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PRELIMINARY EVALUATION OF AIR POLLUTION ASPECTS OF THE DRUM-MIX PROCESS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Enforcement
Office of General Enforcement
Washington, D.C. 20460

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PRELIMINARY EVALUATION OF AIR POLLUTION ASPECTS OF THE DRUM-MIX PROCESS

Prepared by

JACA Corp.
506 Bethlehem Pike
Fort Washington, Pennsylvania 19034

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EPA Project Officer: Kirk Foster

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LIST OF EXHIBITS

Section 1

INTRODUCTION

New Source Performance Standards for the asphalt concrete industry were published on March 8, 1974 (39 FR 9308), pursuant to Section 111 of the Clean Air Act (42 USC 1857 et. seq.). These standards are applicable to sources whose construction or modification commenced after June 11, 1973.

There has been a new process development of significance in asphalt concrete production technology since the promulgation of the standards. A new production process called the "drum-mix" process (also known as "drum dryer", "turbulent mass") has gained increased commercial acceptability in the industry and now constitutes an important portion of new asphalt concrete plants. It is estimated that 30% of new asphalt concrete plant construction over the past 3 years is of the drum-mix type.

Although various versions of the drum-mix process have been in existence for a number of years, its significant use in the production of asphalt concrete is a recent phenomenon. There are at least eight manufacturers of such plants (See Appendix A). Based on information gathered during this evaluation, it is estimated that there are at present approximately 130 to 150 asphalt concrete plants in the U.S. using the drum-mix process. New Source Performance Standards are applicable to between 50 and 70 percent of these plants. It was the intent of this preliminary evaluation to rely on existing data rather than develop new data through extensive plant inspections and emission testing. Although this approach would be susceptible to data inadequacies since there was no control over the source test reporting, it was felt that such an approach was commensurate with the modest time and funds available for the task.

EPA regional offices, state air pollution control agencies and manufacturers of drum-mix plants were therefore the chief sources of data. Seventy emission tests were obtained and screened for methodology, calculations, isokinetic conditions, etc. Sixty-three tests were found acceptable for inclusion in the analysis contained in Section 5. Even these tests, however, often inadequately described process materials, control equipment operating parameters, and process operating conditions. One drum-mix plant was tested by the contractor using EPA Method 5 with some equipment changes.

Section 2

THE DRUM-MIX PROCESS

There are approximately 4000 asphalt concrete plants in the United States of the familiar "conventional" type described in several publications.[3,4,5] The salient features of the newer drum-mix process can best be described by comparing it with the way in which asphalt concrete is produced in these "conventional" asphalt plants.

The conventional process begins with the conveying of a pre-determined mixture of different sized cold aggregates from separate storage bins into an inclined rotary drum which drys the aggregate by counter-current flow interaction with combustion gases from a burner mounted at one end of the drum. The dried, heated aggregate is then transported by a hot elevator to a set of vibrating screens located over storage bins where it is sized and stored. Pre-designed quantities of the sized, dried aggregate are weighed and fed into a pugmill where it is mechanically mixed with heated asphalt to produce the desired finished product. The mixing of the aggregate with the asphalt is accomplished by either a batch or continuous process. Thus the drying and heating of the aggregate, and its mixing with asphalt are carried out in separate stages in the conventional asphalt plant. A majority of the emissions are from the drying and heating stage in the form of entrained particles, the remainder coming from vents from the mixing tower which is nearly totally enclosed.

In the drum-mix process, the aggregate is dried, heated and mixed with asphalt in the same vessel -- a specially designed rotary drum dryer. This obviates the need for a separate mixing tower with screens, weigh hopper and pugmill, thereby reducing plant capital costs and improving portability. These are two of the advantages cited by drum-mix process manufacturers in selling their equipment.

The major equipment differences can be shown in table form as follows:

Conventional Plant	Drum-Mix Plant
Cold Storage bins & hoppers usually with vibratory feeds	Same
Load cells sometimes used	Load cell nearly always used
Dryer with less sophisticated flight design & counter current flow - no asphalt injection	Dryer with sophisticated flight design, parallel flow and asphalt injection
Hot elevator	Not required
Hot screens	Not required
Weigh Hopper	Not required
Pug Mill	Not required
Storage silo and conveyor optional but usually found in continuous process	Storage silo & conveyor required

The different versions of the drum-mix process can be classified in two ways: the manner in which the material flows with respect to the flow of gases, and the point at which asphalt is introduced into the drum.

The majority of the designs currently marketed in the U.S. utilize a parallel - flow dryer, where the flow of material and hot gases is in the same direction. The hottest flame and gases exist at the charging end of the drum, where the aggregate is at its coldest temperature. It is felt that in this manner, asphalt is best protected from oxidation by moisture. Another characteristic of the parallel-flow dryer is that lower aggregate discharge temperatures result.

In the counter-flow dryer design, the aggregate and asphalt are combined at the inlet end of the drum, and the drying-mixing process proceeds toward the burner end of the drum, where the mixture is discharged before it comes into direct contact with the flame. It is estimated that the counter flow dryer design accounts for only 5-10% of the drum dryer market, and plants using this design are generally lower in capacity than the parallel-flow dryer. Typical capacities of a counter-flow dryer are 40-50 tons per hour, whereas those of the parallel-flow dryer range from 100 to 600 tons per hour.

Parallel-flow dryers which comprise 90% of known drum-mix plants can be divided into two general types based on the point of introduction of the asphalt.

In the Shearer process, the aggregate and asphalt arrive in the mixer at the same time, alongside a stainless steel firebox which shields the mixture from direct contact with the burner flame. A chute then discharges the mixture into the next section of the drum where the flight design produces a mixing action without developing a full curtain of material through the flame. In the following section of the drum, the flight design causes a full curtain of material to develop, where mixing action takes place in an atmosphere of steam and hot gases. The finished mix is discharged at the end of the drum mixer onto a conveyor where it is transferred into a heated storage silo for delivery into trucks. This process is shown schematically in Figure 1.

Another version of the Parallel-flow design introduces the aggregate separately into the dryer drum. Drying of the aggregate begins immediately in direct contact with the burner flame. A full curtain of aggregate is developed in the first section of the dryer drum. In the next section of the drum, out of direct contact with the flame, adjustable

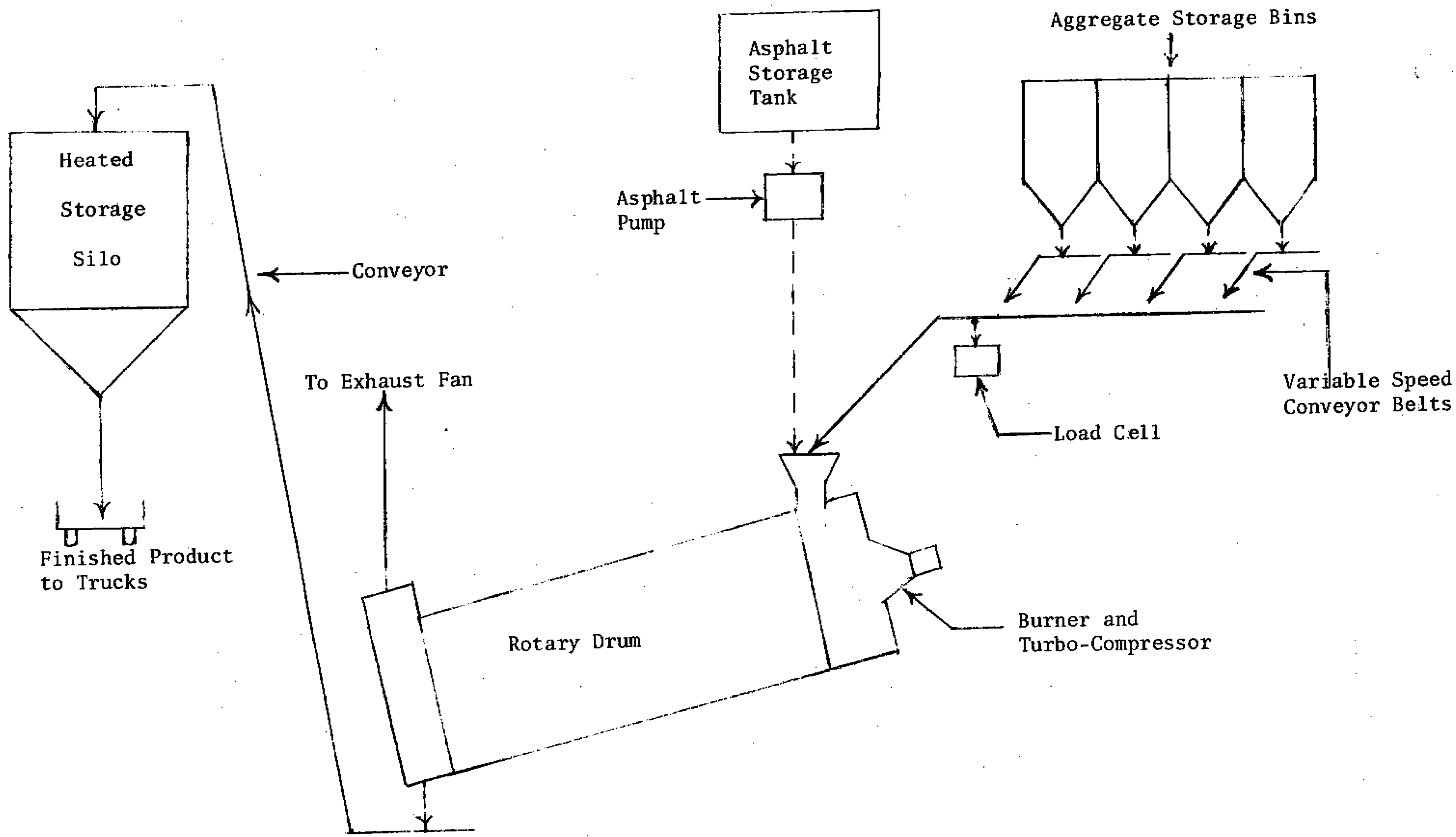


Figure 1

SCHEMATIC OF SHEARER TYPE DRUM-MIX PLANT spray bars coat the aggregate with hot asphalt. Mixing is completed further along in the drum and the mixture is discharged as described previously. This process (shown in Figure 2) can be further described by the moisture content and mix temperature changes in the dryer as shown in Figure 3. This shows that the bulk of the moisture is removed during Phase 1 where the aggregate is in the burning zone. Asphalt is generally introduced during Phase 2 where it is assumed[1] that moisture trapped deeper into the aggregate surface begins to vaporize. The escape of this moisture through partial coating of the asphalt, in Phase 3, produces violent foaming, which is said to increase the uniformity of the asphalt layer coat on the stone particles. Phase 4, at the far end of the drum, sees a rapid increase in the mix temperature after the moisture has escaped from it.

The extent to which these drum-mix plants will be found in new asphalt concrete plant construction depends on the resolution of a number of questions concerning product quality, efficiencies of operations, and the nature of emissions from the drum-mix system as opposed to what has been called the "conventional system." The nature of drum-mix system emissions is discussed in subsequent sections of the report, while the product and efficiency questions will be briefly covered here. It is not the intention of this brief discussion to present an authoritative, quantifiable analysis of the two systems since that was not the primary purpose of the project. Readily available data was used which was not verified in all cases although some effort was expended to resolve obvious ambiguities. Information frequently advanced by manufacturers, users, and state personnel which may have a bearing on the growth of the market and hence the amount of effort EPA should devote to enforcement related activity in this area is presented in reportorial fashion with limited analysis of the information advanced by the various sources.

Feed

Since the drum-mix process does not use hot screens to control the aggregate blend, more careful control of cold aggregate gradation is necessary. Usually three or four cold aggregate storage bins are employed with variable speed conveyor belts from each bin, sometimes coupled with variable gates that feed the aggregate onto a main conveyor belt, where the aggregate weight is monitored by means of a load cell. Some plants monitor the aggregate weight on each belt conveyor being fed by the storage bins.

The rate of asphalt feed is controlled either manually or automatically to maintain the proper ratio of asphalt to aggregate. The trend in asphalt plants of both the conventional and drum-mix type is to make greater use of automatic control. Where automatic control is used a frequent technique employed is to feed the signal from the aggregate load cell(s) back through a control loop which actuates a pump to feed the heated asphalt into the dryer drum.

The combination of aggregate feed rate and size control, and asphalt injection rate, allows the operator to change both the production rate and product mix throughout the cycle.

Asphalt

Penetration grade asphalts are used in the drum-mix process, often in conjunction with proprietary chemicals to insure proper coating and adhesion.

Product

Asphalt concrete top mixes can be produced at a temperature of 210 to 220^{o}F, compared to 300 to 325^{o}F in the conventional process. At these discharge temperatures, the mixture contains from 1 to 3% moisture, compared to 1/4% or less in conventional mixtures. Manufacturers of drum-mix plants claim that this higher moisture assists in laying the product;in that during the field compacting operation, it acts as a lubricant. Moisture equilibrium of the layed product from a drum-mix plant is attained by a loss of moisture while the layed product from a conventional plant reaches moisture equilibrium by a gain in moisture from the surroundings.

Fuel

The burners are usually fired with fuel oil although liquid propane can also be used when available.

Since the asphalt concrete produced by drum-mix plants is at a lower temperature, fuel savings are claimed from the process. A conventional plant uses an average of 2 gallons of fuel oil to produce one ton of mix. A drum-mix plant under the same conditions of aggregate moisture and ambient temperature is reported to require an average of 1 1/2 gallons of fuel oil per ton of mix.

Process/Product Considerations

Major commercial advantages of the drum-mix process over the conventional process as cited by drum-mix manufacturers are overall lower capital costs and increased portability due to the elimination of the mixing tower. This portability advantage is reflected in the high number of portable plants. It is estimated that more than 70% of the drum-mix plants currently in operation are portable. This portability poses secondary control problems when wet collection systems are employed. Each new site must have an appropriate water supply available, and must have a proper water disposal facility to assure that applicable water pollution control tations. The majority of drum-mixer plants thus exist in the Western half of the United States as can be seen from Table 1 which shows known plant location by state. It should be noted that the plants can be moved so that locations shown are subject to change.

Table 1

NUMBER OF DRUM-MIX PLANTS BY STATE

Arizona	5
California	1
Colorado	5
Georgia	2
Illinois	1
Indiana	4
Iowa	4
Kansas	9
Louisiana	2
Maryland	1
Michigan	2
Minnesota	7
Mississippi	2
Montana	1
Nebraska	1
Nevada	3
North Dakota	11
Ohio	1
Oklahoma	4
Oregon	10
Pennsylvania	4
South Dakota	4
Texas	12
Utah	5
Virginia	1
Washington	3
Wisconsin	3
Wyoming	3

Section 3

EMISSIONS

Sources of air pollution from the drum-mix process include both fugitive and stack emissions. In both instances, the source, nature and magnitude of the emissions are considerably different from their counterparts in the conventional process. This difference is attributable to the marked difference in the processing techniques.

The sources of emissions of the conventional and drum-mix plant are shown in the following table:

Conventional	Drum-Mix
Fugitive emissions from stockpiles, cold feed bins and conveyors	Same
Fugitive emissions from finished product discharge to trucks, or to storage	Finished product conveyor to silo
Stack emission from scavenger ductwork to hot elevators, hot screens, bins, weight hopper, mixer	None
Stack emissions from dryer	Stack emissions frm drum-mix

Fugitive emissions from stockpiles, cold feed bins and the conveying machinery prior to the introduction of the aggregates into the drum-mix, are, as in the case of the conventional process, dependent of the moisture content, size of aggregate and ambient conditions. The conveying of finished product from the drum-mix to the storage silo produces fugitive emissions similar to those in conventional plants with continuous processes which are generally equipped with storage silos.

Stack emitted dust from scavenger ductwork connected to emission sources such as the hot elevator, screens, bins and mixer are eliminated in the drum-mix process. Any fugitive emissions from these sources are also eliminated in the case of drum-mix plants.

Fugitive emissions from the finished product in discharge to trucks or storage from conventional plants have been characterized in a study done by the Asphalt Institute and the Exxon Research and Engineering Company, and are summarized in Table 2. These data identify the various components in the fugitive emissions from the handling of the finished product.

As in the conventional plant, stack emissions are the major air pollution source in the drum-mix plant. The new source performance standards apply to the stack emissions in the form of emission concentration and opacity. The opacity standard, however, also applies to the entire process subsequent to the introduction of the aggregate in the drum, and therefore covers fugitive emissions from that point on.

Both particulate as well as gaseous components are present in the stack emissions from a drum-mix operation. The particulate emissions generally include mineral, hydrocarbon and carbonaceous matter. Aggregate dust entrained during the drying-mixing action in the drum is the source of the mineral matter, while the hydrocarbon and carbonaceous matter results primarily from the exposure of asphalt to various degrees of oxidation in the drum. This, as well as the combustion of the fuel, also accounts for the gaseous emissions in the stack. Section 5 includes data on emission tests of plants with varying production capacity and different degrees of control.

The test data indicate that uncontrolled stack emissions from drum-mixers are significantly less than those from the conventional plant, by almost an order of magnitude. The simultaneous drying and mixing of the

Table 2

COMPOSITION OF ASPHALT HOT-MIX EMISSIONS FROM TRUCK LOADING OF PRODUCT
(Conventional Plants)

Sample Location	Edison, N. J.	Greensboro, N. C.
Number of Samples	6	2
Non-Visible Components (ppm)		
Carbon monoxide (CO)	4-6	3-4
Nitrogen dioxide (NO_2)	<0.1	.05-.08
Sulfur dioxide (SO_2)	<2	<0.5
Hydrogen sulfide (H_2S)	<0.2-1.5	<0.2
Carbonyl sulfide (COS)	<0.2	<0.2
Mercaptan (RSH)	<0.2	<0.2
Aldehydes (RCHO)	<0.1	0.3-0.4
Phenol (ØOH)	<1	<1
Ozone (O_3)	<0.1	---
Methane (CH_4)	2-3	2-3
Non-methane Hydrocarbons (C_2-C_6) (NMH)	<1	<1
Volatile organic compounds (C_7-C_{14}) (VOC)	0.5-1.5	0.5-1.0
Particulates (mg/m^3)		
Total particulates	2.6-7.2	0.5-5.7
Benzene solubles	0.3-2.8	0.2-5.4
Polynuclear aromatics (total), max.	0.00034	0.00016
Nickel (Ni), max.	0.000005	0.00004
Vanadium (V), max.	0.00008	<0.0001
Cadmium (Cd)	---	<0.00005
Lead (Pb)	---	<0.00005

NOTE: Where the less than (<) values are indicated, the numbers represent the sensitivity of the sampling or testing procedure used. If the component is present at all, it is below the value shown.

Source: Reference 2

aggregate with asphalt in the drum tends to trap a large portion of air-entrained mineral particles in the asphalt spray resulting in "balls" which further breakdown, coating the surface of the aggregate. Manufacturers claim that this considerably reduces the amount of mineral dust carried over by the exhaust gases, and promotional literature from manufacturers prominantly advertises this attribute. However, a reduction in the uncontrolled emissions does not generally make it any easier for a drum-mixer to meet the new source performance standards as will be discussed in Section 5.

An increase in the asphalt-related emissions is generally found in the drum-mix exhaust, as compared to the exhaust from a conventional plant. In a conventional plant, this type of emission is vented into the exhaust from the enclosed mixer, accounting for approximately 5 to 10 percent of the total exhaust flow rate directed to the control device. The generation as well as entrainment of asphaltic emissions is therefore limited. In the drum-mixer, on the other hand, the asphalt is exposed to the total exhaust in a turbulent fashion, thereby tending to increase the entrainment of asphaltic products.

While the uncontrolled mineral dust is generally less in a drum-mix plant, and the asphalt-related emissions greater, than a conventional plant, the amounts are a function of process design and operating variables of a facility.

Section 4

EMISSION CONTROL TECHNIQUES

Control techniques applied to existing drum-mix process plants have varied from state to state because of the varying stringency of regulations for existing plants which are included in the State Implementation Plans.

In the case of plants that should fall under the New Source Performance Standards, another preliminary study for EPA[7] has indicated that reporting of such new plants may suffer appreciable omissions so that it can be expected that some plants, that should be classified as new, and hence under federal regulations, may be classified under SIP. Such plants will then be frequently operating at levels that meet the SIP, but which may not meet the NSPS.

Controls at the 63 plants reported in the various test records reviewed included the following:

Type of Control	No. of Plants	Percent of Plants Reported
None (May have knockout boxes as an integral part of the output ducting)	14	22
Cyclones or multicyclones	7	11
Low energy wet scrubbers	24	38
Venturi scrubbers	18	29
Baghouses	0	0
Electrostatic precipitators	0	0

An important word of caution concerning the above table and the description of control devices that follow: This preliminary evaluation of air pollution aspects of the drum-mix process did not involve development of primary data. Instead, it is based on information available in stack test reports that were available to us, sometimes only after they were several times removed from the actual testing organization. In almost all cases the stack test reports gave no or only meager data on the type of control system being used. For example, in the case of wet systems the liquor flow rate and pressure drop was not usually presented. Details of stack sprays insofar as their location, type and number of nozzles and liquor flow rate was not stated. It was therefore necessary to ascribe pressure drops and some operating characteristics to some of the vague descriptions given in the reports based on experience with conventional reports.

Fourteen reports indicated no controls used. We believe that in these cases there may have been a knock-out box which was never mentioned in the report. Such boxes operate on the principal of abruptly changing the direction of the gas stream so that inertial force of the heavier particles overcame the entrainment forces of the gas stream and they are essentially "knocked out" of the stream. This phenomenon is an undesirable effect where it inadvertently occurs in poor duct design causing duct wear and pile-up of material. The technique has only low efficiency, operating best when the size distribution of particles is heavily toward larger and/or more dense particles.

Primary cyclones of the type generally used with conventional plants are more efficient that the knock-out boxes in that they remove between 50 and 70% by weight of the entrained dust from conventional asphalt batching plants. Such cyclones operate on the centrifugal force principle. Practical limitations on their use usually involve re-entrainment problems and unworkable high pressure drops. The overall efficiency of the cyclone depends on particle size, geometric design of the cyclone and pressure drop. In most practical situations involving mineral dust, pressure drops are on the order of 2 to 4 inches of water. Table 3 shows the particle size distribution before and after entering a cyclone collector on a conventional asphalt plant.

Stack sprays were mentioned in the reports, but as previously stated there was no detail on the type nozzles, location, and liquor rates. The techniqe however is to inject water droplets into the exit stack relying on impaction and agglomeration of the dust particles to produce particles either heavy enough to overcome the upward force of the gas stream so that they settle to a collection sump, or of sufficient mass to be removed by baffle plates upon which particles can impinge, or by centrifugal forces applied by mechanical means subsequent to the introduction of the spray.

Another type of wet collector frequently encountered in conventional plants and what we think the testers generally meant when they referred to "wet scrubber" in their test reports on the drum-mix plants used in this preliminary investigation was a dynamic scrubber which incorporates a wet fan as an integral part of the unit. A spray of water is either directed toward an impeller type fan or is fed axially in the case of paddle-wheel fans. The mechanism is mainly one of impingement of dust particles on the wetted rotating blades. The purpose of the sprays is to keep the fan blades wet and to flush away the collected dust. This technique also relieves the abrasion and condensation buildup which would otherwise accumulate on the blades. Our experience with these devices on conventional plants indicates that they usually operate at 5" to 10" water gauge.

Table 3

PARTICLE SIZE DISTRIBUTION

BEFORE AND AFTER PRIMARY COLLECTION

FROM DRYER AND VENT		FROM PRIMARY COLLECTOR	
Size μ	% Less Than	Size μ	% Less Than
5	19.5	5	78.00
10	30.5	10	96.40
15	38.2	15	97.50
20	45.1	20	97.80
25	50.1	25	97.90
30	55.5	30	98.03
35	60.0	35	98.20
40	64.0	40	98.28
45	67.5	45	98.40

Source: Air Pollution Control Technology and Costs In Nine Selected Areas, Industrial Gas Cleaning Institute

Those installations which exhibited the best degree of control were venturi scrubbers. Again, the reports did not adequately describe them nor note the pressure drop or liquor flow rate. Such venturi scrubbers could fall into several categories as shown in Figure 4, but their operating principles are essentially similar.

These scrubbers, with pressure drops in the range of 20 inches of water, or greater, generally are capable of reducing emissions of conventional plants to below the required NSPS of 90 mg/scm (0.04 gr./dscf).

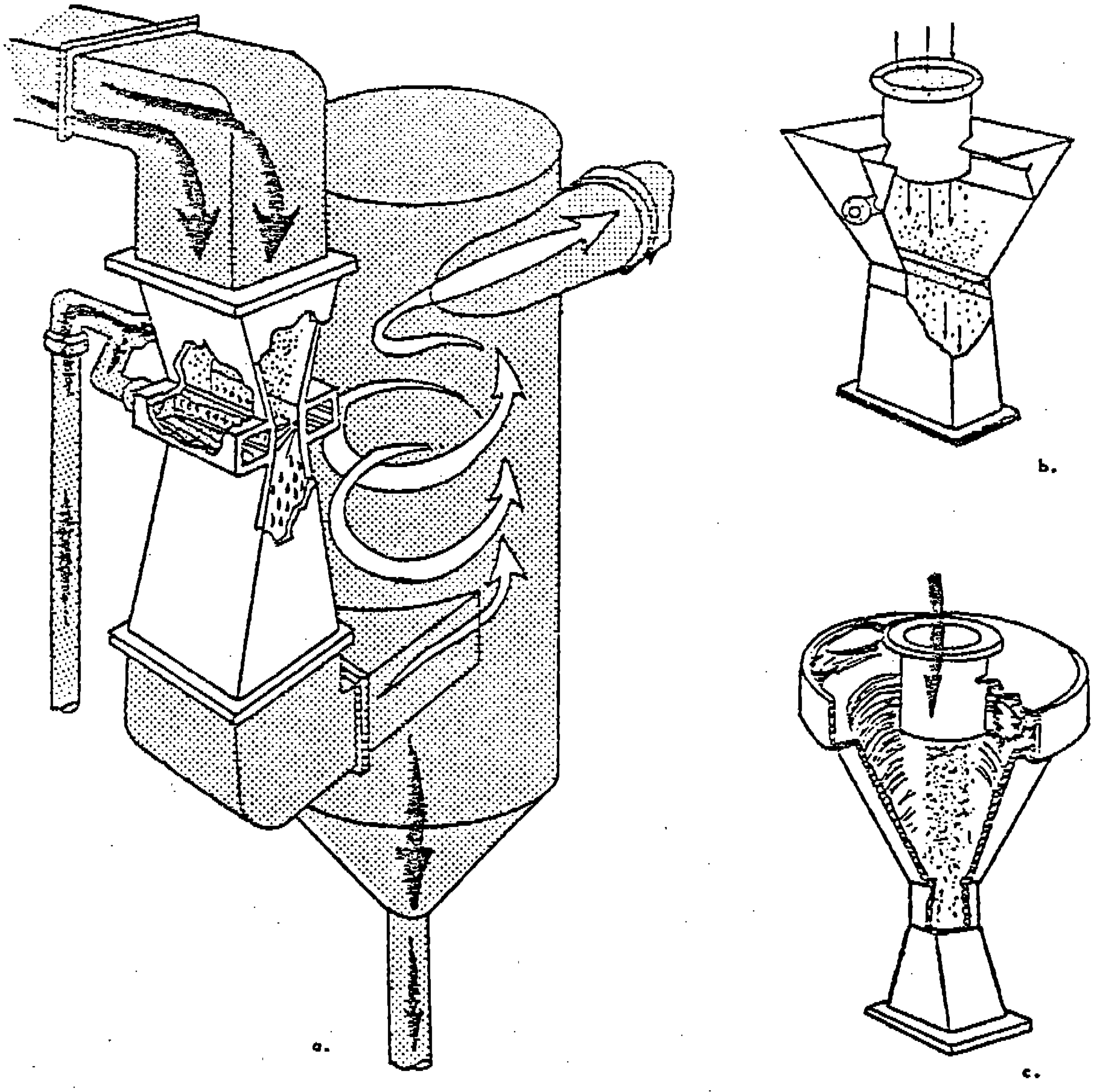
The venturi scrubber is a high efficiency wet collector that operates by impinging particulates on atomized water droplets. The effective mass of the particle thus increased, cyclonic separation is then possible.

As the particle laden gas enters the device, a constriction reduces the cross-sectional area of the gas stream, thereby increasing the stream velocity. This correspondingly increases the velocity of the particles relative to the formerly stationary water droplets that were introduced at the apex of the constriction. Increasing the relative speeds heightens the probability that a particle will impinge upon the water droplet. As the dust-laden water droplets leave the venturi constriction, they further agglomerate due to deceleration. The gas stream then passes through a cyclonic separator, which removes the larger, heavier particles formed during the agglomeration phase.

Venturi scrubbers can achieve collection efficiencies in excess of 99%. Variables affecting efficiency include pressure drop, water injection rates, venturi design, and particle concentration and size. Collection efficiencies improve with higher pressure drop, attainable by increasing the throat velocity by constricting the throat and to a lesser extent by increasing the water injection rate. Pressure drops will probably be 20"

Figure 4

VENTURI SCRUBBER



Venturi scrubber may feed liquid through jets (a), over a weir (b), or swirl them on a shelf (c).

Source: Control Techniques for Particulate Air Pollutants, USDHEW 1969 or more for most venturies while water injection rates normally encountered will nominally be 6 and 10 gallons of water per minute per 1000 acf of gas. Efficiencies fall rapidly at injection rates below this range; rates in excess of 10 gallons of water per minute 1000 acf of gas produce lesser increases in collection efficiencies.[6]

Greater particle concentration also improves collection efficiency. Assuming the number of water droplets formed in the system is constant, the frequency of particle collisions is increased when more particles are introduced into the system. Figure 5 shows a nominal collection efficiency and particle size relationship for a typical venturi scrubber. Note that the efficiency is greater than 97% for particles larger than 1.5 microns; note too that the efficiency falls sharply for particles less than 1 micron for a fixed set of conditions.

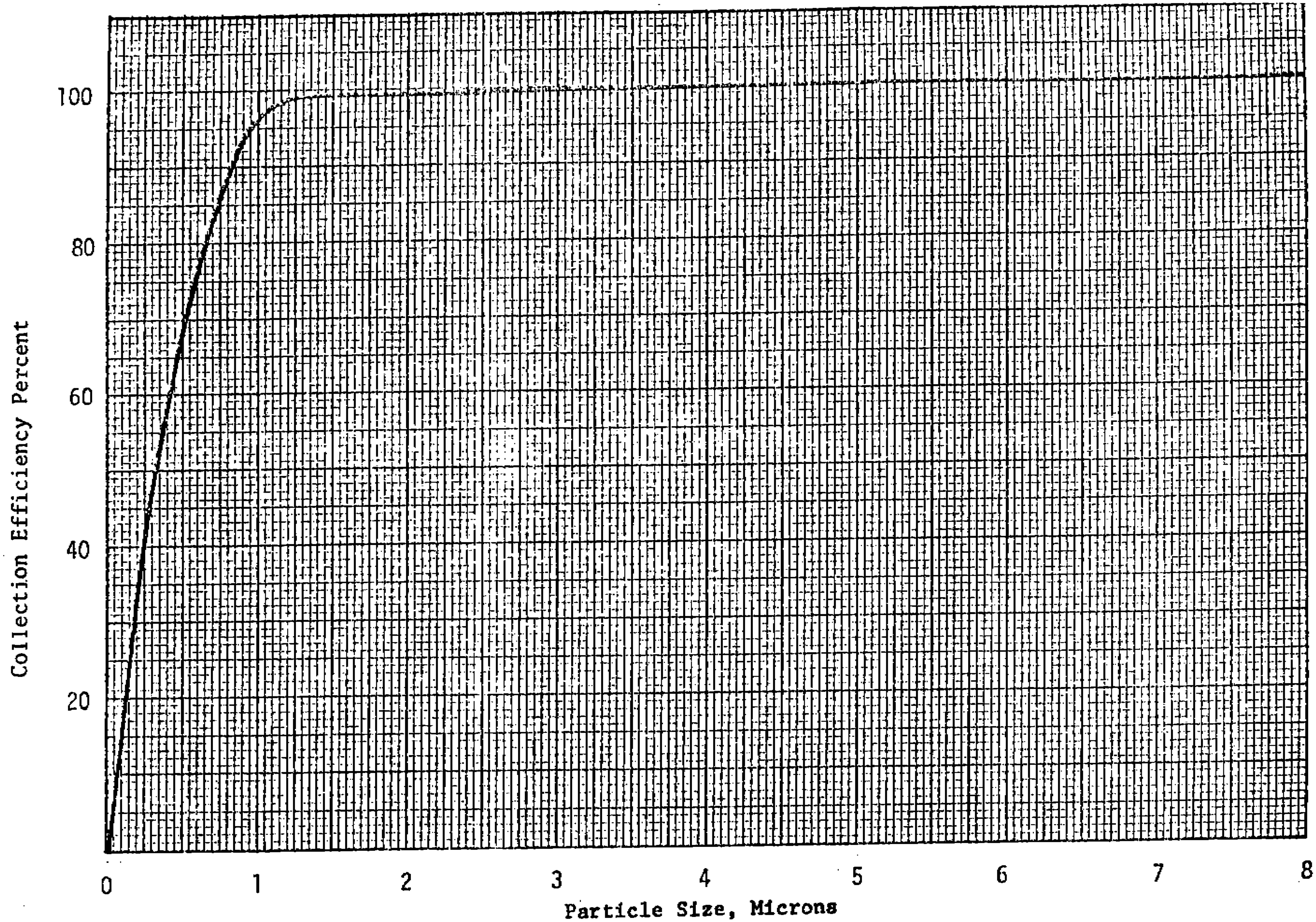
Disadvantages of venturi scrubbers include high operation costs associated with producing high pressure drops, and also the need for large quantities of water which entails elaborate recycling of alkaline, acidic or adoriferous water. This would require the use of settling basins which also present a problem of solid waste disposal when they must be dredged.

Advantages of venturi scrubbers include their relatively low initial cost and [illegible] the hydrocarbon emissions from the drum-mix op[illegible]

No drum-mix plants using fabric filter controls were encountered in this preliminary investigation. The asphaltic emissions from the drum-mix process as well as mineral particles coated with asphalt are difficult to control with fabric filters because of sticking and blinding of the filter medium. Two sources have reported that they were experiencing plugging even using cyclones from these emissions.

Figure 5

EFFICIENCY vs. SIZE FOR TYPICAL VENTURI



Electrostatic precipitators were also not encountered. The low gas volumes associated with conventional asphalt concrete plants and the high fixed costs for the portion of the precipitator that develops the high voltages needed generally renders such devices economically less attractive than other solutions. They can however attain collection efficiencies of over 99% in conventional plants with proper gas conditioning.* Wet electrostatic precipitators that do not require rapping, but remove the captured particles by a film of water on the collector wall might reduce some of the sticking problems. Even with the somewhat higher gas volumes found in the drum-mix plants, however, they may not be economically attractive, and they may impose some plant portability restrictions.

Important trends are discernable in the development of this relatively young process technology. One manufacturer has reported to us that they are trying to affect certain changes in the process variables (such as flight design through sections of the drum, rotational speed, slope, and the point at which the asphalt is sprayed in the drum) whereby asphaltic emissions could be reduced, even at the cost of increasing the mineral particulate emissions, so that a fabric filter could be used for the control of process emissions.

* Stack Test performed by JACA Corp. for compliance with Pennsylvania Regulations

Section 5

EMISSION DATA ANALYSIS

The preceding sections provide general background of the drum-mix process, and control techniques employed. Quantitative information about the emissions from the drum-mix process, collected during this study, is presented here.

It is important for the reader to keep in mind the sources and limitations of the data which are described below. The analysis is based on information obtained from regional EPA offices, state air pollution control agencies, independent stack testing companies and drum-mix manufacturers. One counter flow drum mix plant was tested using Method 5 with slightly modified equipment.

The test information was obtained in various forms. While most of the information analyzed here is based on actual emission test reports; in other cases, it was necessary to utilize aggregated summaries of test results in others. In one instance only the combined results of 31 tests were made available to us by a drum-mix manufacturer.

Thorough analysis and comparison of data contained in information gathered from such diverse sources is hampered by two limitations: (1) the various modifications of the basic EPA sampling train used and approved in various parts of the country does not permit full comparison of data results from all tests and, (2) adequate information on source conditions and description of control equipment and parameters was usually unavailable. For example, some tests report particulate concentrations based on the front half catch, some of the 'total' catch, and some do not report the 'condensible' fraction. None of the reports give important details of control equipment configuration and only a few specified production rates, liquor rates and pressure drops on wet scrubbers.

Another limitation is that the source test data had to be judged as to its acceptability on the basis of broad yardsticks such as isokineticity, thoroughness in reporting the various stack-test related variables, although a majority of the tests were conducted for compliance purposes and were presumably accepted by the relevant government agency.

As a result of the data gathering phase, emission tests results were obtained from 70 different plant tests (not including 31 test runs from plants where only the aggregate data were made available to us by a manufacturer). Of these 70 different plant tests we decided to exclude a total of seven tests, 2 because the tests were run outside the isokinetic range, 3 due to a paucity of information available (including the only two counter current plants) and 2 because they were repeat runs on the same plants included in the analysis.

Of the 63 tests found to be acceptable for inclusion in the analysis, 14 were on uncontrolled plants, 7 were on plants with dry mechanical controls such as cyclones and multicyclones, 24 were from plants with scrubbers of the spray, impingement or wet fan type, and 18 were on plants with venturi scrubbers of varying pressure drops.

The 63 tests gave a total of 158 independent runs for analysis, of which 108 reported only "front-half" results, 7 reported only the "total" particulate matter, and 43 reported both front-half as well as total particulate concentrations.

The emission concentrations obtained from the above tests are reported below, in order of increasing level of controls, for parallel flow plants which account for more than 90% of known drum-mix plants (the one counter current flow plant is plant D of Figure 6). Due to the large variability associated with these results, they have been plotted, in Figures 6, 7, 8 and 9, on a logarithmic scale. Plants identified with letters are on the horizontal axis, and information regarding control device, production rate and capacity, where available, is indicated below each plant. Where available, maximum, minimum and arithmetic average concentrations are shown for each plant tested. The percentages shown above the test results for some plants are percentage opacity readings reported in the test records.

The opacity data suffers from many of the problems encountered in the test reports. There was no data sheet showing number of readings, specific time, position of the observer, atmospheric conditions, etc. Information on opacity in those reports where it was mentioned was almost parenthetical, a brief statement that the opacity was a particular percentage.

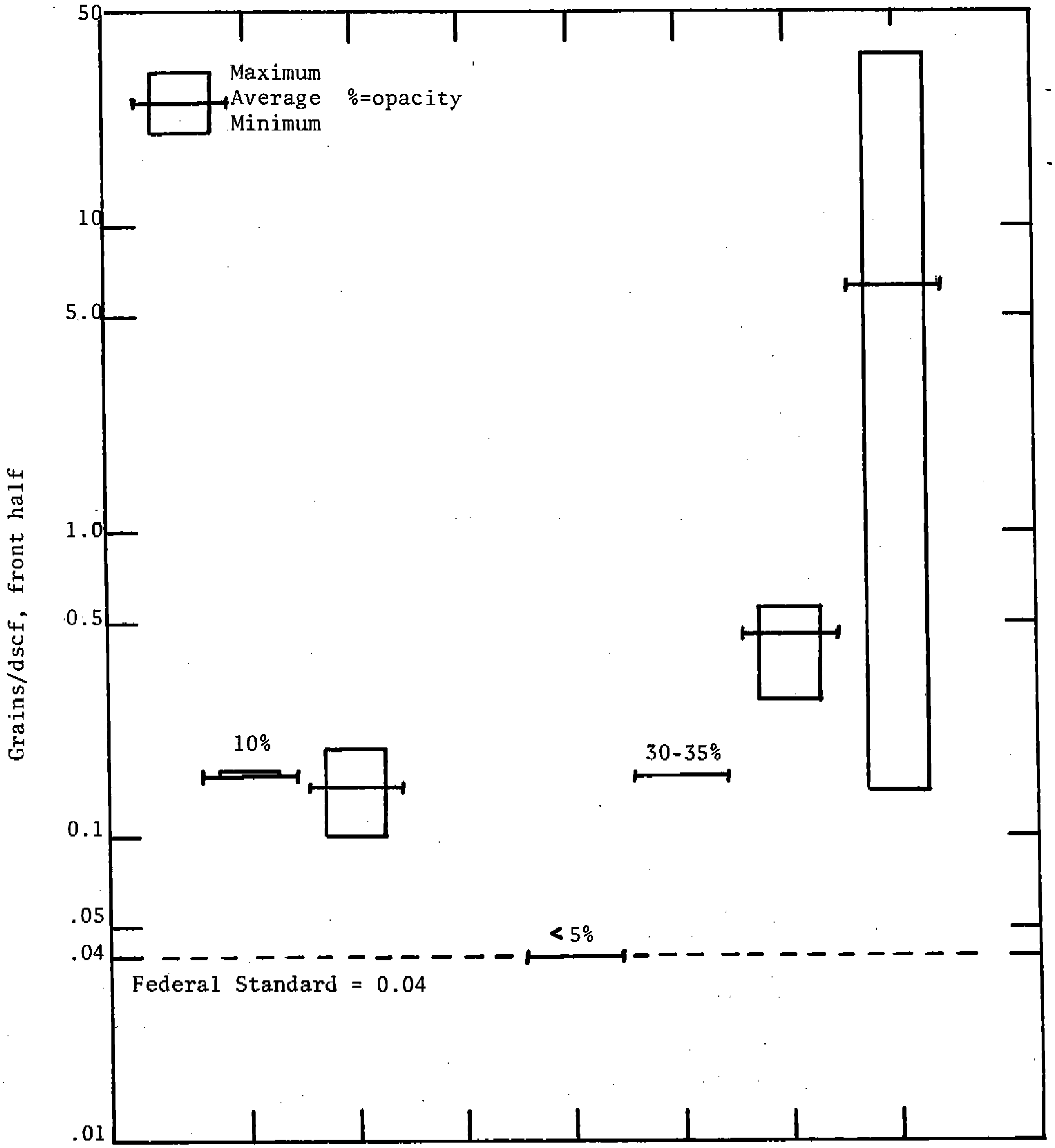
Figure 6 shows the range of particulate emission concentrations for uncontrolled plants. (Figures 6 through 9 include results from parallel-flow plants except for plant D of Figure 6).

The combined results from 31 tests on 9 uncontrolled plants (Figure 6) with capacities varying from 300 to 350 tons per hour, at maximum moisture removal rates, shows an extremely wide range of particulate concentration, a maximum grain loading of 40.5 gr./scfd, a minimum of 0.14 gr./scfd, a mean of 6.19 gr./scfd with a standard deviation of 8.2 gr./scfd! The other five plants all have much lower average readings and the ranges of plant B & F are more like those encountered in conventional plants. Of the three plant reports with opacity data only plant E was outside of NSPS.

The significant variation in uncontrolled emissions from plant to plant suggests that process variables might be one of the principal causes. Plant D for example was known to be a counter current flow plant as described

Figure 6

UNCONTROLLED EMISSIONS FROM DRUM-MIX PROCESS



Plant	A	B	D	E	F	Combined Data from 31 tests, 9 plants
Avg. Production Rate, tph	200	175	60	166	95	300-350
Capacity, tph	?	?	100	200	200	300-350

on page 5 while all others are parallel flow plants. The other plants are made by a variety of vendors and plants have a considerable range of process settings - much more so than do conventional plants. Some vendor companies indicated that they were conducting research on product characteristics and emissions as a function of several process variables including:

- Point of injection of asphalt
- Flight design
- Aggregate mix
- Moisture content
- Temperature gradient through the dryer
- Drum rotational speed
- Rate of production
- Temperature of mix
- Type of Asphalt

The analysis of the effect of these parameters was not attempted in this work, and would entail quite a large study because of the number of different suppliers and the present state of design flux.

Emission concentrations from seven plants controlled with dry mechanical collectors are shown in Figure 7. The results fall between a high of 3.0 to a low of 0.03 grains/scfd. Plant L for example just met the NSPS standard of 0.04 gr./scfd. The mean of all the results was 0.853 gr./scfd, with a standard deviation of 1.16! Of the three plants reporting opacity readings only one was within NSPS.

Results of emission tests from 24 plants controlled with wet scrubbers as described in Section 4 are shown in Figure 8. Seven out of twenty-four plants were within NSPS. Excluding plants N and T for which only the total

Figure 7

EMISSIONS WITH DRY MECHANICAL COLLECTORS

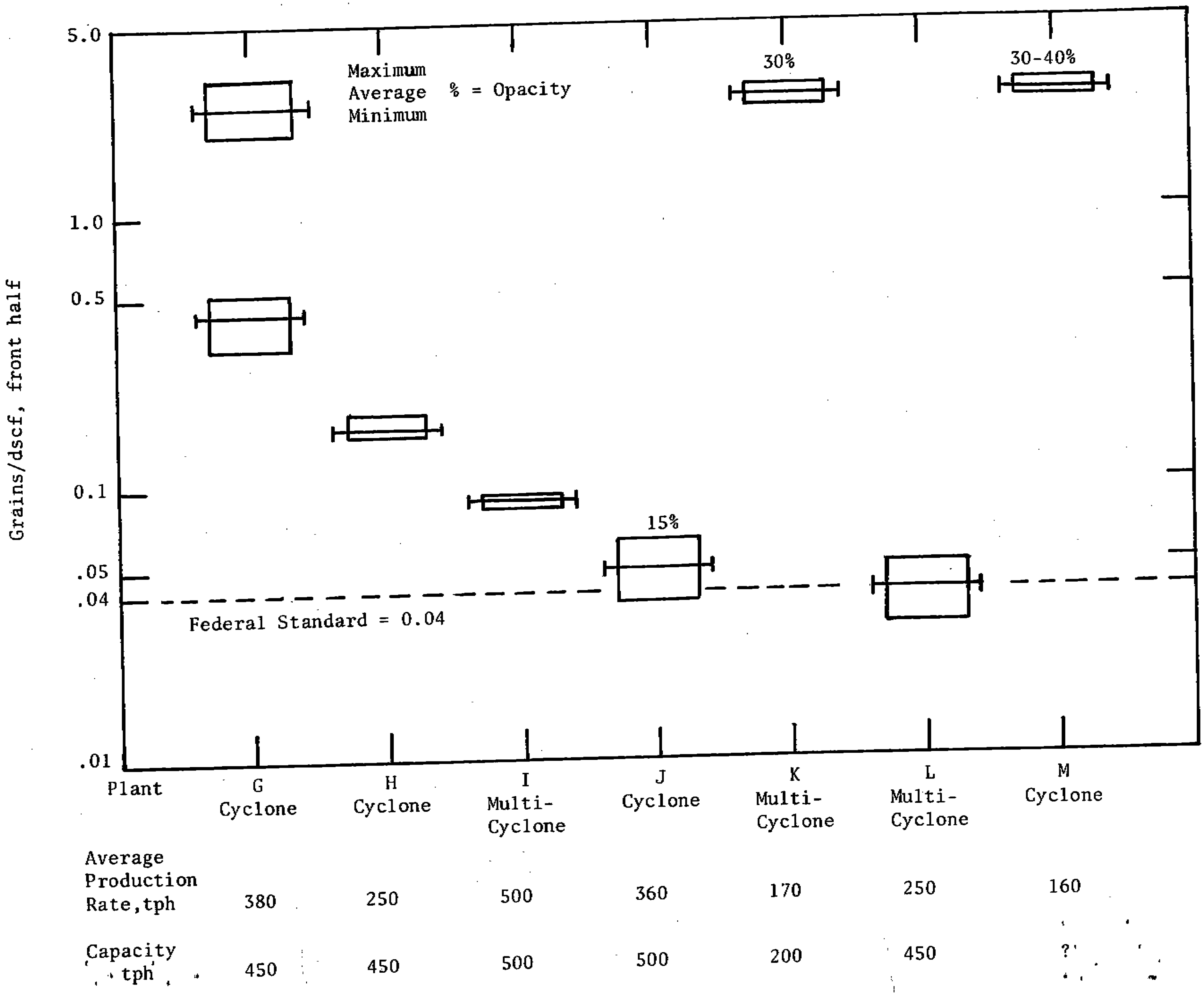
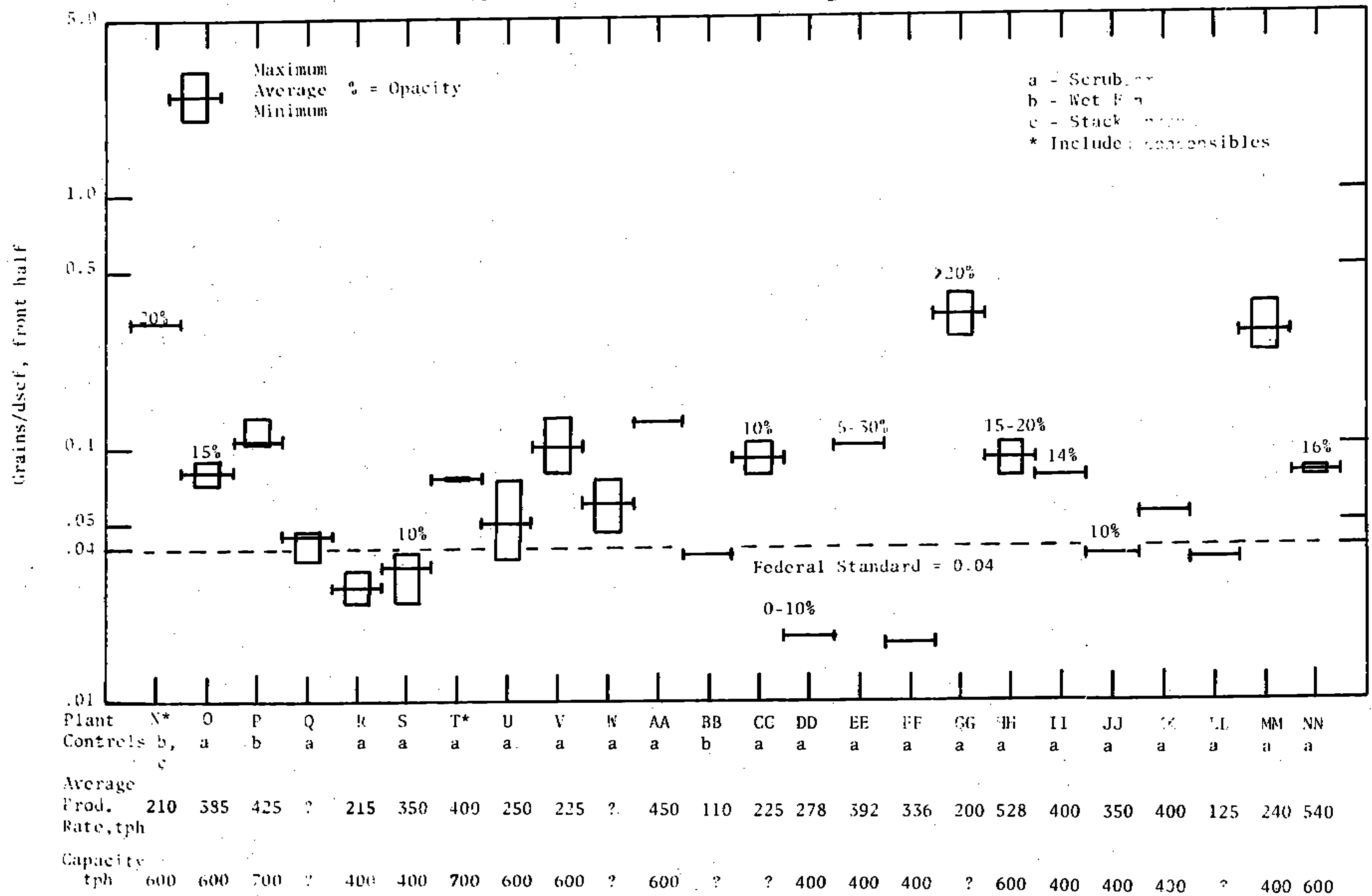


Figure 8

EMISSIONS WITH WET SCRUBBER CONTROLS



catch results were available, the values range from 0.394 to 0.017, with a mean of .094 gr./scfd, with a standard deviation of 0.089 gr./scfd. Of the twelve plants reporting opacity readings, two were greater than 20 percent.

Figure 9 shows the results of emission tests on 18 plants with venturi scrubber controls. The pressure drops across the venturi scrubber are only known for three plants. These are shown in inches water gauge in the lower right of the data plot. The emission values vary from a maxium of 0.191 to a low of 0.005 grains/dscf. The mean of these values is 0.0557 and the standard deviation is 0.052. Of the eight plants reporting opacity readings, all were within NSPS.

The data (excluding the one countercurrent flow plant) shows that the percentage plants passing NSPS was:

- Uncontrolled 0%
- Dry Mechanical (Multicyclone) 14%
- Wet Scrubber (Per the broad description in Section 4) 29%
- Venturi Scrubber (Pressure drop known in only 3 instances) 50%

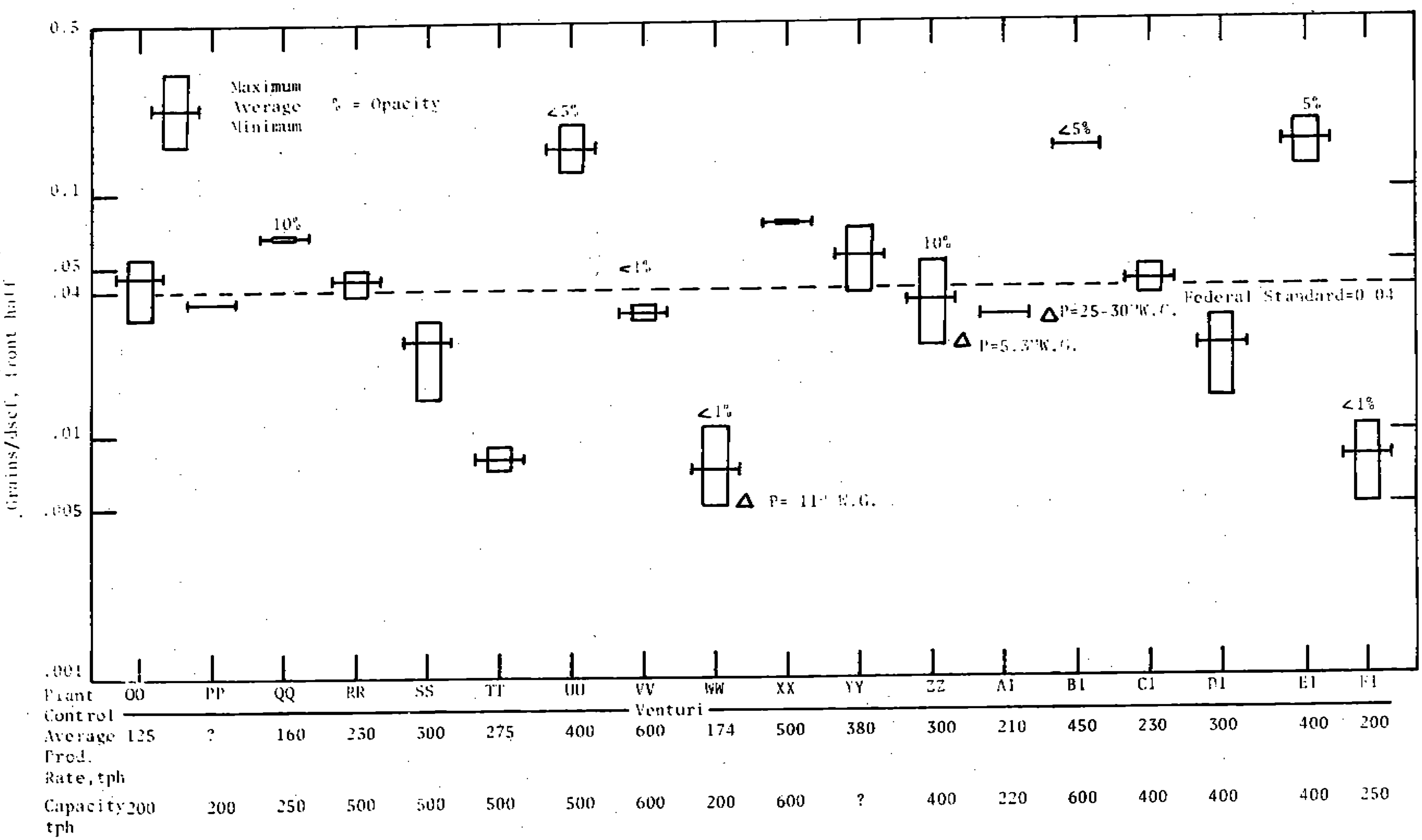
Attempts to relate emission concentrations with production rates, or production rate as a fraction of the plant capacity for each of the four sets of data presented above failed to show any consistent pattern.

Bearing in mind the nearly total lack of process and control setting data, the tests reported shows:

1. Emissions associated with drum-mixers show a very large variability. Process factors discussed previously may be responsible for these differences.

Figure 9

EMISSIONS WITH VENTURI SCRUBBER



2. No uncontrolled parallel flow plant met NSPS
3. The single countercurrent flow uncontrolled plant marginally met NSPS, but we are advised that such designs have inherent limitations in production capability, and are not expected to be a significant part of the market
4. All but one of the mechanical collector controlled plants failed NSPS on grain loading as did two out of three of these plants reporting opacity readings
5. All eight plants reporting opacities which were controlled by venturi scrubbers were within NSPS opacity limits.

Although an extensive hydrocarbon emission analysis was not undertaken as a part of this study, several of the particulate emission tests contained various hydrocarbon analysis. The results are described below:

- Analysis of the particulate catch from a test performed on Plant K, controlled by a multicyclone, showed that 21% of the filterable particulate was hydrocarbon. The test lab assumed this material was asphalt.
- Total hydrocarbon (THC) analysis were run on Plant II controlled by a venturi scrubber. Tests were performed by chromotography and the results for the three test runs were 163 ppm, 501 ppm and 112 ppm.
- A more extensive hydrocarbon analysis was performed on samples from Plant U controlled by a wet scrubber:

Section 7

SOURCE TESTING

Difficulties in source testing drum-mix exhausts by means of the EPA train have been reported. The chief reason for this is the clogging of the filter in the front half of the test train with asphaltic emissions, which prevent isokinetic flow rates through the train because of high pressure drop created at the filter.

Source testing personnel who have had experience with drum-mixers were contacted during this study, and the conclusion is that clogging of the filter diminishes as the degree of control increases. Tests on plants with no controls or with dry mechanical controls asphaltic emissions appear to be the cause of filter blinding since plants with wet controls were reportedly not as difficult to test in this regard.

Based on JACA's test experience on an uncontrolled drum-mixer, and the experience of EPA's Emission Measurement Branch on the source testing of asphalt roofing plant exhausts, the following techniques are suggested to minimize the clogging problem and to reduce the need to frequently change the filter during a run.

- A loosely packed portion of glass wool, inserted into the top half of the filter holder causes the sticky, asphaltic material to adhere to it, without causing excessive pressure drops through the train (See Appendix B).
- A cyclone and flask inserted in the hot box between the probe tube and the filter holder retains bigger particles, thereby reducing the build up on the filter medium.

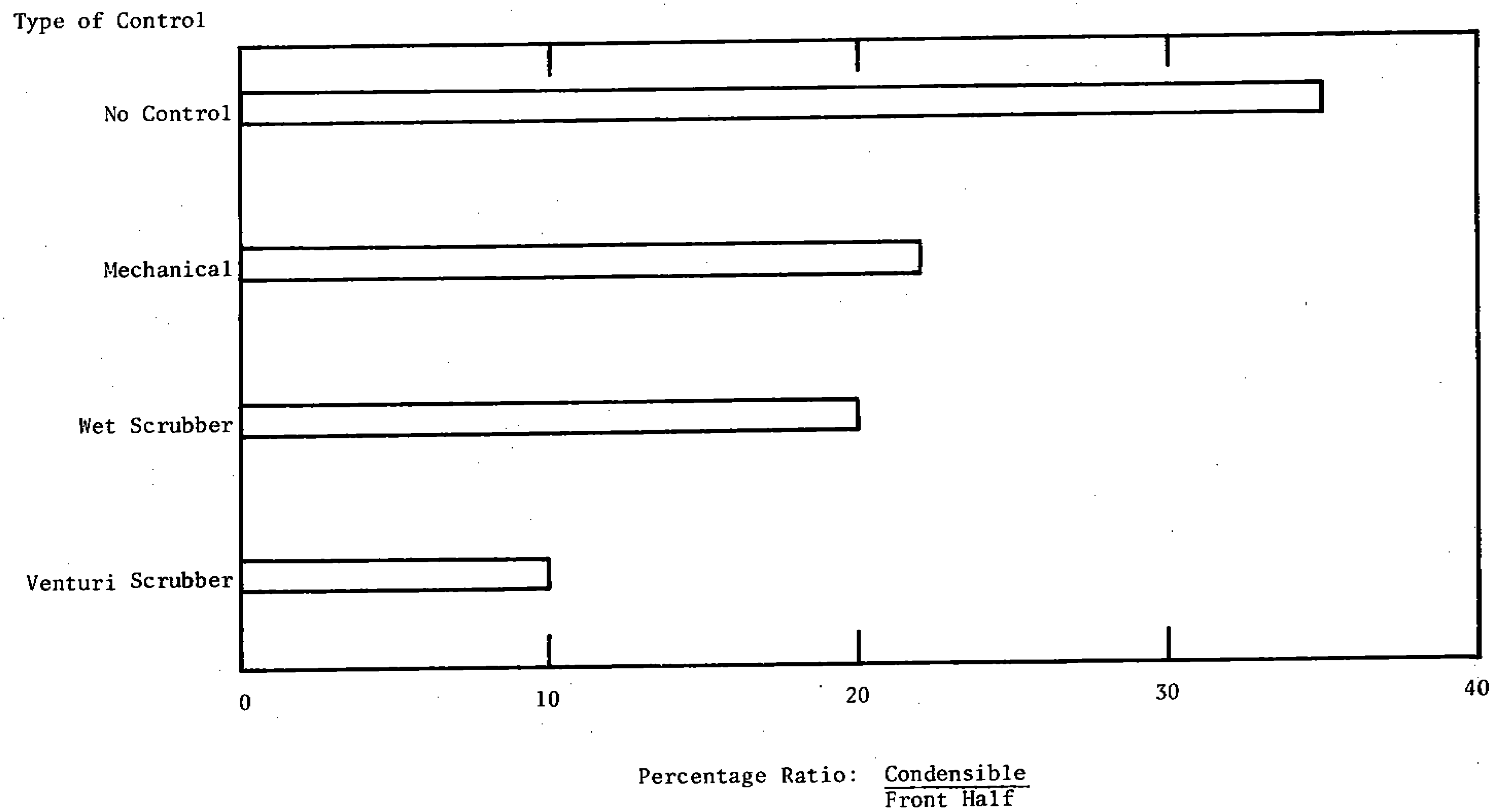
- Methylene chloride is the preferred solvent for use in the sample recovery operations.

Another potential area of concern was whether, due to the presence of asphaltic matter in various stages of oxidation, the process emissions contain large amounts of matter which escapes the filter but gets caught in the impingers as "condensibles" matter.

This aspect was studied by analyzing the ratio of "condensible" to "front-half" catch for a total of 43 runs for which such data was available. Figure 10 shows how this ratio varies with degree of control. For uncontrolled plants, the condensible catch is on an average 35% of the front half catch, but as the degree of control increases, this ratio decreases. For drum-mix plants where the test reports cited venturi control devices, this ratio reduces to 10%, although one anomalous result was found here with a ratio of 83%.

Figure 11

RELATIONSHIP BETWEEN CONDENSIBLES AND TYPE CF CONTROL



Section 8

FINDINGS & RECOMMENDATIONS

Drum-mix asphalt concrete plants are likely to constitute an important fraction of new asphalt concrete plant construction, falling within the New Source Performance Standards. There are at present approximately 150 drum-mix plants occuring in 27 states in the United States of which it is estimated that 50-70% fall under the provisions of NSPS. At least eight companies are engaged in the manufacture of drum-mix plants.

Some product use restrictions imposed by state departments of transportation at present inhibit the market acceptance of the process, but further product test evaluations and experience by highway officials may reduce this barrier. The fact that eight manufacturers including four prominent in conventional plants have entered the field indicates an expanded use of the drum-mix process.

This source can be typified as a growing one with relatively young process and control experience.

Although uncontrolled emissions are less than those from a conventional plant of comparable production capacity, they clearly exceed NSPS.* These uncontrolled plant emissions also generally exceed 100 tons per year. Furthermore, this potential of exceeding 100 tons per year is enhanced because the production capacities of drum-mix plants often exceed those of conventional plants.

An analysis of 63 stack tests which included 158 test runs showed high variability of emissions at each level of control which may be related

* One reported countercurrent flow plant met NSPS emissions.

to a variety of process designs marketed by different manufacturers and continuing refinements in design, in addition to the normal causes of such variations such as raw material, and condition of a given type of control. Control results improved from mechanical (14% meeting NSPS) through wet scrubber (29%) to venturi scrubbers (50%). Baghouse and precipitator controls were not encountered in this study.

The ratio of "condensibles" to the "front half" catch averaged 35% for uncontrolled plants and decreased to 10% for venturi scrubbers. This means that a considerable amount of emissions are not measured by Method 5 under the NSPS since the back half of the measurement train that reports condensibles is not used. Secondly it may mean that water pollution problems could be encountered in a drum-mix plant using wet collection techniques unless appropriate ponds or closed loop recycling is used.

Recommendations

Better primary data are needed if firm, accurate information on emissions and control efficiency on drum-mix plants is desired. This preliminary study pointed out the shortcomings of relying on published test reports. To provide meaningful primary data it is necessary that future reports include more data on the model and type of drum-mix plant, details on the control device(s) including as a minimum design feature, pressure drops, and liquor flow. Information in the test reports as to the type of raw material and the size gradation should also be included.

We would recommend a two-pronged approach in developing these data:

1. New drum-mix plants being tested by either the federal government or the states should be provided with data sheets or asked to report the data noted above. If convenient, federal representatives should witness the tests

2. An effort should be launched to develop better data from the tests already reported. While it is difficult if not impossible to identify some factors that held during the test such as pressure drop, liquor rate, and raw material gradation, it may be possible to obtain better information on the type drum-mix and a better description of the controls, and the design parameters of the control system.

There is significant current R&D effort by manufacturers in improving the product and air pollution characteristics of the drum-mix process. (One goal is to make fabric filters feasible). This indicates the need for continuing attention by EPA as these R&D efforts are reflected in equipment and emission changes.

Method 5 testing of drum-mix asphalt concrete plant emissions is feasible with minor modifications to the sampling train.

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Appendix A

MANUFACTURERS OF DRUM-MIX PLANTS

Manufacturer	Type of Flow
Aedco, Inc. 13333 U.S. Highway 24 West Fort Wayne, Indiana 46804	Counter
Astec Industries, Inc. P.O. Box 2787 Chattanooga, Tennessee 37407	Parallel
Barber-Greene Company Aurora, Illinois 60507	Parallel
Boeing Construction Equipment Co. P.O. Box 3707 Seattle, Washington	Parallel
CMI Corporation P.O. Box 1985 Oklahoma City, Oklahoma 73101	Parallel
Iowa Manufacturing Company Cedar Rapids, Iowa 52401	Parallel
Stansteel Corporation 5001 S. Boyle Avenue Los Angeles, California 90058	Parallel
Portec, Inc. Minneapolis, Minnesota 55414	Parallel

Appendix B

SAMPLING TRAIN MODIFICATION

Desiccate a quantity of Pyrex glass wool for 48 hours. Using large tongs, loosely pack the top of the glass filter holder with the glass wool. Remove and weigh the wool to a constant weight. Repack the glass wool into the filter holder top and assemble the filter holder.

During the sample recovery procedures in the laboratory, remove the glass wool from the filter holder and place it on clean, tared pyrex dish. Desiccate the glass wool for 48 hours and re-weigh it to a constant weight. Include the net weight gain in calculating the particulate emission rate.

If any tarry residue is trapped on the filter holder top, rinse it with methylene chloride and include the washings with the probe and nozzle washes.

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		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS JACA Corp. 506 Bethlehem Pike Fort Washington, PA 19034		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-1356
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency Division of Stationary Source Enforcement Washington, DC 20460		13. TYPE OF REPORT AND PERIOD COVERED Final
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16. ABSTRACT

This report focuses on the air pollution aspects of a process of recent practical application in the asphalt concrete industry, called the Drum-Mix process. Included in this report is a description of the drum-mix process, factors affecting its use in new asphalt concrete plant construction, its air emission potential, and applicable emission control techniques. Data from emission tests on uncontrolled and controlled drum-mix plants are analyzed, and emission factors for various levels of control are reported. Also included in this report is a discussion on the ways to overcome sampling problems particular to the drum-mix exhaust.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Asphalt Concrete Plants Air Pollution Control	Emission Factors Emission Testing Drum-Mix Process	

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