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Louisiana Highway Research

AIR POLLUTION

FROM

HOT MIX PLANTS

Louisiana Department of Highways – Research & Development Section

AIR POLLUTION FROM HOT MIX PLANTS

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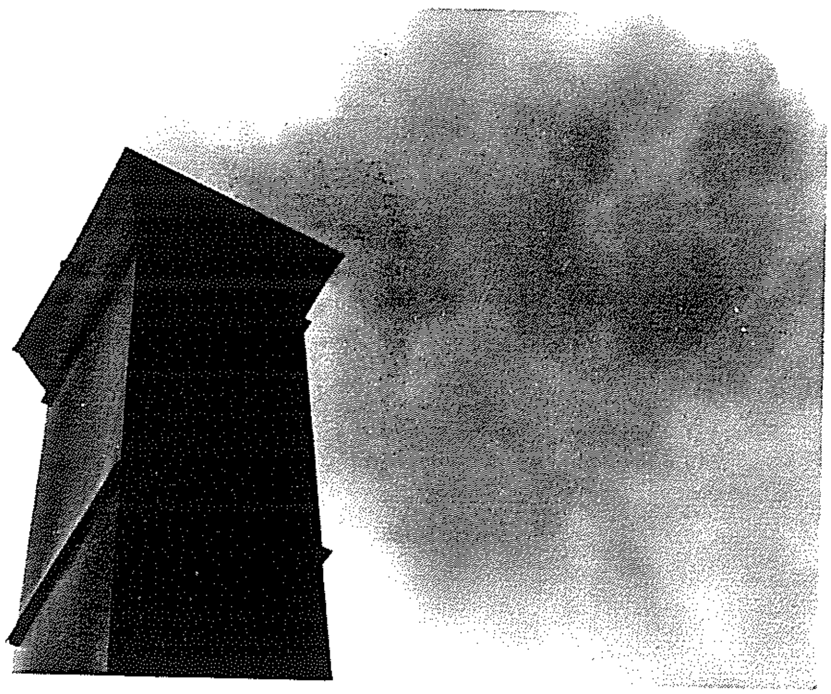


FIGURE 1
AIR POLLUTION FROM STACK EMISSION

ABSTRACT

The Louisiana Air Control Commission adopted Regulation II, effective 1969, which sets stringent limits on suspended particulates. Because of the lack of knowledge concerning air pollution caused by hot mix plants within the State and because of the unknown consequences of strictly applying the new regulation, a moratorium of one year was allowed the hot mix industry. This study was undertaken to determine the pollution caused by hot mix plants.

A wide range of operating conditions was found to exist. The worst condition observed (by a similar study prior to this project) was approximately 1000 micrograms/cubic meter/day. The best plant had approximately 175 micrograms/cubic meter/day. No plant now operating in the State consistently operates within the regulations while maintaining reasonable production. All plants could improve their particulate emissions through more care of and concern for their present equipment and procedures. Almost half of the pollution caused by most plants originates from sources other than the stack. Air pollution from these secondary sources could be significantly reduced. The stack emissions should be reduced by the use of water scrubbers or bag collectors.

It is recommended that the present regulation be slightly altered for a period of three years to allow for purchase of better equipment, for proper repair and cleanup procedures to be effectively implemented, and for production personnel to acclimate themselves to the necessary techniques. It is also recommended that the hot mix industry self-regulate themselves immediately.

IMPLEMENTATION

These findings, implemented properly, will result in improved ecological benefits through the reduction of air pollution.

This report suggests means to implement these recommended improvements through:

(1) Self-regulation by industry

(2) More meaningful methods of control

(3) More reasonable standards of control

INTRODUCTION

The Air Control Commission of the State of Louisiana adopted Regulation II, effective 1969. This regulation places limits upon smoke, suspended particulates and certain chemicals. It establishes unacceptable ambient air quality standards.

This regulation, strictly enforced, is quite stringent. It could possibly have created undue hardships for the hot mix asphalt industry since little knowledge existed concerning the emissions from and general conditions at hot mix plants within the State. Also, exact remedies or corrections necessary to meet the new requirements were unknown. Therefore, the Air Control Commission suspended the regulation for one year while this study was undertaken to acquire needed information.

SCOPE

The objective of this study was to determine the amount of particulates, both suspended particles and dustfall, blown into the atmosphere by hot mix plants. These findings will aid in the control of air pollution at hot mix plants.

DESCRIPTION OF EQUIPMENT

There were three different pieces of equipment that were used for collecting information in this investigation.

1. High Volume (Hi-Vol) Air Sampler - This sampler is composed of a filter coupled with forced air. It has a turbine type blower powered by 0.49 h.p. electric motor. It is designed for 24 hour indoor or outdoor sampling and can be used in either a horizontal or vertical position. Rate of air flow is measured by means of an indirect variable orifice meter. The intake part of the sampler is shaped like a funnel, with the larger upright end of the funnel having an 8 inch by 10 inch rectangular filter holder with a screen to protect the filter.

A special wooden housing was made for the sampler. This housing, having a slanted roof, was designed so that the air was drawn in from under the eaves of the roof and through the filter paper (Figures 2 and 3).

2. Dust Collection Bucket - The dust collection bucket is plastic and stands 7 inches high with an 8 inch opening at the top. Two types of wooden stands were used for holding the buckets in-place during plant sampling (Figures 4 and 5).

3. Mechanical Weather Station (MRI) - The mechanical weather station is a multiple data system of single unit design. The station has the capability of 60-day unattended operation without the need of external power. All information (temperature, wind speed and wind direction) is recorded in a rectilinear form on a dependable battery or hand wound spring driven strip chart recorder (Figures 6 and 7).

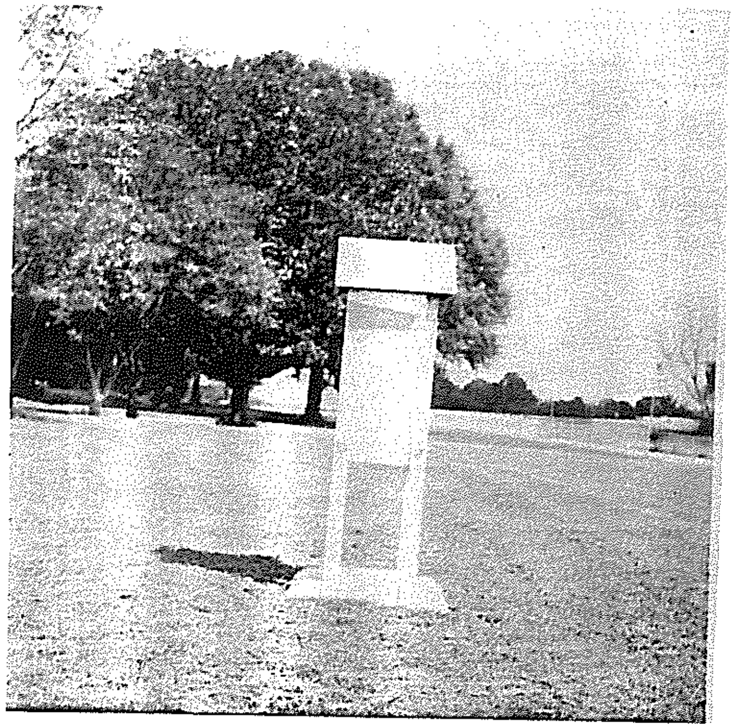
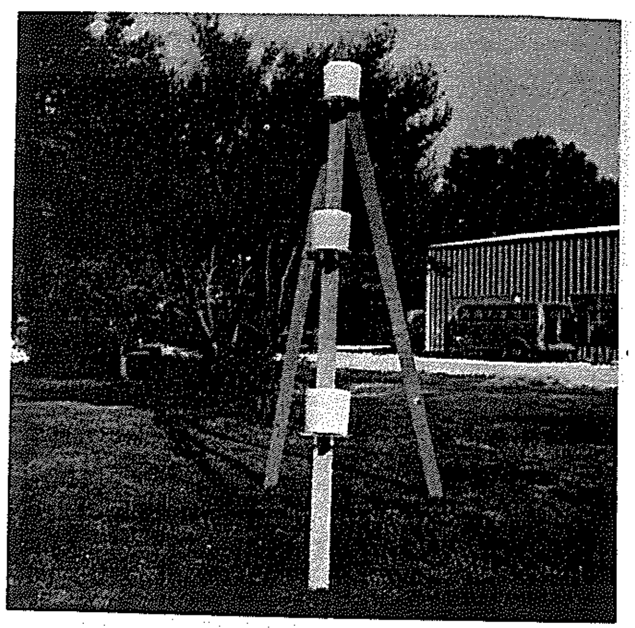


FIGURE 2
HI-VOL SAMPLER

FIGURE 3
HI-VOL SAMPLER

FIGURE 4
DUSTFALL BUCKET AND STAND



DUSTFALL BUCKETS WITH TRIPOD STAND
FIGURE 5

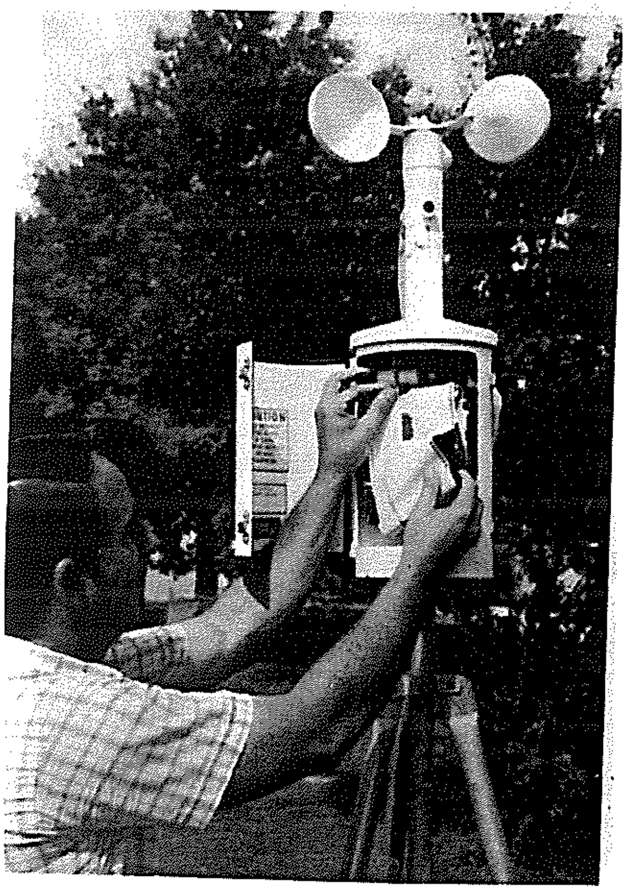


FIGURE 6
WEATHER STATION

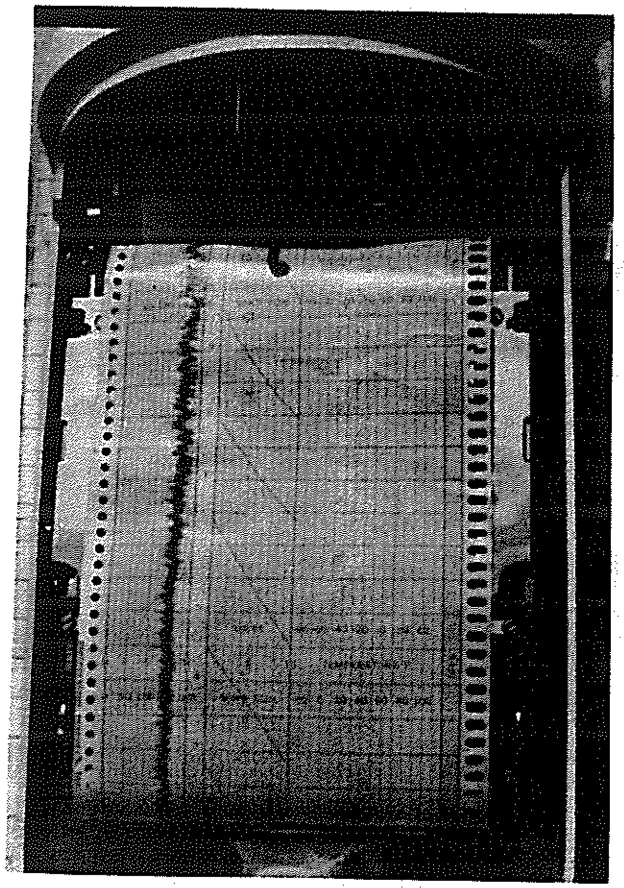


FIGURE 7
PRINT-OUT CHART

METHOD OF PROCEUDRE

Since the Louisiana Air Control Commission is the air pollution control agency for industry in this state, it was decided to use sampling devices, techniques and an approach similar to that of the commission so that the data and findings would be meaningful. Therefore, Hi-Vol samplers (based upon a 24 hour sampling period), and dust buckets (which measures tons/sq. mile for a 30 day period) were used in a property line placement concept.

A wide variance was expected in the test results from using these devices and techniques. Direct or indirect relationships were anticipated between air pollution and various factors such as the location for sampling, wind direction, wind intensity, plant and ground conditions, plant production, operating time and the aggregate composition. Therefore, to evaluate these relationships and factors, six Hi-Vol samplers and twelve dustfall buckets were obtained and placed around the control plant as close to the property line as possible (see Figure 8). The mechanical weather station was also placed on the property line. The position of the Hi-Vol samplers and dust collection buckets ranged in distance from 142 feet to 368 feet away from the plant's stack because of the variation of the property line (see Figure 9).

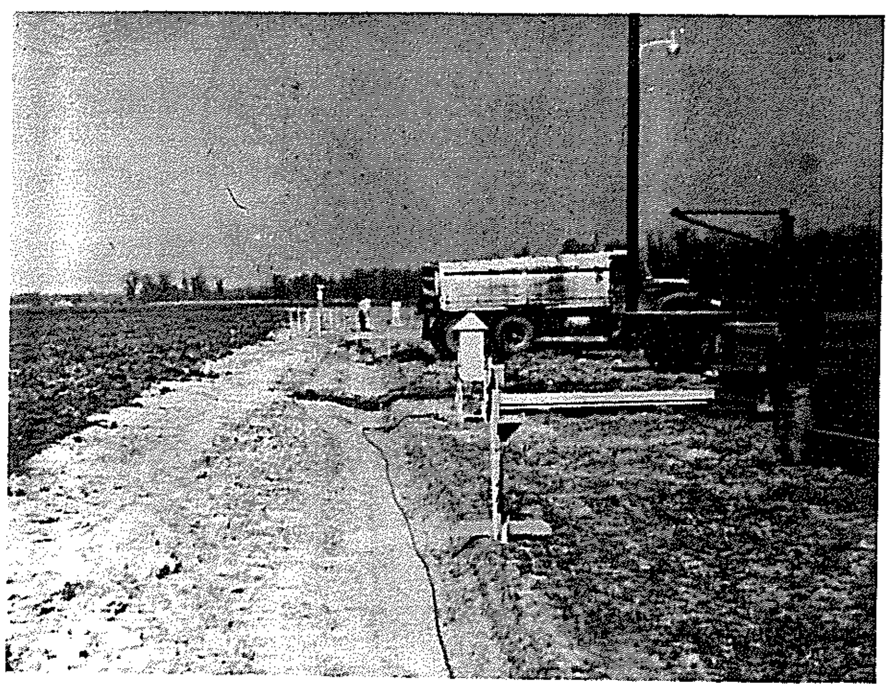
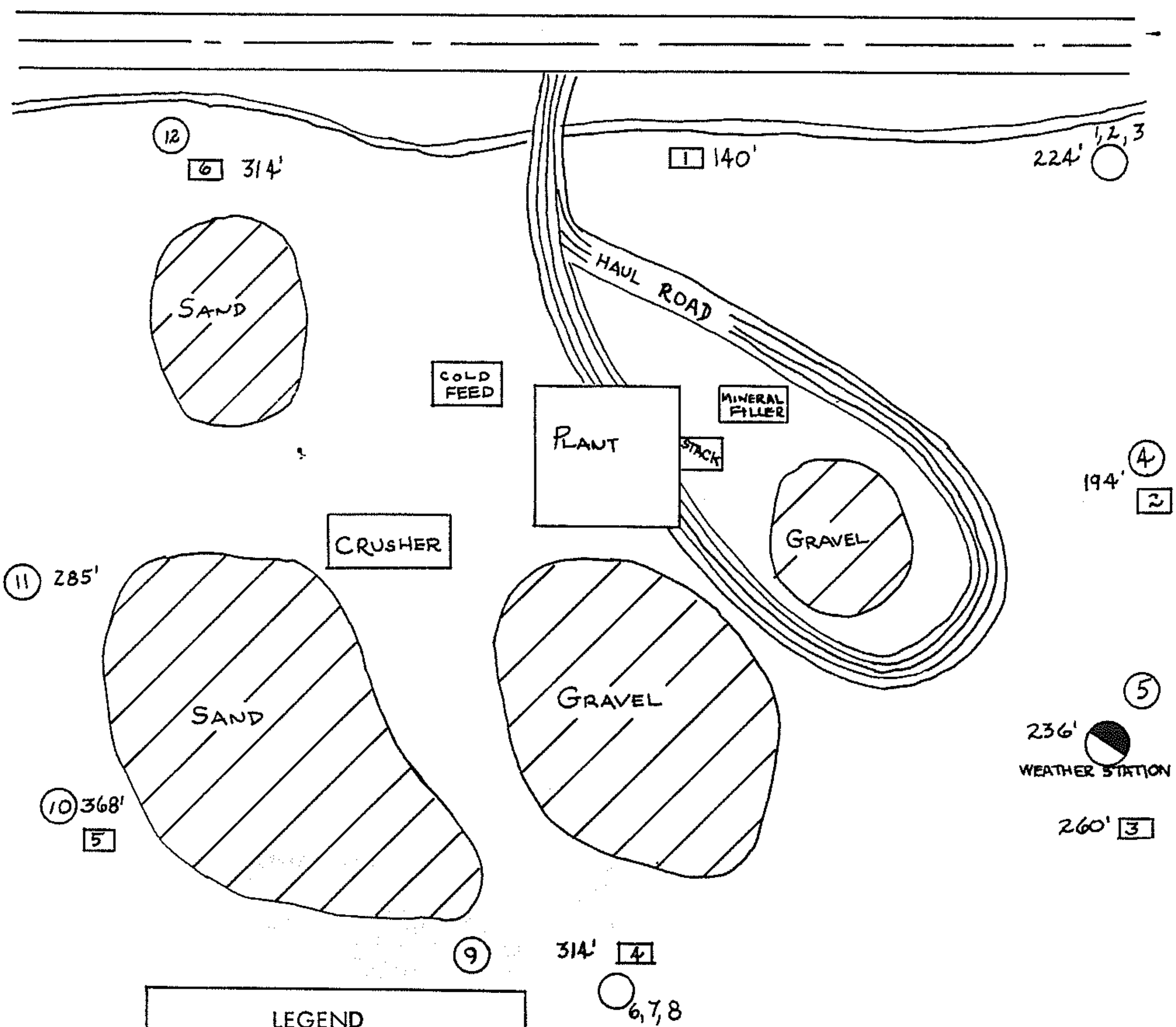


FIGURE 8
HI-VOL SAMPLERS AND DUSTFALL BUCKETS PLACEMENT

LOCATION OF AIR POLLUTION SAMPLERS AT THE CONTROL HOT MIX PLANT



LEGEND
SAMPLER LOCATION

DUST BUCKET LOCATION

HI-VOLUME SAMPLERS

WEATHER STATION

DISTANCES SHOWN ARE DISTANCES FROM PLANT STACK TO SAMPLER LOCATION.

FIG. 9

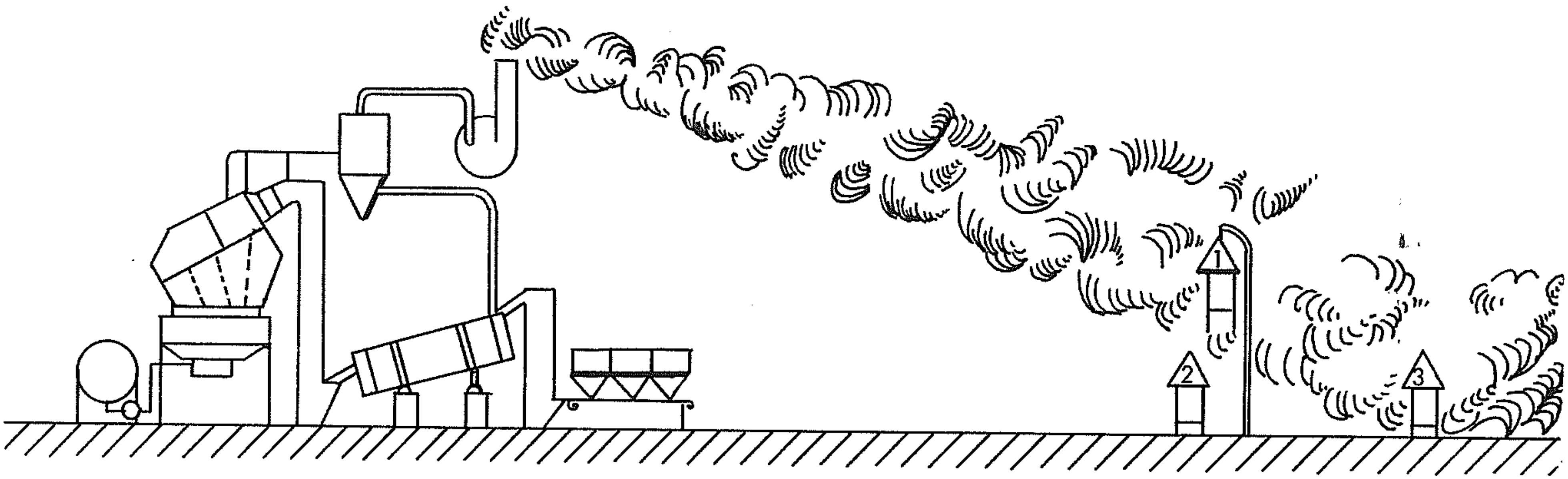
The control plant was using chert gravel aggregate when sampling for the study began. The haul roads were not paved. The plant was sampled five days a week, 24 hours a day for eight weeks. At the request of the study team, the contractor then oiled down the haul roads. Sampling continued for another three weeks. The contractor then switched from gravel to lightweight aggregate (a kiln fired expanded clay) and sample collection continued another three weeks for comparison of air pollution results due to aggregate composition. These results are tabulated in Table 1.

A comparison was also made of height above ground versus distance from the stack. This was done to see what the difference in sample concentration would be at a higher elevation and also at a distance further from the property line at ground level. In doing this, one of the samplers was placed on a tower 32 feet in the air (see Figure 10) and another at ground level directly below the tower, both being 314 feet from the stack in a northerly direction. The third sampler was then placed at ground level in line with the tower and stack an additional 100 feet from the stack (see Figure 11). Distance effects were very important because of the variability of property lines. However, due to equipment malfunction, a complete set of data was not obtained. The results are listed in Table 2.

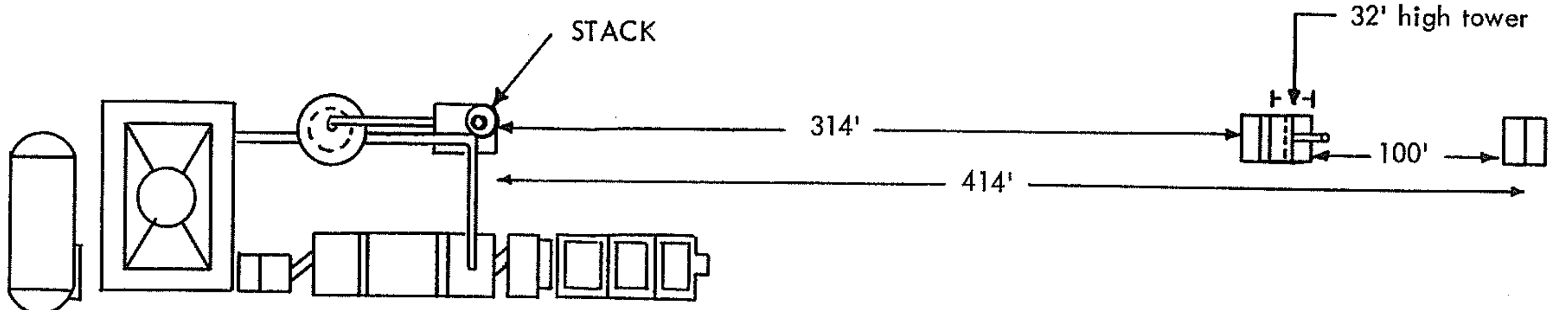
Observations were made of each plant currently operating in the state (see Table 3) to provide subjective personal opinions of plant conditions. From this information a number of plants which appeared to have the best operating conditions were selected for sampling to determine the amount of pollution and how these plants compared with the requirements by law. Hi-Vol samplers (one upwind and two downwind) were set up at five of these plants along with dustfall buckets (one upwind and one downwind). The Hi-Vol samplers were placed at the plant for one to two weeks of sampling and the dust buckets were placed for 30 days of sampling.

Work on air pollution has been done by the Department prior to this project. This information, previously published by the Department under "Air Pollution Study of Hot Mix Plants" by David Azar in August, 1967, has been recapitulated to convert the data to a sampling time of twenty-four hours and has been summarized in Table 4.

SAMPLING VARIATIONS DUE TO HEIGHT - DISTANCE



SIDE VIEW



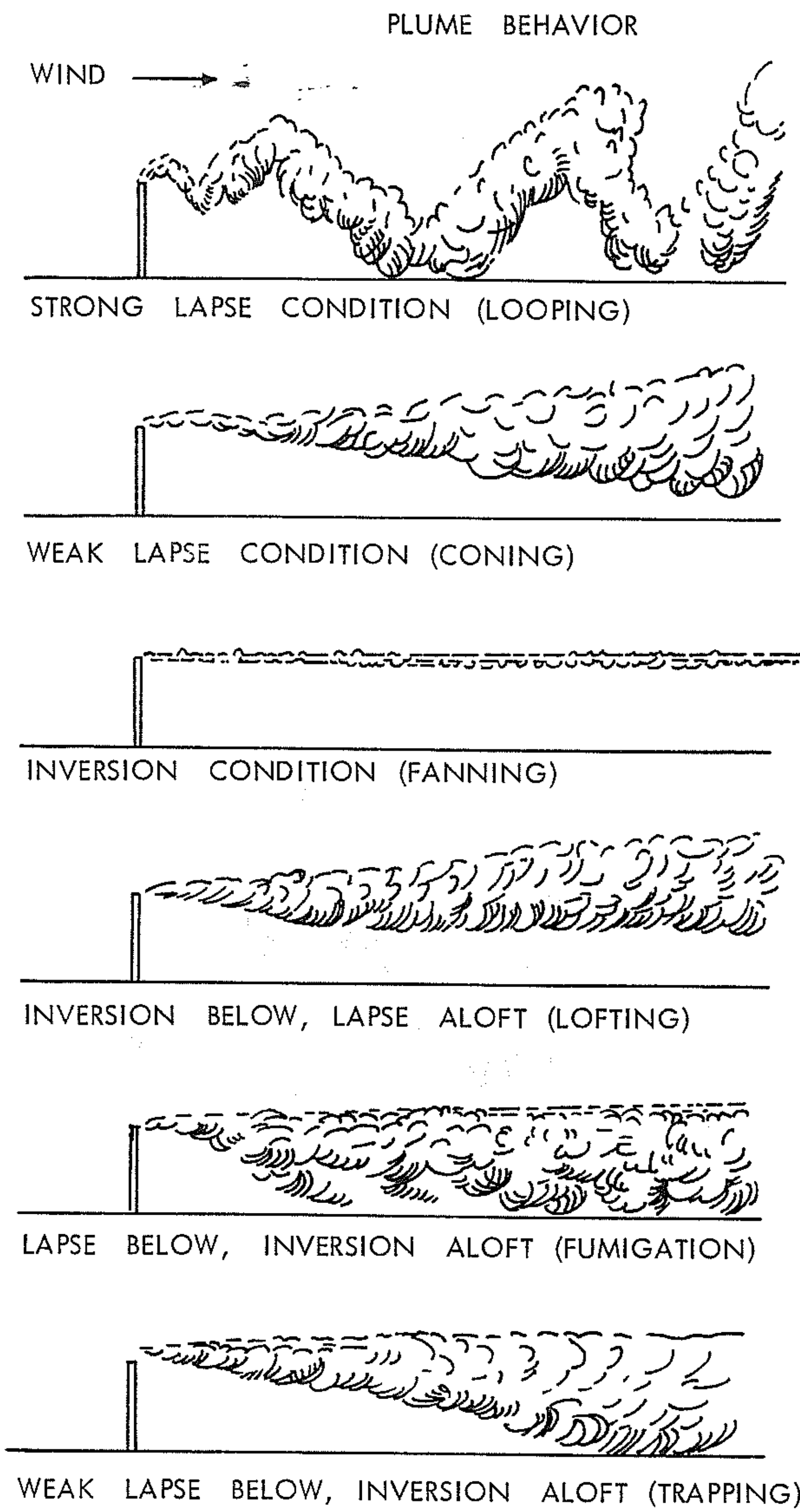
TOP VIEW

FIG. 11

Other influential meteorological factors are illustrated in Figures 12 thru 16. Figures 14, 15 and 16 illustrate one of these factors, looping or aerodynamic downwash, and Figure 11 illustrates the sampler setup to record this phenomena. The results tabulated in Table 2, show the effects of downwash. Under meteorological conditions conducive to the occurrence of downwash, even though the particulate density is theoretically dispersing in direct proportion as the distance to the stack, the ambient air quality is poorer at a considerable distance from the plant than it is in the immediate plant vicinity. However, on another day, under different meteorological conditions, the opposite may be true.

FIGURE 12
PLUME LOOPING

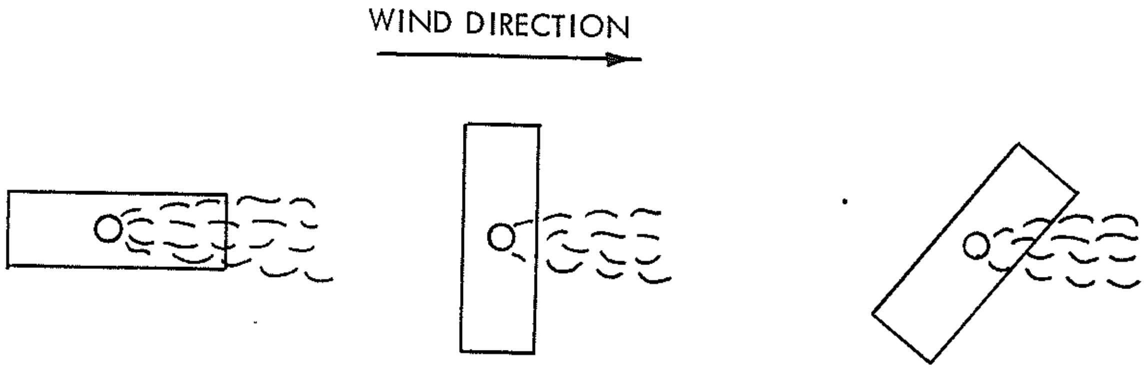
Therefore, it is easily understood that, while data collection appears to be a simple matter, extremely close scrutiny of the methods of collection, the available information and the methods of interpretation is of absolute necessity. In essence, to obtain results is simple, to obtain accurate results difficult.



Six types of plume behavior under various conditions of stability and instability.

FIG. 13

FACTORS INFLUENCING DOWNWASH



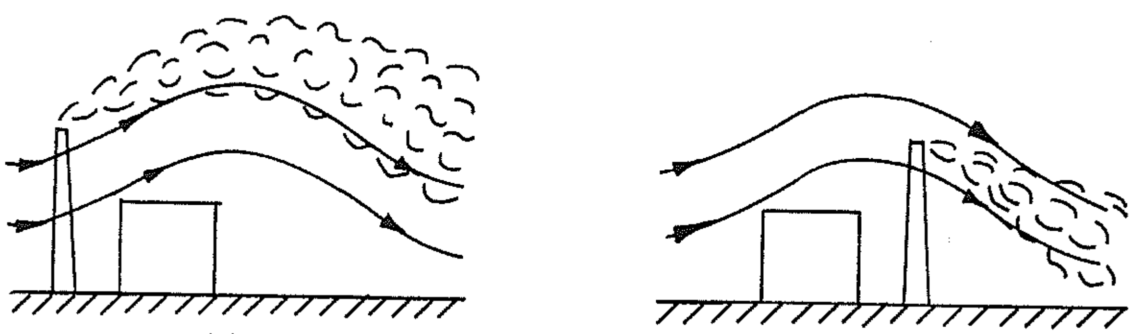
(a) MINIMUM DOWNWASH

(b) INTERMEDIATE DOWNWASH

(c) MAXIMUM DOWNWASH

Variation of aerodynamic downwash with plant orientation in relation to direction of prevailing strong winds.

FIG. 14



(a) LESS DOWNWASH

(b) MORE DOWNWASH

Variation of aerodynamic downwash with position of stack relative to Hot Mix Plant.

FIG. 15

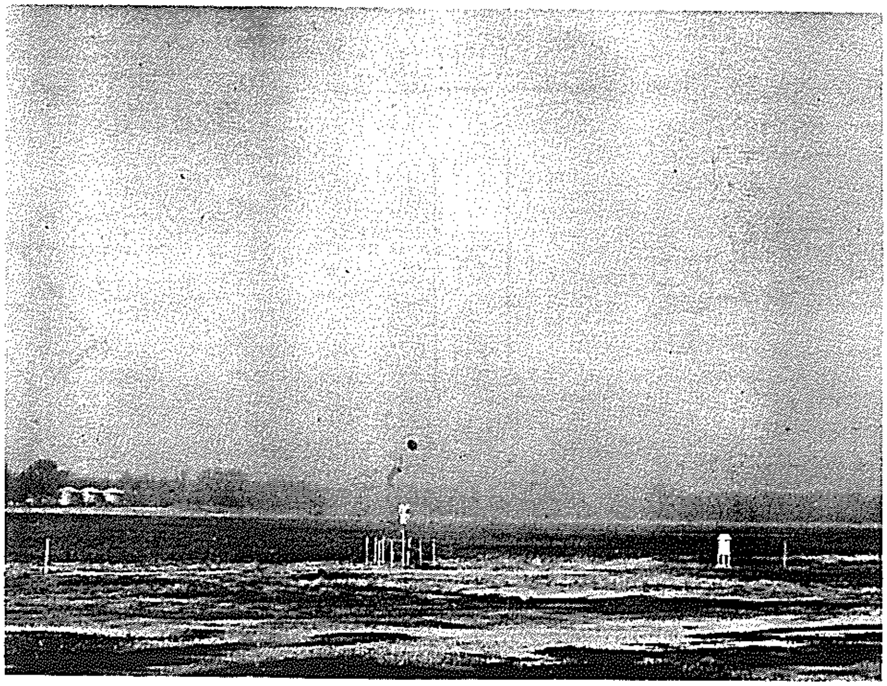


FIGURE 16
EXAMPLE OF DOWNWASH

Data Collection

Before initiation of this project, some data (see Table 4) directly related to this subject had been collected by the Louisiana Department of Highways. Most of these same plants are still operating within the state under conditions very similar to the original investigation. Based upon the original investigation, this project was proposed to more thoroughly investigate various plants using the sampling equipment on hand. The original concept was to place one Hi-Vol sampler upwind and one Hi-Vol sampler downwind from the plant, both to be placed on the property line. The difference in particulate collection between the two samplers would indicate pollution directly attributable to the plant. These levels could be compared to the legal limits.

Upon initiation of this project, the scope and methods of procedure were thoroughly discussed with the Air Control Commission. Their sampling techniques included use of Hi-Vol samplers with all rates based upon a twenty-four hour sampling period. The present Regulation II, Air Control Commission (12), effective 1969 states within:

5.0 Control of Air Pollution from Suspended Particulate Matter

5.1 Ambient Air Quality Standards for Suspended Particulate Matter

5.2 The ambient air quality for suspended particulates for an area shall be determined on the basis of a sufficient number of samples to adequately characterize the the area being evaluated.

5.2.1 Type A-Land Use - Residential and Recreation

The average value shall not exceed 80 micrograms of suspended particulates per cubic meter of air.

5.2.2 Type B - Land Use - Commercial and Business

The average value shall not exceed 110 micrograms per cubic meter of air.

5.2.3 Type C - Land Use - Industrial

The average value shall not exceed 140 micrograms of suspended particulate per cubic meter of air.

5.2.4 Type D (1) Land Use -

The average value shall not exceed 80 micrograms of suspended particulate per cubic meter of air.

5.2.5 Type D (2) Land Use -

The average value shall not exceed 140 micrograms of suspended particulates per cubic meter of air.

Therefore, these standards and limits are not necessarily the particulates emitted by any one plant but, rather, apply to the quality of air itself. In other words, the levels are not necessarily the results of the upwind sampler subtracted from the results of the downwind sampler, but the 'average' quality of air within a specific area.

According to the same regulations, the control of air pollution from Particle Fall (Dustfall), states:

6.1 The ambient air quality for particle fall (dustfall) for an area shall be determined on the basis of a sufficient number of samples to adequately characterize the area being evaluated.

6.2 The Commission declares that dustfall levels from the ambient atmosphere higher than the levels specified below constitute undesirable levels, whether the sources are from natural causes or from the activities of man, and that a state of air pollution exists when dustfall exceeds these levels.

Land Use Type	Standard (30 Day Sample) (Tons per square mile per month)
A	15
B	25
C	35
D (1)	15
D (2)	35

It was decided that meteorological information was of absolute necessity. Also it was desirable to place all of our equipment at one plant to monitor in detail the effects of pollution at a typical plant (see Method of Procedures for details). By doing this, confidence levels could be established for our sampling techniques, data collection and final analysis.

As demonstrated by a cursory evaluation of Table 1, little confidence can be placed on any one result or even on a set of results for any given day. The problem was simply too complex and the variables too great using simplified equipment. However, using several samplers, considering meteorological influences and maintaining a minimum sampling period of seven days, a fairly accurate recording of particulate collection was possible. As stated previously in Meteorological Influences, a close scrutiny of the data was necessary. For Plant 28 in Table 1, one of the unstated, confounding influences was the gradual drying of the yard from the wet winter-early spring months to the drier, late spring-early summer months. The disturbing result was that the average of all the data before yard cleanup shows less pollution than the average of all the data after cleanup. However, an examination of the results when general meteorological conditions were similar, the two week period immediately preceding cleanup and the two week period immediately after cleanup, showed that yard cleanup reduced the overall pollution by 25 percent. The total data also indicated that, in the wet winter-spring months, the levels of pollution were considerably less than in the drier summer months, even when the yard was oiled down. The cooler temperatures of the earlier period also help in allowing the stack emissions to rise more rapidly and thus be dispersed more easily.

The data shown in Tables 4 and 5 represent a 'normal day' which the author defines as a late spring day following seven days without rain, with winds less than ten mph and the plant producing 1000 tons of mix. It is estimated that a plant's pollution (measured by the methods herein described) would be worse than the 'normal day' conditions about 30 percent of the time. As shown in Tables 4 and 5, no plant now operating in the state consistently operates within the present legal limits. Undoubtedly, on a winter day following a wet period with winds more than fifteen miles per hour, many plants would meet the present limits.

Present Equipment

Present hot mix equipment is highly efficient for producing hot mix but not necessarily efficient for the reduction of dust.

Emissions from plant driers are reduced by three different systems, a 'cyclone' or dust collector dependent on air speed reduction to affect fallout; a water scrubber, which wets the particulates and collects them; and a 'bag' collector which actually filters the particulates out. The above systems are listed in the order of efficiency and cost, with the bag collector being the most efficient and expensive.

Improvements in plant equipment are needed from the manufacturers. Additional covers and improved, tighter fitting covers need to be designed. Parts should be removable for plant cleaning. Frequently removed plates should be more sturdily built or have an additional, flexible type cover to prevent leakages due to dents and warpage due to temperature. These 'secondary' sources of pollution are frequently quite significant (see Figures 17 and 18).

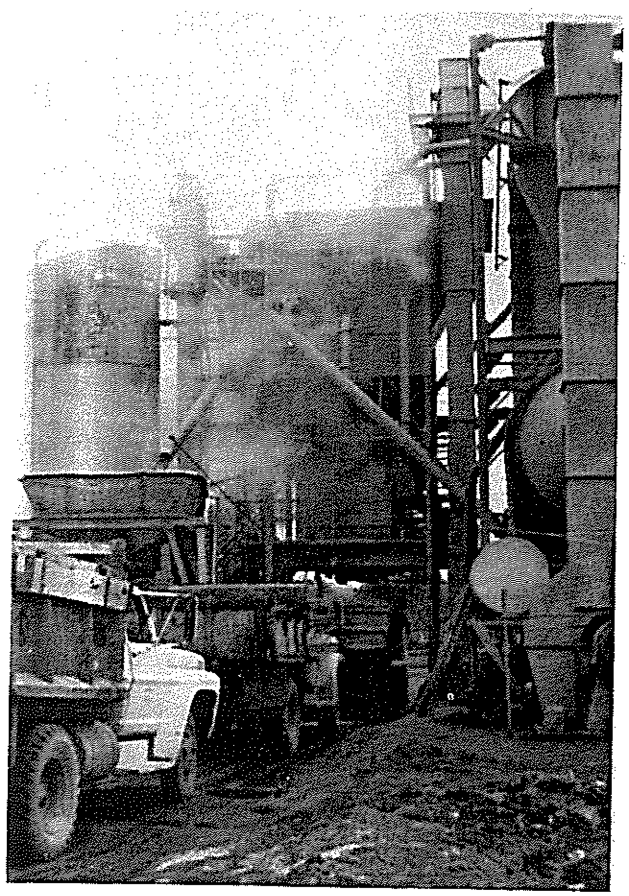


FIGURE 17
DUST LEAKAGE FROM PLANT EQUIPMENT

FIGURE 18
DUST LEAKAGE FROM PLANT EQUIPMENT

One especially underdesigned feature is the lack of sufficient height of stacks. There are several restrictive meteorological conditions that should be considered when designing stacks for waste disposal. These conditions are "fumigation", "aerodynamic downwash", "plume looping", and "trapping" (see Figures 14, 15 and 16). Generally, the higher the stack, the less these undesirable conditions occur.

Permanent plants in particular should rely upon meteorological measurements when considering of the most efficient location, design and operation of the plant. A meteorological survey of a number of proposed plant sites may permit the choice of one where air pollution problems are minimized. Meteorological factors may influence plant design in the following ways: in the shape and orientation of buildings, in determining stack heights and in the choice of capacity of precipitating, washing and filtering equipment. Finally, weather measurements may aid plant operation by permitting, where possible, a varying rate of emission of contaminants on the basis of current or predicted weather conditions.

Plant Conditions

At most of the plants observed, almost half of the total pollution originated from sources other than the stacks. Trucks continually hauled materials in and hot mix out; when the haul road was dirt or gravel (see Figure 19), this was a major contributor to air pollution. At Plant 28, there was a pressure relief valve atop the mineral filler silo. Each time mineral filler was unloaded into the silo, the pressure relief valve opened and a considerable amount of mineral filler, a fine graded material which is easily air-borne, was emitted. Occasional careless handling of the mineral filler resulted in spillages which were never cleaned up (see Figure 20). At other plants, the covers over the aggregate screens were very often missing or badly leaking. Bin overflow chutes leaked; leakages from the bins and pugmill were commonly observed. Covers were missing from the chain buckets bringing material from the cold feed to the drier. Spillage from the buckets and the drier was never picked up. Covers were missing from the crushers. All of the cited examples are easily correctable, and should now be included in each plant's routine maintenance, with special emphasis given to leakage repairs and spillage cleanups.

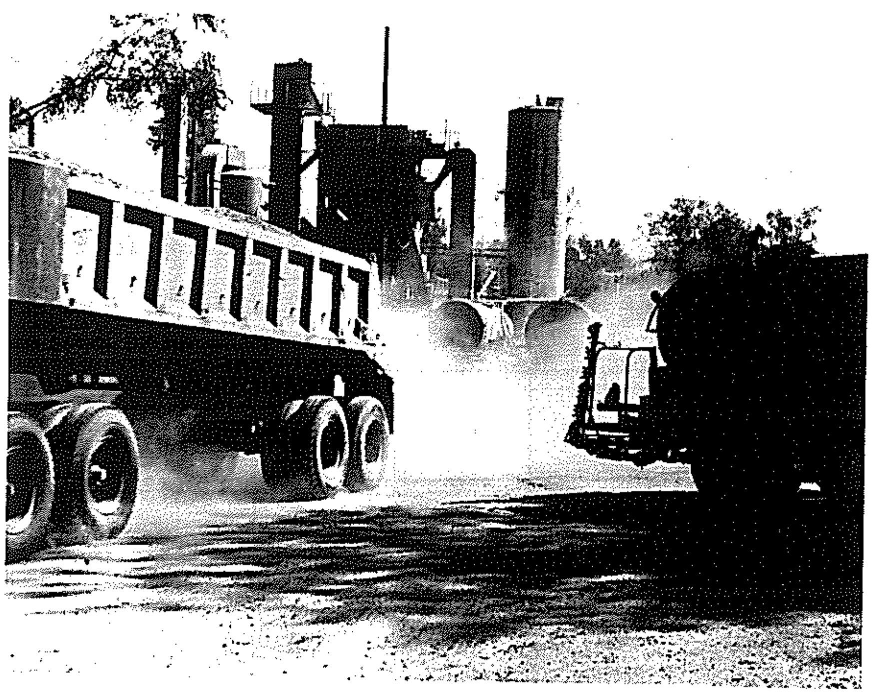


FIGURE 19
AIR POLLUTION FROM HAUL ROAD

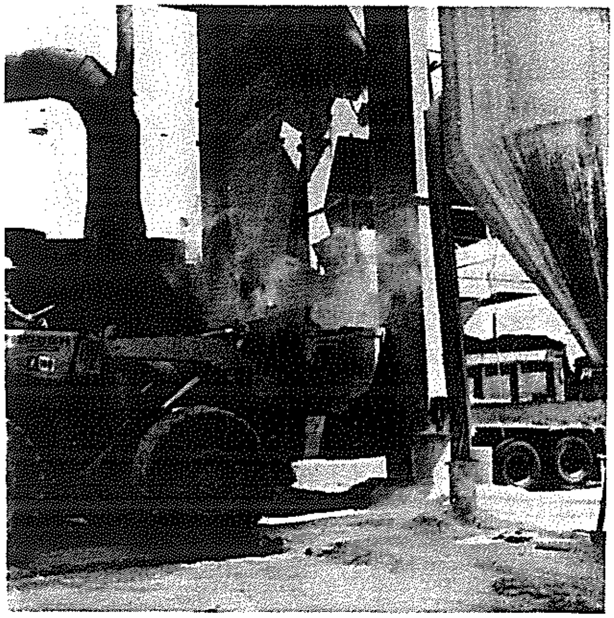


FIGURE 20
MINERAL FILLER SPILLAGE

To cite a specific case illustrating the significance of pollution contribution from sources other than the stack, please note the sampler placement diagram (see Figure 9) and Table 1. The predominant wind at the control plant was northerly during the winter months, then southerly during the summer months; very rarely was the wind easterly or westerly. When the plant was using gravel, the amounts of particulates collected by sampler one and sampler six should be equal and that collected by sampler four and sampler five should be equal. However, note that the aggregate stockpiles tended to block yard dust from samplers five and six. Thus, samplers five and six collected particulates originating primarily from the stack, while samplers one and four collected particulates from the stack and yard.

Sampler Number	1	6		4	5
Number of Days with Highest Amount	40	0		32	8
Average Amount $\mu g/m^3$	310	100		234	133

Some operations contributing to air pollution, common to all plants are not easily correctable. Material handling, done in the open air, now contributes a minor amount of the total suspended particulate to the air. When plants are properly cleaned up and operating with efficient particulate collection equipment, this material handling will become a larger contributor to the total pollution. This handling includes hauling and stockpiling material, crushing aggregate, placing aggregates into cold feed hoppers, rejection of oversize material, rejection of bin overflow, rejection of 'batches' containing no asphalt because of unbalanced bins or incorrect weighing, and the handling of mineral filler (see Figures 21, 22, 23 and 24).

FIGURE 21
DUST FROM REJECTION OF BATCH CONTAINING NO ASPHALT

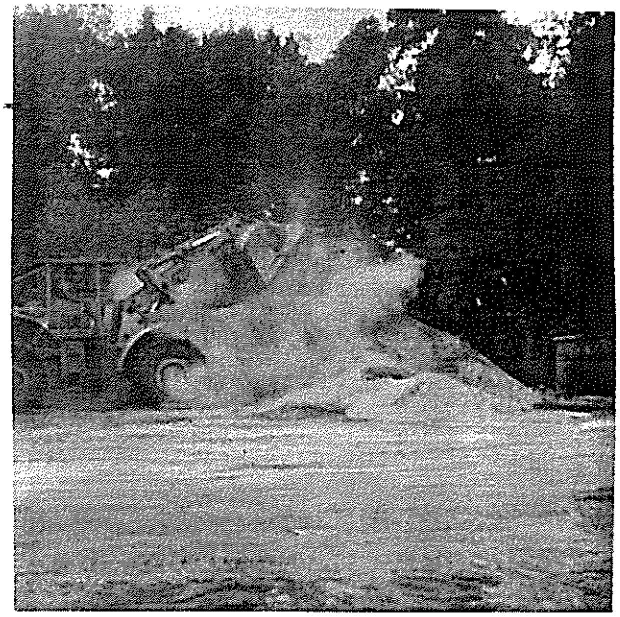


FIGURE 22
AIR POLLUTION FROM MATERIAL HANDLING

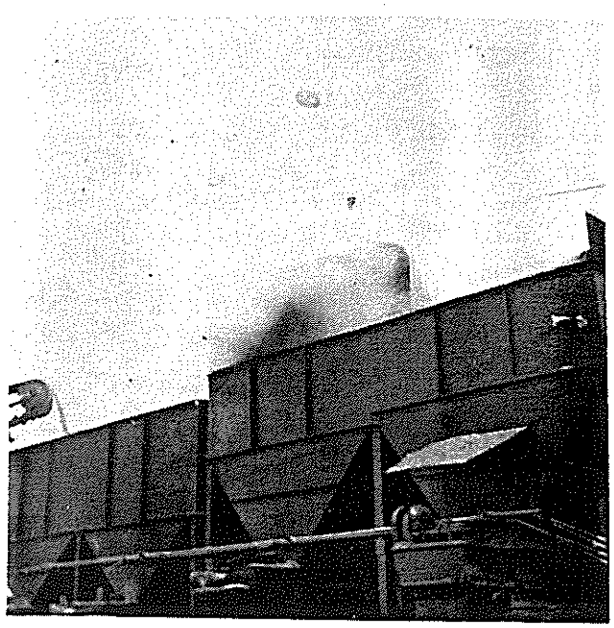


FIGURE 23
AIR POLLUTION FROM FILLING COLD FEED HOPPERS

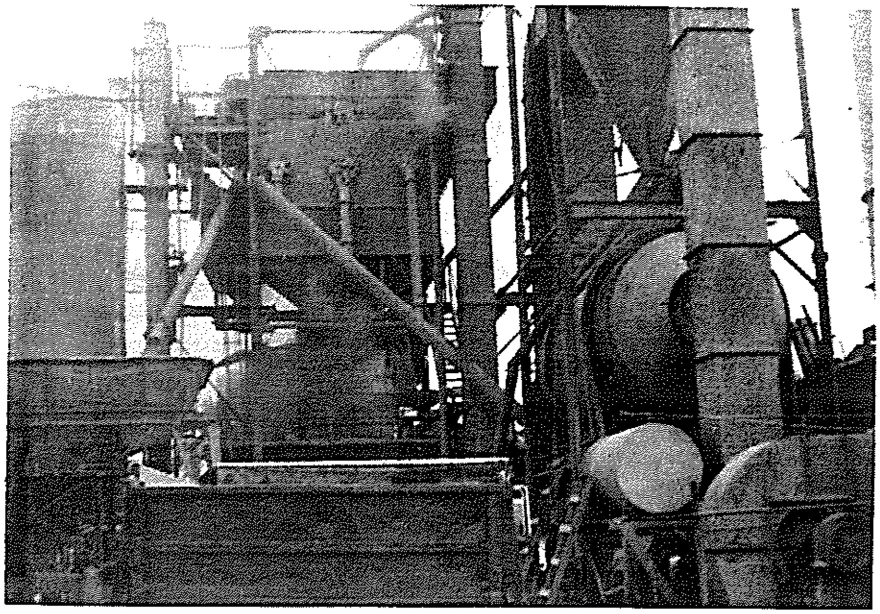


FIGURE 24
DUST LEAKAGE FROM OVERFLOW CHUTES AND SCREENING

These cited operations exist regardless of scrubber equipment and yard conditions. Several things can be done to improve materials handling procedures to reduce air pollution. Though the following suggestions cannot always be followed, the plant operator should strive to:

(1) Haul, stockpile and crush aggregate on days when the plant is not running. This will reduce the pollution rates at the most critical times.

(2) Blanket spaces between stockpiles (where material handling equipment travels) with gravel or coarse sand.

(3) Clean tracks or tires of material handling equipment before allowing the equipment on the yard or around stockpiles. Many times, a bulldozer will track mud from another temporary duty onto the gravel or sand stockpile. This mud, when dry, will eventually dust adding to the pollution problem, in addition to being detrimental to the hot mix itself.

(4) Build or place covers over places where material is discharged from belts, crushers, overflow chutes and other operations concerning mineral filler.

Self Regulation

Most hot mix manufacturers have expressed concern about environment pollution. Although there were a few exceptions, this concern has not yet been translated into overt acts using abatement techniques and equipment now available. This is unfortunate, for in addition to the obvious detrimental effects to the ecology, lack of action invites criticism and stringent regulatory procedures upon their industry. The Louisiana Air Control Commission investigates and constantly monitors those industries, processes, or conditions which arouse the majority of complaints. The majority of pollution caused by hot mix plants is inert, causing no chemical hazards or such immediately noticeable effects as paint peeling, nylons disintegrating, plant kills or other effects which bring numerous and swift complaints. Under normal conditions, if the ambient air quality in the hot mix plant vicinity is kept below 280$\mu g/m^3$/day (double the maximum allowed level), there would probably be extremely few complaints and thus, little pressure from regulatory agencies. However, when a plant emits 1000$\mu g/m^3$/day (10,000 $\mu g/m^3$/day if the plant actually runs the full twenty-four hours), or when dust control equipment is so poor that significant amounts of coarse sand (material retained on the No. 40 sieve) are emitted from the stack, these conditions degrade the whole industry and invite trouble.

Therefore, it behooves the industry to concern itself with self-regulation before stringent regulatory requirements are strictly enforced. These requirements, self-imposed by the industry, should emphasize general conditions, plant locations and equipment, rather than ambient air quality standards. Suggested self-regulations are:

(1) The yard and especially the haul roads should be treated or, preferably, paved. (Frequent watering is not effective).

(2) All spillage should be picked up.

(3) The plant and yard should be regularly cleaned. (Preferably on a weekly basis).

(4) A minimum stack height should be specified based on an air pollution engineer's recommendations (not the majority of plant owners ability to meet such a minimum height restruction).

(5) All plants should have water scrubbers or bag collectors in operation during production.

(6) All plants should be inspected periodically by the industry.

CONCLUSIONS

(1) When sampling is conducted on the property line, no plant now operating in the state can consistently meet the present regulations while maintaining reasonable production.

(2) Plants should be designed for pollution control, water scrubbers or bag collectors required according to the plant. Cyclone dust collectors alone are not sufficient.

(3) Almost half of the air pollution created by most hot mix plants originate from sources other than the stack.

(4) Haul road or yard conditions create from 20 percent to 35 percent of a plant's air pollution.

(5) Based on the limited data from this study an evaluation of air pollution at a hot mix plant should consist of a minimum of three Hi-Vol samplers carefully situated around the plant taking care that no immediate pollution influence is nearby. A minimum observation period of seven operating days should be used and the wind direction and wind speed should be accurately recorded. Dustfall buckets should be placed and observed during the same period.

RECOMMENDATIONS

(1) The hot mix industry should adopt and vigorously enforce self-regulatory standards immediately.

(2) The Air Control Commission should consider temporarily raising the ambient air quality to approximately 200 micrograms of suspended particulates per cubic meter of air and 75 tons per square mile per month of dustfall for land types C and D(2) for about three years to allow adjustments by the hot mix industry.

The present regulations, if enforced by literal interpretation, are overly restrictive at this time. Extremely abrupt changes could be required of equipment and men. No plants now operating, including those with water scrubbers, consistently meet the present ambient air quality requirements. Many plants may be forced out of business or have to seriously reduce their production. Bag collectors, a highly expensive system, would not guarantee compliance with this regulation since the air quality independent of hot mix plant contribution may exceed the requirements.

(3) The Air Control Commission should consider changing its regulation system to a process emission type in conjunction with or in lieu of an ambient air quality standard. Reference 4 suggests such a type as below:

Location: No urbanized area within one-half mile of plant.

Requirement: 0.3 pounds per 100 pounds of exhaust gas or 0.16 grain per standard cubic foot.

It is difficult to place responsibility on a plant for a definite amount of pollution under the present air quality standard because too many variables exist making subjective interpretation necessary. A hot mix plant should not be penalized for a general ambient air quality condition that might be outside of its control. In some cases, the gravel parish roads where plants are located may cause as much pollution as do the plants.

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TABLE 1
TEST RESULTS OF CONTROL HOT MIX PLANT
PLANT 28

Date	Amount Produced (Tons)	Hours Operated	Wind Speed	Wind Direction and Hours from Direction	Temperature High	Temperature Low	Hi-Vol Samplers $\mu g/m^3/24$ hours 1	2	3	4	5	6	Remarks
2/12/70	1980	10 1/2	2-10	S-1 1/2, N-8 1/2, W-1 1/2 Var. 12 1/2	55	40°	614	275	237	149	79	208	Before Clean up
2/17/70	1501	7	1-5	W-1, N- 3 1/2, S-5, Var. 14 1/2	54	40°	144	71	72	93	102	63	Using hard rock
2/18/70	1470	9	1-10	S-18, Var. 6	60	30	201	89	125	102	540	102	
2/19/70	1949	10	1-10	N-17, W-1, Var. 6	60	50	832	176	56	38	41	134	
2/23/70	1860	10		NE-10, Unknown 14	65	50	466	684	95	106	85	83	
2/24/70	930	7		N-7, Unknown 17	60	30	125	100	58	127	267	100	
2/26/70	1110	12	1-5	Var. 24	50	48	155	496	122	338	217	140	
3/2/70	2011	10 1/2	2-5	E-7 1/2, SE-13, S-2 Var. 1 1/2	75	60	245	178	79	293	65	65	
3/3/70	1665	8 3/4	3-15	S-16, Var. 8	65	60	268	455	97	85	123	245	
3/9/70	877	3	3-10	S-22 1/2, Var. 1 1/2	67	60	199	138	170	285	121	75	
3/10/70	2290	9 1/2	1-10	Var. 13, S-5, E-6	66	60	226	686	530	153	91	78	
3/25/70	1700	10 1/2	1-15	S-18 1/2, E-4 1/2, NW-1	74	50	177	110	51	485	171	64	
3/31/70	650	8 1/2	3-14	S-8, E-16	77	55	218	316	750	177	85	101	

TABLE 1 (CONTINUED)
TEST RESULTS OF CONTROL HOT MIX PLANT
PLANT 28

Date	Amount Produced (Tons)	Hours Operated	Wind Speed	Wind Direction and Hours from Direction	Temperature High	Temperature Low	Hi-Vol Samplers $\mu g/m^3/24$ hours 1	2	3	4	5	6	Remarks
4/1/70	225	4	7-20	S-4, E-10, Var. 10	84	64	425	347	204	322	213	207	
4/6/70	1430	9	3-5	N-10 1/2, S-5 1/2, Var. 8	70	45	290	352	208	192	151	248	
4/8/70	369	8	5-15	SE-8, S-8, Var. 8	82	50	1364	511	317	489	205	102	
4/9/70	759	8	14-21	NW-8, Var. 16	79	57	314	168	154	230	348	91	
4/20/70	2718	10 3/4	10-12	SE-16, SW-8	84	53	368	477	552	114	266	98	
4/21/70	1965	8			86	54	129	455	399	102	52	67	After cleanup
4/22/70	1570	10	4-19	SE-12, S-12	89	73	140	188	615	123	188	68	Using hard rock
4/23/70	2495	11	5-14	SE-10, S-14	88	72	196	163	226	1727	66	131	
4/24/70	1967	9	4-13	S-8, SW-8, SE-5, E-2, W-1	86	71	109	60	216	651	84	40	
4/27/70	2050	11	8-15	SE-16, S-8	97	72	202	135	549	242	66	63	
4/28/70	1600	9	4-13	S-8, SE-13, SW-3	88	73	189	137	885	118	114	67	
5/1/70	1656	9	5-11	Var. 24	86	64	62	33	46	88	51	17	
5/4/70	2174	9 1/2	0-11	Var. 24	76	45	250	46	51	84	68	90	
5/5/70	360	9	0-7	N-20, W-3, NW-1	81	51	271	86	151	91	66	70	
5/6/70	905	9	3-12	Var. 24	85	57	890	116	108	202	89	132	
5/7/70	2189	8	0-13	Var. 24	86	60	464	606	664	607	100	97	

TABLE I (CONTINUED)
TEST RESULTS OF CONTROL HOT MIX PLANT
PLANT 28

Date	Amount Produced (Tons)	Hours Operated	Wind Speed	Wind Direction and Hours from Direction	Temperature High	Temperature Low	Hi-Vol Samplers $\mu g/m^3/24$ hours 1	2	3	4	5	6	Remarks
5/8/70	555	6	0-14	Var. 24	85	58	120	92	101	526	119	64	
5/12/70	750	8	3-13	Var. 24	86	66	253	153	483	526	82	58	After cleanup
5/13/70	1626	9	0-13	Var. 24	86	64	368	266	424	602	104	67	Using lightweigh
5/14/70	475	9	0-15	Var. 24	87	63	272	487	1184	508	84	71	Aggregate
5/15/70	938	7 1/2	0-12	E-12, N-2, SE-7, NE-3	85	64	451	233	444	213	41	38	
5/18/70	1389	9 1/2	5-13	E-7, NE-10, SE-7	84	64	752	1831	371	161	97	112	
5/19/70	1401	12 3/4	0-20	Var. 24	88	64	490	1685	61	181	120	88	
5/22/70	438	7 1/2	0-15	Var. 24	87	65	180	198	688	411	67	53	
5/25/70	812	8	0-8	Var. 24	86	64	475	586	386	375	324	275	
5/26/70	837	7 3/4	0-13	Var. 24	89	70	339	563	268	286	194	281	
5/28/70	725	8	3-13	Var. 24	85	64	993	471	860	678	196	96	

NOTE: Weather Station broken from April 19 to June 1. Meteorological information obtained from Airport.

TABLE 2
TEST RESULTS WITH HEIGHT, DISTANCE VARIABLES

Plant	Date Sampled	Type of Pollution Equipment	Amount of Suspended Particulates Per 1000 Tons Hot Mix In 24 Hours $\mu g/m^3$ Below Tower	Tower	Field
28	1970	Cyclone filter	190	590	290
	1970	Cyclone filter	234	684	373
	1970	Cyclone filter	540	1000	630

TABLE 3
VISUAL PLANT INSPECTION

Plant	Make	Capacity	Dust Condition	Dust Collector	Location	Stack % Opacity
1	Simplicity	3000	Poor	Cyclone filter & Scrubber	Urban	-
2	Simplicity	5000	Good	Cyclone filter & Scrubber	Urban	20
3	Standard	5000	Fair	Cyclone filter	Rural	20
4	Cummer	5000	Good	Cyclone filter & Scrubber	Urban & Commercial	20
5	Cedar Rapids	4000	Good	Cyclone filter & Scrubber	Urban & Commercial	20
6	Cedar Rapids	5000	Fair	Hurriciane filter	Rural	-
7	Warren Bros.	4000	Fair	Cyclone filter & Scrubber	Urban & Commercial	-
8	Barber Green	4000	Good	Cyclone filter	Urban	-
9	Barber Green	4000	Poor	Cyclone filter	Rural	-
10	Barber Green	6000	Fair	Cyclone filter & Scrubber	Commercial	-
11	Simplicity	6000	Good	Cyclone filter & Scrubber	Urban	20

TABLE 3
VISUAL PLANT INSPECTION (CONTINUED)

Plant	Make	Capacity	Dust Condition	Dust Collector	Location	Stack % Opacity
12	Cedar Rapids	6000	Good	Hurricane filter	Rural	20
13	Cedar Rapids	6000	Fair	Cyclone filter	Rural	10
14	Standard	5000	Good	Cyclone filter	Rural	20
15	Standard	3000	Fair	Cyclone filter	Rural	20
16	Gifford	5000	Fair	Cyclone filter	Rural	-
17	Gifford	5000	Fair	Cyclone filter	Rural	20
18	Cummer	5000	Good	Cyclone filter	Rural	20
19	Madsen	5000	Good	Cyclone filter	Rural	10
20	Madsen	3000	Fair	Cyclone filter	Urban	20
21	Simplicity	3000	Good	Cyclone filter	Rural	20
22	Madsen	2000	Fair	Hurricane filter	Rural	10

TABLE 3
VISUAL PLANT INSPECTION (CONTINUED)

Plant	Make	Capacity	Dust Condition	Dust Collector	Location	Stack % Opacity
23	Madsen	4000	Fair	Cyclone filter	Commercial Urban	20
24	Standard	5000	Good	Cyclone filter	Rural	-
25	Standard	6000	Good	Cyclone filter	Rural	20-30
26	Standard	7500	Good	Cyclone filter	Rural	20
27	Cedar Rapids	6000	Good	Cyclone filter & Scrubber	Urban	20
28	Barber Green	6000	Fair	Cyclone filter	Rural	20

TABLE 4
SUMMARY OF DATA TAKEN PREVIOUS TO THIS PROJECT

Plant	Date Sampled	Type of Pollution Abatement Equipment	Amount of Suspended Particulates Per 1000 Tons Hot Mix in 24 Hours
Plant Number 3	June, 1967	Cyclone Filter	1000
Plant Number 12	May & June 1967	Cyclone Filter	450
Plant Number 20	June, 1967	Cyclone Filter	300
Plant Number 29	May, 1967	Cyclone Filter & Scrubber	350
Plant Number 30	May, 1967	Cyclone Filter & Scrubber	280
Plant Number 31	June, 1967	Cyclone Filter	750
Plant Number 32	January & February 1968	Cyclone Filter	450
Plant Number 33	March & May, 1967	Cyclone Filter	450
Plant Number 34	November & December 1967	Cyclone Filter & Scrubber	280

NOTE: The majority of this data has been collected on a six to eight hour sampling period and extrapolated to a twenty-four hour result considering plant production, operating time and assuming "background" rates of suspended particulates collection as similar to the rates found during downtime periods. The data was liberally interpolated considering rates of production, sampler placement and quantity of data.

TABLE 5
SUMMARY OF TEST RESULTS

Plant No.	Date Sampled	Type of Pollution Equipment	Amount of Suspended Particulates Per 1000 Tons Hot Mix $\mu g/m^3/day$	Amount of Dustfall Tons Per Square Mile Per Month
5	1970	2 scrubbers - cyclone filter	250	48 & 176
19	1970	Cyclone filter	360	134 & 187
20	1970	Cyclone filter		248 & 637
21	1970	Cyclone filter		49 & 50
23	1970	Cyclone filter		107 & 140
24	1970	Cyclone filter		96 & 414
25	1970	Cyclone filter		45 & 146
26	1970	Cyclone filter	350	97 & 106
27	1970	Cyclone filter & Scrubber	250	53 & 89
28 A	1970	Before Plant Yard Cleanup Using Hard Rock Cyclone filter	350	-
28 B	1970	After Plant Yard Cleanup Using Hard Rock Cyclone filter	280	211-247
28C	1970	After Plant Yard Cleanup Using Lightweight Aggregate Cyclone filter	377	-