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CONTROL OF ASPHALTIC CONCRETE BATCHING PLANTS IN LOS ANGELES COUNTY

by

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ABSTRACT

Dust emissions from asphaltic concrete plants in Los Angeles County are controlled by the use of one or more dry centrifugal separators in series followed by a water scrubber. This paper discusses these air pollution control devices and basic plant variables affecting dust emissions. Included in the study are the design features of several scrubbers, the importance of an adequate scrubbing water to effluent gas ratio, critical points of hooding and ventilation, characteristics of the aggregate charged to the drier, type of fuel fired, operational factors, and the need for a strict maintenance program.

Results of many tests are summarized showing exhaust air volumes, grain loadings, collection efficiencies of scrubbers and other data. Particle sizes and quantities of dust entering and leaving the scrubber are shown.

The total air pollution from these plants in Los Angeles County is graphically depicted from 1948 through 1958 with the general trend indicating a decrease in the weight of dust emissions and an increase in materials produced and volume of gases handled.

CONTROL OF ASPHALTIC CONCRETE

PLANTS IN LOS ANGELES COUNTY*

BY

Ray M. Ingels**, Norman R. Shaffer+ and John A. Danielson++

Introduction

The phenomenal growth of population in Southern California during the last two decades has resulted in large demands for asphaltic concrete. To meet these demands, in Los Angeles County alone, 48 asphaltic concrete plants have been built which produce an average of 14,000 tons per day.

Prior to the installation of well-designed air pollution control equipment, dust losses from asphaltic concrete plants were nearly 25 tons per day. In 1949, the Air Pollution Control District of Los Angeles County adopted a rule which limited the discharge of dust from each of these plants to 40 pounds per hour[1]. To meet this prohibition, it became necessary to install dust collection equipment capable of high collection efficiencies. This was accomplished by the use of centrifugal or impingement type scrubbers which provided collection efficiencies, in most cases, of 90 per cent or greater. The design of these control devices has improved over the years, and as described later in this paper, total emissions have decreased substantially in spite of increased production.

Description of Basic Equipment

Generally, an asphaltic concrete plant consists of a rotary dryer, screening and classifying equipment, an aggregate weighing system, a mixer, storage bins and conveying equipment. Sand and aggregate are charged from bins into a rotary dryer. The dried aggregate at the lower end of

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the dryer is mechanically conveyed by a bucket elevator to the screening equipment where it is classified and dumped into storage bins. Weighed quantities of the sized products are then dropped into the mixer along with asphalt where the batch is mixed and dumped into awaiting trucks for transportation to the paving site. The combustion gases and fine dust from the rotary drier are exhausted through a precleaner which is usually a single cyclone, but twin or multiple cyclones and other devices are also used. The precleaner catch is then discharged back into the bucket elevator where it continues in process with the main bulk of the dried aggregate. The air outlet of the precleaner is vented to air pollution control equipment.

Air Pollution Control Equipment

In Los Angeles County two principal types of control equipment have evolved from many types employed over the years--the multiple centrifugal type spray chamber and the baffled type spray tower. Of these two types, the multiple centrifugal type spray chamber (Figure 1) has proven to be the more efficient. It consists of two or more internally fluted cylindrical spray chambers in which the dust-laden gases are admitted tangentially at high velocities. Each of these chambers is identical in size and has dimensions approximately 6' dia. x 15' long. Usually 5 to 10 spray nozzles are located evenly spaced within each chamber. Water rates to the nozzles are usually in the range of 70 to 250 gpm at 50 to 100 psi and the water generally is not recirculated. In the baffled type spray tower (Figure 2), there have been many variations in designs, but fundamentally, each consists of a chamber which is baffled to force the gases to travel in an S-shaped pattern, encouraging impingement of the dust particles against the sides of the chamber and the baffles. Water spray nozzles are located between the baffles and water rates through the spray heads usually vary between 100 to 300 gpm at 50 to 100 psi.

In addition to venting the dryer, the dust collection system also ventilates several other dust sources which include: (1) the lower end of the dryer where the stationary burner box attaches to the rotary dryer; (2) the aggregate screening and classifying system; (3) the bucket elevator; (4) the aggregate storage bins; and (5) the weigh hopper.

Asphaltic concrete plants vary in size with the majority capable of producing 100 to 150 tons per hour. However, in the last two or three years, several plants have been installed in Los Angeles County which are classified as 6000-pound plants, capable of producing 200 to 250 tons per hour.

The major source of dust originates from the rotary dryer. Very little work has been done in the study of dust emissions from rotary dryers. Friedman and Marshall[2] obtained data showing that dryer dust emissions, expressed as per cent of feed, increase with air mass velocity, increase with increasing rate of rotation, are independent of dryer slope, and decrease with increasing feed rate. The absolute amount of dryer dust, in weight per unit time, increases with feed rate. Dust emissions depend to a large extent on the particle size distribution of the dryer feed. While the dust from the rotary dryer is undoubtedly the greatest source, the dust collected from the vibrating screens, the bucket elevator, the bins and the weigh hopper is also considerable in quantity. In one plant, 2000 pounds per hour of particulate matter containing 39.7 per cent of 0 to 10 micron material was produced by these secondary sources [3].

Study of Stack Test Data

In the process of granting permits to operate, many stack tests were conducted by the District to insure that each plant was operating in compliance with air pollution laws. As these data became available, a study was made to determine which variables were most significant in affecting emissions to the atmosphere. A preliminary observation disclosed that the water scrubber efficiency varied with the scrubber inlet dust loading as shown in Figure 3. Higher dust collection efficiencies were obtained at the higher inlet dust loadings. Plants with less effective cyclone precleaning had, on the average, larger particles entering the water scrubber, and consequently better scrubber collection efficiencies were obtained. In fact, scrubber efficiency was so dependent upon the degree of precleaning that the effect of other variables on collection efficiency was completely masked in the available data. However, the fractional collection efficiency of particles larger than 10 microns in diameter proved to be 99.7 per cent. Consequently, the variables and operating conditions which affect the amount and collection efficiency of the 0 to 10 micron fraction should be reflected in the absolute stack emissions. This was found to be the case. The magnitude of the stack emissions were found to depend mainly upon the scrubber water-gas ratio, the type of fuel used in the rotary dryer, the type of scrubber, and the quantity of minus 200-mesh material (minus 74 microns) processed in the dryer [4]. It would be expected that the particle size distribution of the minus 200-mesh fraction of the dryer feed would have a large effect on stack losses, but sufficient data were not available to investigate it.

Twenty-five source tests of asphaltic concrete plants were available (from some 115 tests which have been performed since 1949) which had sufficient data to attempt to correlate the major variables affecting stack losses. Aggregate feed rates, screen size analyses, scrubber water and gas rates, as well as particulate matter emissions to the atmosphere were obtained during each of these tests. The data are tabulated in Tables I and II. The aggregate dryers were fired with PS 300 or heavier oils during nineteen of the tests and natural gas fired during six. Seventeen of these tests were performed on multiple centrifugal type scrubbers with spiral baffles and tangetial entrances. The other eight tests were performed on simple baffled tower scrubbers.

A curvilinear multiple correlation was required to represent the data satisfactorily. Ezekiel's[5] graphical procedure of successive approximations was used to fit the curves (see Appendix for correlation methods).

Effect of Variables on Scrubber Emissions

The effect of scrubber water-gas ratio on stack emissions is shown in Figure 4, for multiple centrifugal type scrubbers and baffled tower scrubbers, with the aggregate fines rate (the minus 200-mesh fraction) held constant at the average. Low scrubber water-gas ratios are more than proportionately less effective than higher ratios. Possibly, the water rate was insufficient for good spray coverage for ratios in the lower ranges.

The effect of aggregate fines rate on stack emissions at constant water-gas ratio is shown in Figure 5 for multiple centrifugal type scrubbers and baffled tower scrubbers. Stack emissions increase linearly with an increase in the amount of minus 200-mesh material processed.

Stack emissions were 5.1 pounds per hour higher when the dryer was oil fired, rather than gas fired. The difference is believed to represent particulate matter in or formed by the fuel oil, rather than additional dust from the dryer and mixer. It has been similarly observed that burning heavy fuel oils in other kinds of combustion equipment results in higher emissions of particulate matter. For example, glass furnaces discharge significantly more particulate matter when fired by PS 300 or heavier fuel oils than when natural gas or light fuel oils are used[6].

As expected, centrifugal type water scrubbers were more effective than simple baffled tower water scrubbers. The difference averaged 5.0 pounds per hour at constant aggregate fines rate and constant water-gas ratio.

The data, even when corrected for the variables studied, tend to scatter rather badly. However, the results do represent average trends of plants operating in the Los Angeles area. Curves are presented in Figures 6 and 7 from which the most likely stack emissions can be predicted for oil and gas fired plants with either multiple centrifugal or baffled tower scrubbers. These curves present emissions for various scrubber water-gas ratios and aggregate fines rates.

During the course of conducting several particle size analyses of scrubber inlet and outlet dust, an unusual observation was made. In all of these tests as shown in Table II, the fractional collection efficiency of the 44+ micron material was less than for the 10-20 and the 20-44 micron fractions, which of course is opposite to what would normally be expected. However, microscopic examination of the samples indicated that the particles in the scrubber outlet were agglomerated. Apparently, the fine particles agglomerate within the scrubber, but part of the resulting agglomerates escape to the atmosphere. This potentially recoverable material constitutes 5 to 10 per cent of the scrubber emissions. However, these emissions are minor and even perfect collection of this material would not reduce total emissions over 3.5 pounds per hour.

Survey of Dust Emissions in Los Angeles County

In order to evaluate the effect of the control program on dust emissions from the asphaltic concrete industry, it was necessary to acquire information concerning the number of plants in operation, emissions of dust to the atmosphere, amount of asphaltic concrete produced, and volume of air handled.

To obtain the data on production, number of plants, types of controls and operating schedules, a questionnaire was devised and sent to each company operating an asphaltic concrete plant. The data obtained from this survey indicated that in 1957 there were 19 companies operating 48 plants in Los Angeles County. These plants produced a total of 14,000 tons per day. The data also indicated that asphaltic concrete was produced over a 13-hour day with a maximum hourly output of 1200 tons.

To augment the data obtained from this survey and to make comparisons with data obtained from previous surveys, the analytical test data in the District's files on asphaltic concrete plants were studied. From these studies, average yearly dust emissions to the atmosphere were determined. During the early stages of the development of the control program, many stack tests disclosed emissions of dust in excess of the weight per hour allowed. As the design of control equipment improved, violations became less frequent. During recent years, excessive emissions could be traced to either poor experimental scrubber designs, or more frequently to poor maintenance. It was observed that even well-designed scrubbers would emit excessive dust if a sound maintenance program was not being enforced.

Figure 8 illustrates the effect of the increasing efficiency of the control equipment from 1948 to 1958. Prior to the development of the control program, little or no control devices were installed and an average of 5 pounds of dust were emitted per ton of asphaltic concrete produced. As the control program progressed and the efficiency of control equipment was increased, dust emissions were reduced until today only 0.15 pound is emitted per ton of asphaltic concrete produced. The major reduction of dust was accomplished between 1948 and 1950. During this period, an average reduction of 150 pounds per hour per plant was achieved. From 1950 to the present time, an average reduction of 12 pounds per hour per plant has been accomplished due to improvements in controls and better maintenance programs.

The increased efficiency of the control equipment was accomplished even though the average volume of gases handled per plant has increased from 13,000 standard cubic feet per minute in 1951 to 21,000 standard cubic feet per minute in 1958. Figure 9 illustrates this increase in volume.

A reduction in volume between 1948 and 1951 is believed to be partially due to conservation of gas volume to allow smaller control devices to be installed. Subsequent to 1951, better control of dust emissions from sources other than the dryer required an increase in gas volume. Moreover, plants have increased in size in recent years.

The data obtained from surveys conducted periodically on the asphaltic concrete industry show that production has increased since 1948 from an average of 10,000 tons per day to more than 14,000 tons per day in 1957 (Figure 10), an increase of 40 per cent. During the same period, dust emissions decreased from 25 tons per day to 1 ton per day, a decrease of 96 per cent overall.

Conclusions

In conclusion, it is emphasized that the variables studied only represent average trends of asphaltic concrete plants in Los Angeles County. With this point in mind, it can be concluded that:

1. Multiple centrifugal scrubbers have proven to be more efficient than baffled towers.
2. Scrubber water-gas ratio is equally important in both types of scrubbers. The best utilization of water is achieved up to a ratio of 6 gallons per 1000 standard cubic feet of gas. Above this ratio, efficiency still increases within the bounds studied, but at a lesser rate.
3. Scrubber stack emissions increase linearly with an increase in the amount of minus 200-mesh material charged to the dryer.
4. The burning of PS 300 or heavier fuel oils rather than natural gas results in higher stack emissions. Under constant conditions, an increase of approximately 5 pounds per hour was observed. Although the available data are not conclusive, it appears that dust emissions are significantly decreased when PS 200 oil is substituted for PS 300 oil.

Through the use of scrubbers, dust emissions from asphaltic concrete plants have been reduced from a total of 25 tons per day to 1 ton per day. If this is related to the increase in production over the 10-year period, then the control program is responsible for a net removal of 34 tons per day of dust from the Los Angeles County atmosphere.

REFERENCES

1. Rule 54, Rules and Regulations of the Los Angeles County Air Pollution Control District. In essence, this rule limits the amount of dust and fumes discharged to the atmosphere in any one hour from any source based upon the process weight. For example, if 100 tons per hour of sand and aggregate are charged to the dryer of an asphaltic concrete plant, the process weight is then 200,000 pounds per hour. The rule states that for process weights of 60,000 pounds per hour or more, the maximum weight of dust and fumes discharged to the atmosphere shall not exceed 40 pounds per hour.

2. Friedman, S.J., and Marshall, W.R., Jr., "Studies in Rotary Drying", Chem. Eng. Prog., 45, 8, p. 482 (August 1949).

3. Los Angeles County Air Pollution Control District, Test Report Series C-426, unpublished reports.

4. Ingels, R.M., and Richards, G.S., Los Angeles County Air Pollution Control District, unpublished report.

5. Ezekiel, M., "Methods of Correlation Analysis", 2nd Edition, p. 220, John Wiley and Sons, New York (1941).

6. Los Angeles County Air Pollution Control District, Test Report Series C-372, unpublished report.

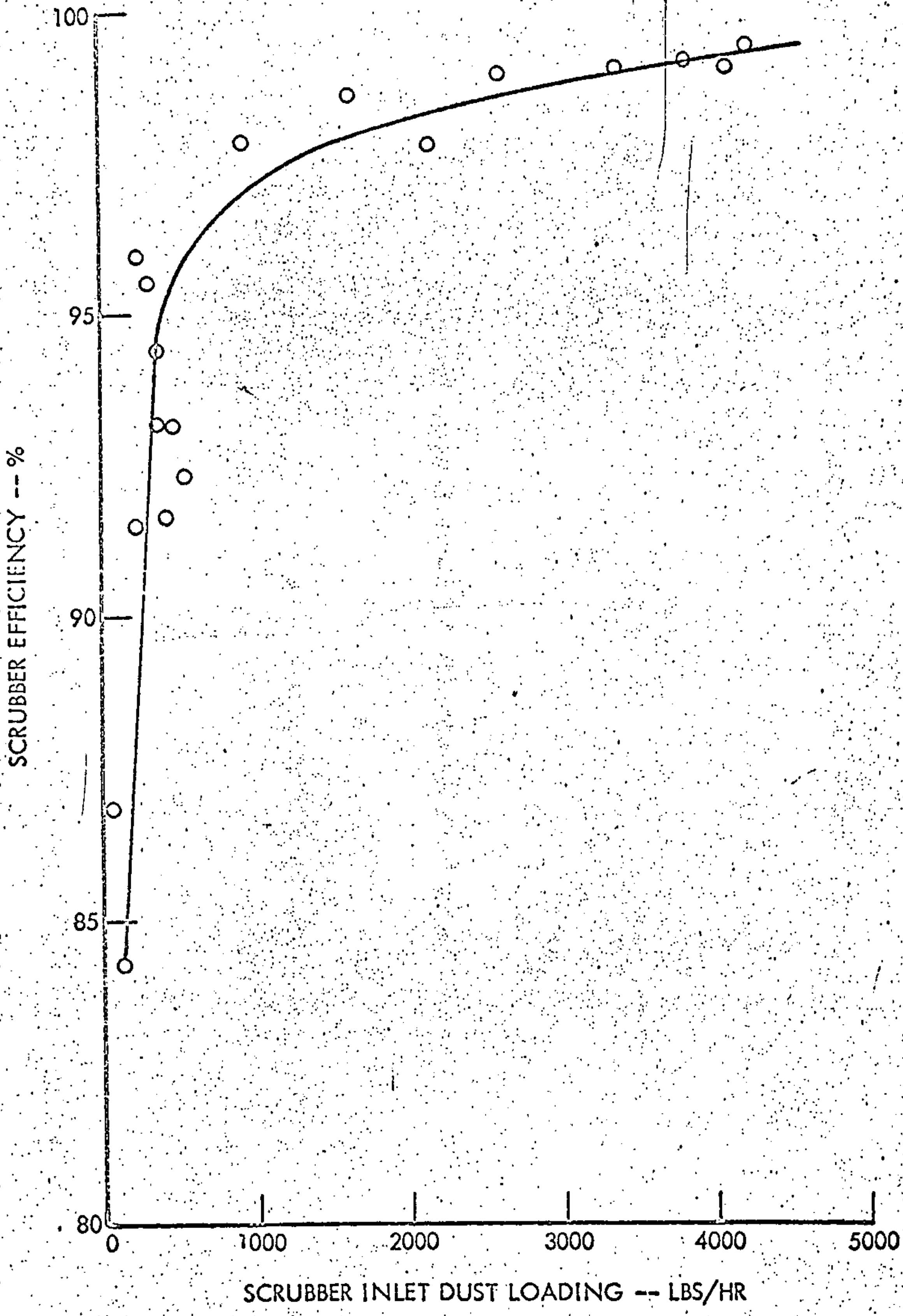

Figure [illegible]. Relationship between scrubber inlet

TABLE 1

TEST DATA FROM ASPHALTIC CONCRETE PLANTS CONTROLLED BY SCRUBBERS

TEST NUMBER	SCRUBBER INLET DUST LOADING lbs/hr	STACK EMISSION lbs/hr x_1	AGGREGATE FINES RATE* lbs/hr x 10^{-3} x_2	WATER-GAS RATIO gal/1000 scf x_3	log x_3	TYPE OF SCRUBBER+	TYPE OF FUEL	PRODUCTION tons/hr	GAS EFFLUENT VOLUME scfm
357	940	20.7	9.55	6.62	0.82	C	Oil	183.9	23,100
82	427	35.6	4.46	3.94	0.60	C	Oil	96.9	19,800
379	4110	37.1	8.35	6.38	0.81	C	Oil	174.0	26,200
355	2170	47.0	14.00	6.81	0.83	C	Oil	209.1	25,700
372B	121	19.2	2.29	10.99	1.04	C	Oil	142.9	18,200
72A	76	10.0	2.84	11.11	1.05	C	Gas	158.0	18,000
369	352	24.4	4.75	5.41	0.73	C	Oil	113.0	16,100
393	4260	26.9	4.05	12.01	1.08	T	Oil	92.3	19,500
354	--	27.8	6.37	6.10	0.79	T	Oil	118.4	7,720
85	1640	21.3	5.22	19.40	1.29	T	Oil	137.8	18,700
173	--	31.0	8.85	20.40	1.31	T	Oil	184.2	17,000
tside lab.	--	33.5	7.52	11.01	1.04	T	Oil	144.6	23,700
79	3850	30.3	6.50	5.92	0.77	C	Gas	191.3	28,300
337	305	13.6	2.51	11.11	1.05	C	Oil	114.6	24,300
tside lab.	--	21.1	3.73	7.28	0.86	T	Gas	124.4	15,900
34	372	21.2	2.53	5.70	0.76	T	Gas	42.0	17,200
426	2620	25.5	10.20	7.75	0.89	C	Oil	182.0	22,000
417	560	39.9	3.05	2.94	0.47	C	Oil	138.9	24,600
425	485	32.9	2.89	4.26	0.63	C	Oil	131.4	18,000
tside lab.	--	25.5	6.59	6.60	0.82	C	Gas	131.7	18,200
385	212	17.5	4.89	4.56	0.66	C	Oil	174.3	20,000
433	266	11.0	5.96	8.12	0.91	C	Gas	114.5	19,600
422(1)	--	26.6	7.14	4.90	0.69	C	Oil	198.0	21,000
422(2)	--	37.0	3.34	3.02	0.48	C	Oil	152.0	22,200
18	3400	30.8	9.35	8.90	0.95	T	Oil	116.5	17,100
tals		667.4	146.93		21.33				
erages		26.7	5.9		0.85				

Quantity of fines (minus 200 mesh) in dryer feed.

C = Multiple centrifugal type spray chamber.

T = Baffled tower scrubber.

COLLECTION EFFICIENCY DATA FOR SCRUBBERS SERVING ASPHALTIC CONCRETE PLANTS

DUST PARTICLE SIZE	TEST REPORT SERIES C-393			TEST REPORT SERIES C-369			TEST REPORT SERIES C-372A		
microns	Inlet %	Outlet %	Efficiency %	Inlet %	Outlet %	Efficiency %	Inlet %	Outlet %	Efficiency %
0-10	13.0	99.3	95.2	76.4	79.9	92.8	78.0	83.0	85.0
10-20	71.1	0.0	100.0	6.3	3.8	96.0	18.0	5.0	96.2
20-44	9.6	0.0	100.0	2.8	2.0	95.0	2.0	1.0	93.3
44+	6.3	0.7	99.3	14.5	14.3*	93.1	2.0	11.0*	26.5

DUST PARTICLE SIZE	TEST REPORT SERIES C-372B			TEST REPORT SERIES C-422(1)		
microns	Inlet %	Outlet %	Efficiency %	Inlet %	Outlet %	Efficiency %
0-10	91.0	82.0	85.7	80.4	73.2	--
10-20	9.0	3.0	99.4	18.6	5.1	--
20-44	0.0	2.0	--	1.0	4.5	--
44+	0.0	13.0*	--	0.0	17.2	--

* Microscopic examination indicated that the outlet samples were agglomerated.

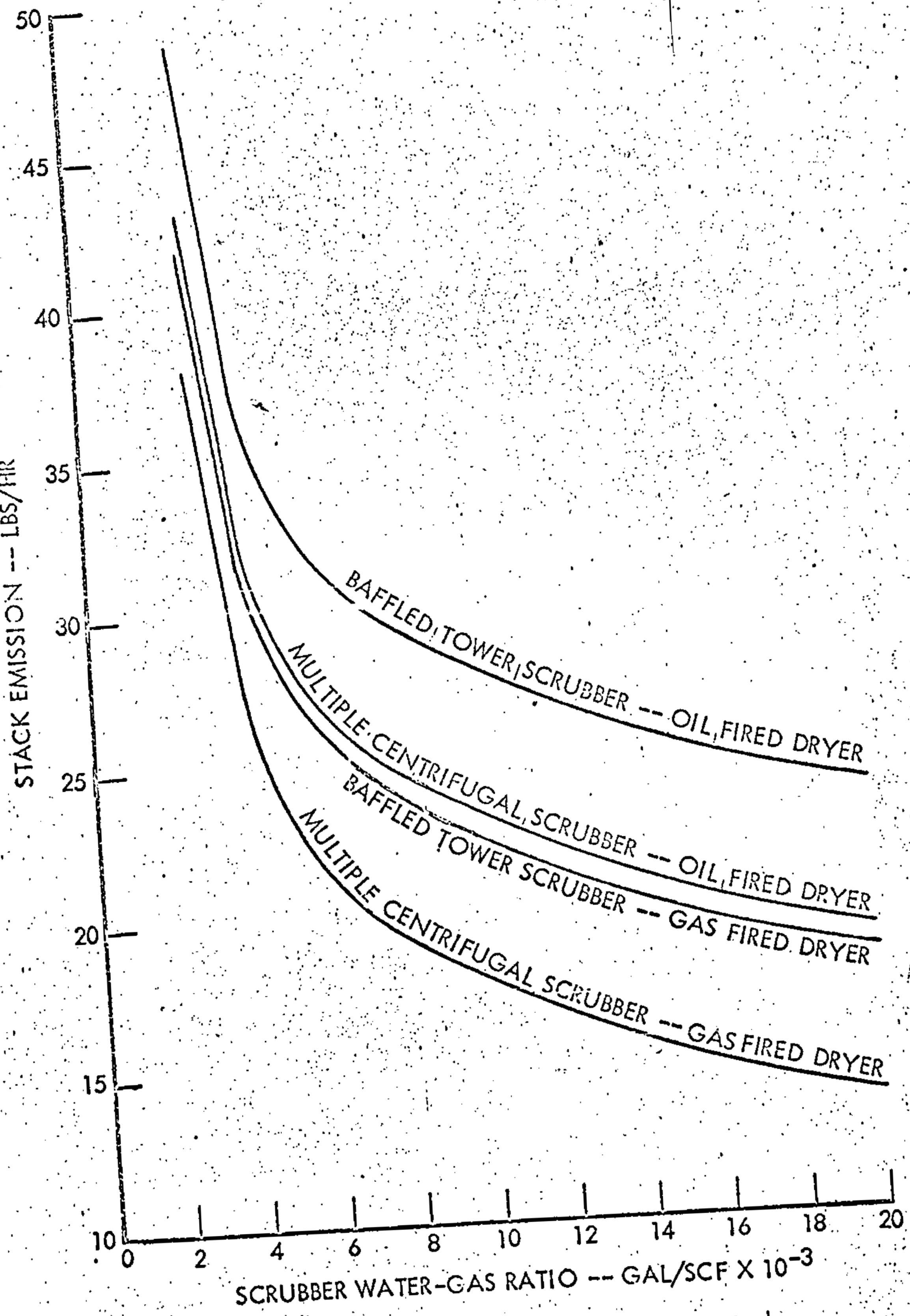

Figure 4. Effect of scrubber water-gas ratio on stack emissions at average aggregate fines rate in the dryer feed.

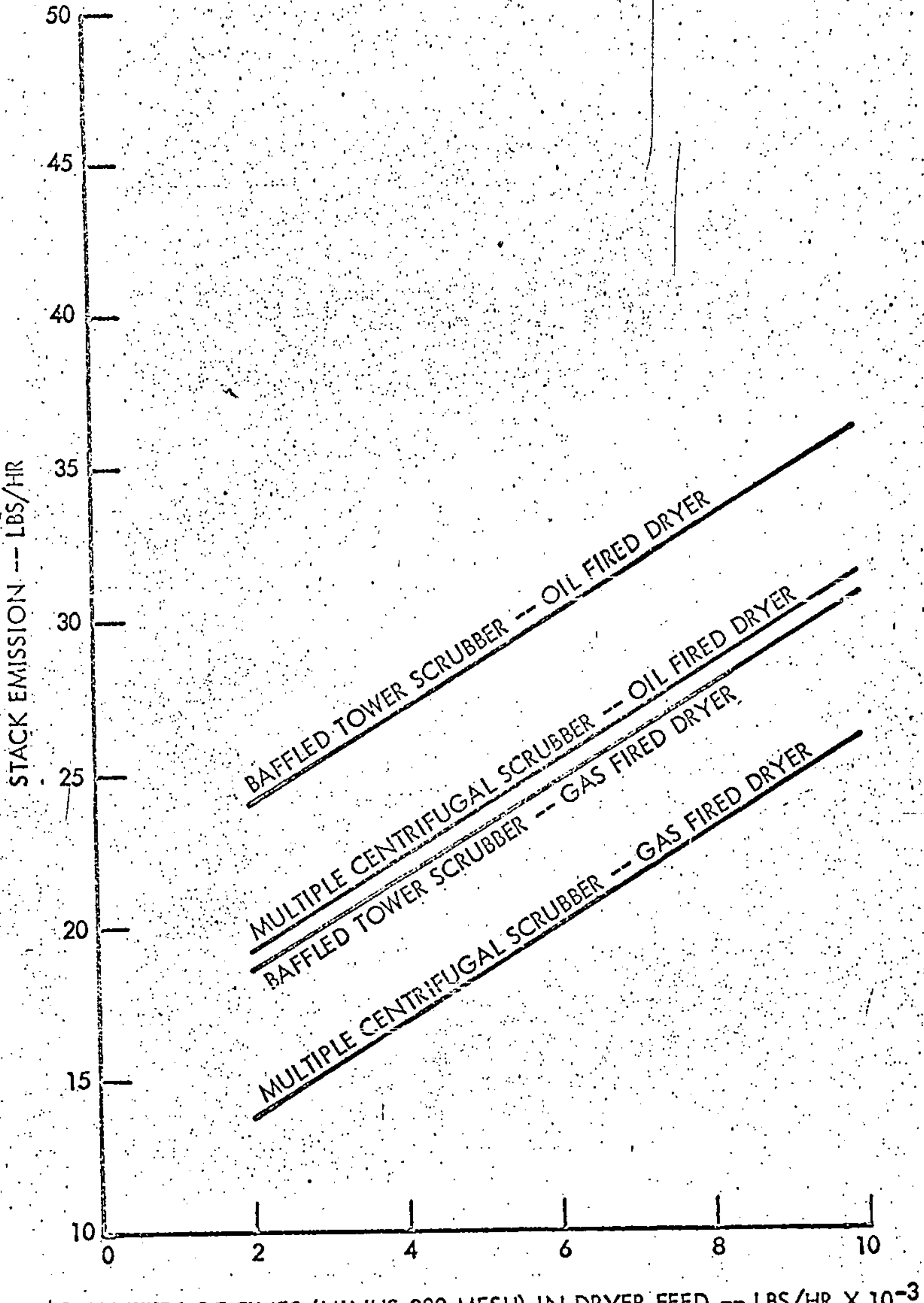

Fig. 5. Effect of aggregate fines rate on stack emissions at average water-gas ratio.

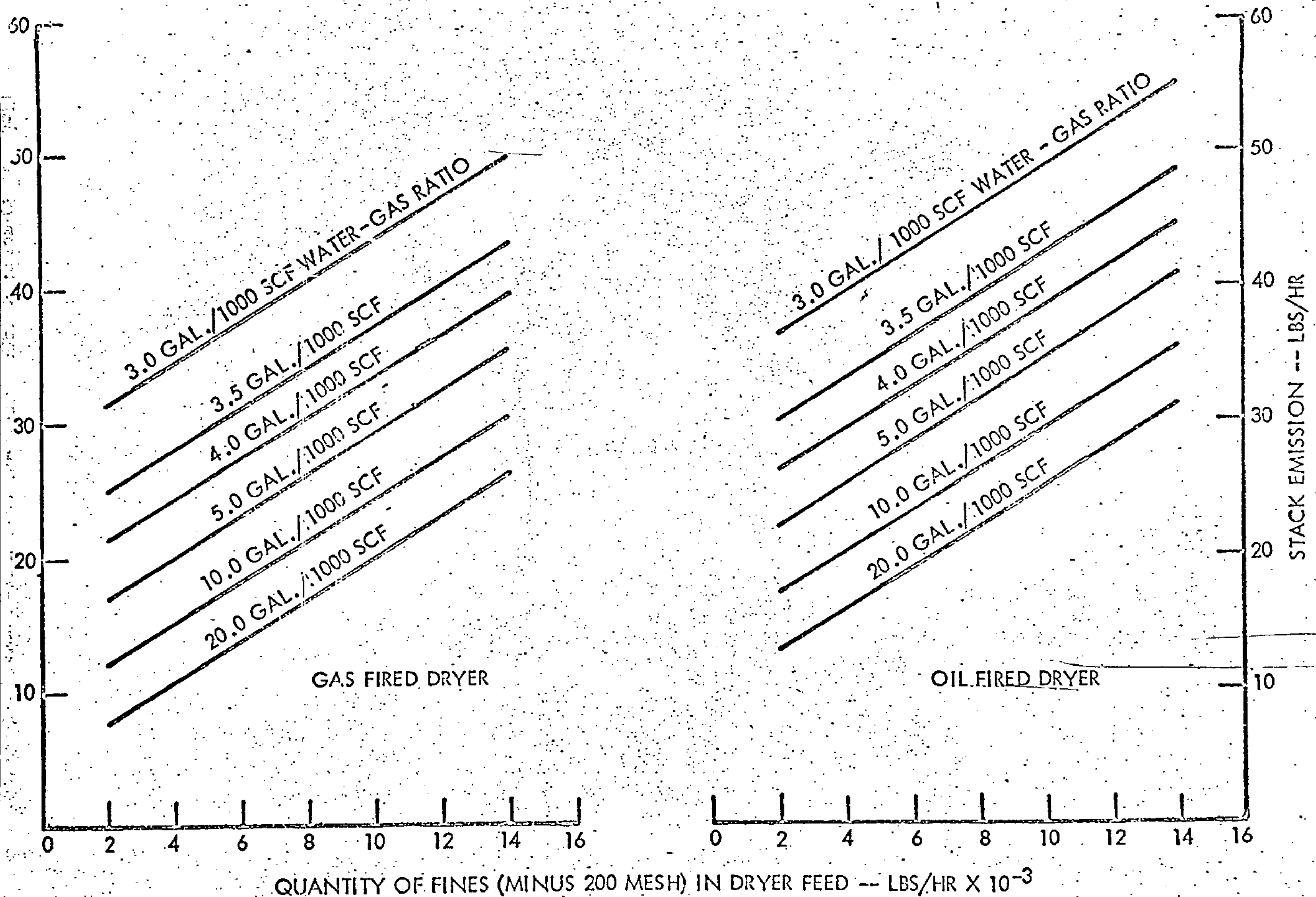

Figure 6. Emission prediction curves for multiple centrifugal scrubbers serving asphaltic concrete plants.

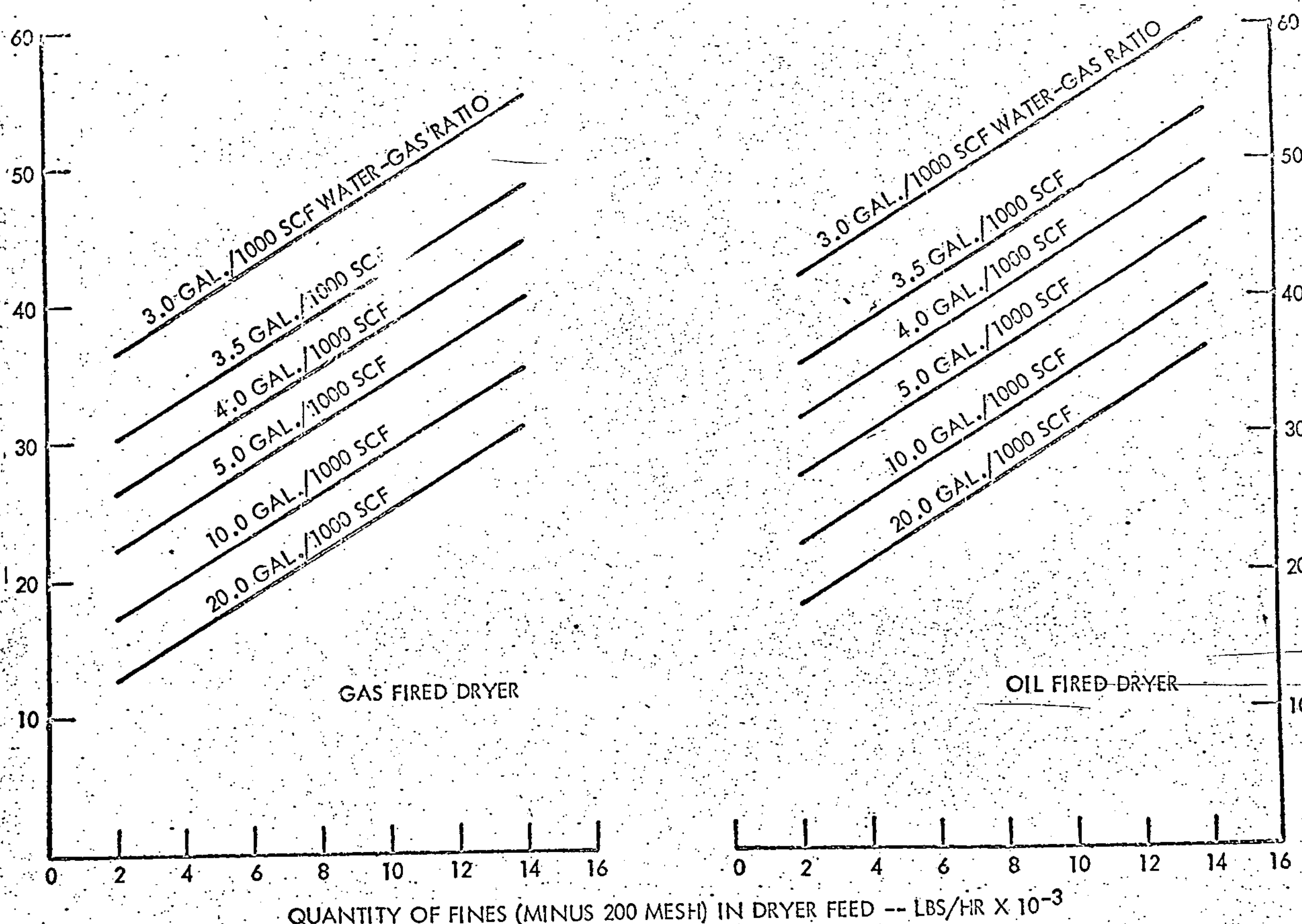

Figure 7. Emission prediction curves for baffled tower scrubbers serving asphaltic concrete plants.

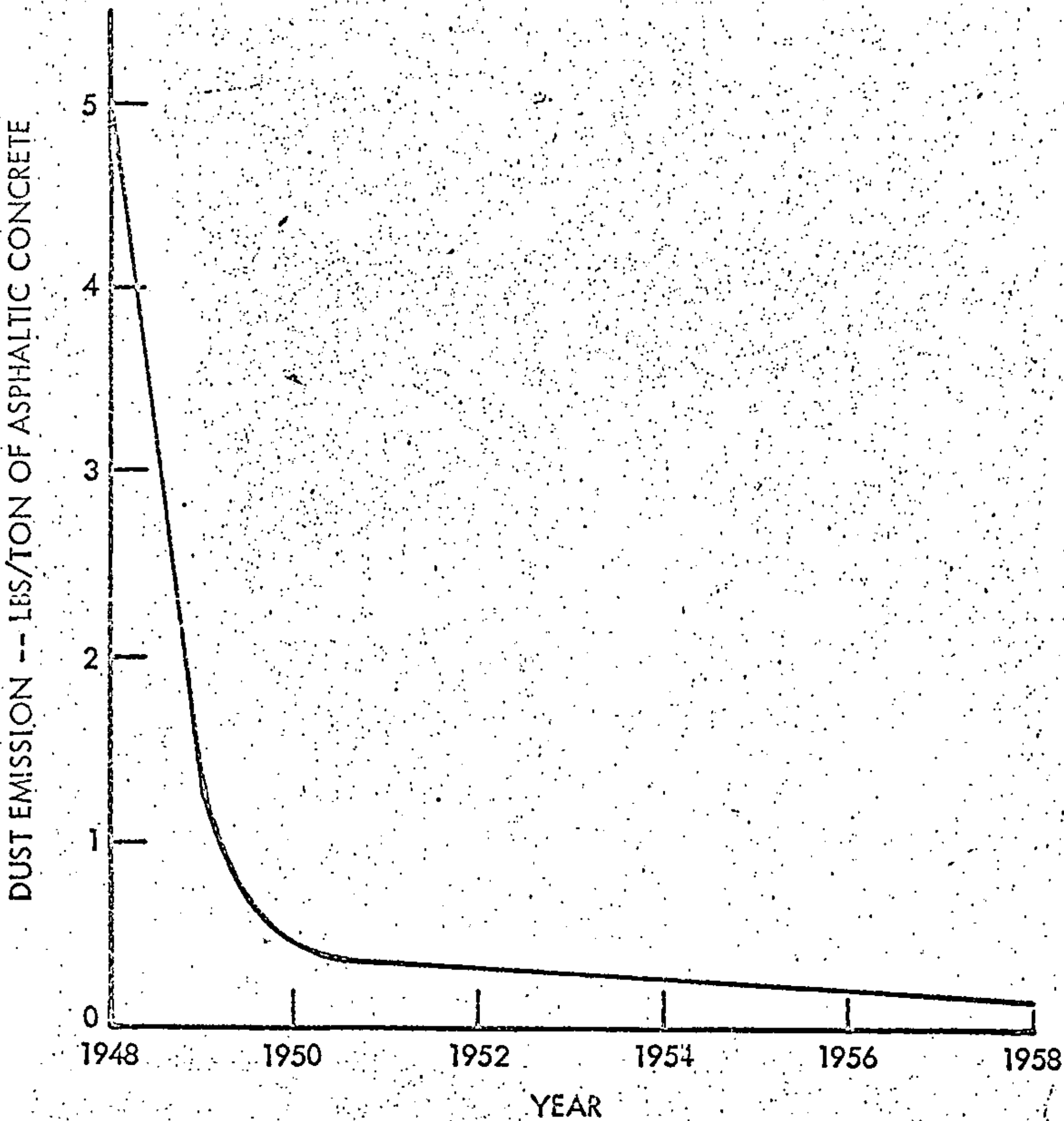

Figure 8. Reduction of dust emissions from asphaltic concrete plants in Los Angeles County during the period 1948 to 1958.

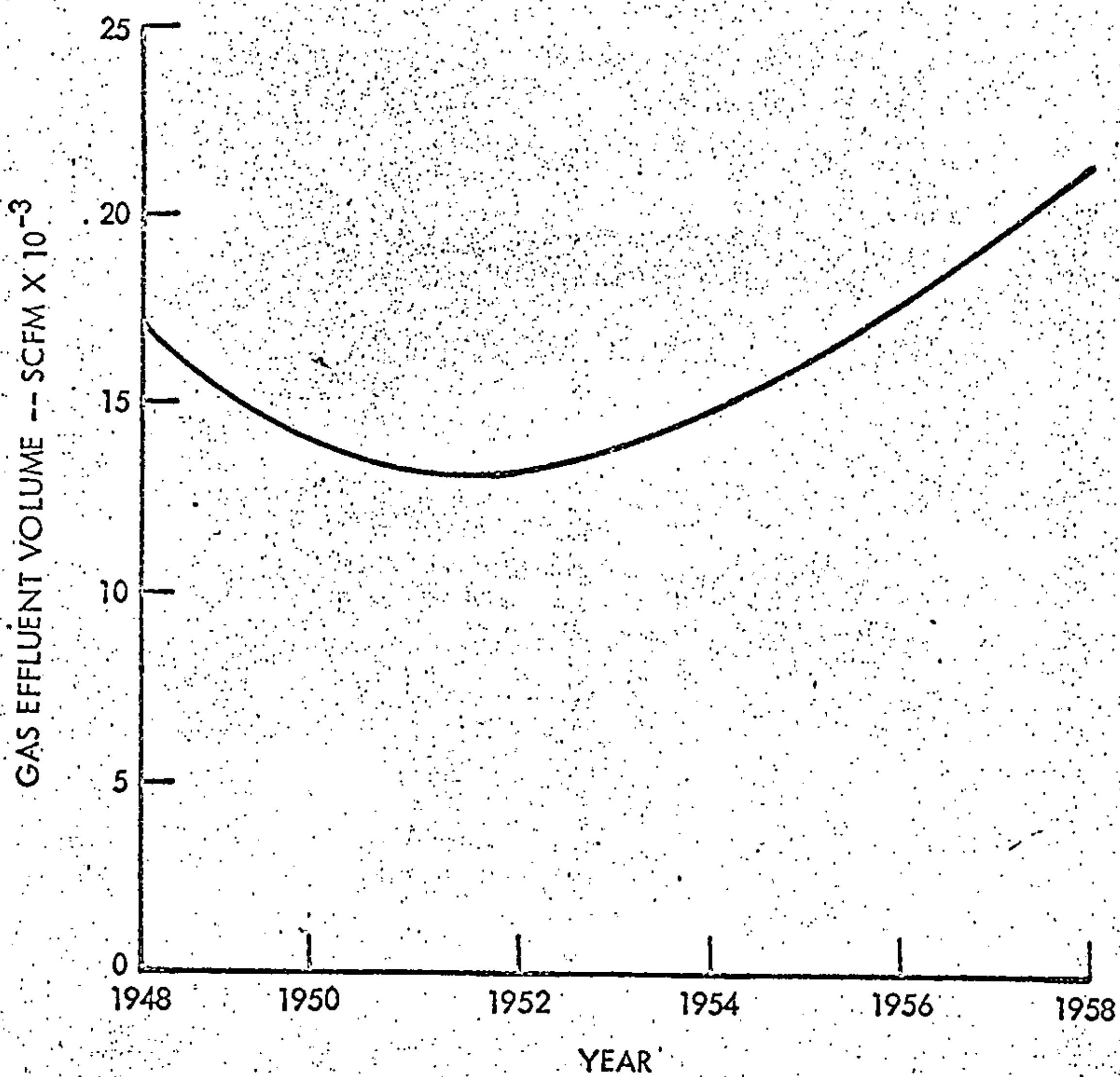

Figure 9. Asphaltic concrete plant average scrubber effluent volume in Los Angeles County during the period 1948 to 1958.

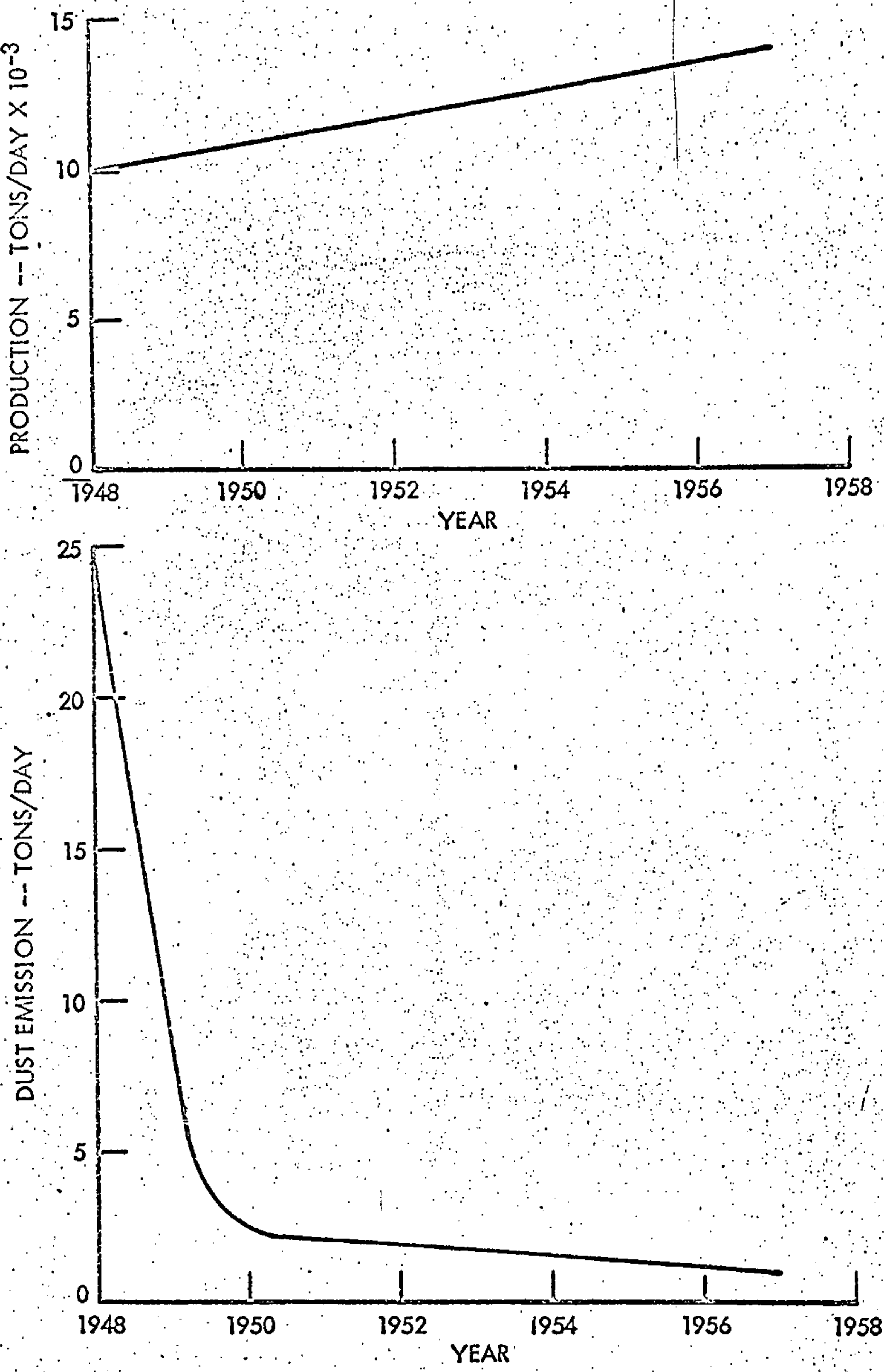

Figure 10. Average daily production and total dust emissions from asphaltic concrete batching plants in Los Angeles County.

APPENDIX

Calculation Procedures

Ezekiel's graphical method of successive approximations was used to correlate the data. The independent variables were log scrubber water-gas ratio, aggregate fines rates, and the non-quantitative factors of type of scrubber and kind of fuel. The absolute stack emission was the dependent variable. The log water-gas ratio was chosen to minimize the deviation from a linear relationship.

In the procedure used, a linear multiple regression equation is calculated by the least squares method and this is adjusted by successive approximations to an appropriate curvilinear relationship. The linear regression equation obtained was as follows:

$$\text{(A)} \quad x_1' = 34.3 + 1.5\, x_2 - 19.5 \log x_3$$

The constants in equation (A) were calculated by standard statistical procedures. The following two equations were solved simultaneously:

$$\text{(B)} \quad \Sigma\, x_2^2\, b_2 + \Sigma\, (x_2 \log x_3)\, b_3 = \Sigma\, x_1 x_2$$

$$\text{(C)} \quad \Sigma\, x_2 \log x_3\, b_2 + \Sigma\, (\log x_3)^2\, b_3 = \Sigma\, (x_1 \log x_3)$$

Substituting in the equations (see Table III) and solving:

$$\text{(B)} \quad 211.23\, b_2 + 2.49\, b_3 = 274.52$$

$$\text{(C)} \quad 2.49\, b_2 + 1.11\, b_3 = -17.92$$

$$b_2 = 1.5$$

$$b_3 = -19.5$$

$$a = M_1 - b_2 M_2 - b_3 M_3$$

$$a = 26.70 - (1.53)\,(5.88) + (19.49)\,(0.85)$$

$$a = 34.3$$

Regression equation:

$$x_1' = a + b_2\, x_2 + b_3 \log x_3$$

$$x_1' = 34.3 + 1.5\, x_2 - 19.5 \log x_3$$

Equation (A) was used to calculate the estimated stack emission for each test point and the results were tabulated in column five of Table IV. The differences between the actual and the estimated stack emission are tabulated in column six. These values were averaged for each type of scrubber and the averages subtracted from the residuals in column six to obtain revised residuals which are tabulated in column seven. The procedure was repeated for averages of residuals in column seven for the two types of fuel, resulting in the values tabulated in column eight in Table IV.

Figures 11 and 12 were plotted as follows: Average values of x_2 and log x_3 were substituted in equation A and the resulting straight lines were plotted. Then the corrected residuals from column eight, Table IV, were plotted as deviations from the straight lines. The resulting plots were examined for linearity. It appeared that a curve would better represent the data of Figure 11, and a first approximation curve was drawn using averages values as a guide. No change was made in the linear relationship of aggregate fines rate versus stack emissions at constant water-gas ratio (Figure 12).

The procedure was repeated using the first approximation curves to calculate estimated stack emissions, and corrected residuals were plotted as deviations from the new curves. The second approximation to the aggregate fines rate curve was closer to the linear relationship than the first approximation in Figure 12. It was judged that additional adjustment of either curve was not required.

NOTATION

Constant in linear regression equation

= Constant in linear regression equation

= Constant in linear regression equation

= Mean of the stack emission, lbs./hr.

= Mean of the aggregate fines rate, lbs./hr. x 10^{-3}

= Mean of the log scrubber water-gas ratio

Number of observations

= Estimated stack emission by the linear regression equation, lbs./hr.

= Stack emission, lbs./hr.

= Aggregate fines rate, lbs./hr. x 10^{-3}

= Scrubber water-gas ratio, gal./1000 SCF

Difference between actual and estimated stack emissions, $x_1 - x_1'$

= Residual stack emission corrected for type of scrubber, lbs./hr.

= Residual stack emission corrected for type of and kind of fuel, lbs./hr.

TABLE III

CALCULATION OF LINEAR LEAST SQUARES REGRESSION EQUATION
FROM ASPHALTIC CONCRETE PLANT TEST DATA

TEST NO.	$(x_2)^2$	$(\log x_3)^2$	$(x_1)(x_2)$	$(x_1)(\log x_3)$	$(x_2)(\log x_3)$
1	91.2025	0.6724	197.685	16.974	7.8310
2	19.8916	0.3600	158.776	21.360	2.6760
3	69.7225	0.6561	309.785	30.051	6.7635
4	196.0000	0.6889	658.000	39.010	11.6200
5	5.2441	1.0816	43.968	19.968	2.3816
6	8.0656	1.1025	28.400	10.500	2.9820
7	22.5625	0.5329	115.900	17.812	3.4675
8	16.4025	1.1664	108.945	29.052	4.3740
9	40.5769	0.6241	177.086	21.962	5.0323
10	27.2484	1.6641	111.186	27.477	6.7338
11	78.3225	1.7161	274.350	40.610	11.5935
12	56.5504	1.0816	251.920	34.840	7.8208
13	42.2500	0.5929	196.950	23.331	5.0050
14	6.3001	1.1025	34.136	14.280	2.6355
15	13.9129	0.7396	78.703	18.146	3.2078
16	6.4009	0.5776	53.636	16.112	1.9228
17	104.0400	0.7921	260.100	22.695	9.0780
18	9.3025	0.2209	121.695	18.753	1.4335
19	8.3521	0.3969	95.081	20.727	1.8207
20	43.4281	0.6724	168.045	20.910	5.4038
21	23.9121	0.4356	85.575	11.550	3.2274
22	35.5216	0.8281	65.560	10.010	5.4236
23	50.9796	0.4761	189.924	18.354	4.9266
24	11.1556	0.2304	123.580	17.760	1.6032
25	87.4225	0.9025	287.980	29.260	8.8825
Totals	1074.7675	19.3143	4196.966	551.504	127.8464
Correction Factor*	863.5375	18.2000	3922.4433	569.4257	125.3607
Sums of Squares and Products	211.2300	1.1143	274.5227	-17.9217	2.4857

* Correction Factor $= (n)(M_1)^2 = (25)(26.6960)^2 = 863.5375$
$= (n)(M_3)^2 = (25)(0.8532)^2 = 18.2000$
$= (n)(M_1)(M_2) = (25)(26.6960)(5.8772) = 3922.4433$, etc.

TABLE IV

CALCULATION OF FIRST APPROXIMATION CURVES
FROM ASPHALTIC CONCRETE
PLANT TEST DATA

TEST NO. (1)	TYPE OF SCRUBBER* (2)	TYPE OF FUEL (3)	x_1 (4)	x_1' (5)	z (6)=(4)-(5)	z_s (7)	z_f (8)
1	C	Oil	20.7	32.96	-12.26	-10.87	-12.43
2	C	Oil	35.6	29.47	6.13	7.52	5.96
3	C	Oil	37.1	31.32	5.78	7.17	5.61
4	C	Oil	47.0	39.57	7.43	8.82	7.26
5	C	Oil	19.2	17.57	1.63	3.02	1.46
6	C	Gas	10.0	18.22	- 8.22	- 6.83	- 1.90
7	C	Oil	24.4	27.37	- 2.97	- 1.58	- 3.14
8	T	Oil	26.9	19.48	7.42	4.47	2.91
9	T	Oil	27.8	28.68	- 0.88	- 3.83	- 5.39
10	T	Oil	21.3	17.18	4.12	1.17	- 0.39
11	T	Oil	31.0	22.34	8.66	5.71	4.15
12	T	Oil	33.5	25.57	7.93	4.98	3.42
13	C	Gas	30.3	29.27	1.03	2.42	7.35
14	C	Oil	13.6	17.71	- 4.11	- 2.72	- 4.28
15	T	Gas	21.1	23.28	- 2.18	- 5.13	- 0.20
16	T	Gas	21.2	23.39	- 2.19	- 5.14	- 0.21
17	C	Oil	25.5	32.59	- 7.09	- 5.70	- 7.26
18	C	Oil	39.9	29.84	10.06	11.45	9.89
19	C	Oil	32.9	26.48	6.42	7.81	6.25
20	C	Gas	25.5	28.43	- 2.93	- 1.54	3.39
21	C	Oil	17.5	28.95	-11.45	-10.06	-11.62
22	C	Gas	11.0	25.72	-14.72	-13.33	- 8.40
23	C	Oil	26.6	31.81	- 5.21	- 3.82	- 5.38
24	C	Oil	37.0	30.09	6.91	8.30	6.74
25	T	Oil	30.8	30.12	0.68	- 2.27	- 3.83

C = Multiple centrifugal, spiral baffled scrubber
T = Baffled tower scrubber

esidual Averages

Centrifugal Scrubber = -23.57 ÷ 17 = -1.39
Baffled Tower Scrubber = 23.56 ÷ 8 = 2.95

Gas-Fired Dryer = -29.55 ÷ 6 = -4.93
Oil-Fired Dryer = 29.57 ÷ 19 = 1.56

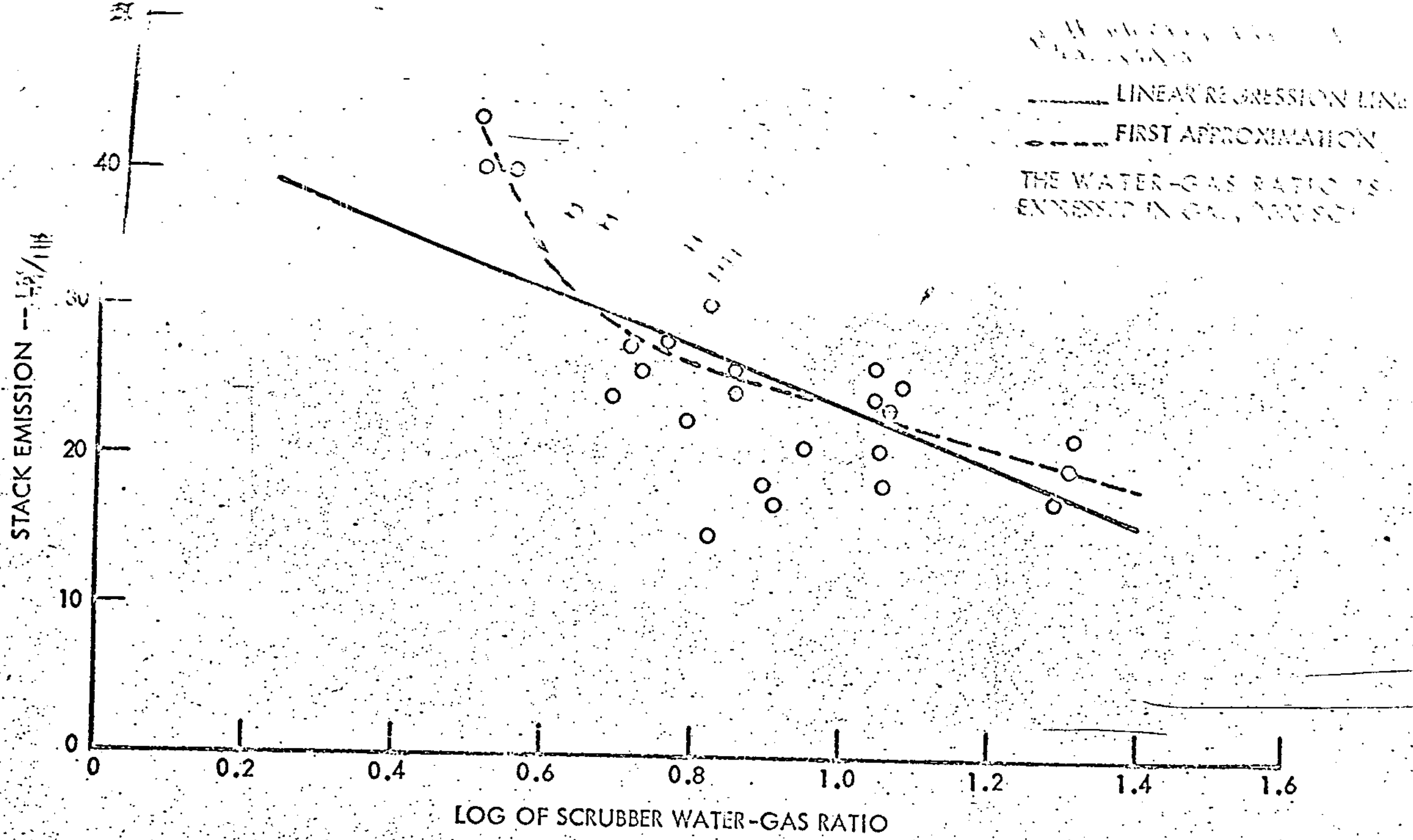

Figure 11. Asphaltic concrete plant stack emissions and log water-gas ratio adjusted for type of scrubber, kind of fuel, and to average aggregate fines rate, and first approximation curve fitted to the averages.

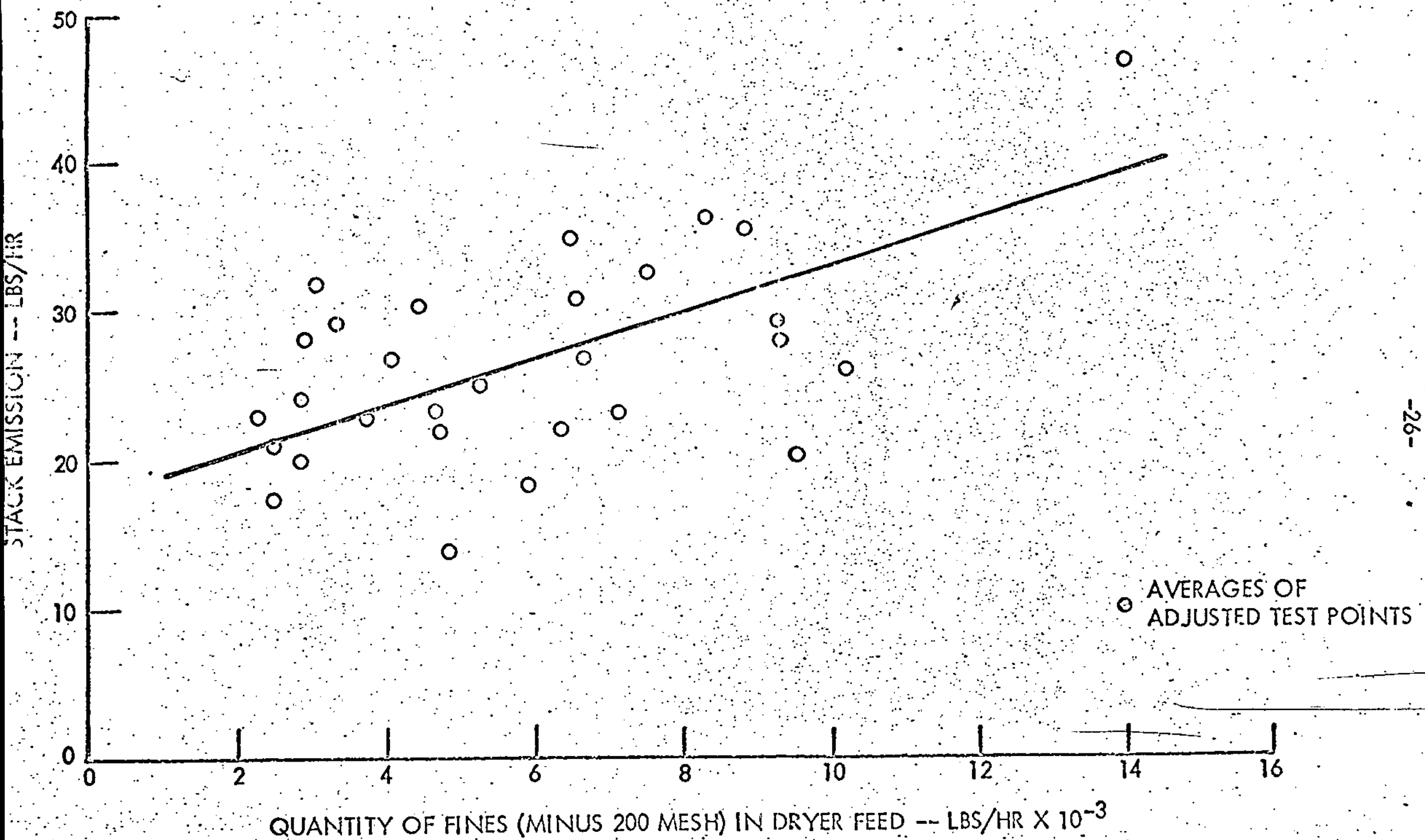

Figure 12. Asphaltic concrete plant stack emissions and aggregate fines rate adjusted for type of scrubber, kind of fuel, and to average scrubber water-gas ratio.