open fields, and it would not be correct to attribute them to paved road travel. Tire (and brake) attrition has been separately considered and was not counted again as a paved road dust area source.

Strictly speaking, the only particulate emissions directly attributable to roadway traffic would be pavement degradation, tire and brake lining attrition, and engine combustion particles. The first item was not quantified by this study, while the second has been separately estimated. The last item has already been discussed. Thus, a large, but unknown, fraction of the particulate emission rates shown in Table 2-11 have been considered elsewhere.

B. Combustion--

Fugitive combustion related sources accounted for ∿3% of the total estimated area source emissions computed in the final 1976 inventory. The area sources and their respective emissions covered under combustion in the final inventory are:

1)	Forest Fires	2400 T/yr
2)	Structural	200 "
3)	Fireplaces	500 "

TABLE 2-11. PAVED ROADWAY PARTICULATE EMISSIONS IN SCAB*

d<10μm, 32 rainy days/year

	Particulate Type, Tons/Year		
Roadway Category	Exhaust	Mineral	Total, Tons/Year
Freeway/Highway	28,000	42,000	70,000
Surface Street	56,000	84,000	140,000
	84,000	126,000	210,000

Note: Particulate emissions from tire and brake wear were separately estimated.

* See text.

4)	Residential natural gas consumption	100 "
5)	Cigarettes	800 "
6)	Agricultural burning	500 "
TOTAL		4500 T/yr

1. Forest fires--Forest fires consumed over 23,000 acres of forest and privately owned lands within the SCAB in 1976. An estimated 570,000 tons of combustible material (fuel) was consumed in the process shown in Table 2-12.

The most apparent atmospheric contaminant from forest burning is particulate emissions. The size and intensity (or even the occurrence) of a wildfire is directly dependent on such variables as the local meteorological conditions, the species of trees and their moisture content, and the weight of consumable fuel per acre (fuel loading). Once a fire begins, the dry combustible material (usually small undergrowth and forest floor litter) is consumed first, and if the energy release is large and of sufficient duration, the drying of green, live material occurs with subsequent burning of this material, as well as the larger dry material. Under proper environmental and fuel conditions, this process may initiate a chain reaction that results in a widespread conflagration.

The complete combustion of a forest fuel requires a heat flux (temperature gradient), an adequate oxygen supply, and sufficient burning time. The size and quantity of forest fuels, the meteorological conditions, and the topographic features interact to modify and change the burning behavior as the fire spreads; thus, a wildfire will attain different degrees of combustion during its lifetime (Ref. 2-50).

Knowledge of the chemical nature of forest fuels, combined with what is known about pyrolysis and combustion, suggests that particulates formed by forest fires will consist primarily of a complex mixture of soot, tars, and volatile organic substances. The majority of particles found in fire smoke are formed from the gaseous organic compounds produced by pyrolysis and combustion. The processes of nucleation, condensation, and coagulation combine in a continuous chain of rapid events to form both liquid and solid particulates ranging upwards in size from about 0.002 microns. Particles are also formed by the mechanical tearing action of turbulent forces present in the fires zone (Ref. 2-51).

Research on forest fire emissions conducted by the USDA Forest Service Southeastern Forest Experimental Station (Ref. 2-51) concluded that:

TABLE 2-12. FOREST ACREAGE, FUEL ESTIMATES, AND EMISSIONS

County-SCAB	Acres	Tons Consumed	Emissions, Tons/yr
Orange	2800	16,000	120
Los Angeles	3400	85,000	700
Riverside	5100	78,000	600
San Bernardino	1800	52,000	430
Ventura	9800	68,000	530
Santa Barbara	430	6,900	50
TOTAL	23,330	368,000	2,400

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1) The median diameter of particles in forest fire smoke is approximately 0.2 micron, i.e. 50% of the particulate weight occurs at this size.

2) Approximately 80% of the mass of all particulates is below 1 micron (see Figure 2-12)

3) Regardless of fuel type, average particle size remains essentially constant.*

A high level of confidence in these indications was reached by the Southeastern Forest Service when coupled with the results of other investigations. However, these conclusions apply mainly to forest acreage located in the Southeastern portion of the United States. Although differences in fuel type do exist between Southern California forests and forests of the southeastern part of the United States, the effects of these differences on particulate size and mass loading are not known at this time. Impactor studies performed by the Pacific Northwest Forest and Range Experiment Station (Ref. 2-52) on the burning of Douglas fir† under laboratory conditions revealed that 82% of the particulate mass was <1μm aerodynamic diameter and that 69% was <0.3μm. As can be seen in Figure 2-12 these values do not differ significantly from those measured by the Southeastern Forest Service. Therefore, until further studies concerning SCAB forest fire characteristics are conducted, it is assumed that the characteristics of SCAB forest fires do not differ significantly from those characteristics observed by the Southeastern Forest Service.

The emission rate of particulates depends heavily upon the fire type and fuel moisture content, and, to a lesser extent, upon fuel type and arrangement. Heading fires generally produce about three times more particulates than backing fires, everything else being equal. Also, for a given fire, emission rates during the smoldering phase can be eight times higher than in the flaring phase (Ref. 2-51).

Studies (Refs. 2-50,54) have estimated that from 16-17 pounds of particulate matter are released per ton of fuel burned. The acreage of forest and privately owned lands burned in 1976 and their associated fuel loading values were obtained from National Forest Services (Resf. 2-55,56) and the Air Resources Board (Ref. 2-57). The acres burned, material consumed, and estimated emissions are presented in Table 2-12. Figure 2-13 presents the location of the major forest acreage in the South Coast Air Basin.

*Location of four fuel types tested are: Deridder, LA; New Born, NC; Ft. Lauderdale, FL; Round Oak, GA.

†Douglas fir comprises approx. 10% of the total SCAB forest acreage and ∿26% of the forest acreage occupied by trees (Ref. 2-53).

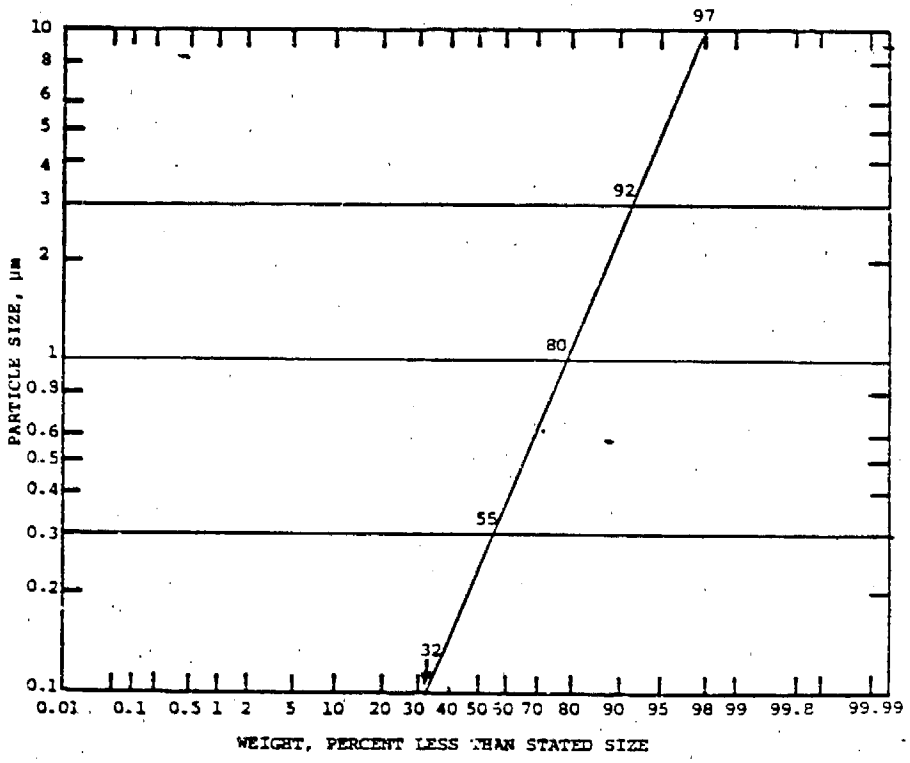


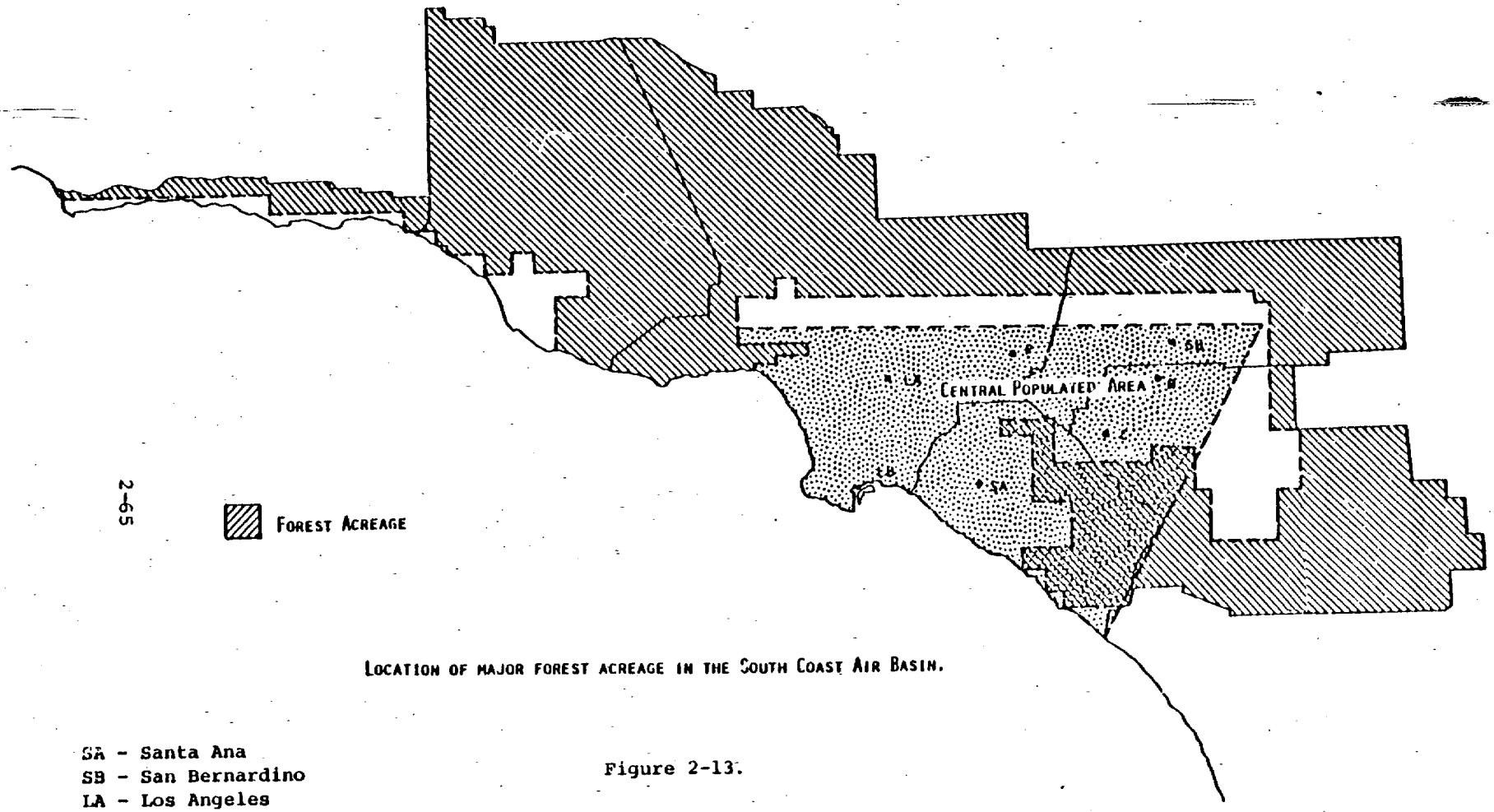
Figure 2-12. Forest fire particle size distribution.

Source: Ref. 2-51

Average of four fuel types from locations at:

a) Derrider, LA
b) New Born, NC
c) Ft. Lauderdale, FL
d) Round Oak, GA

Note: Particle sizing data on fuel types native to Southern California not available; assume differences at this time to be negligible.



LOCATION OF MAJOR FOREST ACREAGE IN THE SOUTH COAST AIR BASIN.

SA - Santa Ana
SB - San Bernardino
LA - Los Angeles
LB - Long Beach
P - Pomona
R - Riverside
C - Corona

Figure 2-13.

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2. Structural fire--A recent study (Refs. 2-53, 59) conducted by the ARB and SCAQMD was employed in estimating the quantity of particulate matter emitted to the atmosphere during a structural or vehicular fire. Emissions of 500 tons/yr or 0.24 tons/yr per 10,000 people were reported for the entire state of California. The SCAB estimate of 500 tons per year was derived by multiplying the 0.24 tons per 10,000 people per year by the 1976 SCAB population (Ref. 2-60).

The approach taken in the above mentioned study was:

1) Using CFIR Reports (Ref. 2-61), establish a monetary value of property, contents, and vehicle loss due to fire in 1976.
2) Establish the monetary value equivalent to the combustion of one house, car, and contents.
3) Establish fuel loading factors per category.
4) Compute emission factors using AP-42 as a guide.
5) Convert the derived emission rate into a population based emission factor to better distribute the calculated emissions.

Table 2-13 presents the above discussed approach, values assigned and emission estimates. Due to the diversity of material consumed within a structural fire, a particle size distribution plot was not available. It was assumed to be similar to the particle size distribution for forest fires.

3. Fireplaces--As shown in Table 2-4, approximately 500 tons of particulate matter (particle <10μm) were estimated to be emanating from the combustion of firewood in residential fireplaces.

A study (Ref. 2-62) conducted on fireplace emissions for the EPA estimated the total average particulate mass emission rate to be 21 pounds per ton wood burned.* Differences in emissions existing between the wood burned in the SCAB (mainly pine, orange and eucalyptus) and of that burned in the above mentioned study (alder, fir, locust, and pine) are assumed to be negligible for this study. A literature search failed to disclose any other applicable data.

* Average soft wood moisture content 12.5% by wt.
Average soft wood density 0.43 g/cc
One cord or wood contains 90 cf wood (Ref. 2-63)

TABLE 2-13. STRUCTURAL FIRES[a]

Category	Dollar Value lost - 1976[b]	Unit Equivalency Factor	Fuel Loading Factor	Emission Factor	Static Emissions Tons
Property	133,018,066	$50,000 per house	20 tons wood[c]	340 lbs/house[d]	452
Contents	80,644,958	$10 per lb.		16 lbs/ton[d]	32
Vehicles	15,906,917	$5000 per vehicle		8.4 lbs/vehicle[e]	13
Sub-Total					500

Population based emission factor - 994,000 lbs particulates x $\frac{1}{21,224,000 \text{ people}}$ ('76 state pop) = 0.047 lbs/person

SCAB Emissions: 0.047 lbs/person x 10,334,520 people x $\frac{\text{Ton}}{2000 \text{ lbs}}$ = 240 tons

(a) Source (Refs. 2-37,38)
(b) Ref. 2-61
(c) Ref. 2-64
(d) Ref. 2-65
(e) Ref. 2-66

Particle sizing data from the above mentioned study is presented in Figure 2-14. Since soft woods are mainly burned in the SCAB, only soft wood particle sizing data was considered. On the average, particulate emissions from residential fireplaces have the following particle size characteristics.

Particle Size	Weight Percent
<1μm	36
1-3μm	12
3-10μm	14
>10μm	38

The median particle size was found to be about 3 microns; 66.3% of the particulate was condensibles caught in the back half of the sampling train.

In establishing an inventory of active wood burning residential fireplaces in the SCAB, local government agencies were contacted as to the number of existing fireplaces. It was soon discovered that such information per se was not available. A second approach of obtaining information on the number of single family and/or dwelling units in a county was taken. County assessor's offices (Refs. 2-67 to 2-70) were contacted.

To this inventory, two assumptions were made due to the lack of available data to characterize the fireplace units located within the inventory:

1. Ten percent of all reported existing dwelling units possess and use their wood burning fireplaces annually
2. Each dwelling unit included in the 10% estimate burns 1/4 cord of wood per burning season.

A census of KVB personnel and their fireplace burning habits was solicited in arriving at the 10% estimate.

An emission factor of 0.45 tons per 10,000 people was entered into the final inventory. A population based emission factor was chosen to best reflect the location of the emissions.

4. Residential natural gas combustion--The Southern California Gas Company (SCGC) (Ref. 2-71) reported that 286 billion cubic feet of natural gas was sold to its residential customers in 1976. The population served was

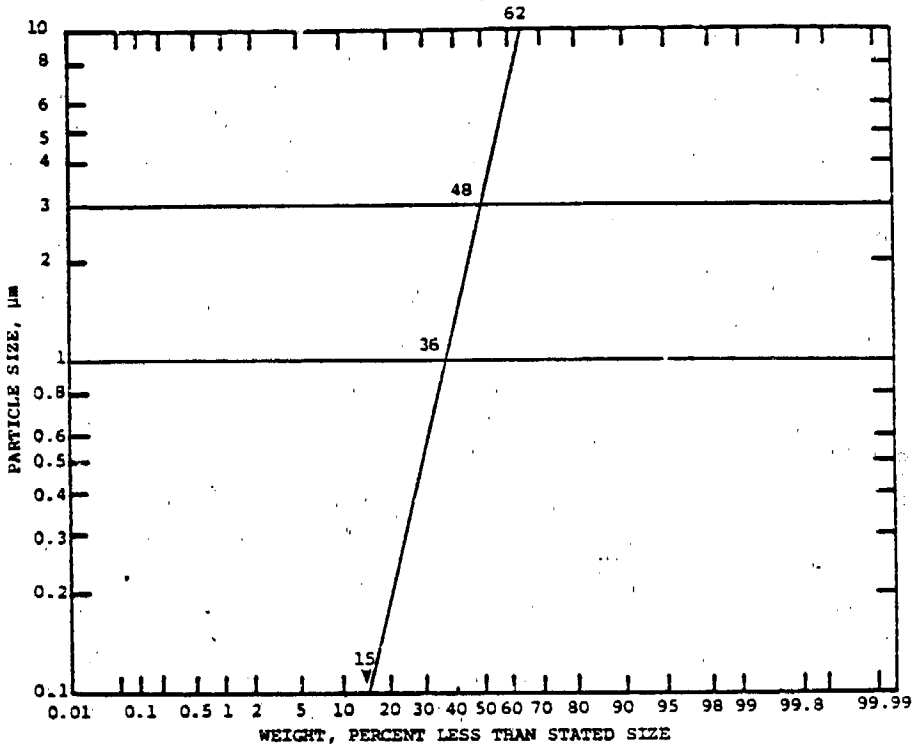

Figure 2-14. Residential fireplace emissions particle size distribution; soft woods.

Source: Ref. 2-62.

approximately 11,300,000 people excluding the city of Long Beach. The SCAB population in 1976 was approximately 10,300,000 people (Ref. 2-60). Realizing that the bulk of its customers do reside in the Basin, the entire 286 billion cubic feet was applied to the SCAB. Also, according to a SCGC fact sheet (Ref. 2-72), space heating accounted for 65% and water heating 21% of the average household appliance operating costs per year on a comparative cost basis.

Studies (Refs. 2-73-74) conducted on natural gas-fired warm air heating systems concluded emission factors of 0.00084 lb/10^6 Btu and 0.00071 lb/10^6 Btu for front half catches only. Back half results were not available. Particle size was considered to be 100% less than 1 micron (Ref. 2-74). The 0.00084 lb/10^6 Btu value was selected to represent emissions from warm air heating units typical of the study area since this study was based on tests run in the Los Angeles area and the other study was not. Gas-fired hot water or steam systems were also found to be similar to warm air heating systems and use the same type of burner. Based on this finding, emissions from water heaters and residential steam heating systems are assumed to be similar to those from warm air heating systems.

Based on the above inventory and emission factors, 100 tons per year of particulate matter was estimated to be emanating from residential natural gas combustion in the Basin. An emission factor of 0.13 tons per 10,000 people/year was entered into the final inventory. A population based emission factor was judged to reflect the location of the dwelling units using natural gas. The Southern California Gas Company estimates that greater than 95% of the single family dwelling units it serves use natural gas for space heating.

Although some correction factor greater than one should have been applied to this emission factor to account for the impinger catch, it was ignored because the basic emission of 100 T/yr is so small that it would not be cost-effective to develop a correction factor.

5. Cigarette smoke--It was estimated that approximately 800 tons per year of particulate matter was generated by the combustion of approximately 30 billion cigarettes in the Basin. Nationwide, 610 billion cigarettes (Ref. 2-75) were consumed by an estimated 150 million adult (over 18) Americans (Ref. 2-75) in 1976. Based on these 1976 statistics, it was estimated that 4100 ciga-

rettes were consumed per adult. Applying this factor to the reported 7.4 million adults (Ref. 2-76) residing in the SCAB in 1976, it was estimated that 30 billion cigarettes were consumed in 1976.

A pa t study (Refs. 2-77, 78) experimentally determined that 1000 cigarettes without filters produced 1.0 pound of smoke--gaseous and particulate matter. Measurements were not made on the quantity of smoke that was contributed by sidestream smoke, however. Sidestream smoke is defined as that smoke which emanates from the burning tip of a cigarette and goes directly into the atmosphere. Researchers (Ref. 2-79) have calculated that even when a smoker inhales, two-thirds of the smoke from a burning cigarette still goes into the environment.

Various studies (Refs. 2-80, 81) done on smoking have classified sidestream smoke as consisti of 90% gaseous and 10% particulate matter. Sidestream smoke has 3.3 times the particulate matter contained in exhaled smoke. A smoker's lungs act as a very effective filtering agent and remove nearly all of the particulate matter in mainstream smoke (Ref. 2-82). Mainstream particulates being exhaled were therefore considered negligible.

The conclusion from the above information and from personal observation is that approximately 50% of the one pound of smoke/1000 cigarettes is sidestream smoke. Ten percent of this sidestream smoke was assumed to be particulate matter. Particle sizing data were not available, but it is assumed that all particles being emitted are <10 microns in diameter.

A particulate emission factor of 0.05 lb per 1000 cigarettes smoked was calculated. This accounts for approximately 2.5% of the total weight of 1000 cigarettes without filters. A number of filterless cigarettes were weighed in KVB's lab to arrive at an average cigarette, without filter weight of 0.9 grams.

Based on the above information, an emission factor for the final inventory was developed as follows:

$$\frac{1.0 \text{ lb smoke}}{1000 \text{ cigarettes}} \times \frac{0.5 \text{ lb sidestream smoke}}{1.0 \text{ lb smoke}} \times \frac{0.1 \text{ lb particulates}}{\text{lb of sidestream smoke}}$$

$$\times \frac{4100 \text{ cigarettes}}{\text{adult}} \times \frac{3 \text{ adults}}{4 \text{ persons}} \times \frac{\text{ton}}{2000 \text{ lb}} = \frac{0.00008 \text{ ton}}{\text{person}} \text{ or } \frac{0.08 \text{ ton}}{10{,}000 \text{ persons}}$$

$\times$ 10,000 persons in the SCAB = 800 tons/yr

6. Agricultural burning--The particulate emissions from the burning of agricultural wastes in California have been recognized for several years (Ref. 2-83). The ARB and the EPA have sponsored several studies (Refs. 2-84,85, 86) with the intent of developing emission factors for such operations.

The ARB and local districts have also implemented regulations that severely restrict the open burning of waste materials. Existing regulations (Ref. 2-87) require burn permits to be issued by local government control agencies prior to the burning of farm wastes, burns conducted for range improvement, forest management, and pest control or the improvement of wild life or game habitats. Such burns could only be conducted during "permissive burn" days as determined by local meteorological conditions. Burn permits recorded the location and quantity of material to be burned. Extensive studies (Ref. 2-84) on emissions from burning agricultural wastes in California were conducted by Dr. Ellis Darley. Some of the pertinent conclusions reached were:

1) As a class, field crops and weeds produce considerably more pollutants (Part., CO, HC) than did orchard and vine crops.
2) Back firing field crops resulted in lower emissions of particulates but not CO and HC when compared with head firing. The use of back fires significantly reduces particle size, the averages being 0.11 and 0.22 microns, respectively.
3) For all fuels (crops) except avocado, it appears that drying down to at least 35% moisture would minimize particulate emissions.
4) The vast majority of particles from burning agricultural waste are submicron in size. The mass median diameter (MMD) of most particles is below 0.3 microns. Orchard fuels tend to yield smaller particles than do field crop fuels. The particle size distribution can be altered by manipulating the firing practice. Examples of Darley's size distribution plots for various crops are shown in Figures 2-15 to 2-19.
5) The average emissions of all plant material tested at the indicated average fuel moisture (dry weight basis) is shown on page 2-78 as follows:

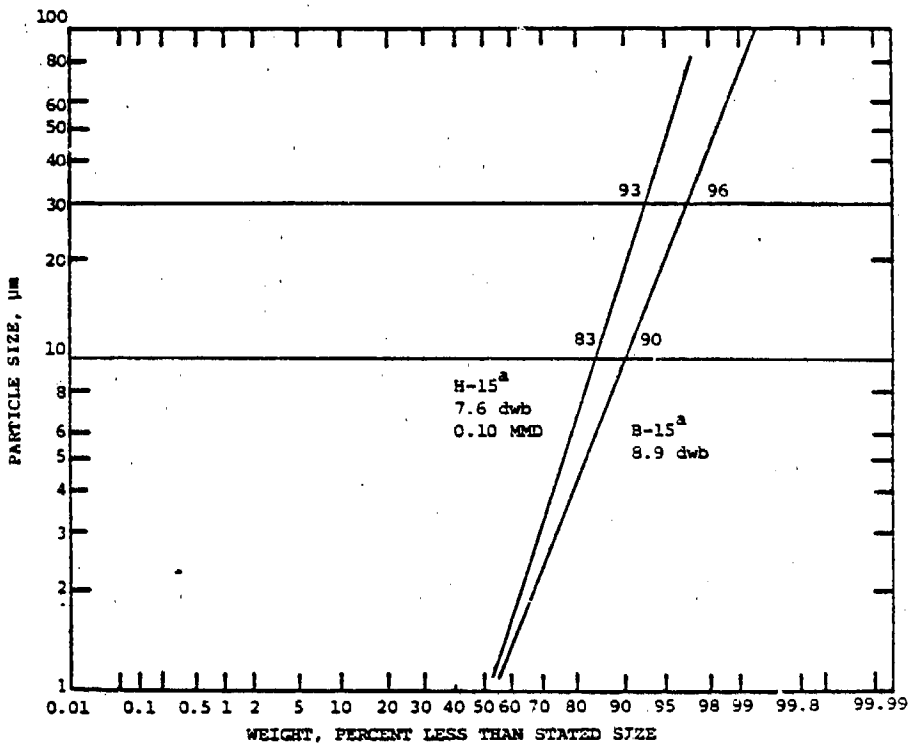

Figure 2-15. Wheat waste burning size distribution.

[a] H and B: head and back fires, respectively; 15 or 25 refers to percent of slope used.

dwb: dry weight basis

MMD: Mass Median Diameters, microns.

Source: Ref. 2-84

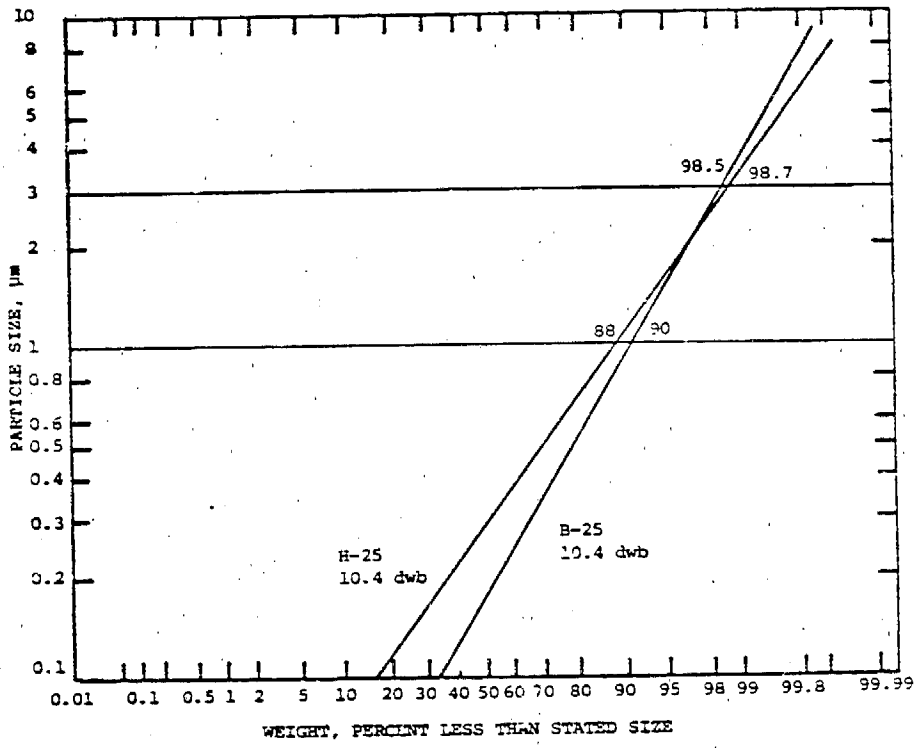

Figure 2-16. Alfalfa waste burning particle size distribution.

Source: Ref. 2-84

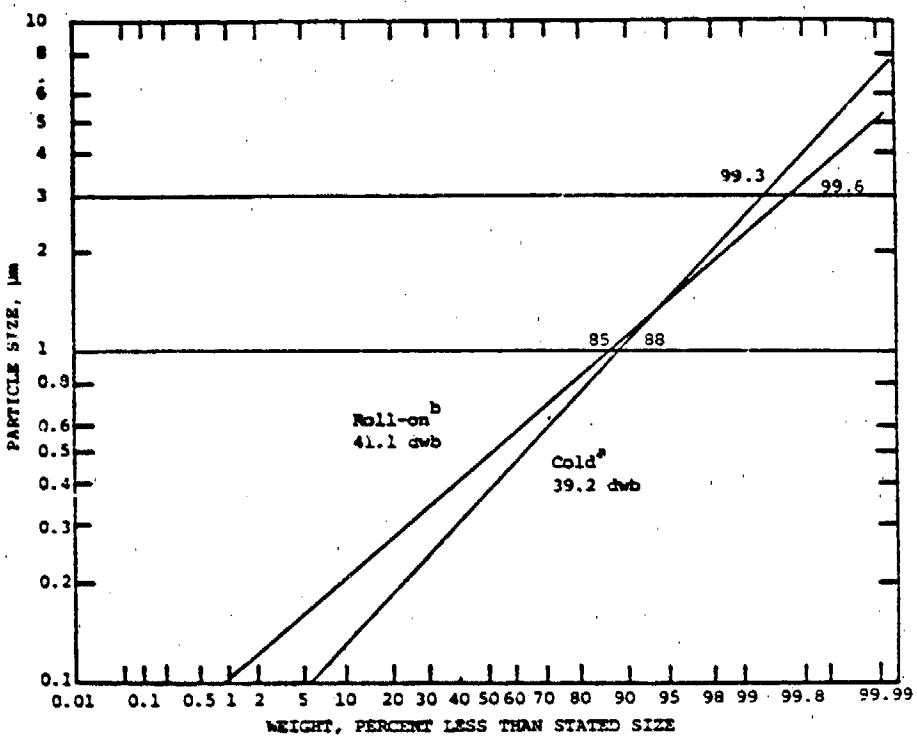

Figure 2-17. Apricot waste burning particle size distribution.

[a] Fuel was ignited at the bottom of the pile with a large propane torch without the aid of hot coals or pre-existing fire.

[b] Fuel was ignited by rolling the pile onto the glowing embers of a pre-existing fire.

Source: Ref. 2-84

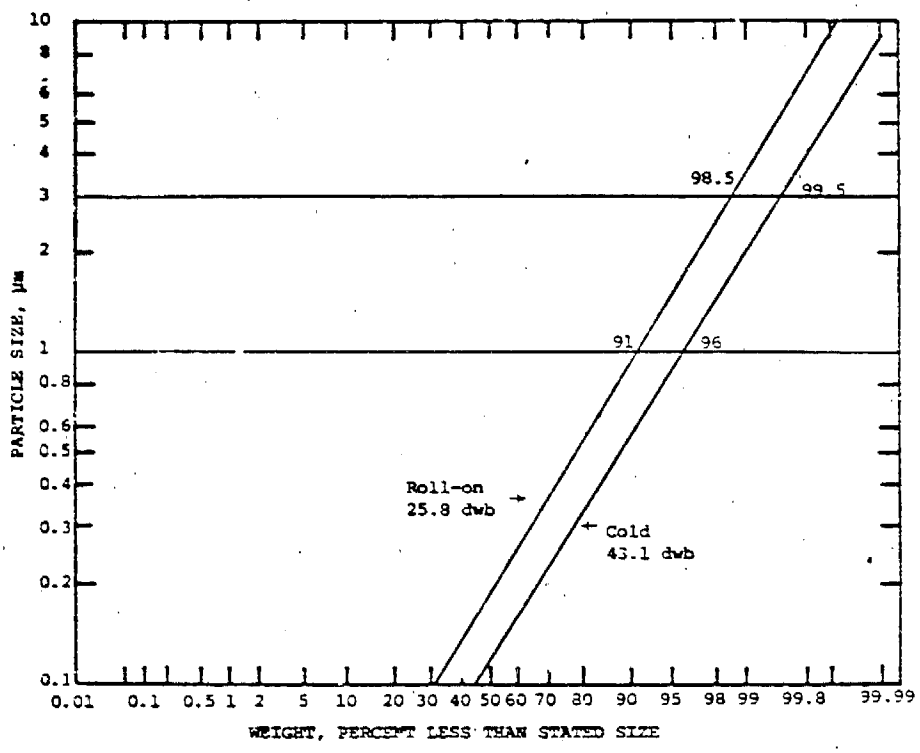

Figure 2-18. Peach waste burning particle size distribution.

Source: Ref. 2-84

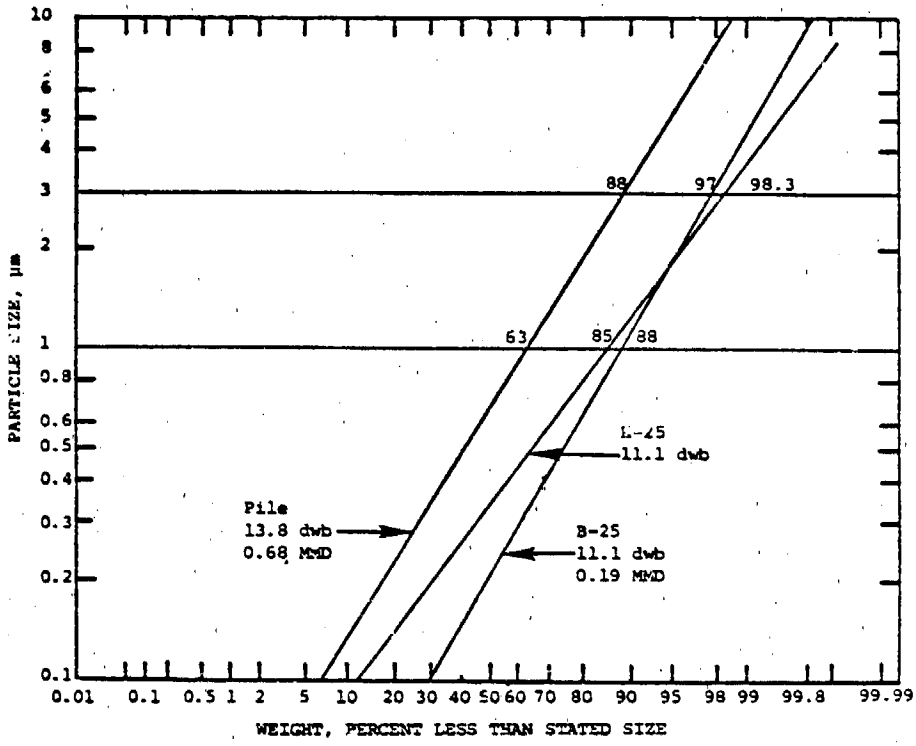

Figure 2-19. Ditch bank weed burning particle size distribution.

Source: Ref. 2-84

	Avg. Fuel Moisture (dry wt basis)	Avg. Part. Emissions lbs/ton Fuel Burned
Field Crops (incl. weeds)	12.3	18.3
Orchard Crops (incl. vines)	40.3 (Test Cond. 1)	8.7
	23.7 (Test Cond. 2)	5.4

A detailed summary of emission factor ranges per crop type is presented in Table 2-14. The factor range selected is based on the assumption that burning would be conducted under those conditions where lower emissions could be expected.

Annual reports by the ARB were issued with estimates of the air pollution impact of these burns utilizing this inventory and the emissions factors referred to above. It was estimated by the ARB that 500 tons of particulate matter were emitted in the SCAB due to agricultural burning in 1976 (Ref. 2-88). These emissions were distributed into the agricultural regions as shown in Figure 2-6.

C. Automotive--

Only two areas of automotive type particulate emissions were considered in the final 1976 inventory. The areas considered and their respective emissions are: tire tread attrition--8400 tons, and brake lining attrition--3100 tons. Combined, they accounted for approximately 8% of the total 140,000 tons of particulate matter attributed to area sources.

1. Tire tread attrition--Every year, U.S. motorists wear off nearly 1.1 million tons of tire tread through the driving of a reported 63 trillion miles (Refs. 2-89,90). Tires provide the sole contact between the vehicle and the roadway surface and must transmit the interactive forces required for propulsion and control. In doing this, tire tread material is worn away by a variety of processes. Many of the factors affecting tread wear are presented in Figure 2-20.

Two schools of thought among scientists exist on the fundamental mechanisms of wear. The first mechanism, called "thermal activated molecular stick slip," results from the extreme heat developed due to the relative motion of the tire at the road surface which breaks down the chemical composition of the rubber causing a loss at the surface of a certain number of molecules. The second mechanism is based on abrasion between the tire and the

TABLE 2-14. AGRICULTURAL WASTE BURNING EMISSION FACTORS

Particulates, lb/ton of Fuel Burned				
<5	5-10	10-15	10-20	>20
Field and Weeds				
tule	barley	bean	hay	alfalfa
	cotton	corn	safflower	asparagus
	rice	peas		oats
	mixed weeds	sorghum		
		wheat		
		ditch bank weeds		
Orchard and vines				
apple	almond	olive	avocado	
apricot	cherry			
boysen-berry	date			
	fig			
grape	peach			
nectarine	pear			
prune	walnut			

Source: Ref. 2-84

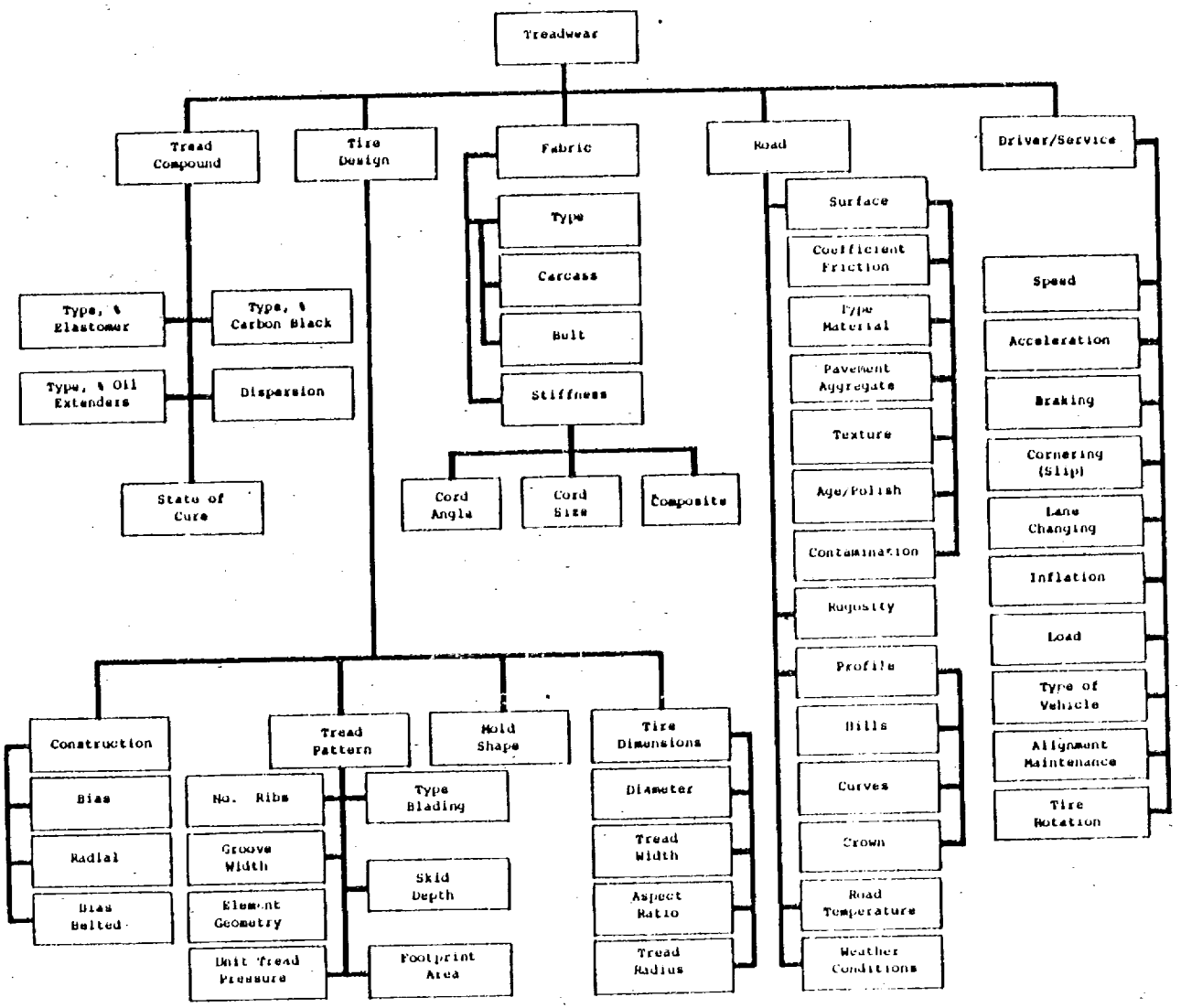

Figure 2-20. Factors affecting tread wear. Source: Ref. 2-91.

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road surface causing mechanical removal of small rubber pieces. A combination of these factors is likely to occur under normal driving conditions.

Numerous studies (Refs. 2-89,92-96) have been conducted to characterize tire tread emissions as to mass loss, particle size, and gaseous emissions. The two most significant studies involving dynamometer and actual road driving tests sited are ones conducted by General Motors (Refs. 2-95,96) and by J. P. Subramani, Ph.D. thesis, University of Cincinnati (Ref. 2-94).

General Motors estimates a tire wear rate of 0.048 g/tire·mile for travel on the San Gabriel Freeway. Eighty percent or 0.038 g/tire·mile was estimated to settle out within a few meters of the road's edge. Tests conducted for rubber content on roadside soil and dust samples proved this to be true. The remaining 20% is believed to consist of gaseous and airborne (<7 micron) particles. This line of reasoning falls into line with General Motors (Ref. 2-96) overall tire tread wear conclusion that the emission rate of gases and airborne particulate matter is nearly independent of wear rate and accounts for only 1-20% of the total emissions.

Particle sizing data taken on GM dynamometer tests concluded that 24% of the airborne mass under dynamic sampling conditions was composed of particles <0.43 microns and that tires emit particles into basically two size fractions, large particles >7 microns and small particles <0.4 microns.

In the J.P. Subramani thesis project, actual road wear rates as well as dynamometer wear rates were measured. To establish an actual road wear rate, 43 cars were driven under winter and summer conditions in the City of Cincinnati. Wear rates of 0.146 g/tire mile and 0.0873 g/tire·mile respectively were measured.

Dynamometer tests involving two automobiles reported wear rates of 0.05 g/tire·mile and 0.0431 g/tire·mile. Further testing to correlate dynamometer and road tests was advised.

Particle sizing data was obtained during the dynamometer tests. Particle measurements were made in three sizes of fractions: >10 micron, $\leq$2 microns, and those caught in a millipore filter. Conclusions drawn were

that 50% by weight of the particles were in the >10 micron size fraction, with the remainder consisting of particles $\leq$2 micron in size. This conclusion is similar in size classification to that of General Motors.

Based on the foregoing discussion, an automobile tire wear rate of 0.070 g/tire mile was derived. Of this, 30%, or 0.021 g/tire mile was estimated to consist of particles <10 microns in size, 5-10% wt. to be gaseous, and the remaining 60% to consist of primarily sedimentary type particles--particles which settle out within a few meters of the road's edge.

The basis for the 0.070 g/tire·mile was the fact that Southern Californians do a lot of freeway as well as city type driving. An average value composed of General Motor's freeway estimate of 0.048 g/tire·mile and J. P. Subramani's city summer estimate of 0.087 g/tire·mile was therefore concluded to be applicable to Southern California. The particle size distribution was derived through the averaging of the dynamometer test results conducted by J. P. Subramani and General Motors.

Taking into account the semi-quantitative particle size distribution expressed by General Motors and Subramani, the following particle size distribution for the non-gaseous factor of worn tire tread was prepared for use on this inventory.

Particle size:	>10μm	10-3 μm	3-1μm	<1μm
Percent:	60	5	15	20

Tire attrition rates of 0.203 g/tire·mile and 0.161 g/tire·mile for medium (5,000-10,000 lb curb wt.) and heavy duty (>10,000 lb curb wt.) vehicles, respectively, were also calculated. Differences existing in wear rates and total tread loss (Ref. 2-97) are the criteria for the above wear rates. The particle size distribution is assumed to be similar to that of automobile tires.

Once vehicular tire wear rates were established a vehicle inventory for 1976 needed to be developed. Information from a recent 1976 vehicle inventory for the SCAB, developed by the SCAQMD (Ref. 2-97), and an ARB document entitled "Data Base & Documentation for Estimating Emissions from Motor Vehicles in California" (Ref. 2-98) was solicited for this purpose. Vehicles were grouped into basically three weight groups:

1) Automobile and commercial two axle;<5000 lb curb wt.
2) Medium duty;5,000-10,000 lb curb wt.
3) Heavy duty;>10,000 lb curb wt.

In addition, annual mileage estimates were assigned to each class based on the above mentioned sources. Table 2-15 presents the results of the foregoing discussion. Emissions totaling 28,000 tons were estimated. Of this, 8100 tons are estimated to consist of particles <10 microns in size with a majority in the respirable size range. Also, infrared and pyrolysis analysis of airborne particulates indicated that the airborne particulate is not simply composed of small pieces of rubber, but that some of the particulate is degraded polymer and/or extender oil (Ref. 2-95).

That portion of the total particulate loss labeled as sedimentary is believed to settle out within a few meters of the roadway's edge. Tests (Ref. 2-95) conducted along a stretch of the San Gabriel Freeway proved this to be partially true.

Roadway tread rubber removal mechanisms such as chemical degradation, and to a lesser extent in Southern California, rain runoff, were also cited. Information on particle re-entrainment which is probably significant was not available, however.

2. Brake lining attrition--Brake lining attrition from vehicles operating within the SCAB in 1976 accounted for an estimated 3100 tons of asbestos material. A literature search for information on emissions from brake lining attrition failed to disclose any information on the subject. The Environmental Protection Agency is planning to conduct research into this area in the future, however.

The approach taken in establishing an emissions estimate was one of coupling a vehicle brake lining attrition factor to a vehicle annual mileage estimate. Information from a recent SCAQMD inventory (Ref. 2-97) on brake lining emissions was solicited for the purpose of developing an attrition factor. Discussions with brake lining manufacturers and actual physical measurements by SCAQMD were made to determine the quantity of lining material available per brake shoe, per weight class and average lining life. Basic assumptions made were:

TABLE 2-15. SUMMARY OF TIRE ATTRITION EMISSIONS

	Estimated Annual Mileage	No. of Tires	Vehicles in SCAB	Total Attrition	Airborne <10 micron 30% wt.	Emissions tons/yr Total	Emissions tons/yr Airborne
Light Duty Vehicles							
Automobiles	12,000	4	4,950,066	0.070[a]	0.024	18,317	5,495
Comm'l 2 axle <5000# curb wt.	12,000	4	813,041			3,009	903
Trailer 1 Axle "	1,000	2	195,179			30	9
2 Axle "	1,000	4	36,296			11	3
3 Axle "	1,000	6	723			5	<1
						21,400	6,400
Medium Duty Vehicles							
Comm'l 2 axle >5000-10,000# curb wt.	88,000	4	86,162	0.203[b]	0.071	680	
" 3 " "	49,100	10	449			50	
Trailer 1 Axle "	1,500	2	29,399			47	
2 " "	44,000	8	28,240			2,268	
3 " "	44,000	6	314			19	
4 " "	3,500	8	36			<1	
						3,100	900
Heavy Duty Vehicles							
Comm'l 2 axle > 10,000 # curb wt.	88,000	6	22,630	0.161[c]	0.056	212	
" 3 " "	49,100	10	24,330			2,118	
" 4 " "	8,800	14	343			8	
Trailer 1 axle	7,900	4	1,800			10	
" 2 "	44,000	8	19,639			1,226	
" 3 "	7,900	12				3	
" 4 "	7,900	16				<1	
						3,600	1,100
							8,400

a) Source: KVB Attrition Study

b) Proportional SCAQMD's medium to light emission factors--2.9 correction factor

c) Proportional SCAQMD's heavy to light emission factors -2.3 correction factor

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1) Density of brake lining material is 150 lbs/ft^3

2) Brake Lining on the average contains 80%wt asbestos material

3) 25% of the lining material remains on the shoe or pad

Due to the proprietary nature of brake lining material, accurate information on lining composition was not available. Table 2-16 presents the emission factors calculated per weight class.

In the development of a vehicle inventory, information from an ARB Document on motor vehicle emissions (Ref. 2-98) and a SCAQMD vehicle inventory (Ref. 2-97) were solicited. Results are presented in Table 2-17.

Particle sizing data was not available, but it is assumed that all particles would be less than 10μm

D. Sea Salt Spray--

Presently there is no precise estimate as to the mass of sea salt spray particles emitted into the atmosphere at the surf zone due to wave action. Concentrations of sea salt in ambient air, however, have been measured at several locations in the basin (Refs. 2-99,100). Results from the California Aerosol Characterization Experiment (ACHEX) were used to estimate the sea salt emissions occurring along the SCAB coastline. Two approaches were taken using this information.

The first approach was to use the results from a study (Ref. 2-101) concerned with strategies for approaching and achieving the National Ambient Air Quality Standards for particulates in the Los Angeles Region. Conclusions contained in this report were based on the data contained within the ACHEX study. Sea salt concentrations of 6-10 μg/m^3 were measured in the coastal areas, e.g., Lennox, Dominguez Hills. In addition, to arrive at an emissions estimate, the air flow through this region or window needed to be estimated.

The basic assumptions made were:

1) Average height of the inversion layer is 2000 ft (0.61 Km)--window height.

2) Window length is 190 miles (300 Km), the projected length of coastline in the Basin.

TABLE 2-16. BRAKE LINING ATTRITION EMISSION FACTOR CALCULATIONS

Assumptions: Density of all brake lining material is 150 lbs/c.f.
Brake lining contains 80% wt. asbestos material
Attrition consumes 75% of lining material during lining lifetime

Light Duty Vehicles

Automobile & commercial 2 axle; <5,000 lbs. curb wt.

Without Disc:
1) Average New Lining 6.25 in^3/shoe
2) Average Lining Life 30,000 miles
3) Brake Shoe per axle 4

Lining expended per axle: $6.25\ in^3/shoe \times \frac{4\ shoes}{axle} \times \frac{1\ c.f.}{1728\ in^3} \times \frac{150\ lbs}{c.f.} \times 0.8$ asbestos content

$$\times 0.75\ attrition \times \frac{shoe\ life}{30{,}000\ mi.} \times \frac{10^6\ mi.}{10^6\ mi.} = 43.4\ lbs/10^6\ VMT$$

With Disc:
1) Average New Lining 2.81 in^3/pad
2) Average Lining Life 40,000 miles
3) Brake pads per axle 4

Lining expended per axle: $2.81\ in^3/pad \times \frac{4\ pads}{axle} \times \frac{1\ c.f.}{1728\ in^3} \times \frac{150\ lbs}{c.f.} \times 0.8 \times 0.75$

$$\times \frac{pad\ life}{40{,}000\ mi.} \times \frac{10^6\ mi.}{10^6\ mi.} = 14.6\ lbs/10^6\ VMT$$

Source: Ref. 2-97

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TABLE 2-16. Continued

Medium Duty Vehicles

Commercial Vehicles, 5,000-10,000 lbs. curb wt.

1) Average New Lining	30 in^3/shoe
2) Average Lining Life	50,000 miles
3) Brake shoes per axle	4

Lining expended per axle: 125 lbs/10^6 VMT

Heavy Duty Vehicles

Commercial Vehicles >10,000 lbs. curb wt.

1) Average New Lining	1 & 2 axles - 2 pads -		84 in^3/shoe
	≥3 axles	front	30 m^3/shoe
		rear	84 m^3/shoe
2) Average Lining Life	50,000 miles		
3) Brake shoes per axle	4		

Lining expended per axle: ≥3 axle front--83 lbs/10^6 VMT
Rear or trailer--233 lbs/10^6 VMT
1 & 2 axle--233 lbs/10^6 VMT

TABLE 2-17. BRAKE LINING ATTRITION EMISSIONS SUMMARY

	Estimated Annual Mile..	Number of Vehicles in SCAB	% VMT Using Front Disc Brakes	Emission Factors, lbs/10^6 VMT		Emissions		
				With Disc	Without Disc	With Fr. Disc T/yr	Without Disc T/yr	Total T/yr
Light Duty Vehicles								
Automobiles	12,000	4,950,066	80%[a,b]	14.6+43.4	43.4x2	1378	516	1894
Comm'l 2 axle <5000# curb wt.	12,000	813,041		"	"	226	85	311
Trailer 1 Axle " "	1,000	195,179			43.4			4
2 Axle " "	1,000	36,294			43.4x2			2
3 Axle " "	1,000	723			43.4x3			<1
								2212
Medium Duty Vehicles								
Comm'l 2 axle >5000-10,000# curb wt.	88,000	86,162			125x2			95
Comm'l 3 " " "	49,100	449			125x3			4
Trailer 1 axle " "	3,500	29,399			125x1			6
" 2 " " "	44,000	28,248			125x2			155
" 3 " " "	44,000	314			125x3			3
" 4 " " "	3,500	36			125x4			<1
								264
Heavy Duty Vehicles								
Comm'l 2 axle >10,000# curb wt.	8,800	22,630			2x233	46		46
" 3 " " "	49,100	24,330			549	328		328
" 4 " " "	8,800	343			782	1		1
Trailer 1 axle	7,900	1,800			1x233	2		2
" 2 "	44,000	19,639			2x233	201		201
" 3 "	7,900				3x233	<1		<1
" 4 "	7,900				4x233	<1		<1
						580		3100 Total

a All past-1970 GM passenger cars equipped with front disc brakes

b Source: (Ref. 2-97)

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3) Sea salt concentration of 8 $\mu g/m^3$ is uniform throughout the window

4) Annual average on-shore wind velocity is 6 mph (or 10 kmh) (Ref. 2-102)

5) On-shore sea breeze blows ~36% of the time (Ref. 2-103)

6) 75% by wt of the sea salt particles are <10 microns in size (Ref. 2-100)

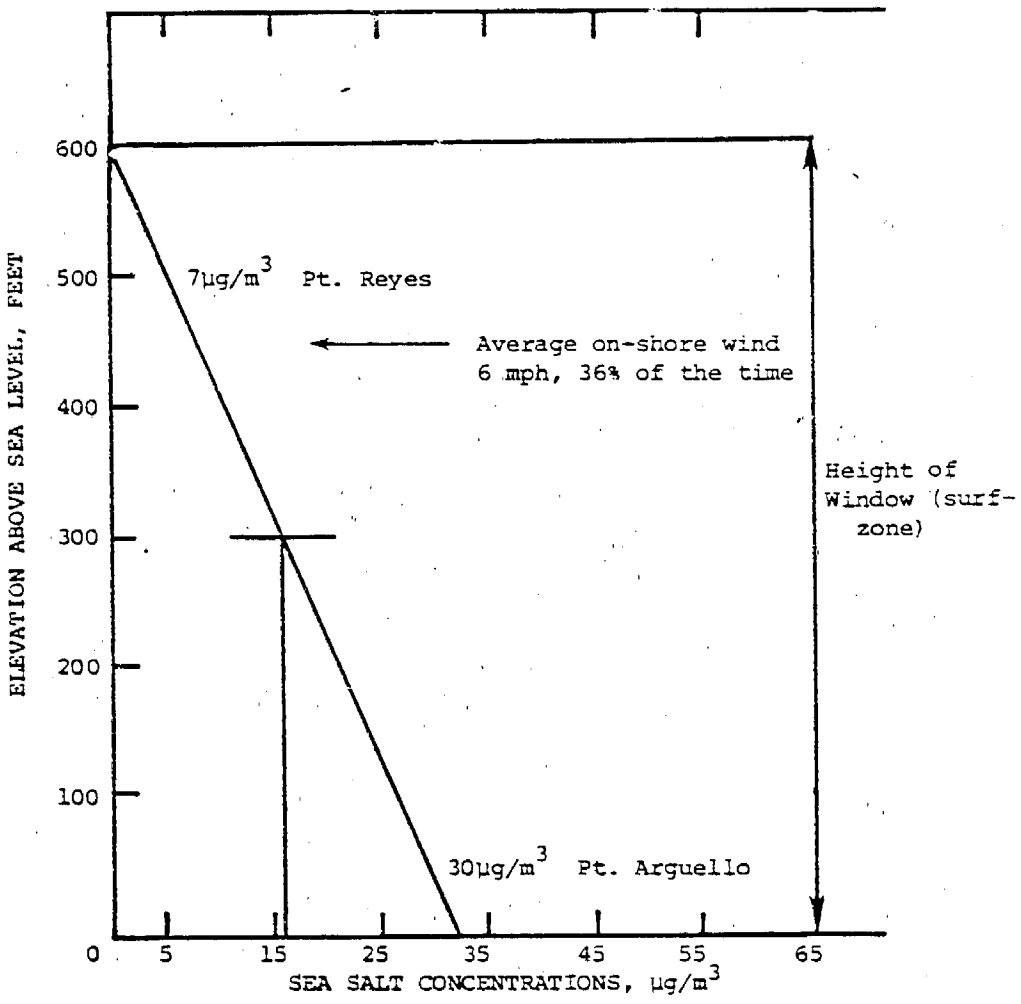
Using this approach, 39,000 tons (particles <10μm) of sea salt was estimated to originate from the SCAB surf zone each year.

The second approach involved using measured concentrations of sea salt at 50 ft above the surf and 500 ft above the surf and establishing a linear concentration gradient as shown in Figure 2-21. As discussed below the measured concentrations were taken at periods of wind velocity higher than the average wind of 6 mph. Therefore, an adjustment was made to the average concentration of 17 $\mu g/m^3$ to account for conditions under average winds. A value of 12 $\mu g/m^3$ was selected. To calculate the emissions, it was assumed that all the salt spray was generated over the height of the gradient which extrapolates to zero concentration at a height of 600 ft. Using this approach and the other assumptions shown in Figure 2-21, a value of 20,000 tons/year of sea salt emissions less than 10 μm in size were calculated.

The following is an explanation of the data used to develop this estimate.

The ambient sea salt aerosol concentrations were measured at two on-shore sites--Pt. Reyes and Pt. Arguello. Source of this information was the ACHEX study.

The sampling station at Pt. Reyes Lighthouse was on a cliff 500' (0.18 Km) above sea level and well exposed to the winds. The data collected here is presumed to be representative of background marine coastal conditions along the Central Pacific Coast of the United States, however, this data may not be applicable along the Southern California coastline.



Other assumptions: a. Length of coastline including curvature - 220 miles (350 Km)

b. 76% by weight of sea salt particles are less than 10µm in size (Ref. 2-100)

Figure 2-21. Salt spray emission calculation model.

Source: Ref. 2-100)

Data were collected over a ten day period. During the first week of testing, concentrations of 9.5 $\mu g/m^3$ with 4-11 mph (6-18 kmh) onshore winds were measured. During the second week of testing, concentrations of 4.4 $\mu g/m^3$ with a 22-34 mph (35-55 kmh) on-shore winds were measured. Winds were higher during this period, but surface trajectories were generally off-shore.

At Pt. Arguello the air was dominated by the ocean breeze. The sampling site was located within 100 yds of the sea and about 50' above the surf zone. The atmosphere was disturbed during the period of sampling by a weak storm front passing through Central Southern California. This period was also characterized by a wide range of conditions from weak winds ~4 mph (6 kmh) to rather high winds of 12 mph (19 kmh). Winds in this area generally blow from the north at 6-10 mph (10-16 kmh).

Sea salt concentrations during this period ranged from 1-100 $\mu g/m^3$. Based on the available information extracted from the ACHEX study, a value of 30$\mu g/m^3$ was chosen to represent the average sea salt concentration at Pt. Arguello. Particle sizing data were also taken. Figure 2-22 presents the results of the particle sizing test.

Based on these data, the 20,000 ton/yr of sea salt emissions were estimated to have the following particle size distribution:

Particle Size	Weight Percent
<1μm	2
1-3μm	20
3-10μm	54
>10μm	24

For the final inventory, the second approach was selected because it appeared to follow the more reasonable approach considering the available data. It was also evident that regardless of the approach taken, the quantity of salt particles being emitted from the surf zone into the atmosphere is appreciable, that is, 39,000 ton/yr or 20,000 ton/yr.

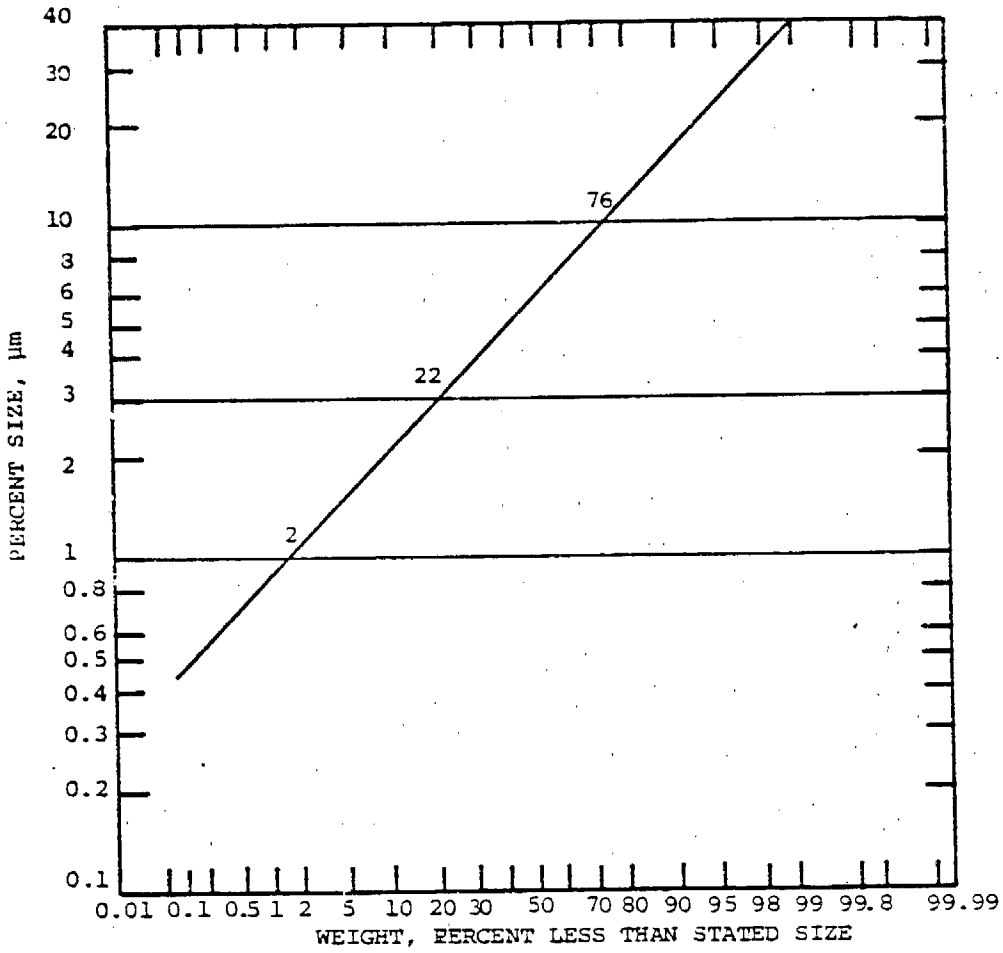


Figure 2-22. Sea spray particle size distribution.

Source: Ref. 2-100

2.4 INVENTORY RESULTS

The final TSP emission inventory was produced in August 1978 using EIS data tapes received from the ARB. The tape from SCAQMD was produced in February 1978 and the tape from Ventura APCD was produced in December 1977. Placing a baseline date on the inventory is difficult. The EIS efforts at SCAQMD and VAPCD were initiated in 1975 but data processing, correcting and updating continued from that time until the tapes used on this inventory were finally produced. Considering the span of time involved in incorporating new source data into the EIS system, the most appropriate time base to assign to the inventory is 1975-76.

The emission factors, area source data and emission profiles used in the inventory are discussed in the previous sections. In this section, the results of the inventory will be discussed.

2.4.1 Physical Description and Use Instructions

The inventory was delivered to the ARB in the form of one bound volume of computer printouts, one printed volume of emission profiles, plus three reels of computer tape. The following is a description of these reports to help facilitate their use.

A. Computer Printouts--

The computer report includes a plant index, an inventory by 10 kilometer grid squares, an inventory by ARB application categories and a SCC report.

The plant index is arranged by county and plant ID number. Because of a continuing problem with the EIS software, it was not possible to sort the plant file to arrange it in alphabetical order. Fortunately, this is not a large inconvenience since for a large part of the listing the plant ID numbers were assigned alphabetically. The index contains (in addition to county and ID) the plant name and address and its Universal Transverse Mercator (UTM) coordinates. Once a plant has been found in the index, the complete emission record can be found in the 10 kilometer grid file by looking up the UTM coordinates and the plant ID number.

The 10 kilometer grid report contains the following information:

a. The UTM coordinates of the grid

b. The major city that the grid includes

c. The population of that grid

d. A listing of each plant in the gird contained in the EIS files and emitting particulates. For each plant, it contains:

   (1) The county in which the plant is located

   (2) The plant ID Number

   (3) The plant SCC and SIC codes

   (4) Summer and winter, week-day and week-end emissions plus the total annual emissions

   (5) A profile key which relates those TSP emissions to a compositional (size and chemical) breakdown contained in the Emission Profile Report

e. A summary of area source emissions by applications category

The application category report contains the identical information; however, the sources are arranged in application categories and the emissions for each category are summarized by point area and total emissions. The terminology "Minor Sources" seen in the summary is obsolete and was not used in this inventory. All entries are zero. All point source emissions are listed under "Major Sources" and area sources are correctly reported as indicated.

The SCC report lists the profile keys, application categories and emission factor corrections for all SCC numbers encountered in the source file. This report is sorted in two orders--by SCC number and by profile key. The latter provides all SCC's covered by a single profile.

B. Emission Profile Report--

The emission profiles are bound in a separate volume. It contains 49 different profiles. Each profile indicates the distribution of TSP emissions into size ranges: >10μm, 3 to 10μm, 1 to 3 μm, and <1μm. For each of these size ranges, a chemical composition of the emissions is provided. Instructions for using the data are included in the volume.

C. Magnetic Tape Files--

The files submitted on magnetic tape include the EIS point source file, the area source file and the SCC file.

The EIS tape file contains, for each point source emitting TSP, all of the information in the EIS files of the SCAQMD, SBAPCD, and VCAPCD. The data are in the EIS format. The file layouts are identical to those for the hydrocarbon file delivered last May. (Refer to Vol. II of the H/C final report - Reference 2-53).

The area source tape file contains the area source data. File layouts were also contained in the H/C final report (Ref. 2-53).

The SCC file contains for each SCC number the applicable profile key, application category and emission factor correction.

2.4.2 Total Suspended Particulate (TSP) Emissions

The TSP emissions in the Basin plus Ventura County are 174,000 tons/year which accounts for 3900 point sources and the area sources presented in Section 2.3.3. A breakdown of these emissions according to application categories is presented in Table 2-18. Also presented in these tables are the data from 1975 inventories obtained from the local control districts (Refs. 2-105 - 110), the ARB (Ref. 2-111) and the Air Quality Management Plan produced jointly by the South California Association of Governments (SCAG), SCAQMD and ARB (Ref. 2-112). The total point source emissions are in close agreement. The EIS/KVB inventory has lower point source combustion emissions because of a reduction in utility boiler emission factor from 7.1 lb TSP/1000 gal to 3.0 lb TSP/1000 gal made by KVB as a result of field tests as discussed earlier in Section 2.3.1. The AQMP has a similar number for utility boilers. The EIS/KVB inventory has larger "Mineral" emissions primarily from two large sources in Ventura County, a sand and gravel plant and a brick plant which account for over 80% of the reported emissions. Again, the AQMP is in agreement showing an even higher emission.

TABLE 2-18. COMPARISON OF EIS/KVB AND OTHER PARTICULATE EMISSION INVENTORIES

TSP Emissions, Tons/Year

Application Category	No. Point Sources	1975-76 EIS/KVB File			Composite AQMD APCD 1975 Inv. Refs. 2-105-110	1975 ARB Inventory (Ref. 2-111)		1976 AQMP Inventory (Ref. 2-112)	
		Point Sources	Area Sources	Total		Point Sources	Area Sources	Point Sources	Area Sources
Petroleum		750		750	1500	1300		3300	
Production	34	50	0	50				1550	
Refining	25	600	0	600		1300		1700	
Marketing	8	100	0	100				25	
Organic Solvent Use		1160		1160	1800	1350		200	
Surface coating	546	1150	5	1150		1000			
Degreasing	5	10	0	10					
Other	4	5	0	5		350			
Chemical	157	540	0	540	1800	550		200	
Metallurgical	547	4200	0	4200	5500	4700		520	
Mineral	480	12600	0	12600	6200	3200		15700	
Waste Burning	48	75	500	600	500	400		20	
Combustion of Fuel		13900		13900	17500	24000		15000	
Utility boilers	187	9100	0	9100		15000		8500	
Industrial devices	1084	2700	0	2700		5500		1800	
Commercial/institut'l	199	600	0	600		3500		600	
Petroleum	316	1500	0	1500				4100	
Wood Processing	25	130	0	130		40		-	
Food and Agriculture	163	460	11000	11000	200	1100		200	
Miscell. Industrial	72	440	10	450				1500	
Unclassified (Misc. Area)	0	0	140,500	140,000			36000		93000
Fugitive dust			105,000	105,000					
Forest & structural fires			4,500	4,500					
Tires and brakes			11,000	11,000					
Sea salt			20,000	20,000					
	1900 Sources								
Total, Tons/Year,		34000	152,000	185,000	31000	17000	16000	37000	93000
(Total), Tons/Day		(93)	(416)	(510)	(90)	(100)	(100)	(100)	(255)

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The KVB area sources were discussed in Section 2.2.3. The area sources accounted for in the ARB and AQMP inventories compared to the KVB inventory are as follows:

Area Source	ARB, Ton/Y	AQMP, Ton/Y	KVB, Ton/Y
Wild fire	22,000	Not indicated	2,400
Structural fire	5,000	Not indicated	200
Farming	3,000	6,800	10,000
Construction & demolition	4,000	84,000	71,000
Unpaved roads	2,000	Not indicated	23,000
Equipment (movers, etc.)	200	260	Neglected

Since the detailed basis for the various estimates (other than for the KVB estimates discussed previously) is not available, there is little to be said regarding the differences in values. Before preparing the final inventory, KVB coordinated their area source estimate with the ARB staff.

2.4.3 Spatial Distribution

A map showing the spatial distribution of the TSP emission in the Basin and Ventura County is shown in Figure 2-23. Table 2-19 identifies the grids with TSP emissions greater than 5 ton/day.

TABLE 2-19. MAJOR 10-KM GRID EMITTERS

UTM Coor. E/W	UTM Coor. N/S	Nearest City	Emissions (Ton/Day)	Principal Source Type
280	3790	W. Ventura	10.8	Ceramic manufacturing
300	3770	Pt. Mugu	7.4	Elect. gen. & area.
320	3800	Fillmore	19.1	Sand and gravel area
360	3750	LA Airport	5.3	Elect. gen. & area
370	3740	Torrance	9.4	280 Pt. sources & area
380	3740	Paramount	6.4	250 Pt. sources & area
380	3730	LA Harbor	5.9	Elect. gen. & area
390	3730	Long Beach	11.5	Steel manufacturing
450	3770	Fontana	11.1	

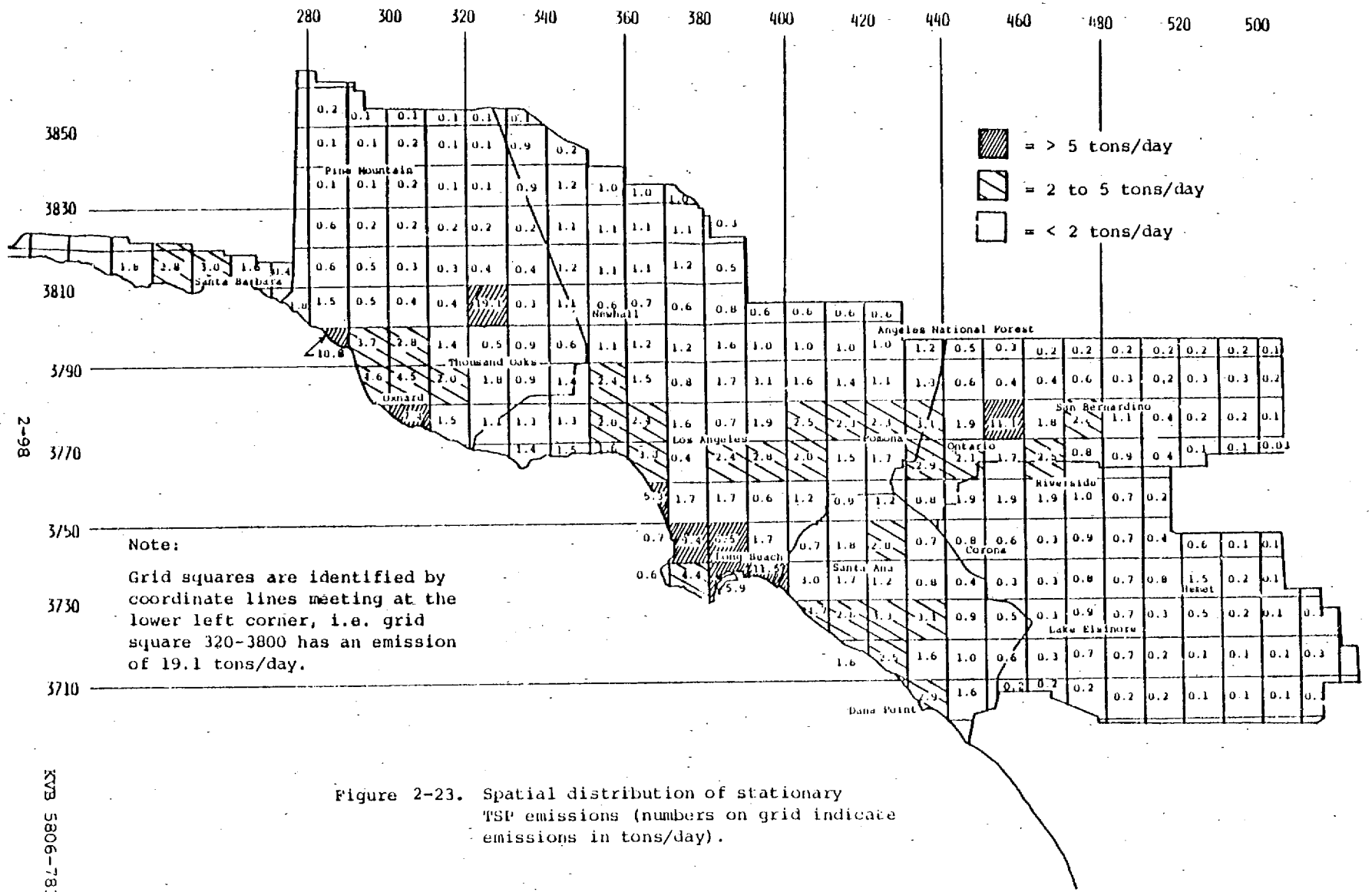

Figure 2-23. Spatial distribution of stationary TSP emissions (numbers on grid indicate emissions in tons/day).

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2.4.4 Fine Particle Summary

The objective of the program was to assess not only the total suspended particulate emissions but also the fine particle emission, i.e., the fraction with particle size less than 10 microns.

Since it was outside of the scope of this contract to program the emission profiles, it was not possible to perform a rigorous computation of the mass of fine particle emissions. Instead, a close approximation was made by estimating the particle size distribution for each application category. This estimate was made by inspection of the emission profile in the Appendix and establishing a percentage of the emissions with particle sizes less than 10μm.

Table 2-20 presents these results. Note that an estimate of the percent of TSP <10μm was made for the point sources in each application category. The area source emissions reported in this inventory (i.e., Table 2-18) were already adjusted so that they only included the <10μm portion.

In summary of the 174,000 ton/year TSP inventoried in this study, 161,000 ton/year or over 90% are less than 10μm. Of the 34,000 ton/year TSP from point sources shown in Table 2-18, 31,000 ton/year or 90% are fine particles.

TABLE 2-20. FINE PARTICLE INVENTORY SUMMARY

Application Category	% of TSP <10μm	TSP Ton/yr (Table 2-17)	Fine Particle Emissions Ton/yr	Ton/day
Petroleum	60	750	450	1.2
Organic Solvent Use	70	1160	800	2.1
Chemical	90	540	500	1.4
Metalurgical	90	4200	3800	10.4
Mineral	20	12600	2500	6.8
Waste Burning	70	600	400	1.1
Combustion of Fuel				
Utility Boiler	97	9100	8800	24
Other	90	4800	4300	11.8
Wood Processing	60	130	70	0.2
Food & Agriculture	80	11000	8800	24
Misc. Industrial	50	450	200	0.5
Area Sources				
Agricultural Tilling	100*	9900	9900	27
Road & Building Construction	100*	71000	71000	195
Livestock Feedlots	100*	1300	1300	3.6
Unpaved Roads	100*	23000	23000	63
Forest Fires	100*	2400	2400	6.6
Structural Fires	100*	200	200	0.5
Other Combustion	100*	1900	1900	5.2
Tire & Brake Attrition	100*	11000	11000	30
Sea Salt	100*	20000	20000	55
		TOTAL	171000	467

* The emissions calculated for area sources only included that portion of TSP <10μm.

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SECTION 3.0

FIELD TESTING

The field tests conducted on this program provided a realistic assessment of the particulate emissions from stationary sources in the Basin. From the outset the experimental plans and procedures were coordinated with numerous government, industry, and research consultants to benefit from the advice of other experts in the field, avoid duplication, identify representative sources and insure high data quality.

The following sections present the experimental methods employed.

3.1 APPROACH

The number of stationary sources of particulate emissions in the Basin is huge. The objective of the test program was to provide as much information as possible to characterize the particulate emissions from these sources. An initial goal of 45-50 sources was established.

The EPA has categorized pollution sources using a system of Source Classification Codes (SCC). The sources in the Basin account for approximately 150 SCC numbers. For each of these an emission factor and an emission profile was desired. In many cases emission factor data were available. Very little data were available on which to base emission profiles. Therefore, the major emphasis was given to obtaining emission profile data.

From the preliminary inventory it was determined that fuel combustion accounted for 54% of the emissions in the Basin and metallurgical and minerals accounted for 24%. Major plants were identified in each source type such as power plant, cement plant, glass furnaces, and asphalt batch plants. Special sources like a steel mill, chemical plant, etc. were also listed.

Industry was found to be cautious and concerned about this testing. They often requested a full technical briefing. The glass industry used the Glass Packaging Institute GPI and the petroleum industry used the Western Oil and Gas Association (WOGA) as agents to monitor and control their participation. As a result of this concern a great deal of engineering time was required to gain entry to plants for testing. Even after tests were completed, there were return visits to review data. In the case of GPI and SCE, formal presentations of plans and results were made for each site tested.

To minimize the amount of coordination work, KVB took the approach of trying to conduct as many of the planned tests at one plant site as possible.

The test crew consisted of two engineers and two technicians. On all tests, all four worked together. Each test required one working day at the plant site plus two days for equipment turnaround and sample processing.

3.2 METHODOLOGY

Sampling and analysis methodology described in this section was evaluated during the Phase I period of the program. This is discussed in Section 4.2.1. The objectives were to (1) determine the particulate emission rate from ducted sources, (2) collect and preserve representative samples of these emissions and (3) analyze the samples for their chemical composition. The general approach to emission rate determination was to either measure the emission rate or to determine it by calculations from process data.

Presented in the following sections are a detailed description of the field test and laboratory equipment, some explanation for their selection, and a detailed description of test procedures and data reduction techniques followed during the program.

3.2.1 Sampling

Two sampling trains were used in the program, an EPA Source Assessment Sampling System (SASS) and a modified Method 5 train. Both trains consisted of heated probe; three calibrated cyclones with nominal cut sizes of 10, 3 and 1 μm contained in an oven capable of being heated to 400°; a millipore filter also in the oven; two impingers containing distilled water; one dry impinger; one impinger containing desiccant; vacuum pump(s); and a drygas meter. The primary difference in the two trains is size. The SASS is larger with a sampling rate of 4.0 SCFM or 6.5 ACFM at 400°F where the Method 5 train has a sampling rate of 1.0 SCFM (1.65 ACFM at 400°F). The SASS requires two vacuum pumps. Both systems are essentially standard, commercially-available equipment except that the standard SASS has an organic sampling module between the filter and the impingers which was not used on these tests and a special cyclone set was designed and fabricated especially for use with the Method 5 train.

The purposes for using two trains were to:

a. Simultaneously sample upstream and downstream of control devices to measure efficiency.

b. Simultaneously sample at the same location to determine measurement accuracy.

c. Provide flexibility in equipment size using the physically smaller Method 5 train in locations where the SASS was too large.

The smaller train was used upstream of all controlled devices and the faster sampling SASS was used downstream where the grain loading was substantially lighter.

Both the small and large cyclone sets were calibrated at the program outset. Pitot tubes, gauges, meter, thermo-couples and pyrometers were calibrated periodically throughout the program.

A. Equipment Description--

1. Source assessment sampling system (SASS) Ref. 3-1--The flow diagram for the SASS is shown in Figure 3-1. The SASS is available as a standard product of the Acurex Corporation, Mountain View, California. A description of the components follows.

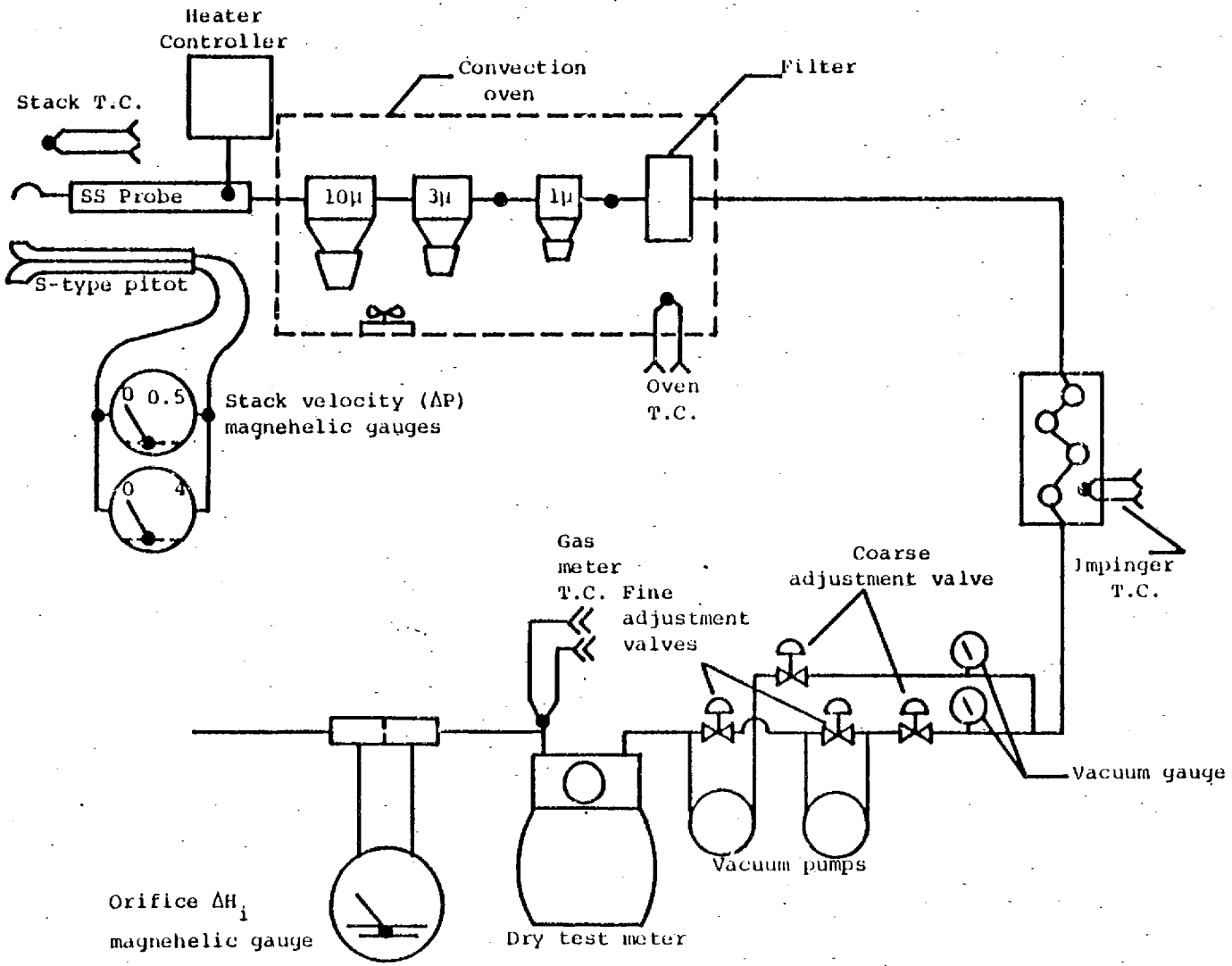

Figure 3-1. Schematic of SASS (Ref. 3-1).

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HEATED PROBE

The SASS probe extracts gas/particulate samples from the source being tested, monitors the temperature and gas velocity of the source, and maintains sample temperatures above the condensation point of water/SO_3 mixtures. Figure 3-2 shows the internal arrangement of the assembled probe. The important features of the probe are the Type 316 stainless steel sampling tube; the fiberglass-insulated strip heater (incorporating a thermocouple for feedback temperature control) wrapped around the sampling tube; a round probe body to allow sealing of the sampling port and rotation of the probe as necessary; strain relief for all electrical, thermocouple, and pitot line connections; a calibrated S-type pitot; and easily interchangeable probe tips with diameters from 1/4 to 3/4 inch in 1/16-inch increments as standard equipment. The probe is designed to withstand duct temperatures of up to 600°F.

PARTICULATE COLLECTION SYSTEM

The purpose of the particulate collection system is to maintain the sample gas stream at 400°F while collecting the particulate in three cyclones and a backup absolute filter. Figure 3-3 shows the system installed in the oven. Figure 3-4 schematically illustrates the three SASS cyclones and shows key dimensions of each. The cyclones were developed by the Southern Research Institute and Acurex's Aerotherm Division. The cyclone assembly is fabricated of 316 stainless steel. In order to be lightweight and compact for easy field use, and to be easily assembled, disassembled, and cleaned in the field, the cyclones were fabricated by spinning with inlet sections attached by welding. Support for the individual pieces in the oven is provided by tubing connections As a result the cyclones are fragile and easily damaged. The middle cyclone failed midway in the program and was replaced by a machined unit which was less expensive and more rugged, but slightly heavier.

The seal between the top and body sections of the cyclones were originally made of Teflon. These Teflon seals proved to be troublesome because of their lack of flexibility and tendency to cold-flow, leading to difficulty in getting satisfactory leak tests. After a few tests, the Teflon was replaced with Viton which has been adopted by the EPA as an acceptable material for the system.

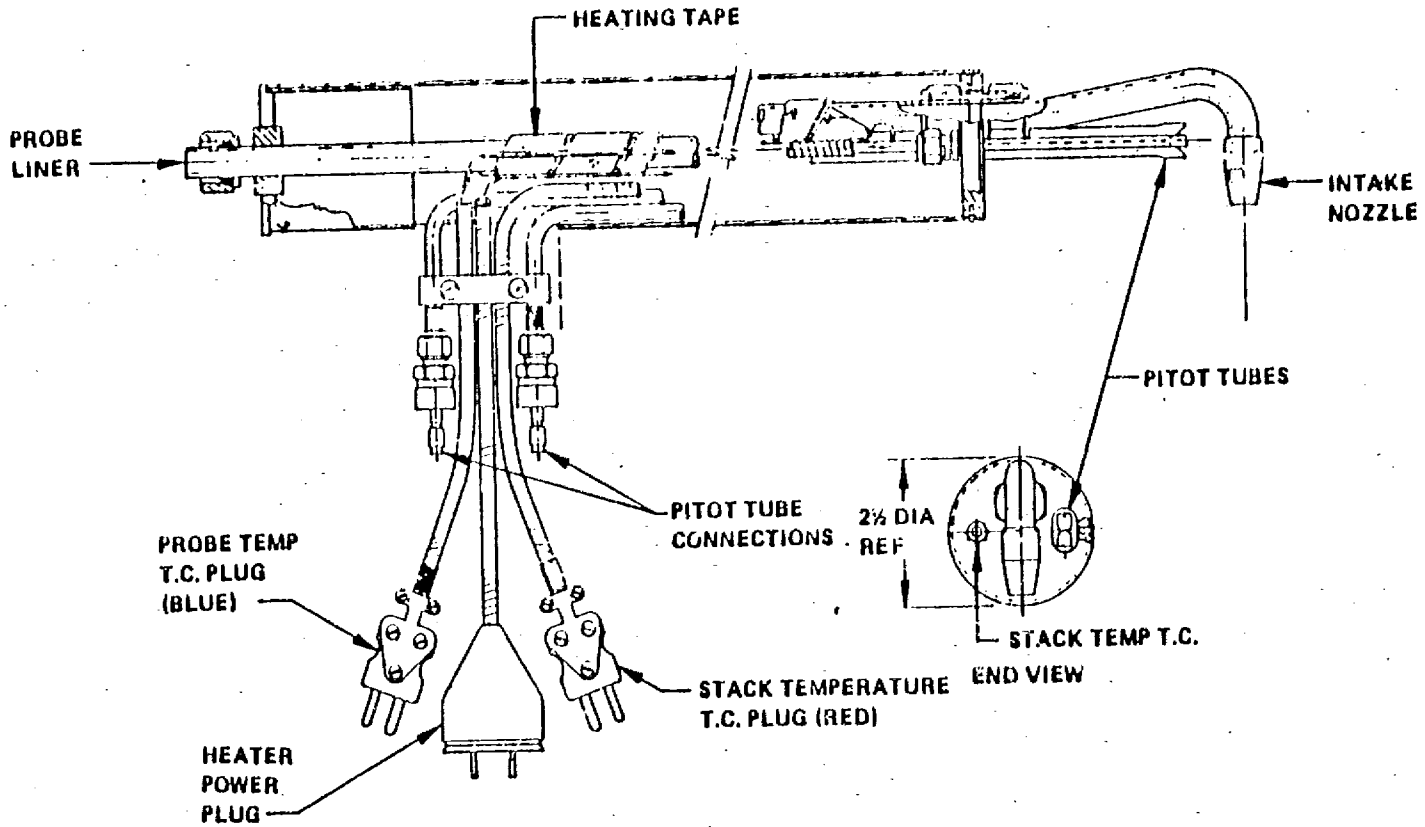

Figure 3-2. Probe Details (Ref. 3-1).

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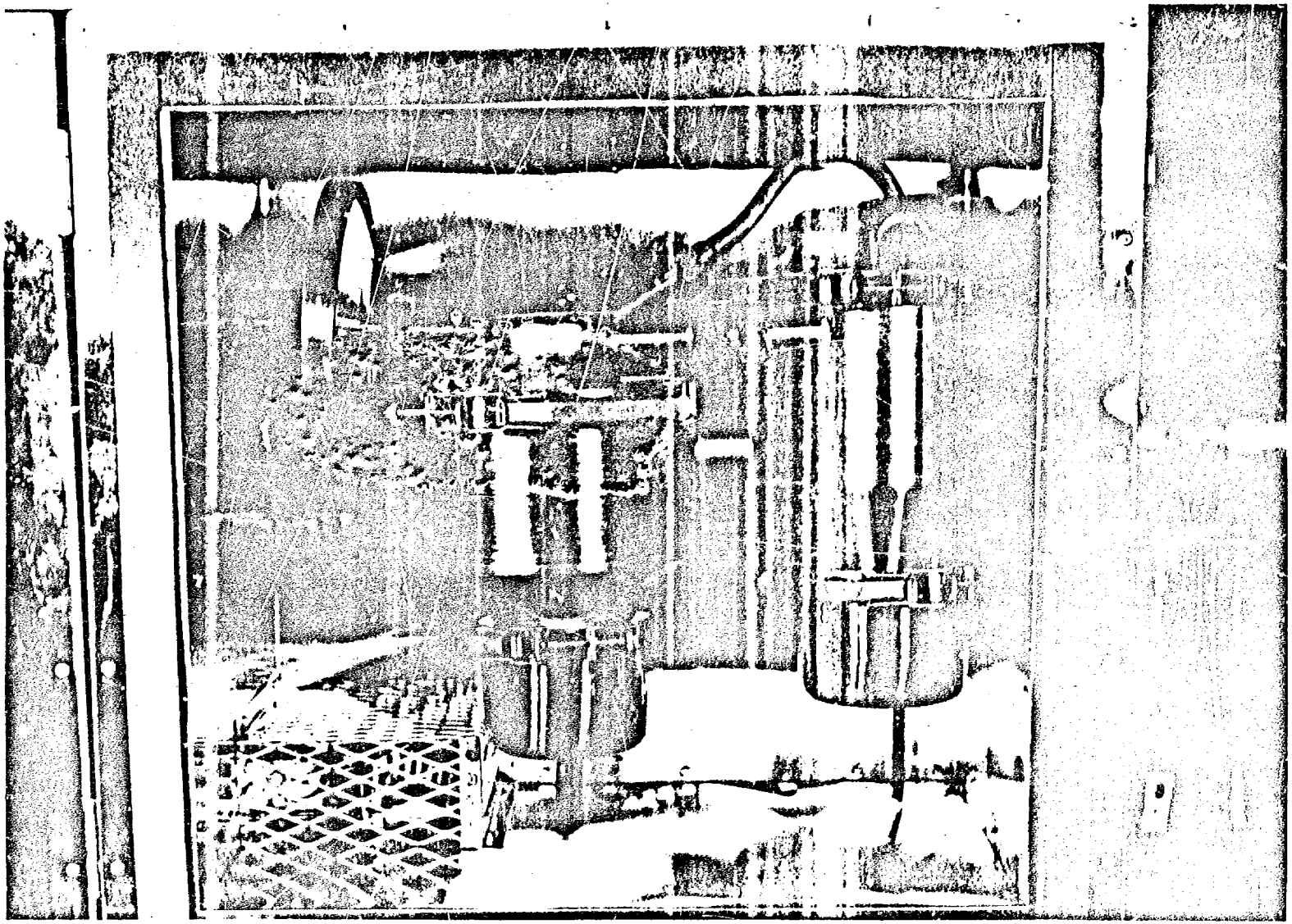

Figure 3-3. Cyclone train and filter holder with oven. (Ref. 3-1)

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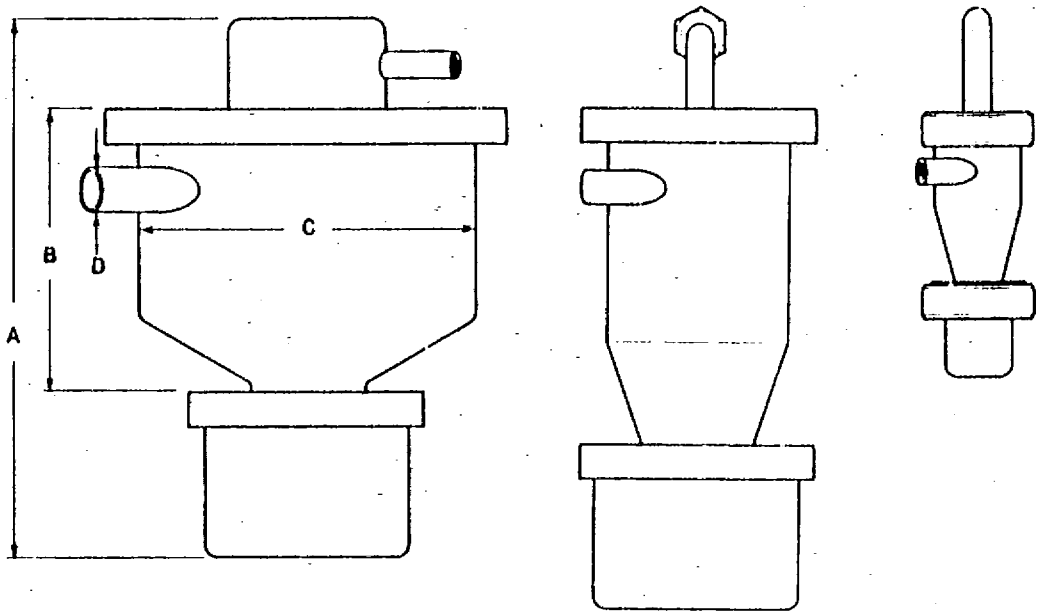


Dimensions				
Cyclone	Total Height A, cm	Body Height B, cm	Body Diameter C, cm	Inlet ID D, cm
10 μm	25.0	13.2	15.2	5.1
3 μm	27.1	15.2	8.1	1.8
1 μm	16.6	7.8	3.7	0.9

Figure 3-4. SASS cyclone dimensions (Ref. 3-1).

The filter holder (Figure 3-3) houses and supports an absolute backup filter for the series cyclones. Because of pseudo particulate problems experienced with other filters (Ref. 3-19), only Reeve Angel 934AH filters were employed in the filter holders of both trains. These filters are made of borosilicate glass fibers and have an estimated porosity of 0.3 - 0.5 μm. The filters were obtained in 150 mm diameters and were individually cut to 141 mm diameters to fit the holder.

The oven provides a constant temperature environment for the cyclones and filter, as well as mechanical protection. It also supports the probe by means of a collar attached to the side of the oven, which securely clamps the probe. The probe and oven collar are so designed that the probe can be rotated to any angular position.

IMPINGER ASSEMBLY

The impinger assembly collects any remaining condensibles in the gas stream and dries the sample gas stream to avoid damaging the gas pumps and flow monitoring instrumentation. The impinger assembly, pictured in Figure 3-6 consists of four heavy wall glass bottles. 316 stainless steel and Teflon tubing directs gas flow. The first two impinger bottles contained 400 ml of distilled water. In each of these bottles, a straight section of tubing ducts the sample gas below the liquid level. The sample gas section of tubing ducts the sample gas below the liquid level. The sample gas bubbles through the liquid, allowing the various pollutant species to be scrubbed out. The third bottle was empty. The fourth impinger bottle contained granular silica gel to dry the gas. In this bottle also, the gas is ducted to the bottom of the bottle by a stainless steel tube and flows upward through the silica gel granules.

The remaining components of the impinger assembly (shown in Figure 3-6) include a thermocouple to monitor temperature of the gas exiting the silica gel, a small pump to agitate the ice/water slurry surrounding the bottles and carrying tray so the entire impinger asembly can be lifted out of its ice bath when required.

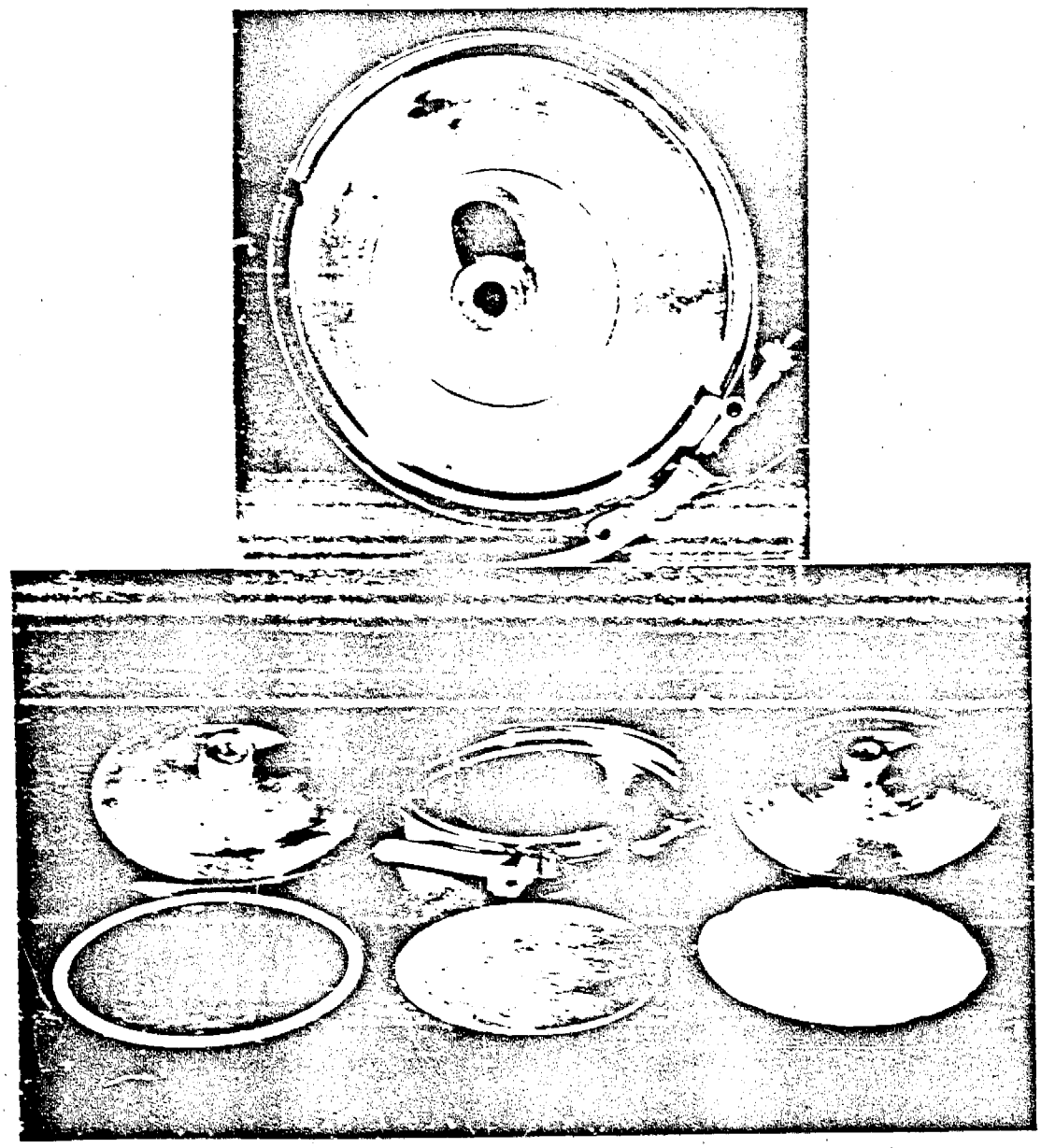


Figure 3-5. Filter housing assembly (Ref. 3-1).

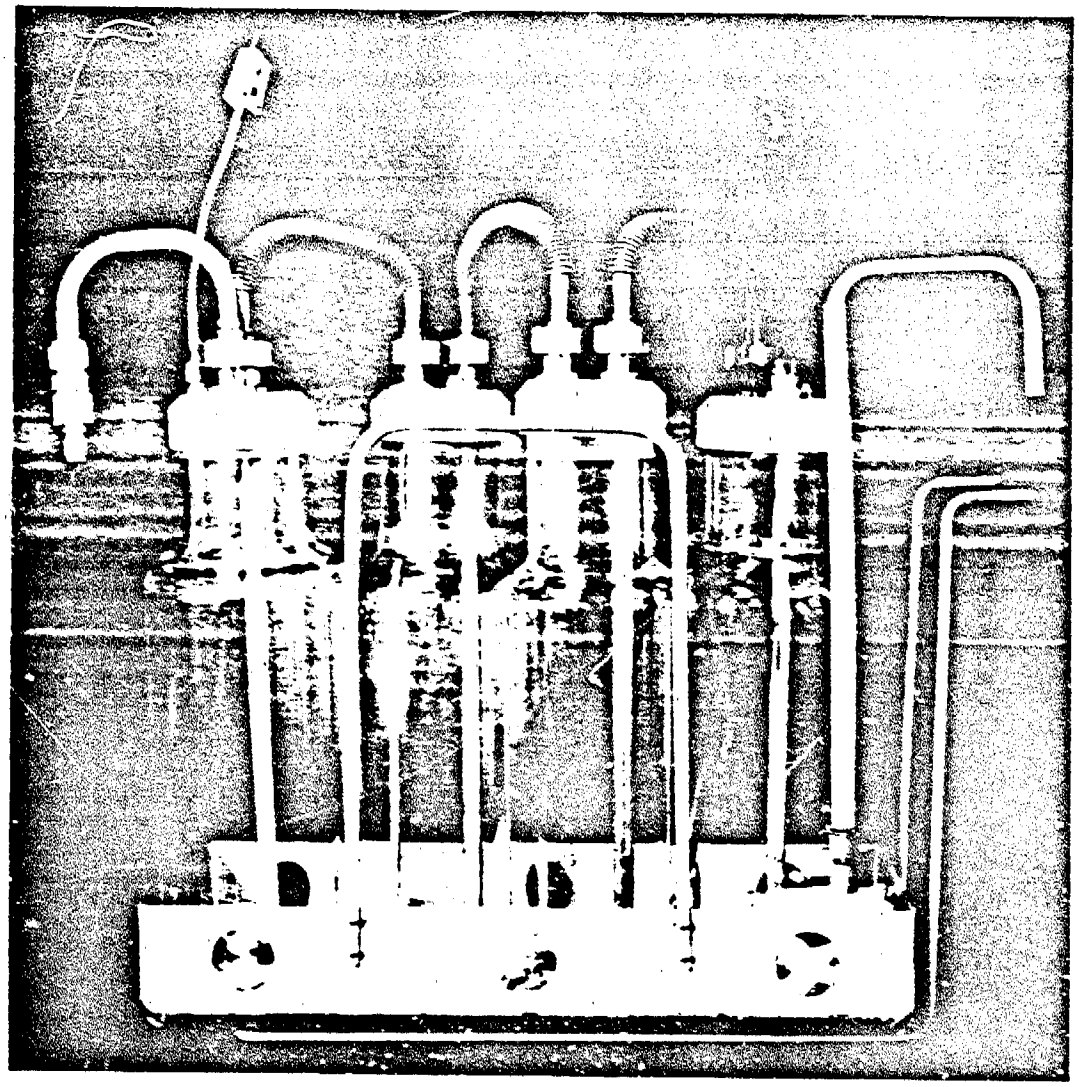


Figure 3-6. Impinger train out of case.
(Ref. 3-1)

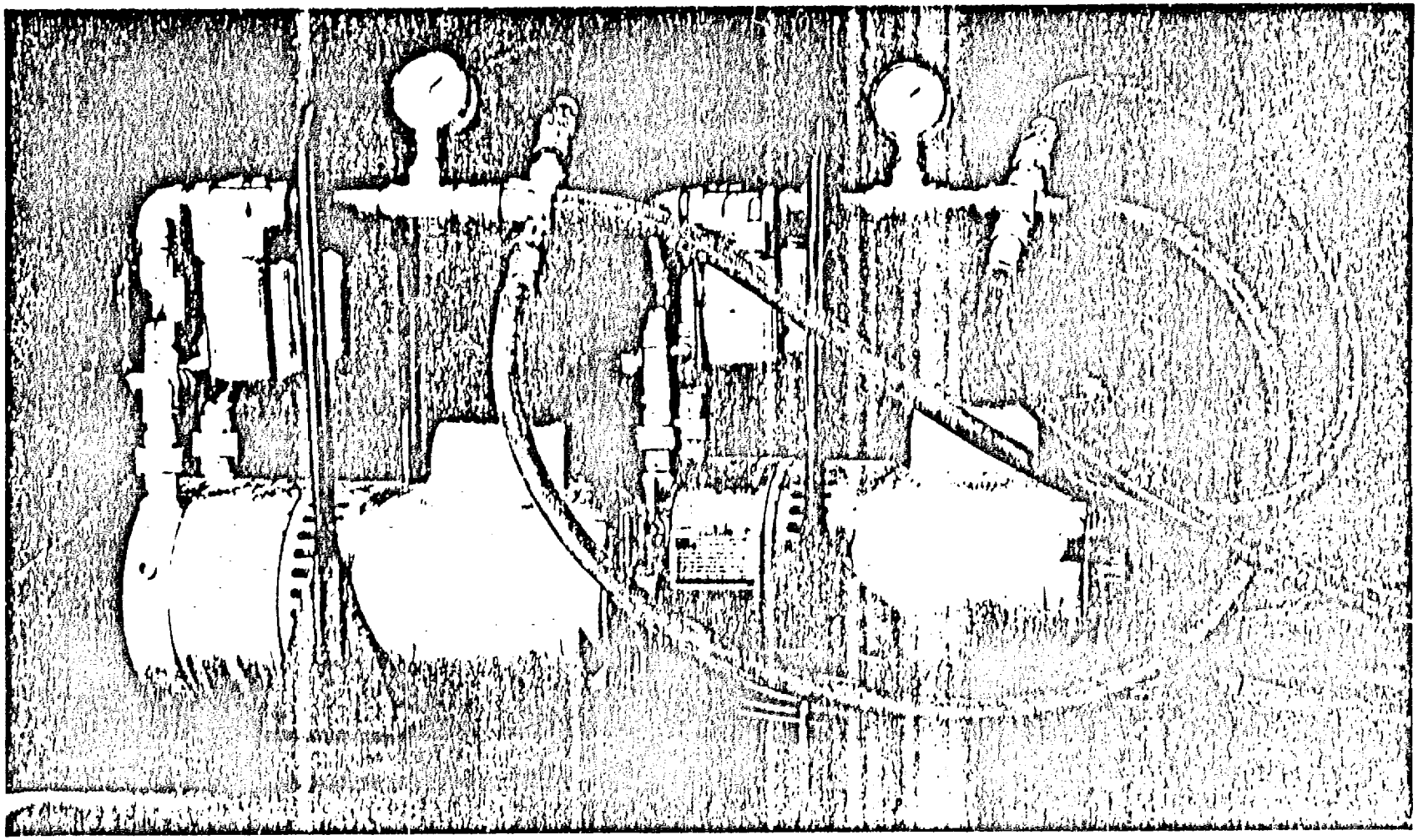


Figure 3-7. Vacuum pump (Ref. 3-1).

VACUUM PUMPS

Two vacuum pumps connected in series are used with the SASS. These carbon vane-type pumps (Gast, Model 1022) are modified by Acurex with a special shaft seal to reduce the leak rate to better than Method 5 standards. Each pump has a 3/4-hp motor, a flowrate of 10 ACFM at zero pressure drop, and weighs 59 lbs including all fittings. Each pump requires 10 amps/115 VAC.

CONTROL UNIT

The control unit contains all of the instruments for measuring stack velocity, sampling flowrate and cumulative flow, and temperatures at various points in the sampling system (Figure 3-8). All of the controls for the sampling system are located in the control unit except the valves for controlling sample flowrate. The valves are mounted on the vacuum pump, which is placed adjacent to the control unit when using the sampling system. Thus all of the controls and measurement displays are centered about the control unit.

The various switches, gauges, and connections seen on face of the control unit are described below:

Switches

There are five electrical switches with the following functions:

- Main power (with pilot light and 3-ampere, 115-VAC circuit breaker)
- Probe heater (with pilot light and 15-ampere, 115-VAC circuit breaker)
- Oven heater (with pilot light and 15-ampere, 115-VAC circuit breaker)
- Fan power
- Elapsed time indicator start-stop switch

The oven circulation fan is connected so that during heating, the fan is in operation regardless of the position of the fan control switch. When the oven heater is "off," the fan may be turned "on" with the oven door open to hasten cooling of the oven, cyclones, and filter.

Elapsed Time Indicator

An elapsed time indicator is used to determine when to move from one traverse point to the next, when performing Method 5 sampling. It is also

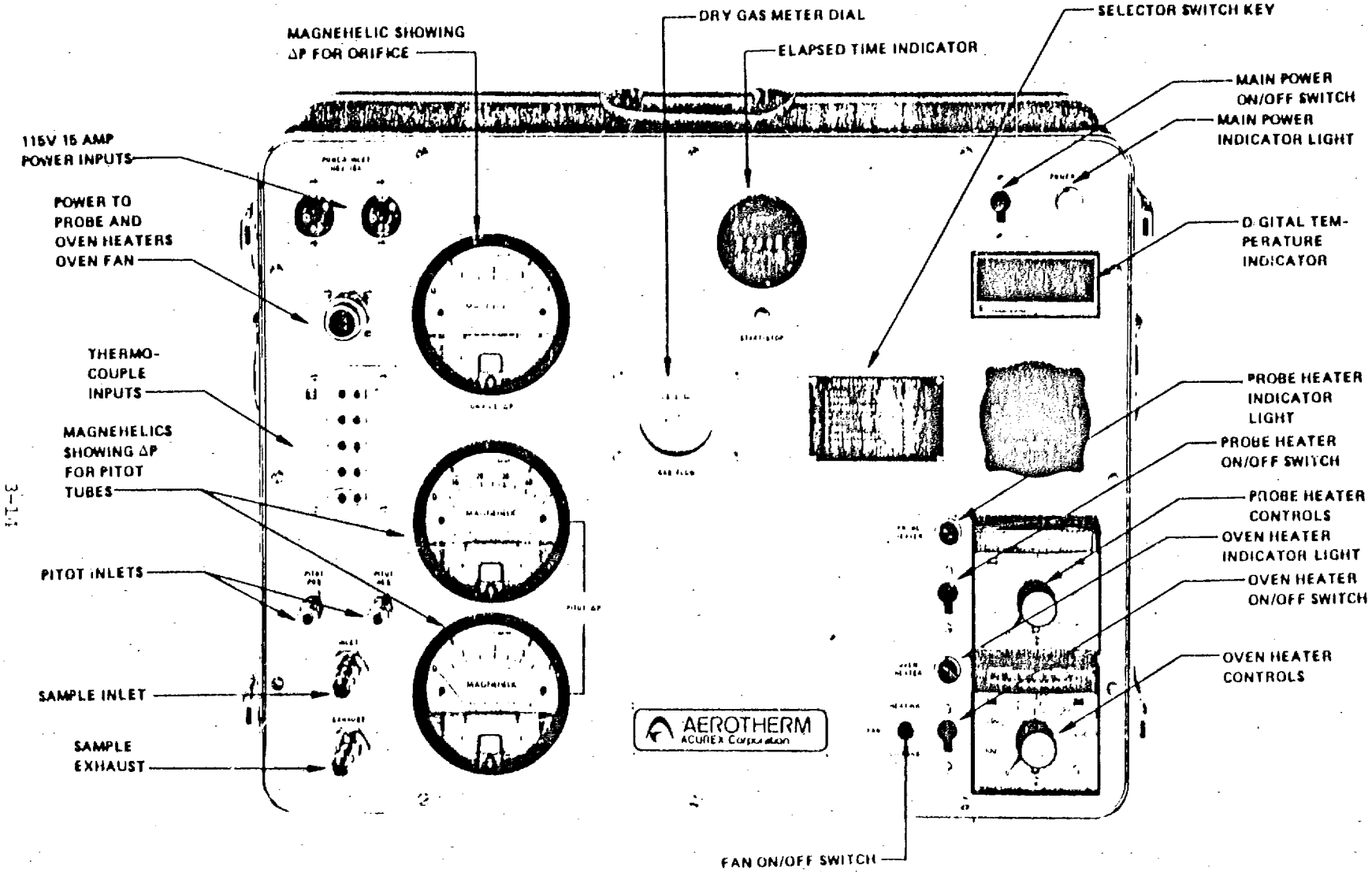


Figure 3-8. Control unit (Ref. 3-1).

useful for SASS sampling to monitor impinger solution change intervals, data logging intervals, and total sampling time. The indicator has a resolution of 1/10 of a minute. The indicator can be reset to zero, and started or stopped with a pushbutton located near the indicator.

Oven and Probe Heater Temperature Controls

Power to the oven and probe heating elements is modulated with adjustable temperature controllers. These controllers use chromel-alumel thermocouples for temperature sensing. Each controller has the following features:

- Actual temperature continuously displayed
- Maximum set-point is limited to 500°F by a mechanical stop
- Power cycling is indicated by red and green lights

The controllers provided with the unit used on this program were of low quality and required continual adjustment to keep them in calibration. After several replacements, the test crew learned to use manual procedures to bring the temperatures to the desired level (i.e., 400°F for the probe and oven) after which the controller would generally hold the temperature, although the indicator might be as much as 100°F off the proper setting. Also, if the contoller was turned to the upper limit of temperature (not beyond the scale), the control would lock, requiring disassembly.

Temperature Display

A digital temperature indicator is used together with an eight-point selector switch. The selector switch permits monitoring the temperature at each of the following locations:

- Stack
- Probe
- Oven
- Impinger train outlet
- Gas meter inlet
- Gas meter outlet
- Two "spare" locations

The temperature range is 0°F to 1500°F with an accuracy of ±4°F.

Gas Flow

The cumulative sample gas flow is measured by a Rockwell Model 415 gas meter, a high accuracy meter used for testing. The measurement is displayed by a digital counter and pointer with a resolution of 0.005 cu. ft.

Pressure Gauges

Three Magnehelic pressure gauges can be seen on the face of the control unit. One is used for monitoring the pressure drop across the orifice meter (see following discussion on orifice meter). The other two gages are connected in parallel and indicate the pressure differential of the pitot tube used for measuring stack velocity. One of the gages has a range from 0 to 0.5 inches of water; the other, usually 0 to 4 inches of water. Thus the pitot tube pressure differential can be determined with high precision over the full range.

Umbilical Line Connections

The umbilical line between the control unit, oven, and probe makes the connections with the control unit as follows:

- Multipoint connector with AC power leads to oven, fan, and probe
- Dual-pin thermocouple connectors for the stack, probe, and impinger thermocouples.

The separate 25-foot sample hose connects to the vacuum pumps. The exhaust hose of the pump is connected to the "inlet" fitting located on the control unit. The sample gas then passes through the gas and orifice meters in the manner of the typical Method 5 sampling train.

A quick-disconnect fitting is provided at the sample "exhaust" outlet on the control unit.

2. Method 5 sampling system (Joy Train)--The Method 5 sampling system is a standard Joy Manufacturing Company unit shown schematically in Figure 3-9. A special particulate sampling system was designed and fabricated to fit inside the standard oven. A description of the system components is presented below.

CYCLONE SET

In designing the cyclone set for the Joy train, KVB visited Southern Research Institute (SoRI), where under EPA sponsorship they were developing a

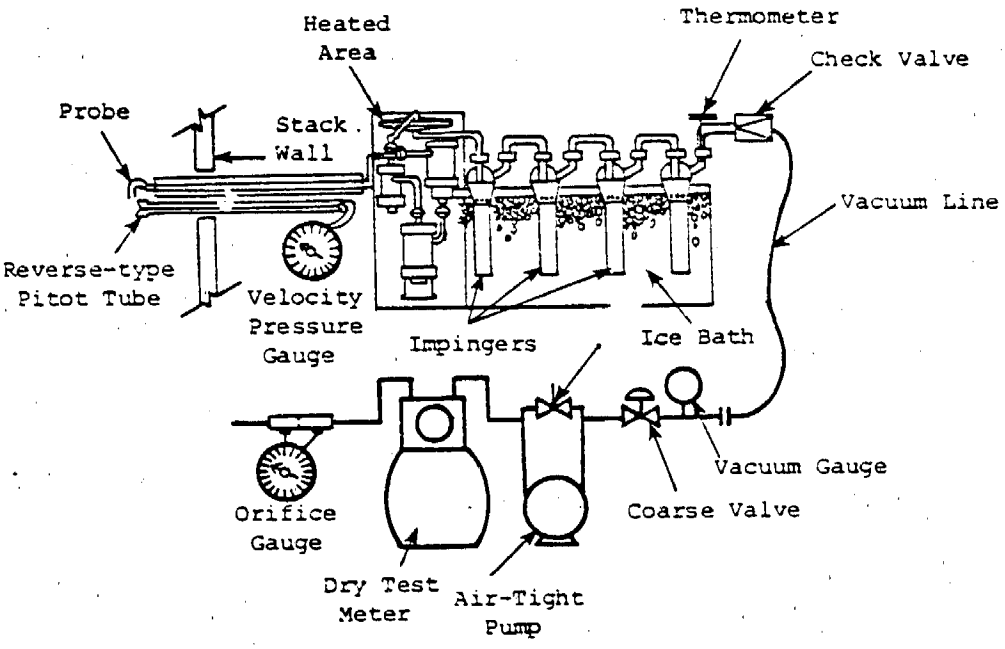


Figure 3-9. Particulate sampling train (modified Joy train).

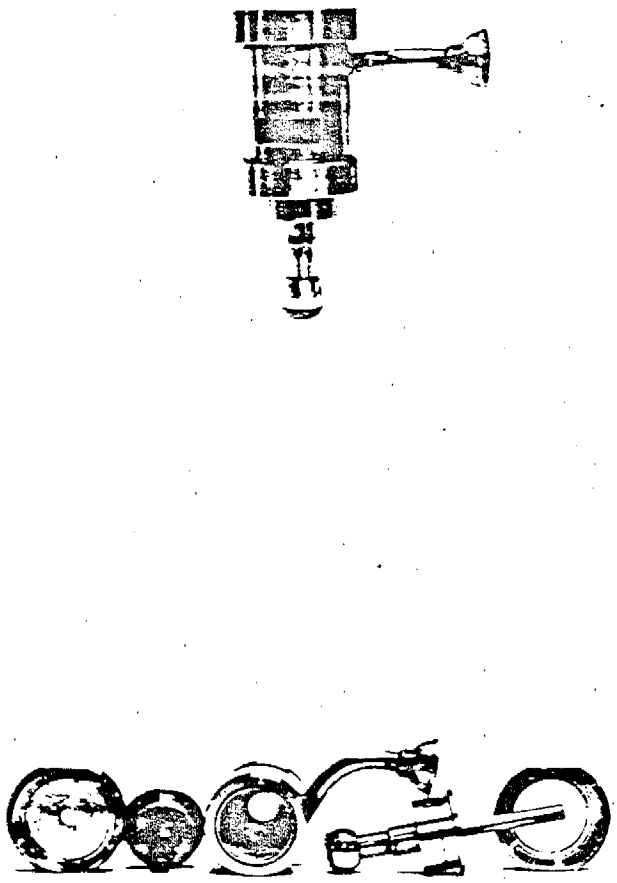


Figure 3-11. Cyclone 1.

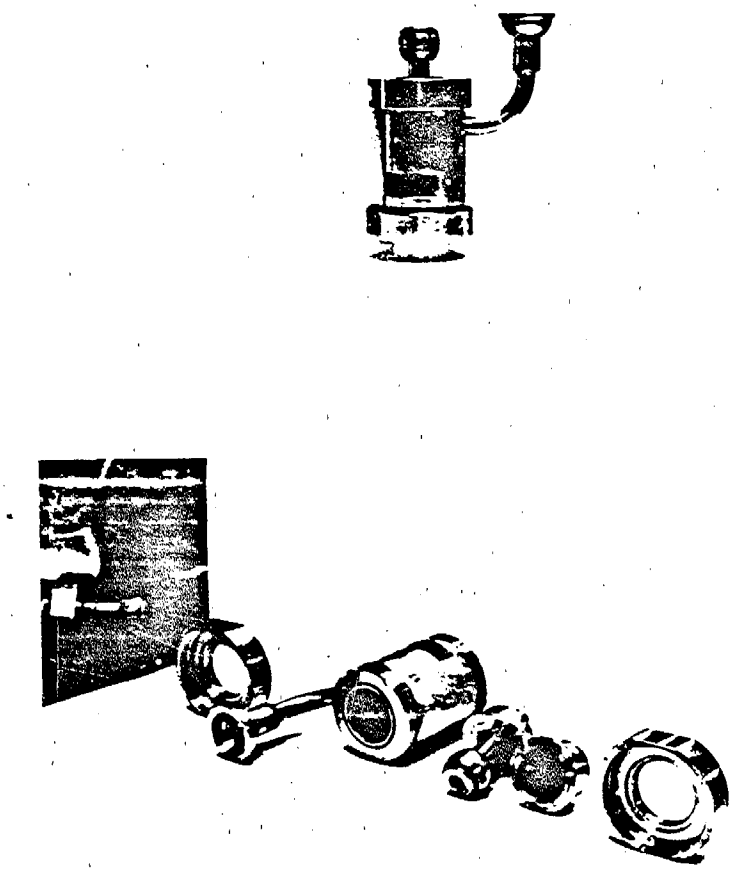


Figure 3-12. Cyclone 2.

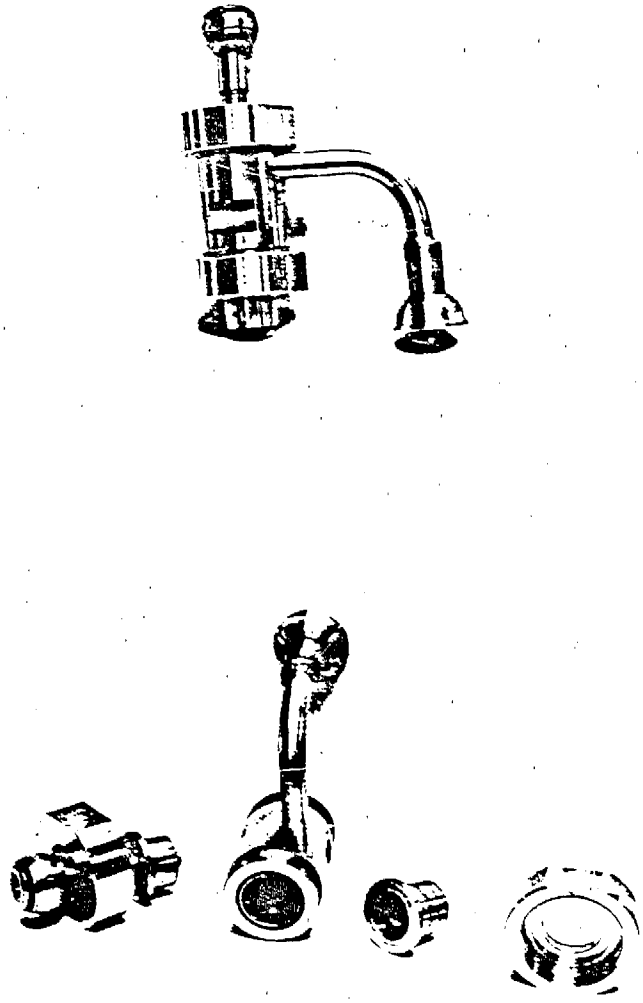
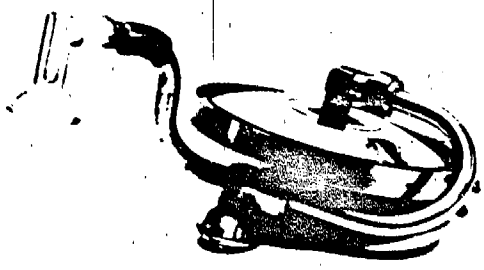


Figure 3-13. Cyclone 3.



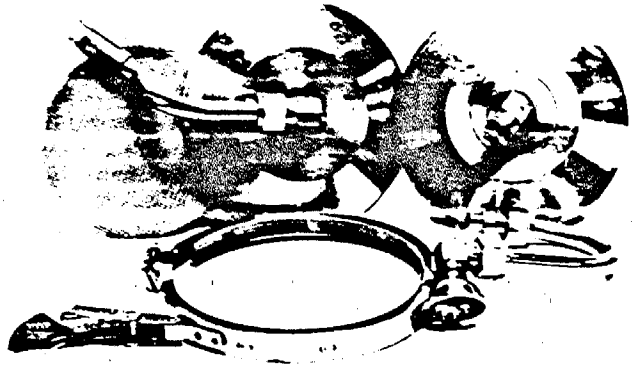


Figure 3-14. Filter holder.

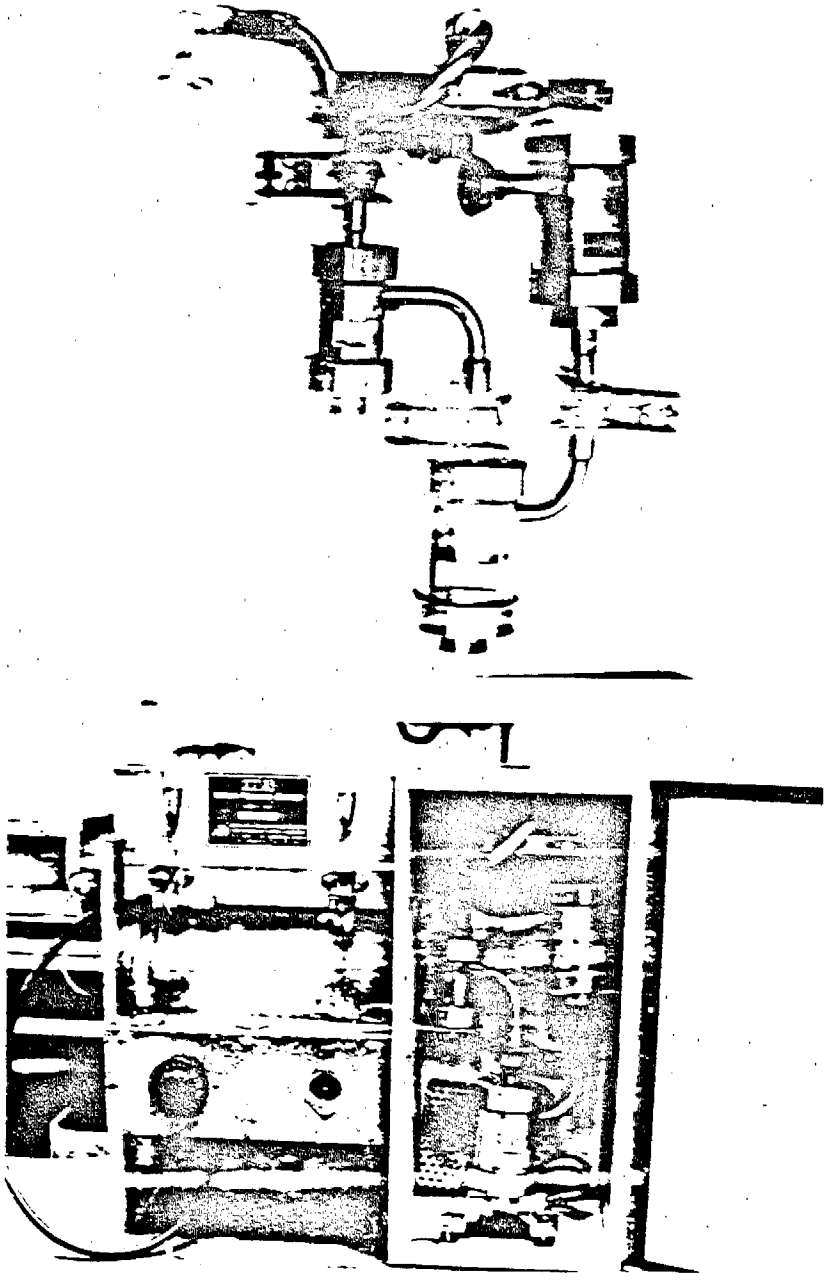


Figure 3-15. Joy train cyclone assembly.

Figure 3-16 A drawing of the front view of the cyclones and filter holder assembled in the Joy oven.

Figure 3-17 A drawing of the top view.

Figure 3-18 Drawing of Cyclone 1.

Figure 3-19 Drawing of reverse exit tube for Cyclone 1.

Figure 3-20 Drawing of Cyclone 2.

Figure 3-21 Drawing of Cyclone 3.

Figure 3-22 Drawing of stainless steel ball and socket joints used to connect the cyclones to each other and to the probe. Note that grooves for "O" rings have been cut in ball joints to assure a positive seal when "O" ring is in place.

The units were fabricated from 316 stainless steel with high quality and precision. Subsequently, the SoRI tests were completed, indicating that the cut points would be as follows:

	400°F D_{50} Cut Point (Ref 3-10)
Cyclone I	9.1 µm
Cyclone II	4.1 µm
Cyclone III	1.3 µm

Throughout the test program the small cyclones performed perfectly. The ball joints provided no sealing problems and are recommended highly for future designs.

After the initial trial runs with the small train it was found that the original filters on the Joy train were becoming clogged within a short duration. To alleviate this condition, a larger filter holder was fabricated and successfully installed in the unit. Where the original filters were only 47mm in diameter, the new filters were 141mm, the same size as the ones in the SASS train. This improved the sampling routine substantially, reducing the number of filter changes. Figures 3-15 and 3-16 show the larger filter in place.

SAMPLING UNIT

The sampling unit, Figure 3-24, consists of a stainless steel cabinet divided into two sections. The first section is a heated compartment containing provisions for a filter assembly and cyclones; the second section is a compartment containing the impinger train. Openings in the cabinet and clamping devices are provided for attachment of the probe in horizontal positions. Sampling train components in the oven are made of stainless steel, joined by ball and socket joints and provided with clamping devices.

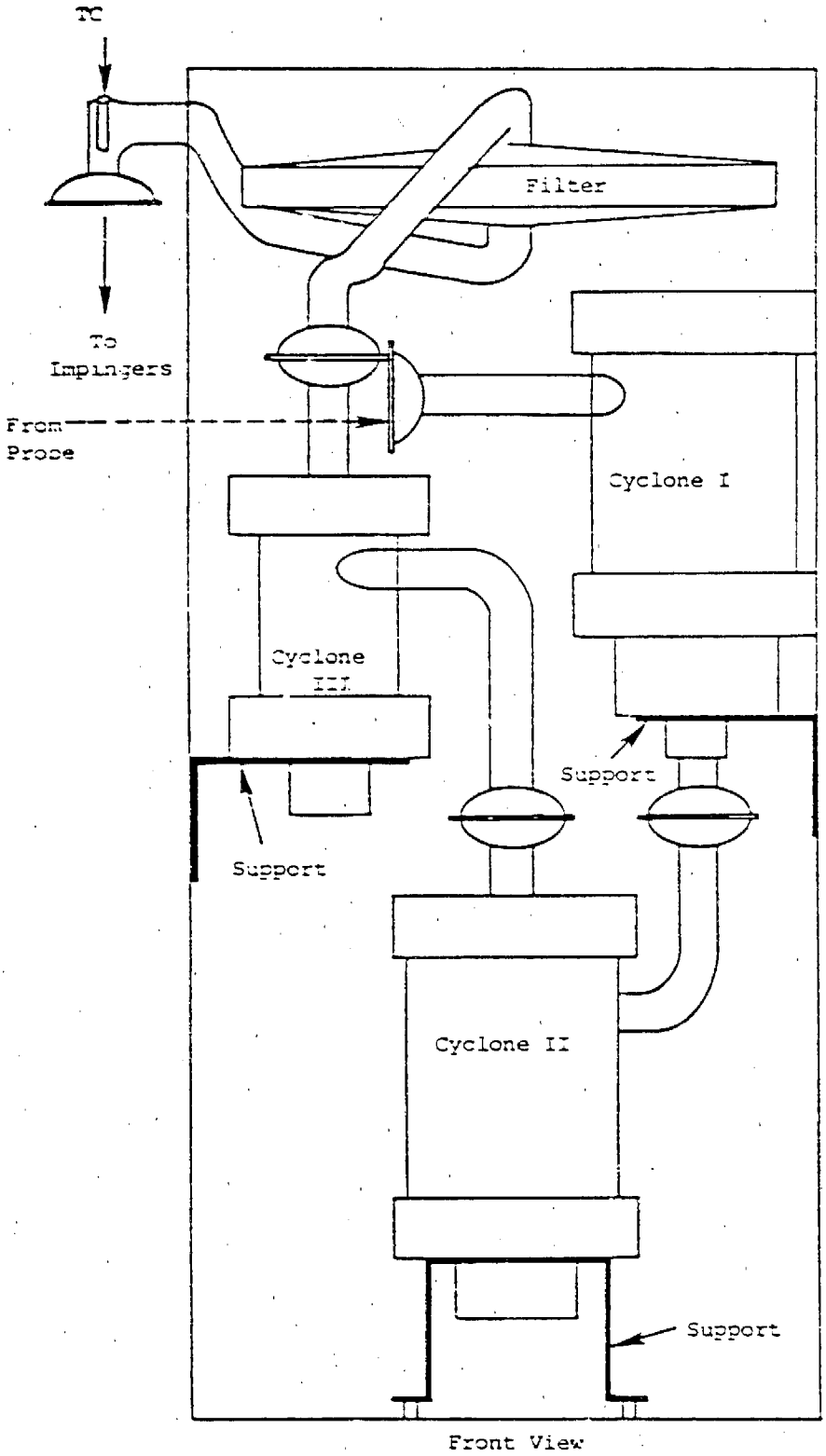
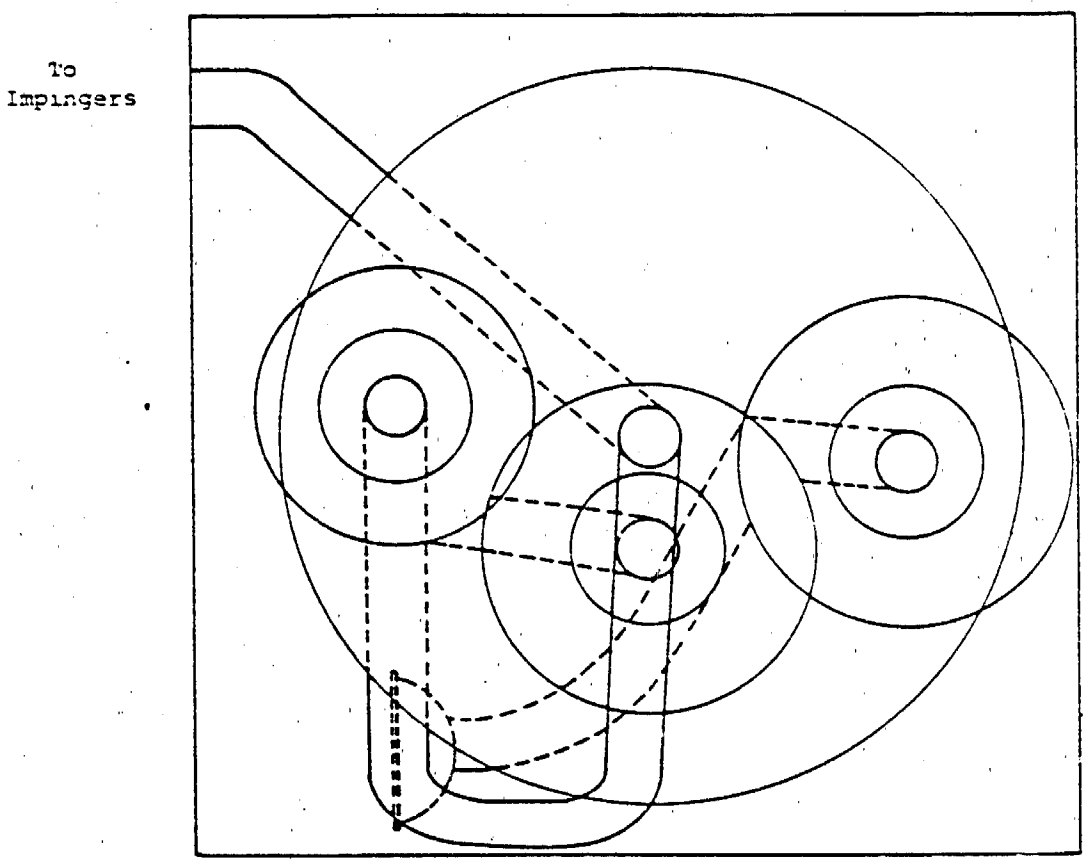


Figure 3-16. Joy train cyclone assembly schematic.



Assembled Top View

Figure 3-17.

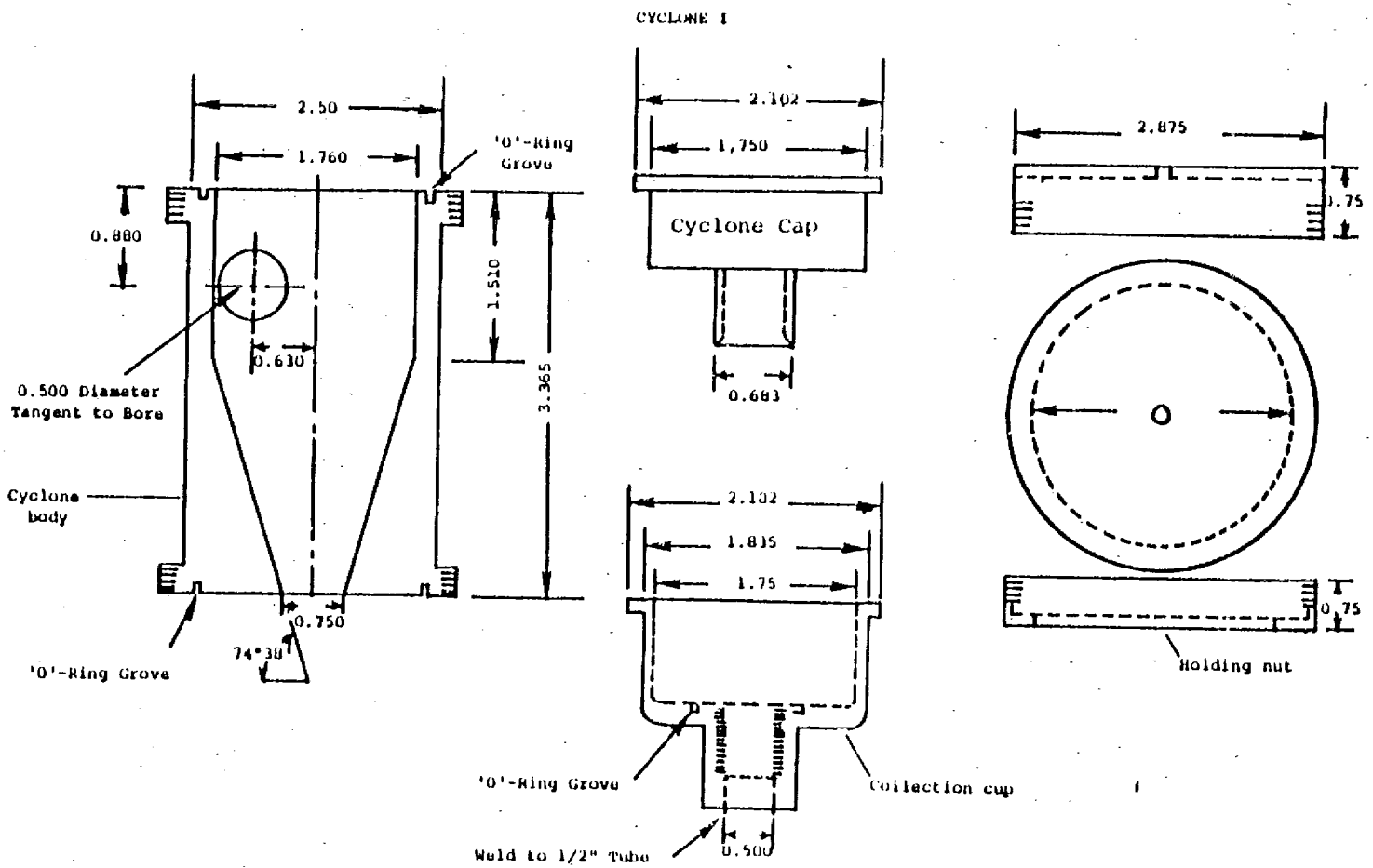


Figure 3-18. Design sketch.

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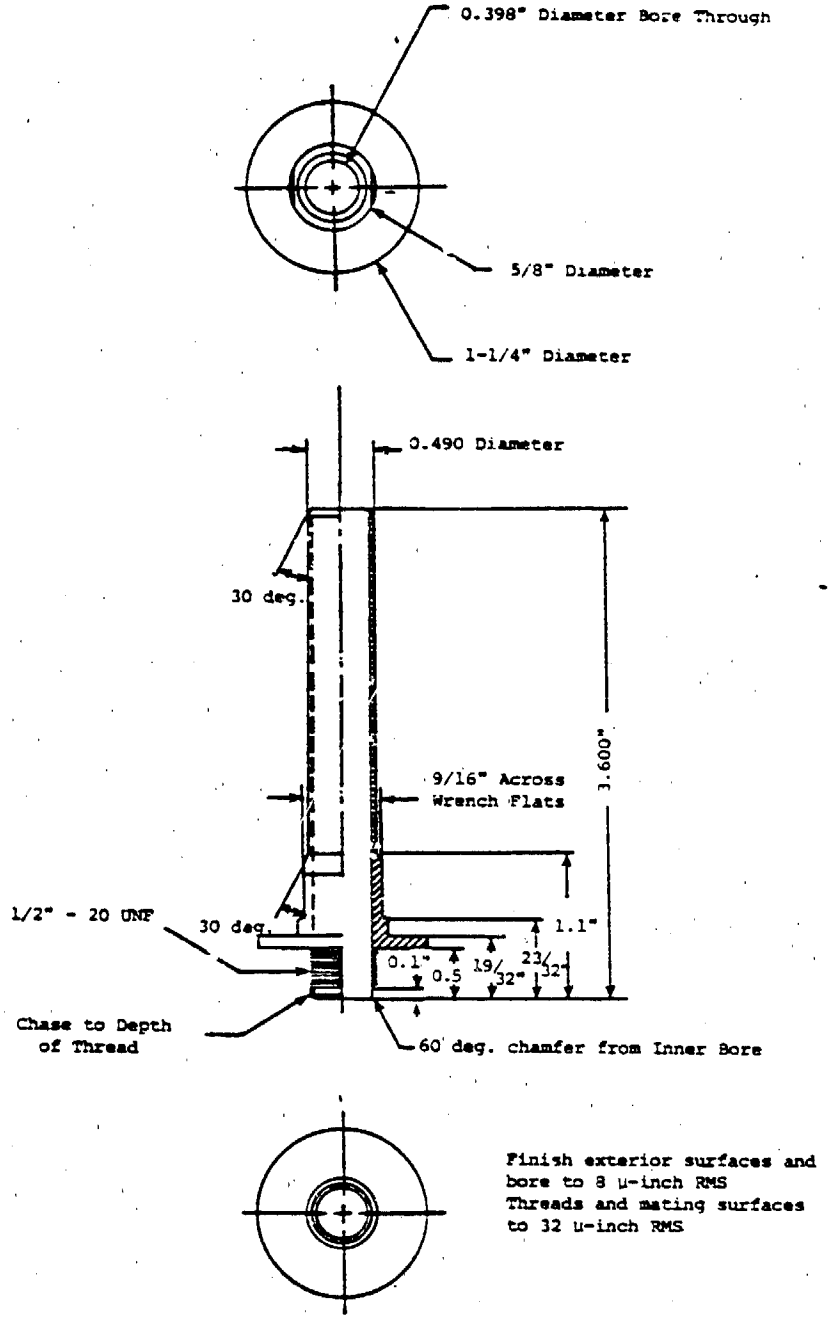

Figure 3-19. Design sketch, reverse exit tube for Cyclone 1.

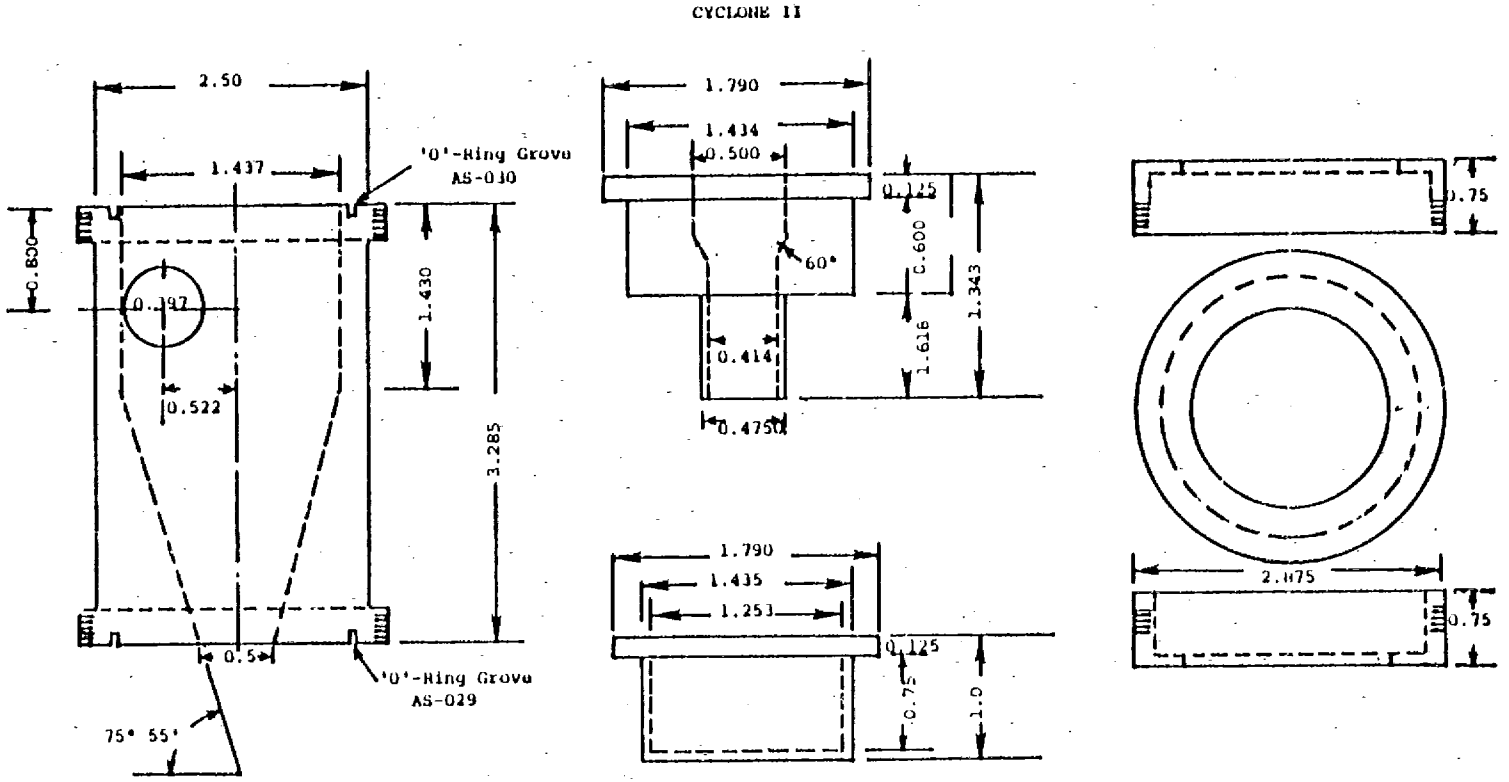

Figure 3-20. Cyclone 2 design sketch.

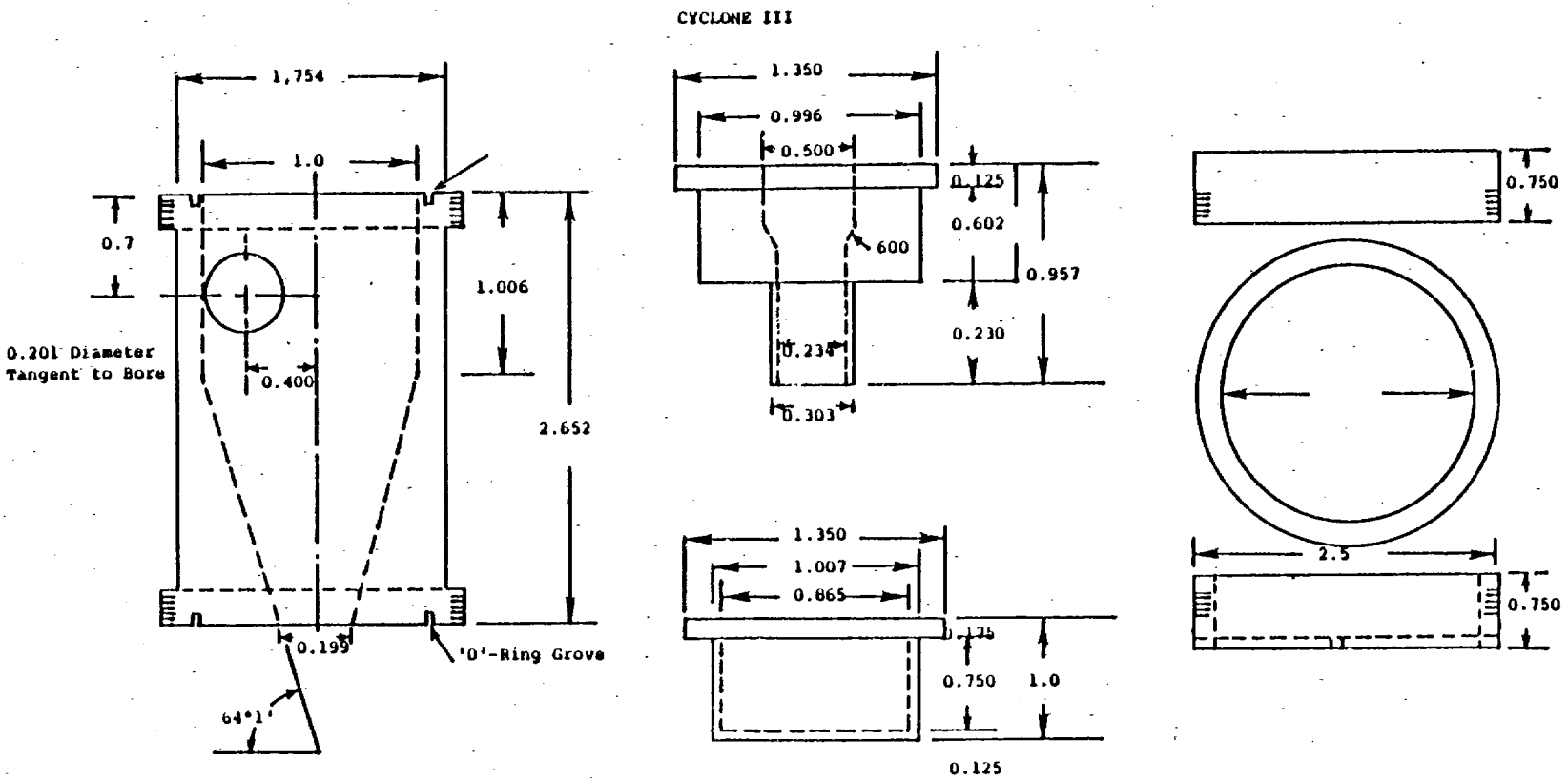

Figure 3-21. Cyclone 3 design sketch.

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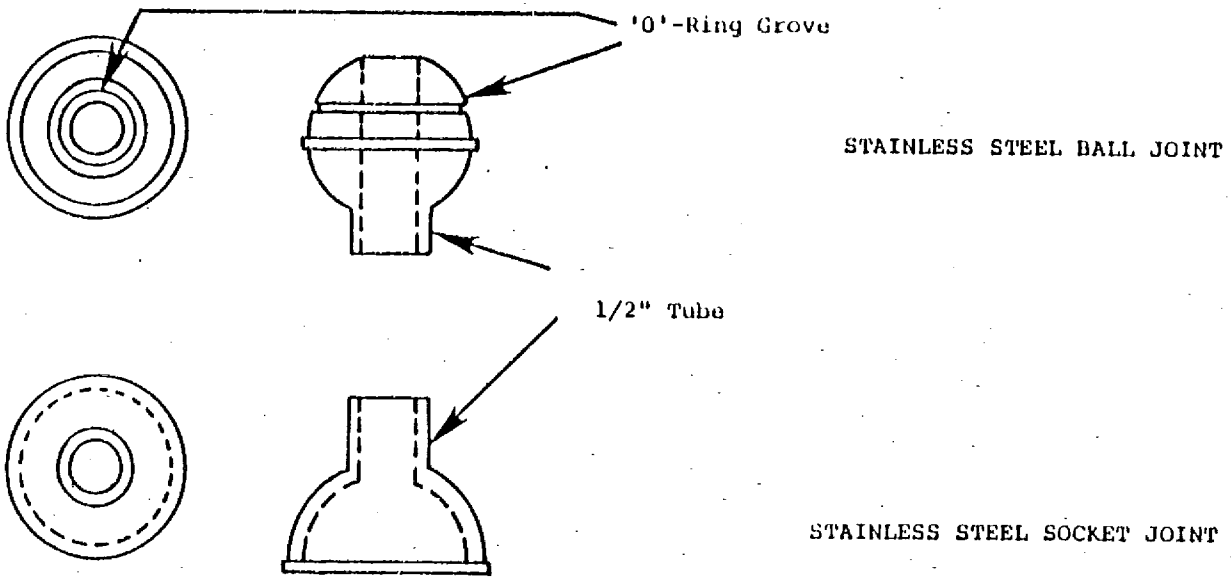

Figure 3-22. Stainless steel ball & socket connectors.

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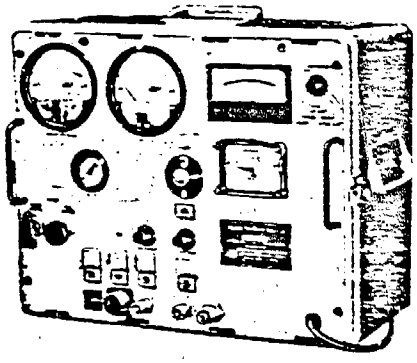


Figure 3-23. Joy Manufacturing Co. control unit.

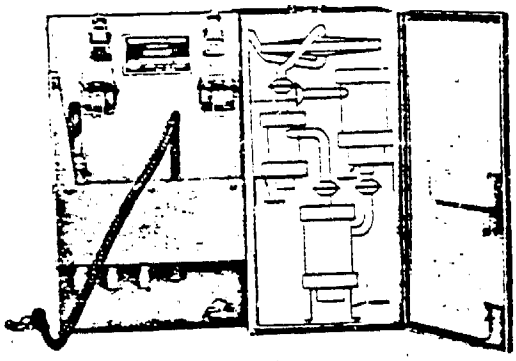


Figure 3-24. KVB modified Joy Manufacturing Co. sampling case.

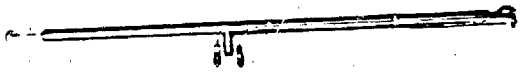


Figure 3-25. Joy Manufacturing Co. probe.

PROBE

The standard probe, Figure 3-25, has an effective length of five feet and consists of a sampling tube, a temperature probe, and a pitot tube. The sampling tube is a length of stainless steel tubing running through the center of an exterior stainless steel tube and terminating in a stainless steel joint a short distance beyond the end of the stainless tube. The stainless steel tubing is heated by a resistance element. Provision is made for use of a variety of sampling nozzles. The pitot tube consists of a pair of stainless steel tubes attached to the assembly.

IMPINGERS

Four impingers are connected in series with glass ball joint fittings. The first, third, and fourth impingers are of the Greenburg-Smith design, modified by replacing the tip with a 1/2" ID glass tube extending to 1/2" from the bottom of the flask. The second impinger is of the Greenburg-Smith design with the standard tip.

METERING SYSTEM

A vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 5°F, dry gas meter with 2% accuracy, and related equipment are provided to maintain the appropriate sampling rate and to determine sample volume.

B. Sampling Procedures--

This section will present the procedures that were employed at the test site, including preparation, sampling, disassembly and sample recovery. Analytical procedures that were employed to determine the quantity and composition of the particulate samples are discussed in Section 3.2.2. These procedures apply to both the SASS and Joy sampling trains. The sampling and laboratory procedures outlined below illustrate the detailed preparations and precautions that were taken to insure quality control.

1. Preliminary evaluation of the test site--An important aspect of the sampling procedures was the preliminary assessment of the sampling test site. For a given industrial operation, a sampling location was selected based on accessibility and exhaust flow characteristics. A minimum of a 3-inch sampling port was required to accommodate the pitot and sampling nozzle and probe.

Ideally, the exhaust flow at this location should be fully mixed from the process or combustion zone and will be steady and uniform, not disturbed by elbows or dampers. This generally was not the case. A pitot tube traverse and temperature measurement was made in accordance with the procedures outlined in the Federal Register (Ref. 3-3). Data was recorded on the sheet illustrated in Form 5804-4 (Sect. 3.4)*. Based on the results of this traverse, sampling locations within the flow stream were selected to provide a spacially integrated sample.

2. Sample flow and isokinetic conditions--To preserve the cyclone "cut-off" points, the sampling flow rate was adjusted to maintain 4.0 SCFM at the required 400°F cyclone oven temperature conditions. Isokinetic sampling was also desired and was achieved to the degree possible by selecting the proper probe nozzle diameter. Isokinetic sampling is a condition where the velocity, V_n, of the sample through the nozzle is the same as the velocity, V_s, of the stack gas. The nozzle velocity V_n is related to the nozzle diameter, d, and to the meter flow rate Q_m by the following equations:

$$V_n = \frac{Q_n}{\frac{\pi}{4}\left(\frac{d}{12}\right)^2} \times \frac{1}{60}$$

$$Q_n = \frac{Q_m}{\left(1 - \frac{\%H_2O}{100}\right)} \cdot \frac{T_s}{T_m} \quad \frac{P_m}{P_s}$$

for the isokinetic sampling the stack velocity equals the nozzle velocity:

$V_s = V_n$

substitute the V_s = $\frac{Q_n}{\frac{\pi}{4}\left(\frac{d}{12}\right)^2} \quad \frac{1}{60}$

value from the above equations

$$V_s = \frac{\frac{Q_m}{\left(1 - \frac{\%H_2O}{100}\right)} \left(\frac{T_s}{T_m}\right) \frac{1}{60} \frac{P_m}{P_s}}{\frac{\pi}{4}\left(\frac{d}{12}\right)^2}$$

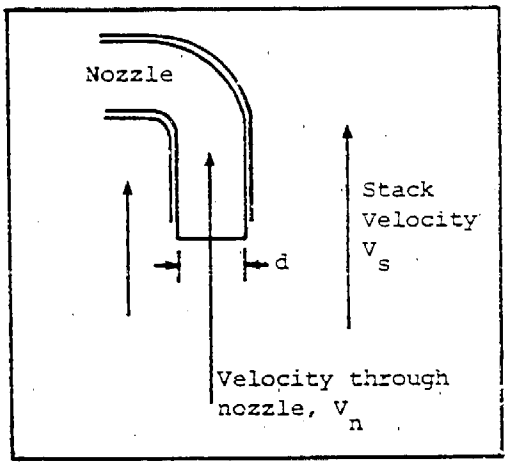
and solve for the nozzle diameter, d.

$$d = 24 \quad \frac{Q_m}{\left(1 - \frac{\%H_2O}{100}\right)} \left(\frac{T_s}{T_m}\right) \left(\frac{P_m}{P_s}\right) \frac{1}{60}$$

Equation definitions appear on following page.

* All prepared data sheets used in these tests are presented in Section 3.4

T_s = stack temperature, °R
T_m = dry gas meter temperature, °R
V_s = stack velocity, ft/sec.
V_n = velocity at nozzle, ft/sec
Q_m = gas flow rate at meter, ft^3/min
Q_n = gas flow rate at nozzle, ft^3/min
d = diameter of nozzle, in.
P_m = meter pressure, psia
P_s = stack pressure, psia
% H_2O = stack gas water content



The sampling flow rate Q_m was maintained at 4.0 SCFM for the SASS and 1.0 SCFM for the Joy to preserve the cyclone cut-off points. The nozzle was chosen to have the closest diameter to the calculated diameter. For the Method 5 procedure, Q_m could be adjusted to account for the nozzle difference.

After the stack velocities and temperature levels have been established by the preliminary stack traverse, the nomogram illustrated in Figure 3-36 was used to select the proper nozzle diameter and for the required sampling rate. If stack conditions were encountered that were not covered by the nomogram, the above equations were used.

3. Preparation of the sampling trains--

a. Cleaning--Prior to sampling, all sampling train components and sample containers were cleaned first with distilled water, and then with acetone. The distilled water was dispensed in plastic wash bottles; the acetone was dispensed using Teflon or glass wash bottles. After each part was washed with acetone, it was dried in a filtered stream of dry air or nitrogen.

Any solid residues adhering to the internal surfaces were removed with tap water and a plastic scouring pad before proceeding with the solvent cleaning procedure.

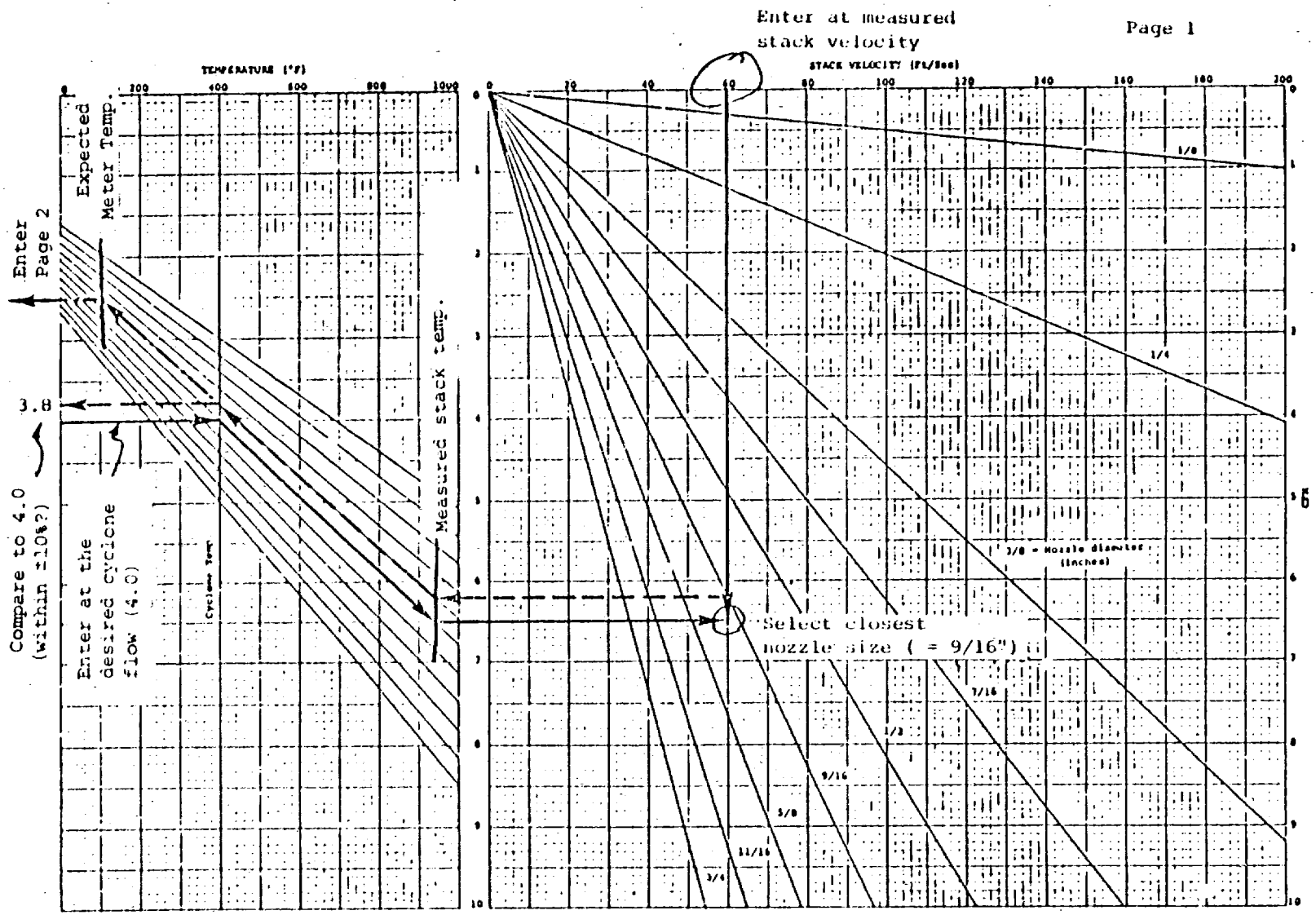


Figure 3-26. SASS operating nomogram.

KVB 5806-783

ΔH ≈ 2.0

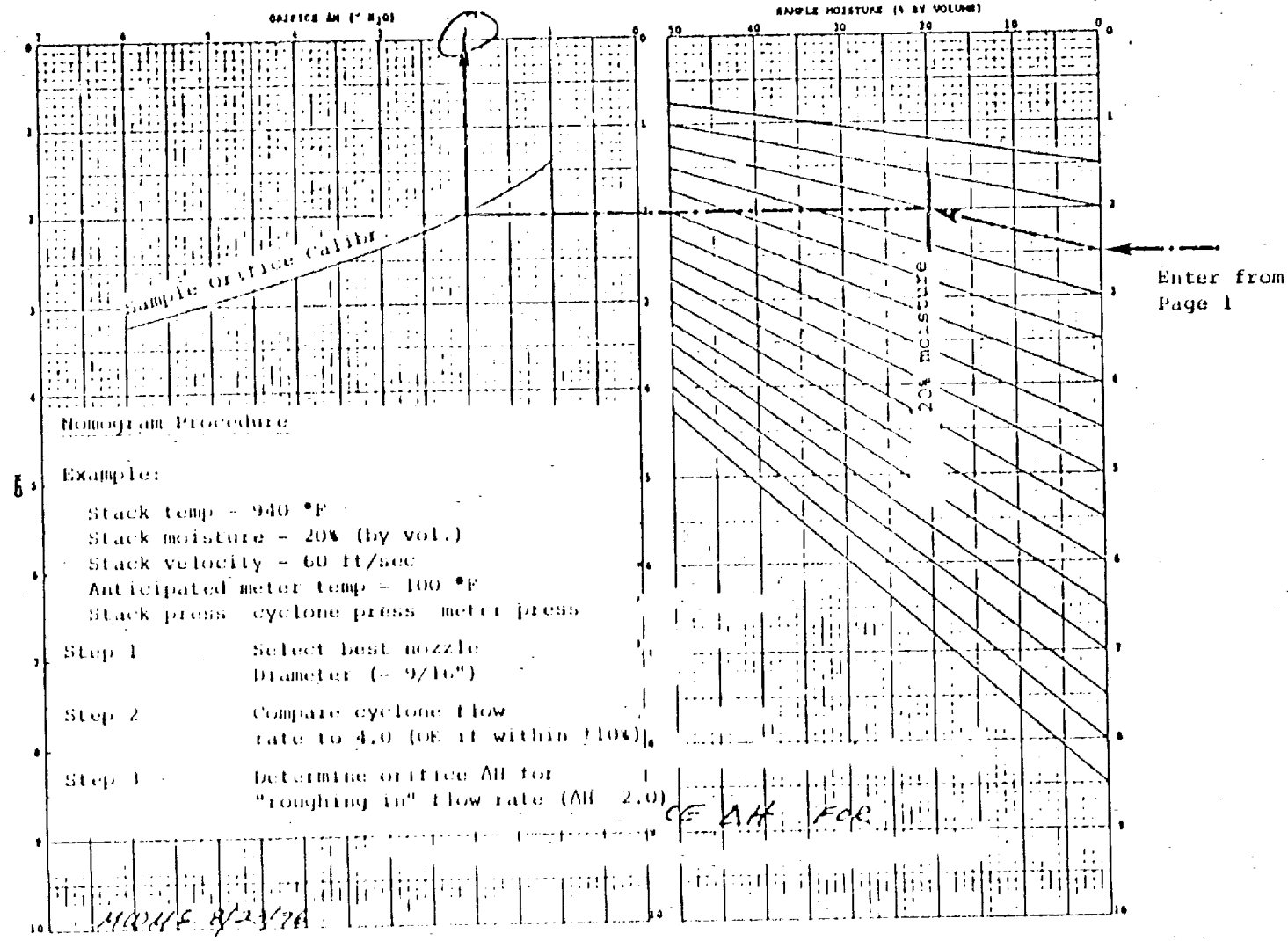


Figure 3-26. (Continued) SASS operating nomogram. KVB 5806-783

After cleaning, the cyclone assemblies were assembled and capped off. The other sections of the train, including the probe, filter housing, impinger trains, and interconnecting hoses, were capped off.

b. Filter preparation--Using stainless steel tweezers, each filter was placed in a clean, numbered 150 glass petri dish. They were baked at 220°F for at least three hours in a drying oven, then immediately transfered to a desiccator to cool.

The filters were weighed once and then a second time several hours later, to confirm the initial weighing. This was the weight used to determine the mass particulate catch on the filter. Several filters were prepared to be used in the event that particulate grain loading was high.

c. Impinger solutions--The following solutions and procedures were used for impinger sample bottles:

Impinger	Reagent	SASS Quantity	Joy Quantity
#1	H_2O	400 ml	100
#2	H_2O	400 ml	100
#3	empty	---	---
#4	$(CaSO_4)$*	750 g	200 g

*8-mesh, color-indicating Drierite

It was sometimes necessary to replace the Drierite several times during a test run. A marked decrease in Impinger #4 outlet temperature (moisture absorption by Drierite produces heat) was found to indicate Drierite depletion when the Drierite color change was difficult to detect.

The spent Drierite was not kept for analysis. However, the weight gain due to added water was recorded and used to determine moisture of the stack gas.

4. Sampling trains assembly and preheating--Each component of the trains was transferred as a separate unit to the test site with all sealing caps in place. Care was taken when removing caps for correction of component so as to make certain that no foreign matter entered the components. A leak check was conducted with the probe capped before installing the probe nozzle. The leak rate was less than 0.05 CFM at 20"Hg pump suction. The proper nozzle selected

on the basis of the isokinetic requirements above was assembled and the sampling train was then ready for use.

The cyclone oven and probe were preheated to 400°F before sampling was started. This was required to prevent the condensation of moisture in the cyclone that may interfere with sample collection.

5. Sampling procedure--Actual sampling was conducted in an identical fashion as employed for EPA Method 5. The nozzle/probe assembly was inserted into the stack in the proper orientation to the initial sampling location in the flow stream.

The sampling run was initiated by turning on the vacuum pump and adjusting the intake valve to achieve the proper flow rate. Periodic checks and adjustment of flow rates and temperatures were made during the course of the sampling run. Data was recorded at periodic intervals on the data sheet shown in Form 5806-2, Section 3.4.

It was often necessary to change filters when sampling effluents with high fine particulate loadings in order to obtain sufficient sample volume. This was generally evidenced by a gradual increase in sample pump vacuum required to maintain sample flow. In this event, the train was shut down and a new filter assembly containing a clean filter was installed.

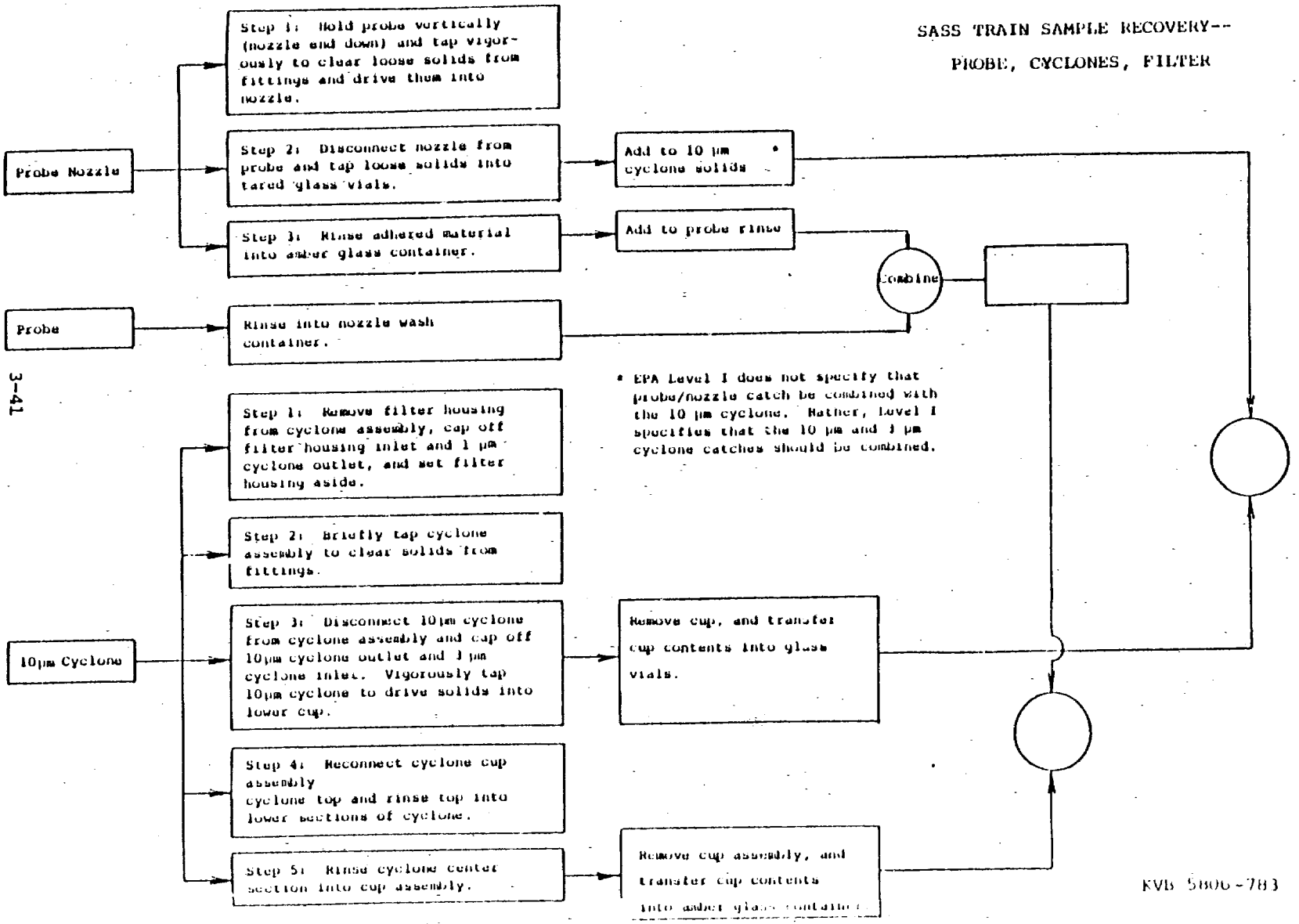
A total sample volume of between 500 and 1500 cubic feet was collected. When sufficient volume had been collected, the pump was turned off, the probe assembly removed from the stack, and the cyclone oven opened to expedite cooling. The nozzle probe and filter holder were disconnected and capped off. These items, along with the impingers with liquids, were transported to the laboratory for sample recovery.

6. Sample recovery--The procedure for transferring samples from the various portions of the SASS train into storage containers is outlined in the flow diagram given in Figure 3-27.

Table 3-1 lists the samples to be recovered from the SASS train and the recommended containers used for sample storage and shipping. In some cases, more than one container was required. All containers were cleaned prior to use according to the procedure used for cleaning the train as described above.

Figure 3-27.

SASS TRAIN SAMPLE RECOVERY--
PROBE, CYCLONES, FILTER



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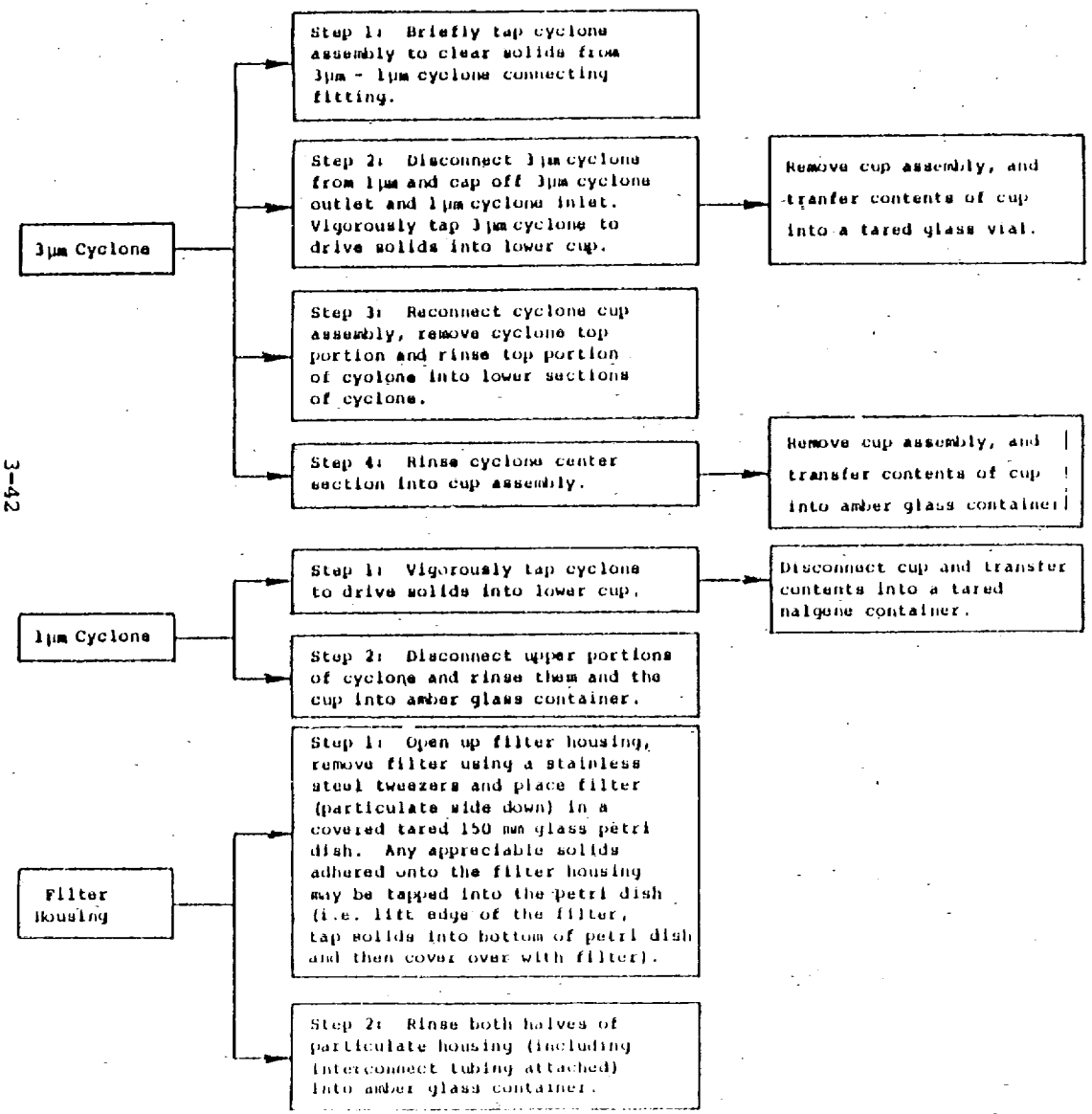

Figure 3-27 (cont.)

SASS AND JOY TRAIN SAMPLE RECOVERY--

PROBE, CYCLONES, FILTER

1. Use distilled water for all rinses.
2. Handle all tared containers with gloves.
3. Transfer of solids may be assisted by the use of stainless steel spatulas and powder funnels. Nylon bristle brushes may also be used if necessary.

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TABLE 3-1. SAMPLE STORAGE/SHIPPING CONTAINERS

Train Component	Sample Type	Container Required*
Probe and nozzle	solid tappings	Tared 4 dram vial
	solvent wash	250 ml amber glass
10μ cyclone	cup solids	Tared 4 dram vial
	solvent wash	250 ml amber glass
3μ cyclone	cup solids	Tared 4 dram vial
	solvent wash	250 ml amber glass
1μ cyclone	cup solids	Tared 4 dram vial
		250 ml amber glass
Filter holder and filter	solid tappings and filter	Tared 150 mm glass petri dish
	solvent wash	Add to impinger
Impinger #1	contents & rinses	1 liter LPE
Impinger #2	contents & rinses	1 liter LPE
Impinger #3	contents & rinses	1 liter LPE

*All glass containers must have Teflon cap liners.

7. Sample processing and analysis--

a. Cyclones--Each cyclone solid catch was transferred to a transporting container, desiccated for one hour, and weighed. These samples were sent to Armament Systems Corporation for predominant elemental composition analysis by X-ray fluorescence, then to Rockwell Air Monitoring Center for sulfate, nitrate, and carbon analysis. The procedures for these analyses are discussed in Section 3.2.2.

Each cyclone was rinsed with distilled water and the rinsed material collected separately. The water was evaporated and the remaining sample baked for one hour at 250°F, desiccated, and weighed on an Ainsworth torsional balance. This weight was included in each of the cyclone's solid weight catches.

b. Filter--The filter was transferred to a petri dish, desiccated, for one hour, and weighed. The filter and particulate were sent to Armament Systems for predominant elemental composition analysis, then to Rockwell for sulfate, nitrate, and carbon analysis. The filter housing was rinsed with distilled water and collected with the impinger rinses.

c. Impingers--The volume of water in each impinger was measured. The water from the first three impingers was combined along with the water rinse from these impingers. The combined solution was extracted five times with 25 ml portions of reagent grade methyl chloroform for each 500 ml of solution to determine the organic content of the impinger catch. The methyl chloroform was transferred to a tared vial and evaporated at room temperature in a dry air stream. This sample was desiccated for one hour and weighed. This weight was the organics content of the impinger catch and was included in the weight of the impinger catch.

The water remaining from the above extraction was transferred to a tared beaker, evaporated to dryness, desiccated for one hour, and weighed. This sample was sent to Armament Systems for predominant elemental composition analysis by x-ray fluorescence, then to Rockwell AMC for sulfate, carbon and nitrate analysis.