AP-42 Section Number: 11.1

Reference Number: 1

Title: Asphaltic Concrete Plants Atmospheric Emissions Study

USEPA

Valentine, Fisher, and Tomlinson

November 1971

0936

PB 210 137

ASPHALTIC CONCRETE PLANTS
ATMOSPHERIC EMISSIONS STUDY

EPA CONTRACT #68-02-0076

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR PROGRAMS
Research Triangle Park, North Carolina 27711

Prepared by

VALENTINE, FISHER & TOMLINSON
Consulting Engineers
520 Lloyd Building
Seattle, Washington 98101
(206) 623-0717

Authors

J.A. Crim
Crim Engineering
Seattle, Washington

W.D. Snowden
Valentine, Fisher & Tomlinson

November 1, 1971

93

ASPHALT CONCRETE PLANTS_ATMOSPHERIC EMISSIONS STUDY

TABLE OF CONTENTS

BIBLIOGRAPHIC DATA SHEET

1. Report No. APTD-0936

2.

3. Recipient's Accession No.

4. Title and Subtitle
Asphaltic Concrete Plants Atmospheric Emissions Study

5. Report Date
November 1, 1971

6.

7. Author(s)
J. A. Crim and W. D. Snowden

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Valentine, Fisher & Tomlinson
Consulting Engineers
520 Lloyd Building
Seattle, Washington, 98101

10. Project/Task/Work Unit No.

11. Contract/~~Grant~~ No.
68-02-0076

12. Sponsoring Organization Name and Address
ENVIRONMENTAL PROTECTION AGENCY
Office of Air Programs
Research Triangle Park, North Carolina 27711

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts This report summarizes previously unpublished emission data on asphaltic concrete plants, shows a comparison between different sampling techniques, and presents guidelines for evaluating the emissions of asphaltic concrete plants. The average emissions from spray towers is 0.65 lb/ton, from Centrifugal scrubbers is 0.28 lb/ton and from baghouses is 0.13 lb/ton of asphaltic concrete produced. Engineering judgment indicates that the emission from well-designed spray towers is 0.3 lb/ton from centrifugal type is 0.10 lb/ton and from baghouses is 0.075 lb/ton of asphaltic concrete produced. Baghouses have been shown to be less efficient than anticipated. Baghouses offer solutions to certain asphaltic concrete procedure problems, (e.g. shortage of water or adequate space for settling ponds). Comparative stack gas sampling with LA and EPA sampling trains was inconclusive. The LA train measured higher emissions on four baghouse systems and lower on one wet scrubber system. The difference in particle size distribution between baghouses and scrubber is expected to be the main contributor to the difference. The equivalent opacity from the wet scrubber control systems is expected to be higher than the equivalent opacity from a baghouse control system if both plants have equal emission concentrations. The particle size distribution from the wet scrubber system is expected to be finer and hence more visible.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Asphalts
Minerals
Processing
Exhaust emissions
Gas sampling
Scrubbers
Dust filters
Flue gases
Particle size

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement
Unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
105

22. Price

I. INTRODUCTION

This report summarizes previously unpublished emission data on asphaltic concrete plants, shows a comparison between different sampling techniques, and presents guidelines for evaluating the emissions of asphaltic concrete plants. Included is a summary of descriptive material on dust control equipment and background information on plant operations. The study is intended to provide the Environmental Protection Agency, Office of Air Programs with sufficient descriptions and data, that when combined with other available information, will allow EPA to provide complete descriptive and background data to local air pollution control agencies and industry related groups. Use of all the information will allow approximation of overall plant emissions from production rate data.

II. DESCRIPTION OF ASPHALT PROCESS

For purpose of discussion and elaboration on points of emission, the asphaltic concrete process is here divided into four parts:

1. Selection and handling of the raw material.
2. Drying the aggregate.
3. Mixing the aggregate with hot asphalt.
4. Fines recovery and dust control.

Selection and handling of the raw material is important because the size distribution of the aggregate entering the dryer ultimately determines the dust concentration loads that the fines recovery and control equipment will have to handle. Since transportation costs (for raw material and final product) are substantial, the plant is usually located in the vicinity of the aggregate pit and close to the job site. Occasionally the choice of raw materials can be enlarged by utilizing waste material such as slag from steel mills or crushed glass.

Different types of application of bituminous concrete (e.g. base course and surface course) require different aggregate size distributions. The local and State specifications also take into account the local variations in available aggregate supplies. Sieve analysis specifications for two typical mixes are listed in Table I. The percent of the aggregate that passes a 200 mesh screen (approximately 74 microns) is particularly important to controlling emissions because this fraction is an important factor for determing the performance of the control equipment.

TABLE I - TYPICAL ASPHALTIC CONCRETE SIZE DISTRIBUTION

SIEVE SIZE	AASHO M62-64 COARSE MIX	AASHO M29-70 FINE MIX
1"	100*	100*
3/4"	85-100	100
3/8"		100
No. 4	45-65	95-100
No. 8		70-100
No. 10	30-50	
No. 16		40-80
No. 30		20-65
No. 50		7-40
No. 100		2-20
No. 200	5-10	0-10

* - percent passing given sieve size

After cruching and screening the raw aggregate is normally stockpiled near the plant where the moisture content will stabilize between 3% and 5% moisture by weight. The aggregate is hauled from the storage piles and placed in the appropriate hoppers of the cold feed unit. The material is metered from the hoppers onto a conveyor belt, up a bucket elevator or a belt conveyor, and into a rotary dryer which is fired either by gas or oil. Since a substantial portion of the heat is transferred by radiation, dryers are equipped with flights which are designed to tumble the aggregate, exposing as much of the rock surface area as possible to the flame (Fig. 1). If the settling velocity* of an aggregate particle dr ping through the hot gas flowing through the dryer is of the same order of magnitude as the gas velocity through the dryer, the particle will probably be swept out of the dryer.

Dryer drum velocities vary between approximately 450 ft./min. and 900 ft./min. (1) Exhaust gases from the dryer comprise approximately 80% - 90% of the total gas flow and therefore a substantial proportion of the dust loading into the fines recovery system. The remainder of the gas and dust comes from enclosures over the conveying, classifying and mixing equipment which are vented into the primary collection equi, ent along with the dryer gas. These vents and enclosures are commonly called the Fugitive Air System or the Scavenger System.

As it leaves the dryer, the material drops into a bucket elevator and is transferred to a set of hot screens where it is classified by size into as many as four different grades. At this point it enters the mixing operation.

Asphalt plants can be classified by the aggregate mixing operations as batch or continuous. A schematic of each operation appears in Fig. 2 and Fig. 3.

In a batch plant, the classified aggregate drops into one of four large bins. These bins provide a substantial amount of surge capacity for the dryer system. The operator controls the particle size distribution by opening one of the bins and allowing the classified aggregate to drop into a weigh hopper until the desired weight is obtained. The bin doors are closed and another bin is opened, etc. After all the material is weighed out, the mixture is dropped into a mixer and mixed dry for about a half a minute. The action of the mixer or pugmill is similar to an egg beater except that the paddles are mounted horizontally instead of vertically. The asphalt, which is a solid at ambient temperatures, is pumped from heated storage tanks into the mixer. The hot mix is then dropped into a truck and hauled away to the job site.

In a continuous plant, the classified aggregate drops into a set of small bins. The purpose of these bins is to collect and meter the classified aggregate to the mixer. Consequently, these bins do not provide a large amount of surge capacity. From the hot bins, the aggregate is metered through a set of feeder conveyors to another bucket elevator and into the mixer. Asphalt is metered into the inlet end of the mixer and the mix is conveyed through by the action of the mixing paddles. Retention time is controlled (and some surge capacity provided) by an adjustable dam at the end of the mixer. The mix flows out of the mixer into a hopper and the trucks are loaded at this point.

* Settling velocity of a particle is the velocity at which the particle will settle in still air and is a function of the particle size, density, and shape.

1. Bituminous Construction Handbook, Barber Green Company, 1963.

II. DESCRIPTION OF ASPHALT PROCESS (Continued)

In some plants, surge capacity is provided by a set of separate storage bins. These bins are sealed from contact with the ambient air to prevent oxidation and may be either heated or non-heated. If storage bins are used, the mix is conveyed from the mixer to the storage bins and trucks are loaded from the bins.

III CONTROL EQUIPMENT

All asphalt plants have some form of dust control equipment. Dust control equipment is needed to: (1) protect equipment following the collector from damage due to the impact of dust particles, (2) avoid the expense of having to purchase sand and mineral dust in order to meet fine particle size specifications in the mix, and, (3) control dust emissions to the atmosphere. The advent of more stringent air pollution control regulations has made emission control aspects the overriding consideration in dust control system design.

Design of dust control systems requires a thorough understanding of the characteristics of both the material being handled and the system or process that produces it. Knowledge of dust control techniques have advanced considerably over the past years and many very capable producers of dust control equipment now exist. Unfortunately, many of these control equipment manufacturers do not appreciate the problems that an asphalt plant operator has to contend with. Manufacturers of asphalt plant equipment conversely, have been slow to respond to the need for better dust control techniques and slow to take advantage of the ability of the dust control equipment manufacturers. Both groups (dust control equipment manufacturers and asphalt plant equipment manufacturers) need to work together to provide the type of control systems the producers want.

The amount of dust carried out of an asphalt plant dryer depends upon the air velocity in the dryer, the particle size distribution of the aggregate, the specific gravity of the particles and the aerodynamic characteristics of the particles. Chief among these factors is the air velocity in the dryer. Figures 4 and 5 show the effect of increasing dryer air velocity upon production capacity and dust carryout. Note that a 50% increase in air velocity will allow about a 30% increase in production while causing a 150% increase in dust carryout.

An asphalt plant producing 150 TPH from aggregate having 5% surface moisture will require an air flow of about 20,000 scfm. The grain loading out of the dryer can vary from 20 gr/scf to 200 gr/scf in extreme cases. Taking 100 gr/scf as being representative, the dust carryout from the dryer will be 17,150#/hr. for the 150 TPH plant. Collection efficiency is usually stated in percentage of incoming material that is collected. Thus a cyclone collector with an 80% collection efficiency will pass 20% (or 3430#/hr. in the example mentioned) on to the next piece of collection equipment. If this cyclone is followed by a wet scrubber having a 98% collection efficiency, then 69#/hr. of dust will be emitted to the atmosphere. The 69#/hr. (i.e., 0.4 gr/scf) can be compared with a 40#/hr, process weight regulation or 0.1 gr/scf concentration regulation to determine what improvement might be necessary. If the efficiency of the first collector can be increased a relatively large amount with reasonable cost, this could be a more economical move instead of trying to gain that last 2% on the wet scrubber. This assumes that the collection efficiency of the wet scrubber is totally insensitive to changes in particle size distribution. An analysis of the entire asphalt plant operation by an engineer with a background in both asphalt operations and dust control techniques will often identify the best compromise approach. The compromise approach is then a plan that meets air pollution regulations at reasonable cost without causing plant operational problems.

III. CONTROL EQUIPMENT (Continued)

The dust control system of an asphaltic concrete plant is normally divided into a primary and secondary collector.

A. PRIMARY:

The simplest type of primary collector is the settling chamber (also known as an expansion chamber or knockout box). The principle of operation is that if the velocity of the gas is lowered, airborne particles will settle by gravity. The velocity is lowered by enlarging the cross-sectional area of the duct that the gas passes through. Typical velocities in the chamber are in the neighborhood of one to five ft./sec. Collection efficiency is directly proportional to (1) the settling velocity of particles in the gas stream and, (2) the length of the chambers. It is inversely proportional to, (1) the height of the chamber and, (2) the velocity of the gas through the chamber. A simple chamber is illustrated Fig. 6. A baffle is often placed in the air path to improve particle removal.

The most common type of primary collector used by the Hot Mix Asphalt Industry is a cyclone or a centrifugal collector (Fig. 7). The particulate laden gas is caused to swirl in the cylinder and cone by admitting it axially or tangentially. The gas proceeds downward to the apex of the cone, forms another spiral upward within the downward spiral, and then exits. Separation is effected by centrifugal forces driving the particles out of the gas stream lines to the wall. The particles are held at the wall and moved toward the dust discharge by the axial component of the vortex flow and gravity.

The efficiency of a cyclone is dependent upon, (1) the flow rate, density, and viscosity of the gas; and, (2) the density, size and concentration of the particles passing through the collector. Pressure drop through a cyclone is in the range between 1/2" and 6" of water. The efficiency range for typical primary collector system is shown in Table II.

B. SECONDARY:

The secondary control system of an asphaltic concrete plant usually consists of a wet scrubber system or a baghouse. The principles of operation of wet scrubbers are similar to those of dry collectors. Wet collectors increase particle removal efficiency because: (1) fine particles are conditioned, so that their effective size and weight are increased, thus enabling them to be collected more efficiently; and, (2) re-entrainment of the collected particles is prevented by trapping them in a liquid film or stream and then washing the liquid (and trapped particles) away.

Problems associated with the operation of a wet collection system are: (1) corrosion, (2) erosion, (3) dust build-up at the entrance (and other areas) of the collection device, (4) mist elimination, and, (5) sludge disposal.

III. CONTROL EQUIPMENT (Continued)

Review of our sampling data indicates that the design of the collection stage or mist elimination stage of the wet scrubber systems is significant in achieving high collection efficiency. the collection efficiency is directly related to the magnitude of inertial forces that are applied to the conditioned particle.

Wet scrubber systems are classified herein as systems using significant centrifugal forces on the conditioned particle to affect separation and those using water impaction or water sprays to wet and remove the particulate from the gas stream. The wet scrubber systems on asphaltic concrete plants are then classified as a "centrifugal" or "water spray" type system.

The most common spray type wet scrubber systems on asphaltic concrete plants are of the gravity spray tower type (See Fig. 8). The tower may be either horizontal or vertical. Advantages of this type of device are: (1) the ability to handle large volumes of gas with a low pressure drop (1 to 4 inches water), and, (2) low cost. Baffles or packing materials are often placed in the path of the gases traveling through the system to increase the probability of particle contact with water droplets. Collection efficiency is relatively low for particle diameters of 10 microns or less. Centrifugal flow within the spray tower is sometimes incorporated to improve collection efficiency.

Centrifugal wet scrubber systems employ significant centrifugal (cyclonic flow), gravitational and/or directional change forces on a pre-conditioned particle to increase collection efficiency. The secondary control system will usually include a pre-conditioning stage followed by an inertial separation stage. The most common centrifugal separation stage for an asphaltic concrete plant wet scrubber system is a cyclonic separator. Collection efficiencies are higher for centrifugal systems than for those of spray type systems. (Ref. Table II).

The pre-conditioning stages of centrifugal wet scrubber systems are most commonly of the venturi and orifice types. In both devices, the cross-sectional area of the duct carrying the particulate laden gas into the scrubber is reduced, creating a turbulent, high velocity flow. Water is introduced before the restriction and as the gas and water droplets pass through the throat of the venturi or orifice, the turbulance and high gas velocities atomize the droplets into a fine mist, thereby increasing the probability of collision and entrapment of a dust particle in a water droplet. The gas and dust laden liquid then enter the cyclonic separator where the liquid is thrown against the walls by centrifugal forces and drains to the bottom by gravity. The treated gas exits out the top. A venturi scrubber is illustrated in Figure 9.

The baghouse filter has been gaining wide acceptance as a form of dust control equipment by the asphaltic concrete industry. A schematic of a shaker type baghouse appears in Figure 10.

The dust laden gas enters the bottom of the collector (in some baghouses the gas enters the top). As the gas passes through the tubes, the dust is deposited on the fabric, forming a cake. A significant amount of the filtration is accomplished by the dust cake after it has been built up. The primary function of the fabric is to support the cake. As time passes, more dust is deposited on the cake, increasing its thickness, and thus the resistance to gas flow through the cake. When baghouse resistance begins to limit the air flow required to properly ventilate the dryer, the fabric is cleaned by removing the dust cake which is allowed to fall into the hopper. There is a variety of different fabric cleaning mechanisms. In the model illustrated in Figure 10, the top of the fabric tube is attached to a vibrating device and the dust is shaken off the tubes. Normally the tubes are divided into airtight compartments and the compartment being cleaned is isolated from the gas stream. Pulse cleaning mechanisms remove the dust cake by flexing the fabric with compressed air. In other designs, the dirty air is introduced into the "shell" side of the fabric tubes and flows out the inside of the tubes. An air jet cleaning mechanism moves up and down each tube, or pulse jets at the top of the bag dislodge the dust.

The air to cloth ratio (i.e. the bulk velocity of the gas divided by the cloth area) for most shaker type baghouses is in the neighborhood of 2-to-3 acfm per square foot of cloth area. The pressure drop of shaker type systems is approximately 3 to 7 inches of water.

The air-to-cloth ratio for the air pulse and/or jet cleaning baghouses is around 5-to-10 acfm per square foot of cloth. The reduced bag area required for the pulse or jet type baghouse has made the pulse and/or jet type baghouses the most widely used on asphalt plants. The pressure drop of such systems is around 5" to 8" of water.

TABLE II COMPONENT EFFICIENCIES

TYPE	EFFICIENCY RANGE
Primary Collectors:	
Large diameter cyclones	60 - 85%
Small diameter cyclones and multiclones	70 - 95%
Secondary Collectors:	
Spray type scrubber	80 - 97%
Centrifugal scrubber	90 - 99.8%
Fabric filter	95 - 99.9%

IV EFFECTS OF OPERATIONAL ENVIRONMENT UPON EMISSIONS

The operational environment that surrounds an asphalt plant is as critical to the atmospheric emissions as the type of control equipment. Variations in aggregate, in how and when the plant is operated, in the local climatic conditions, frequency of plant relocations, quality of maintenance provided, and the degree of automatic control available, can seriously degrade the operation of the most efficient dust control systems. One of the most important factors required to assure adequate control of atmospheric emissions is a proper working relationship between the owner and local air pollution control authority.

The variations in aggregate type that are most important to the performance of a dust control system are those that relate to the fraction of the total feed that will pass a 200 mesh screen. In most mix specifications the maximum percentage 200 minus allowed is 10%. It is not unusual to encounter fines percentages at the inlet to the dryer varying all the way from under 2% to as high as 20%. The primary cause of this variation is the rock available at various geographical locations. Most states regulate percentage fines approximately as shown in Table I, hence possibly requiring wasting of fines to meet state asphaltic concrete specifications. The atmospheric emission control system, therefore, is required to remove the larger amount of fines while still meeting clean air regulations. Some pit locations simply run high in fine natural material, while the type of rock encountered in other areas is such that fines are heavily produced during normal crushing and screening operations. The latter type of rock (such as basalt) shatter to powder when crushed and also break down significantly when processed through the asphalt plant. The size distribution within the fine fraction is expected to be a significant variable in the efficiency of the emission control system. Some geographical areas are short of fines so dry-type emission control systems solves this problem.

An asphalt plant that operates continuously for several hours will allow better emission control than a plant that is being continually started up and then shut down. The very nature of most particle separation mechanisms requires flow conditions that are reasonably stable with time. Gas and aggregate transient flow conditions that are present during start-up and shutdown tend to cause low efficiency in devices that depend upon inertial forces to produce particle separation.

As a plant starts up, a significant time is required to reach stable temperature and pressure conditions. Before the plant is sufficiently warmed up, the moisture from the aggregate will condense on the cool interior surfaces and the water droplets will travel through the plant. This is an abnormal situation for any dust control device and mud will accumulate in low velocity areas. This moisture problem can be very acute in climatic regions that have wide temperature fluctuations. Insulation of ducting and control equipment may be a necessary measure. Upon shutting down the plant, particles that have been trapped in the system by high velocities will become dislodged by gravity. These particles can then be carried out by the lower velocity gases or will settle in the ducts to be picked up the next time the plant is operated.

The measures necessary to make an asphaltic concrete plant easily portable require some compromises on dust control system design. The most easily identified compromise affects the large diameter cyclones and forces them to have short cones or be replaced on small radius multicones in order to stay under highway height restrictions. Sealing of equipment and scavenging the resultant enclosures is often inconvenient on portable plants and therefore neglected. Power for portable plants is frequently furnished by diesel-electric generator sets which dictate low power consumption types of control systems. Restriction or total absence of adequate water supplies often prevent the use of wet scrubbers. Dry fabric type dust collectors will probably gain their quickest acceptance in portable operations. Adequate control of stockpiles from wind, rejecting of excess fines and incident dust from truck traffic are all special problems that can become more serious at a portable plant site.

Several changes in plant operation are necessary when a fabric type dust collector is added to the plant. An upper limit on operating temperature is introduced where none has been present before. The plant operator has previously been interested only in the rock temperature coming out of the dryer. If that temperature is too low then the burner setting is increased. No attention is given to the temperature coming out of the dryer as evidenced by the burned paint existing on most dryer outlet ducts. Such a philosophy can quickly lead to problems in a plant equipped with a baghouse. Continuous monitoring is required on dryer outlet temperature and baghouse inlet temperature. The installation of a primary collector between the dryer and the baghouse can be debated from a collection efficiency standpoint but other considerations such as temperature and erosion protection make it an absolute necessity. The most significant change to plant operation is the requirement to work within a temperature band that has the dew point as its lower limit and about 400° F. as its upper limit.

Automatic controls on an asphalt plant are important in three areas: (1) the cold feed system, (2) the batching tower, and, (3) the burner. The use of automatic controls can help to quickly stabilize the operation of the plant. Flow conditions for aggregate, fuel, and air are more quickly established and maintained without step changes that disturb the plant system. Plants not having remote controls on the aggregate feed rate must be overfired at the beginning of operation so the first batches of mix will be at the proper temperature. Plants having remote control to the cold feed can gradually increase the feed rate during start-up and thus avoid any slugging of the dryer although in practice this is seldom done. During steady operation, changes in the rock chute temperature out of the dryer can be altered by either changing the feed rate or changing the burner setting. Usually, the burner will automatically keep the rock temperature at approximately 325° F.*

The introduction of better surge and hot storage systems to the asphalt industry has caused a change in the attitude of producers toward the desirable production rate their plants should possess. Without any surge or hot

* Remote controls to the cold feed allow easy changes to the proportioning of the aggregate so the dryer is not drying rock that cannot be used in the mix.

storage capacity, the time required to load a truck was directly dependent upon the production capacity of the plant. Taking 45 seconds as the average time between batches and using a truck payload of 28,000 pounds; a 4,000 pound batch plant will require a truck under the plant for 5-1/4 minutes, while a 10,000 pound batch will require a truck for only 2-1/4 minutes. If the 4,000 pound plant has a surge hopper the truck could probably be loaded in about one minute. Now the capacity of the plant is dictated by the number tons that can be laid on a grade rather than the number that can be hauled away. In theory, the hauling should not influence the desired plant production but in practice the trucks will always tend to bunch up and then sit and wait to be loaded. A surge system can overcomes the bunching problem and allow small capacity plant to be fully utilized, and present less of an emission problem.

Once the design of a dust control system is fixed, the single most important item determining its performance is the maintenance it receives. Periodic maintenance of all plant equipment can prevent failures and prolong control equipment life. The maintenance measures for fabric type dust collectors associated with asphalt operations are only now beginning to be studied. Very little factual data is available concerning the cause of performance degradation. Tightening of bags, adequate caulking between clean and dirty air sides, and careful attention to bag wear appear to be items that must be watched. On wet systems, the eroding of spray nozzles should be checked monthly during the operating season. Rust and corrosion of all duct interiors are always encountered and necessitate patching, lining or replacement on a one to three year cycle depending on the local conditions. The conditions under which asphalt paving mix has been produced are difficult to envision and all equipment must be carefully maintained. A thorough once-a-week inspection is performed by good operators.

V. EMISSIONS

Unpublished stack gas sampling data from 45 asphaltic concrete plants which represent over 100 independent samples has been compiled. The raw test data has been reduced using a computer program based on EPA data calculation techniques. The results of the data reduction are listed in Table A1, along with as much additional information about each plant as was available. Table III summarizes the final particulate concentration and emission factors using the classification of control systems presented previously in Section III.

Note that the concentration data in Table III has a fairly well defined lower limit in the "range of concentration" column and that the median in all cases but one is less than the average concentration. Such relationships in the data lead one to believe that the data is actually fitting a nonsymmetrical or skewed-to-the-right distribution. Also, nonsymmetrical distribution is expected because asphalt plants have more difficulty in achieving a low emission than a high one and because air pollution regulations across the United States vary. Notice also that the lower limit on the range of concentration for the data constituting this study compares fairly close to Los Angeles Air Pollution Control District data several years ago which is an indicator of a lower limit on currently available control technology.

The data analyzed in this study was collected primarily to establish current emission factors on asphaltic concrete plants. Approximately half of the data originated from tests prior to modifying the dust control system. Therefore, the data represent current emission from asphaltic concrete plants across the country.

The typical asphalt plant that operates outside of aggressive air pollution control regions has rather elementary dust control equipment. A large diameter cyclone or a pair of such cyclones is typically followed by a low pressure spray chamber. The removal of the wetted dust is done by injecting the flow tangentially to a large diameter stack. The resulting cyclonic flow at the stack exit plane is thus quite common. The accurate measurement of gas velocity and the subsequent calculation of gas flow are subject to significant errors when such cyclonic flow conditions exist. Representative particulate concentration data can be collected from cyclonic flow stack by carefully designed sampling procedures.

It has been recommended by Cooper and Rossano* that cyclonic flow stacks be sampled at an angle from the duct centerline and at a velocity discovered by the maximum deflection of the pitot tube. However, it is also known that the maximum deflection across a "S" type pitot tube occurs at 10-15° offset from the true direction of flow. Therefore, the authors recommend that cyclonic flow stacks be sampled by establishing the average vertical velocity component by measuring the gas flow at a more desirable location in the ductwork. The sampling rate in the cyclonic flow stack can then be set at a constant rate or varied across the duct in proportion to the velocity reading recorded by the pitot tube during sampling. The vertical velocity component is assumed to be the same as the vertical particle velocity as it enters the nozzle so representative sampling velocities can best be maintained.

* Cooper, H.B.H., Jr., Rossano, A.T., Source Testing for Air Pollution Control, Pg. 56, Environmental Science Services, Wilton, Conn.

TABLE III

STATISTICAL SUMMARY OF EMISSION DATA

Type of Control System	Number of Plants	Average Concentration (gr/scf)	Median Concentration (gr/scf)	Range of Conc. (gr/scf)	Standard Deviation (gr/scf)	Average Emission Factor (lb/ton product)	Standard Deviation (lb/ton product)
SPRAY TOWERS	20	0.57	0.31	0.06-2.07	0.582	0.649	0.5672
CENTRIFUGAL SCRUBBERS	20	0.24	0.20	0.04-1.34	0.3385	0.278	0.2949
BAGHOUSE	5	0.15	0.14	0.05-0.31	0.1053	0.134	0.0811
LOS ANGELES DATA*							
"BAFFLED TOWER SCRUBBERS"	8	0.22	0.16	0.13-0.60	0.1551		
"CENTRIFUGAL WET SCRUBBERS"	17	0.14	0.15	0.07-0.21	0.0516		

* Danielson, Los Angeles Air Pollution Engineering Manual, p. 331, USPHS Publication 999AP42

In order to determine the pollutant mass rate in cyclonic flow processes, the gas flow rate must be determined at some other location in the system where more favorable flow conditions exist. Rarely will these more favorable flow conditions meet suggested requirements for distances from the last flow disturbance. Experience from the field evaluations in this study indicate that errors are encountered by using an "S" type pitot tube in cyclonic flow. Velocity readings can be high by a factor of two or three depending on the degree of cyclonic flow.

Asphaltic concrete plants are one of the most difficult industrial sources from which to evaluate atmospheric emissions. It is extremely costly and often impractical to sample a 10 foot diameter stack at 8 diameters from the last obstruction, especially if the stack itself serves as part of the control system.

Dual train source sampling was performed on five plants as an addition to this study. A summary of the tests is shown in Table AII. An EPA source sampling train and Los Angeles source sampling train were used simultaneously in obtaining these results. The two sampling trains used on the additional five plant evaluations are shown in Figures 11 and 12. Clean-up and analysis of the two trains was performed as described in the Appendix. A discussion on the sampling and the reports are included in the Appendix.

Capacities were verified by spot production calculations. The controls systems were in average states of repair and the plants were operated at normal production rates. The data, therefore, represents results that are obtained during day-to-day operations of control systems using recent technology. The plants could perform better with more extensive maintenance programs.

Asphaltic concrete plants often operate on a very cyclic schedule. Start-up and shut-down of the system and sampling train does not favor collection of long duration stack gas samples. Careful coordination was made to avoid shutting down the sampling trains during a test, but the sampling on most of the plants was necessarily interrupted at least once or more, especially on the batch type plants.

Baghouse control systems appeared during our evaluation to have a less equivalent opacity emission than the emissions from wet scrubber systems. Note that the concentration (gr/scf) from the wet scrubber system (Plant #3) in Table AII was less than the concentration from a well-controlled (Plant #2) baghouse system while the equivalent opacity was greater from the wet scrubber system. The limited possibility that an unrepresentative sample may have been obtained from the cyclonic flow wet scrubber system could also explain the difference in emission concentration.

It has been shown that a given concentration of small size particles have a greater light scattering effect (i.e., they are more noticeable) than an equivalent concentration of large size particles. Such a light scattering phenomenon of small particles may help to account for the more noticeable visual effect from wet scrubber systems versus baghouse systems.

V. EMISSIONS (Continued)

It is suggested that the particle sizes emitted by baghouses (installed on asphalt plants) are larger than the particles emitted by wet scrubber systems. The fabric must flex (i.e., by shaking, reverse air, pulse jet, etc.) to properly dislodge the collected material from the bags. This flexing action could sift material through the fabric to the "clean" air side. The wet scrubber system, by virtue of the inertial forces that are exerted on the particulate for removal, definitely tend to remove the larger size fraction more readily from the air stream. This would explain the observations made during the testing and the resulting grain loadings that were calculated.

Estimation of emissions can be determined by establishing the plant flow rate and then applying an average concentration to the stack gases entering the atmosphere. Concentration times flow rate will then yield a pounds/hour of emission. A regression analysis to determine scfm versus given plant production has been performed on the data in this study and is shown in Figure 13. The average concentration values for the control systems as defined in Section III are listed in Table III. An emission can also be calculated by measuring the plant production rates, classifying the type of control system as listed in Section III and then multiplying the production by an emission factor (lb/ton) as listed in Table III. In addition to the emission factors listed in Table III, engineering judgment has been exercised to suggest reasonable particulate emission factors for asphaltic concrete plants. The suggested emission factors are listed in Table IV.

Hydrocarbon emissions from asphaltic concrete plants are not considered to be a problem. Asphalt is a heavy Distillate from the refinery process leaving only trace amounts of low vapor pressure hydrocarbon compounds available to enter the atmosphere. An article by Von Lehmden, Hangebrauck, and Meeker (2) list total polynuclear hydrocarbon emission factors of 1.1 mg/ton of product without control and 0.35 mg/ton of product after a wet scrubber control system. The asphaltic concrete plant evaluated for these numbers vented the pugmill into the nuisance dust control system.

Hydrocarbon vapors from heated asphalt storage tanks can be adequately controlled by fluted, air-cooled vent pipes. Hydrocarbon emission released from loading asphaltic concrete into the trucks can be vented into the dryer. Several methods of introducing the hydrocarbons into the dryer for combustion have been tried but more development work is required.

Particle size data is available in the Los Angeles County Air Pollution Engineering Manual and some was included in this study. Particle size distribution by mass using an Anderson sampler and particle size by count from filter catches on wet scrubber systems has been included in the Appendix. More work should be performed to generate additional particle size data.

2. Von Lehmden, D.J., Hangebrauck, R.P. & Meeker, J.E. Polynuclear Hydrocarbon Emissions from Selected Industrial Processes; Journal of the Air Pollution Control Association, Volume 15, No. 7, July 1965.

TABLE IV

SUGGESTED PARTICULATE EMISSION FACTORS FOR ASPHALTIC CONCRETE PLANTS

(pounds per ton of product)

Source and Type of Control	Emission Factor
Rotary Dryer	
Uncontrolled*	50
Precleaner	20
High-efficiency cyclone	5
Multiple centrifugal scrubber	0.2
Baffle Spray Tower	.3
Orifice-type or venturi scrubbers	.10
Baghouse	.075
Other Sources (Vibrating screens, hot aggregate bins, aggregate weigh hopper and mixer) Uncontrolled.	1.0

* Almost all plants have at least a precleaner following the rotary dryer to return fines for the asphaltic concrete.

VI COST OF CONTROL

The cost of effective dust control systems or equipment covers a wide range. The major variable in determining accurate cost figures is the variation of installation costs. The costs of the bare equipment can be determined on the basis of air flow data. The most frequently used parameter to express the cost of various types of equipment is dollars per actual CFM ($/ACFM). Shown in Table V are cost ranges for complete dust control systems starting from the dryer outlet and including the exhaust fan and dust augers. The systems are categorized by the type of final cleaning equipment in the system.

TABLE V

DUST CONTROL SYSTEM COSTS

TYPE OF SECONDARY CONTROL EQUIPMENT	SYSTEM COST ($/ACFM)
Spray Tower	1.00 - 1.75
Centrifugal Scrubber	1.25 - 2.00
Fabric Collector	2.50 - 4.00

In considering equipment to retrofit an existing dust control system, the cost of major components are only a part of the overall cost. Changes in ducting, changes in fans or fan motors, changes in dust augers and then the electrical changes in the power and control system cause large differences in final cost. For instance, a bare baghouse can be obtained for $1.00/ACFM from many manufacturers. By the time that baghouse is installed the cost will be around $2.00/ACFM. Wet scrubbers can be built for as little as $.30/ACFM but again the ductwork, water supply, and pond system can double or triple this figure.

Maintenance and operating costs are difficult to obtain accurately. Dry fabric collectors are only now beginning to build up enough operational time that intelligent bag life estimates can be made. The increase in demand for "Nomex" material has reduced the price of bags by 15% and 20% recently. However, when compared with the problems associated with ponds and sludge disposal over a bag life of five years the costs are about even. High pressure drop in the wet scrubber results in higher operating costs but in most instances the amount is not important. The most accurate statement about which type of system is best is, "It depends..." Even experienced personnel approach each different plant with no preconceived solutions.

VII SUMMARY & CONCLUSIONS

This study indicates that the average emissions from spray towers is 0.64 lb/ton, from Centrifugal scrubbers is 0.28 lb/ton and from baghouses is 0.13 lb/ton of asphaltic concrete produced. Engineering judgment indicates that the emission from well-designed spray towers is 0.3 lb/ton from centrifugal type is 0.10 lb/ton and from baghouses is 0.075 lb/ton of asphaltic concrete produced.

Baghouses included in the summary and evaluated in this contract have been shown to be less efficient than anticipated. Baghouses offer solutions to certain asphaltic concrete procedure problems, (e.g. shortage of water or adequate space for settling ponds). Extensive, careful maintenance is required for the baghouses to perform to expectation.

Comparative stack gas sampling with LA and EPA sampling trains was inconclusive. The LA train measured higher emissions on four baghouse systems and lower on one wet scrubber system. The authors believe that a difference in particle size distribution of the emissions from the baghouses and wet scrubbers may account for the difference in opacity.

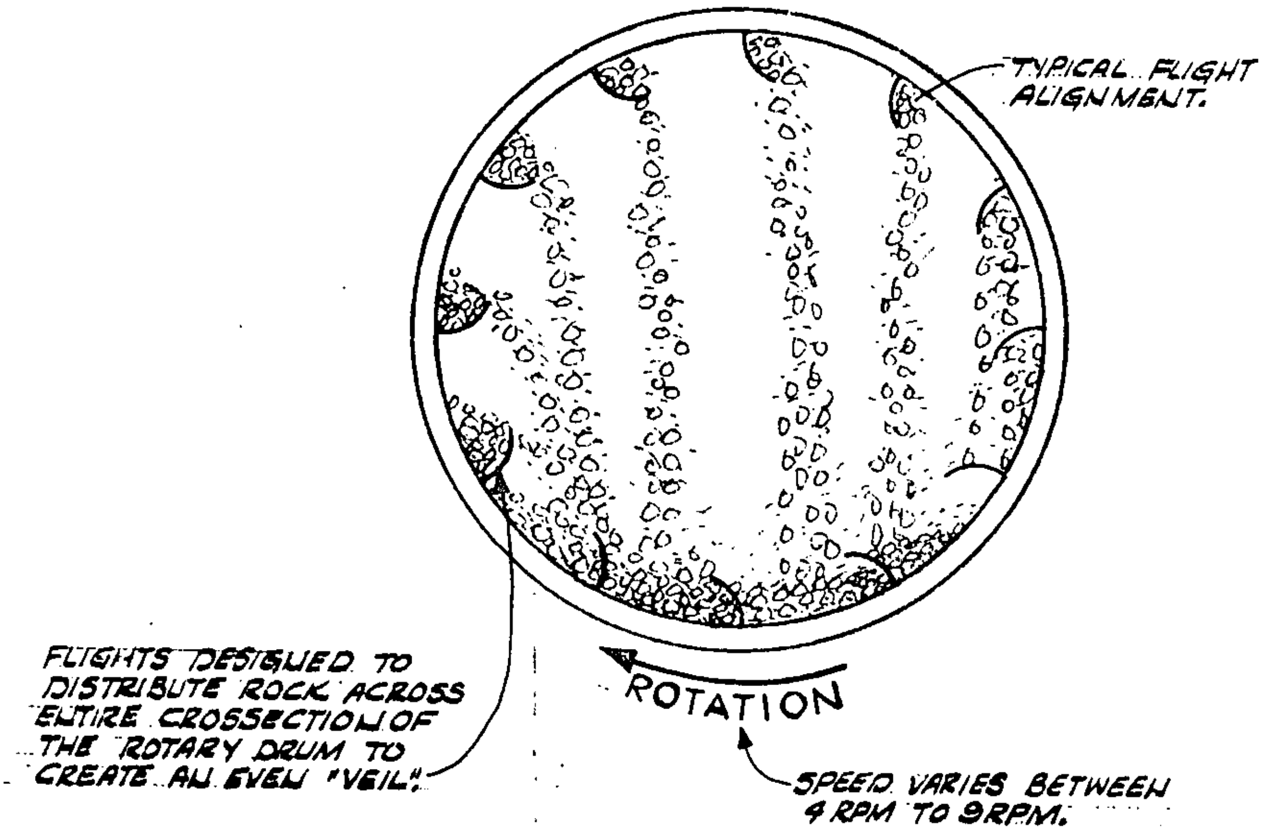


FIG. 1: SECTION THROUGH ROTARY DRIER

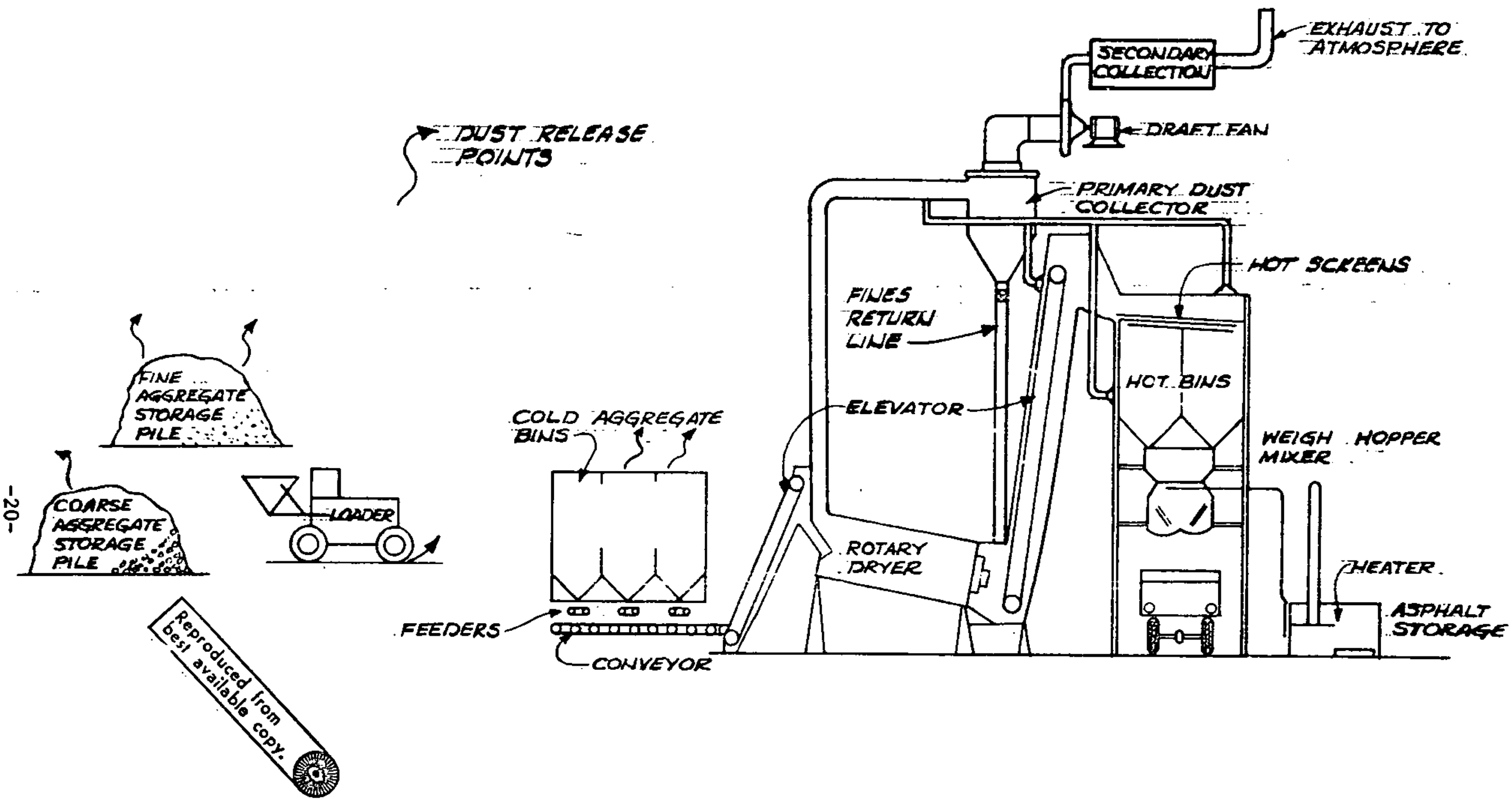


FIG. 2: HOT MIX ASPHALT BATCH PLANT

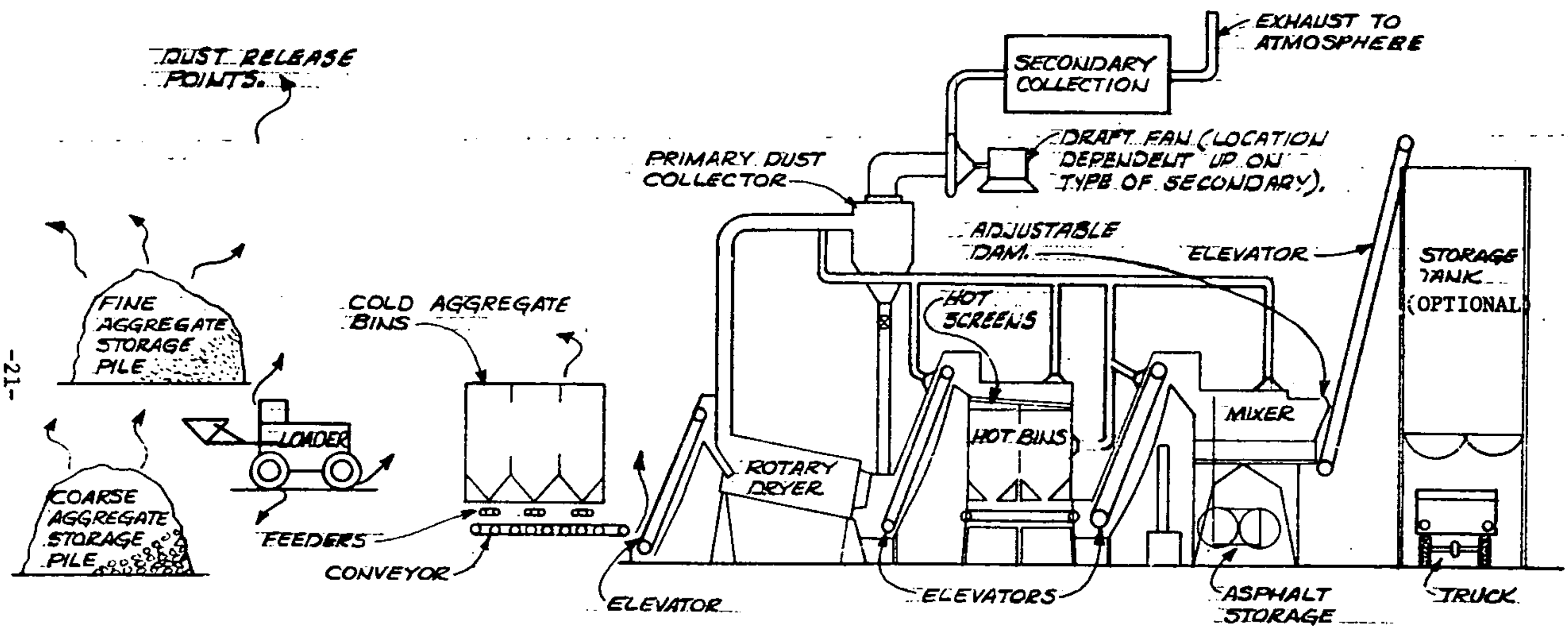


FIG. 3: CONTINUOUS HOT MIX ASPHALT PLANT

DRYER PRODUCTION CAPACITY

VS.

DRUM GAS VELOCITY

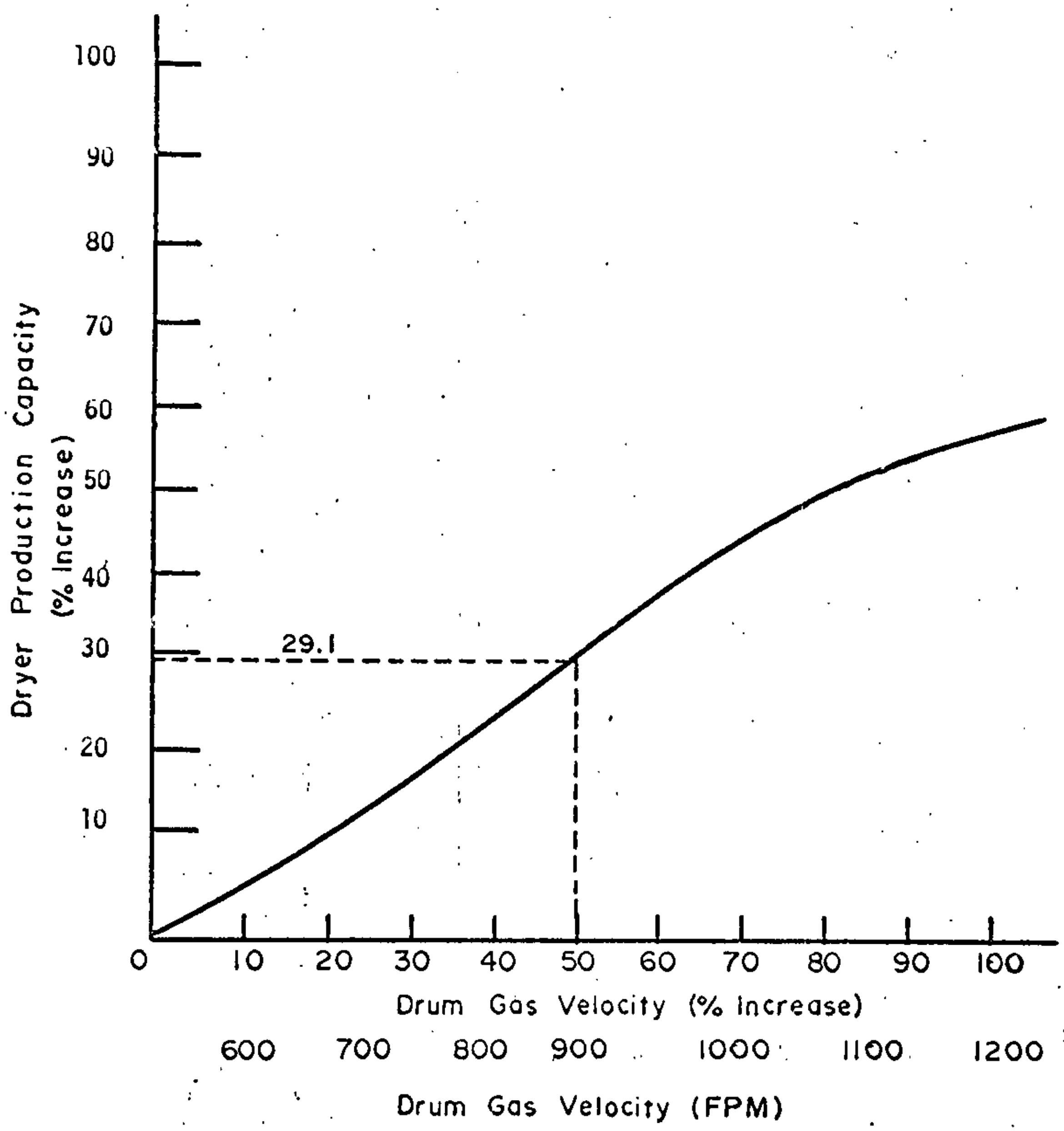


FIGURE 4

Source: Loquercio, P.S. and Skinner, C.F., "Abating Pollution from Asphalt Mixing Plants, Especially by Means of Baghouses", not yet published.

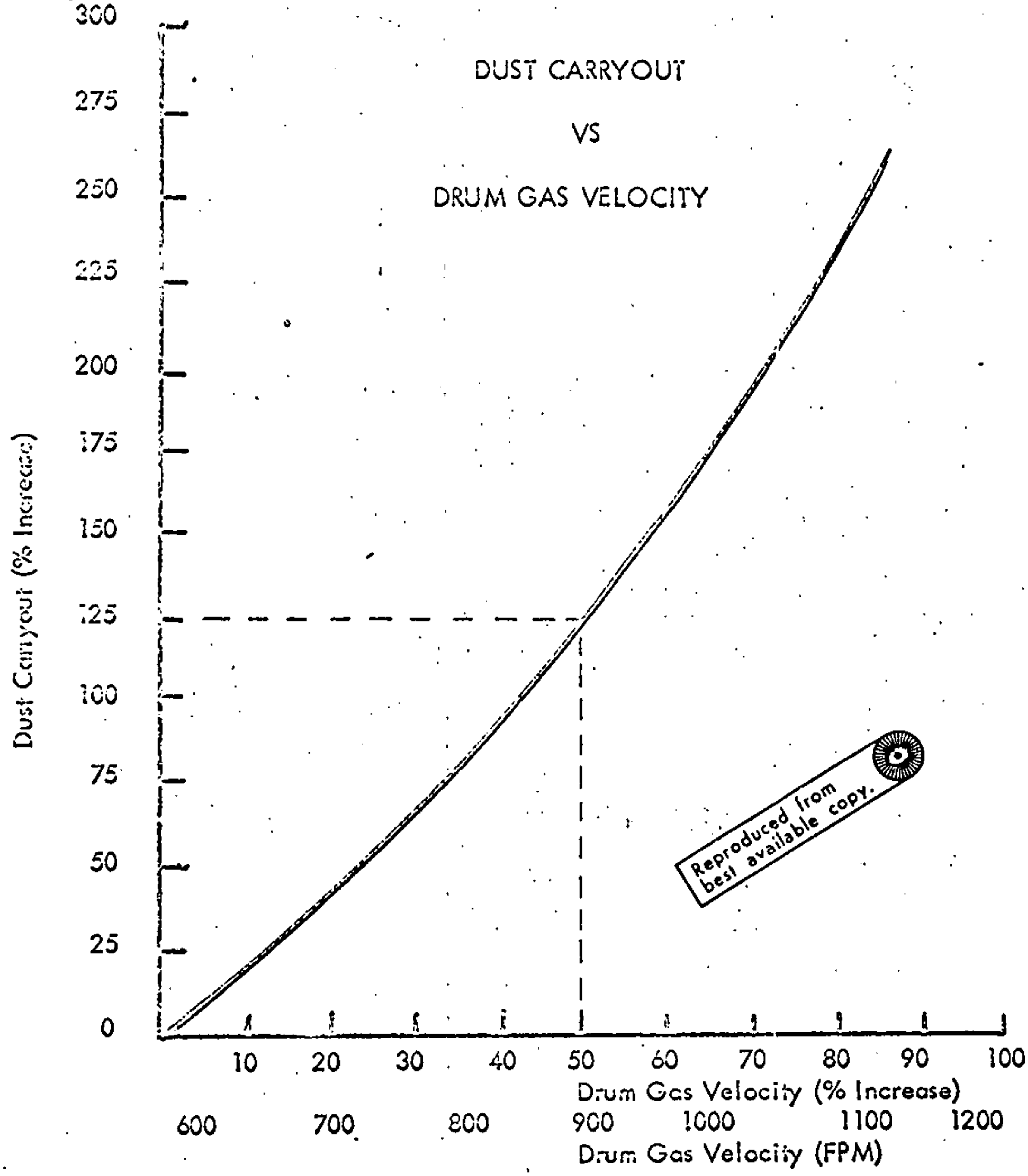


FIGURE 5

Source: Loquercio, P.S. and Skinner, C.F., "Abating Pollution from Asphalt Mixing Plants, Especially by Means of Baghouses", not yet published.

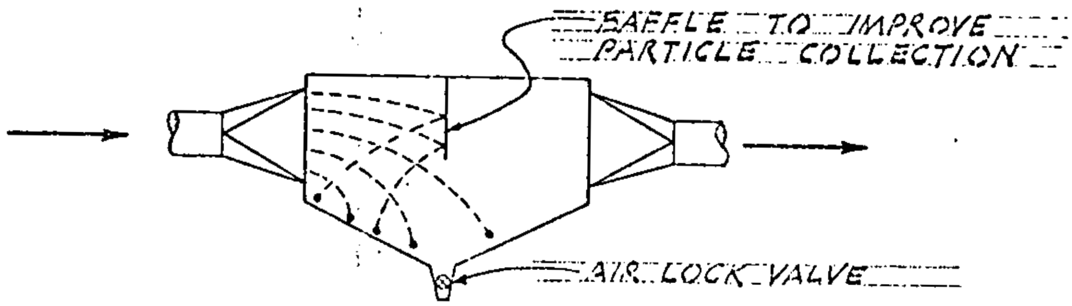


FIGURE 6: SETTLING CHAMBER

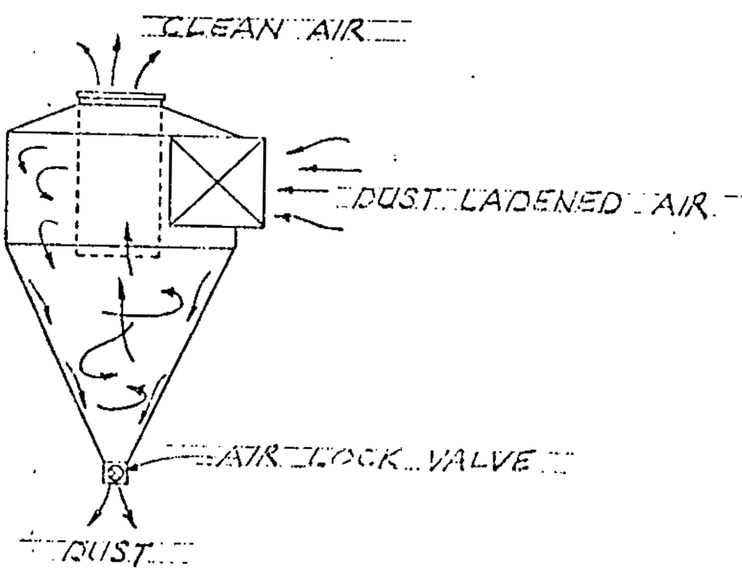


FIGURE 7: CENTRIFUGAL COLLECTOR

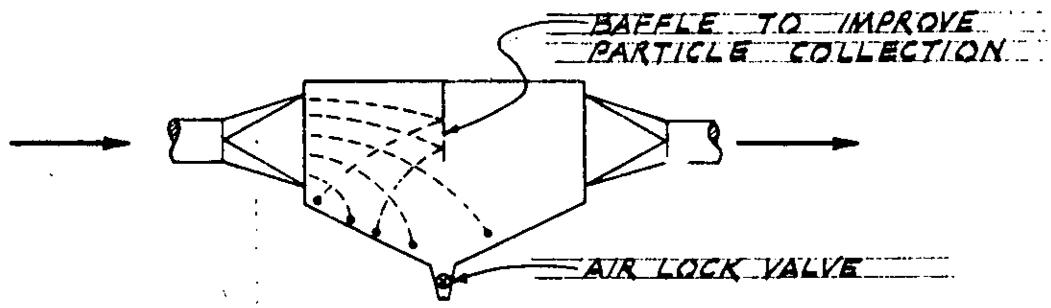


FIGURE 6: SETTLING CHAMBER

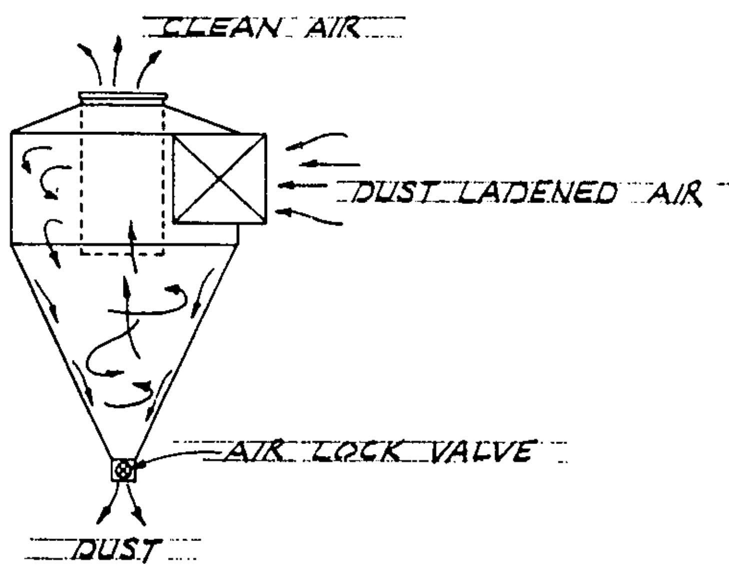


FIGURE 7: CENTRIFUGAL COLLECTOR

Source: National Asphalt Pavement Association

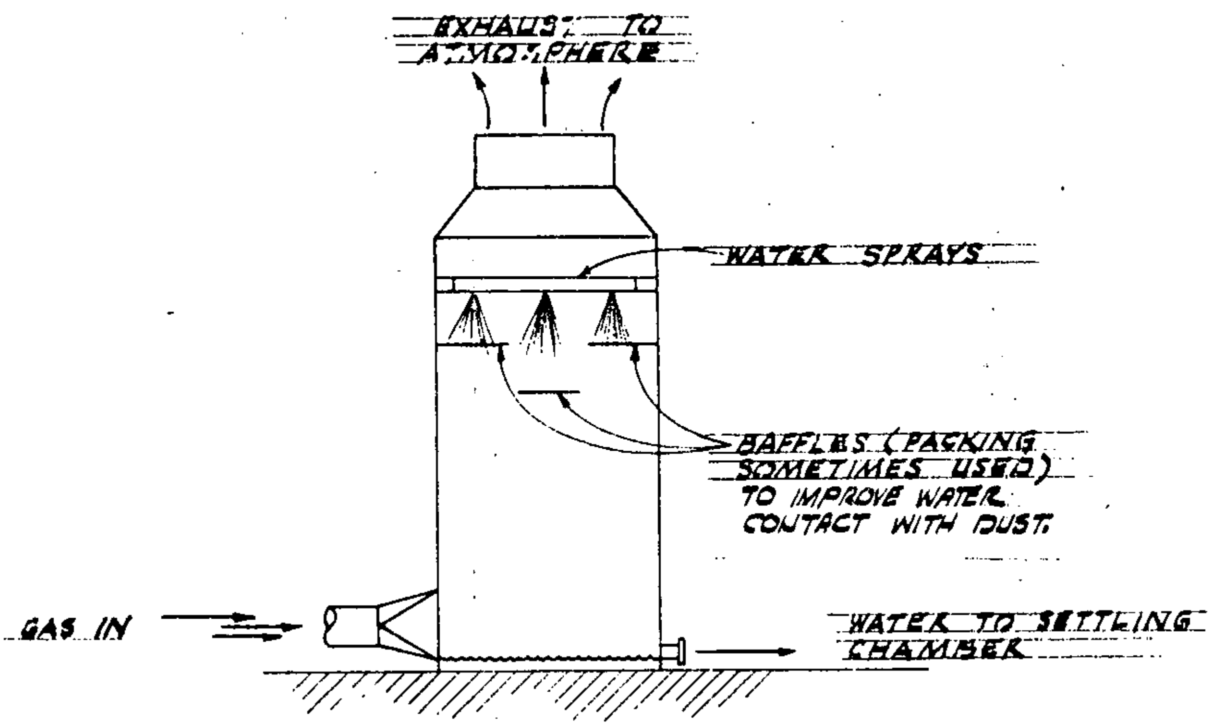


FIGURE 8: GRAVITY SPRAY TOWER

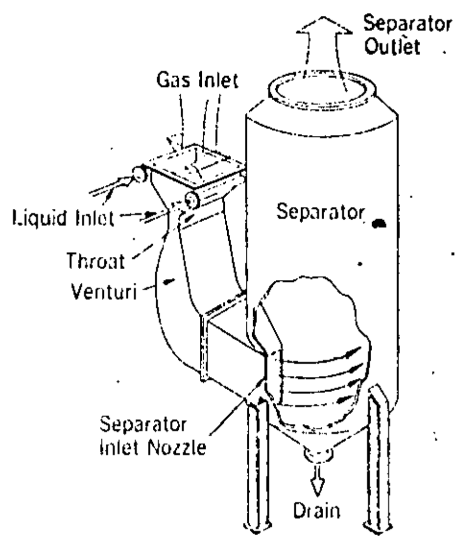


FIGURE 9: VENTURI WET SCRUBBER

Source: National Asphalt Pavement Association

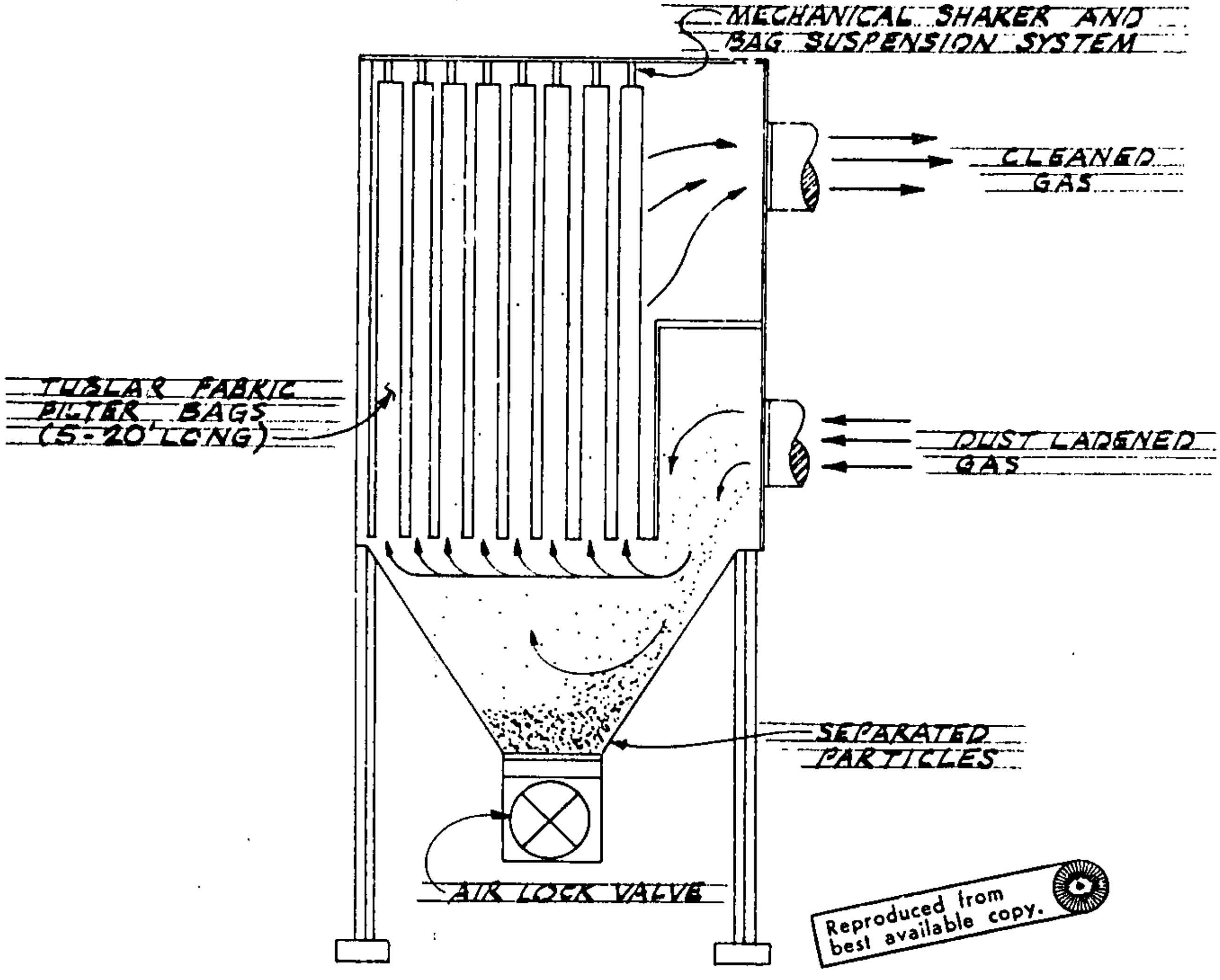


FIGURE 10: SHAKER TYPE BAG HOUSE

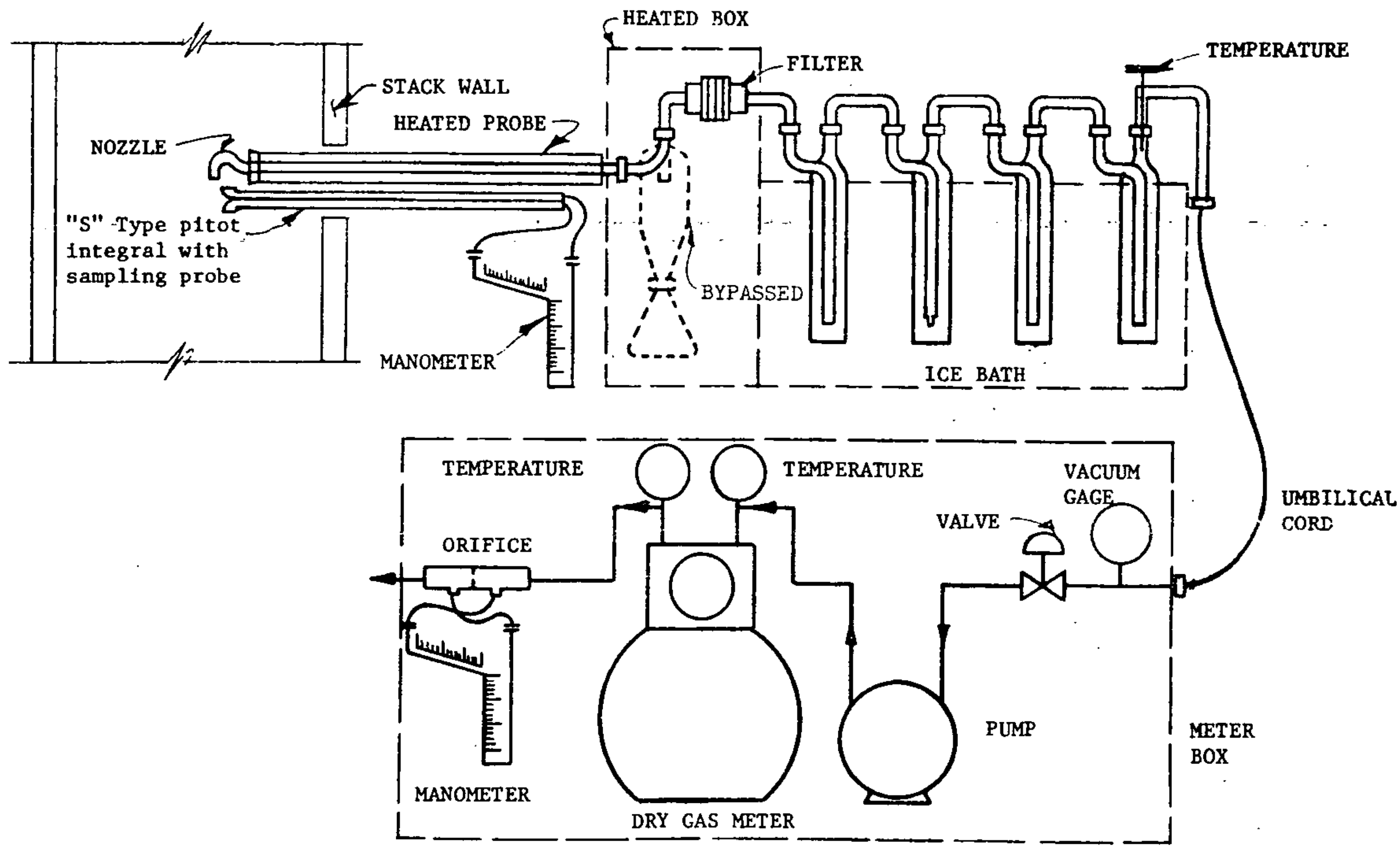


FIGURE 11 "EPA" STACK GAS SAMPLING TRAIN

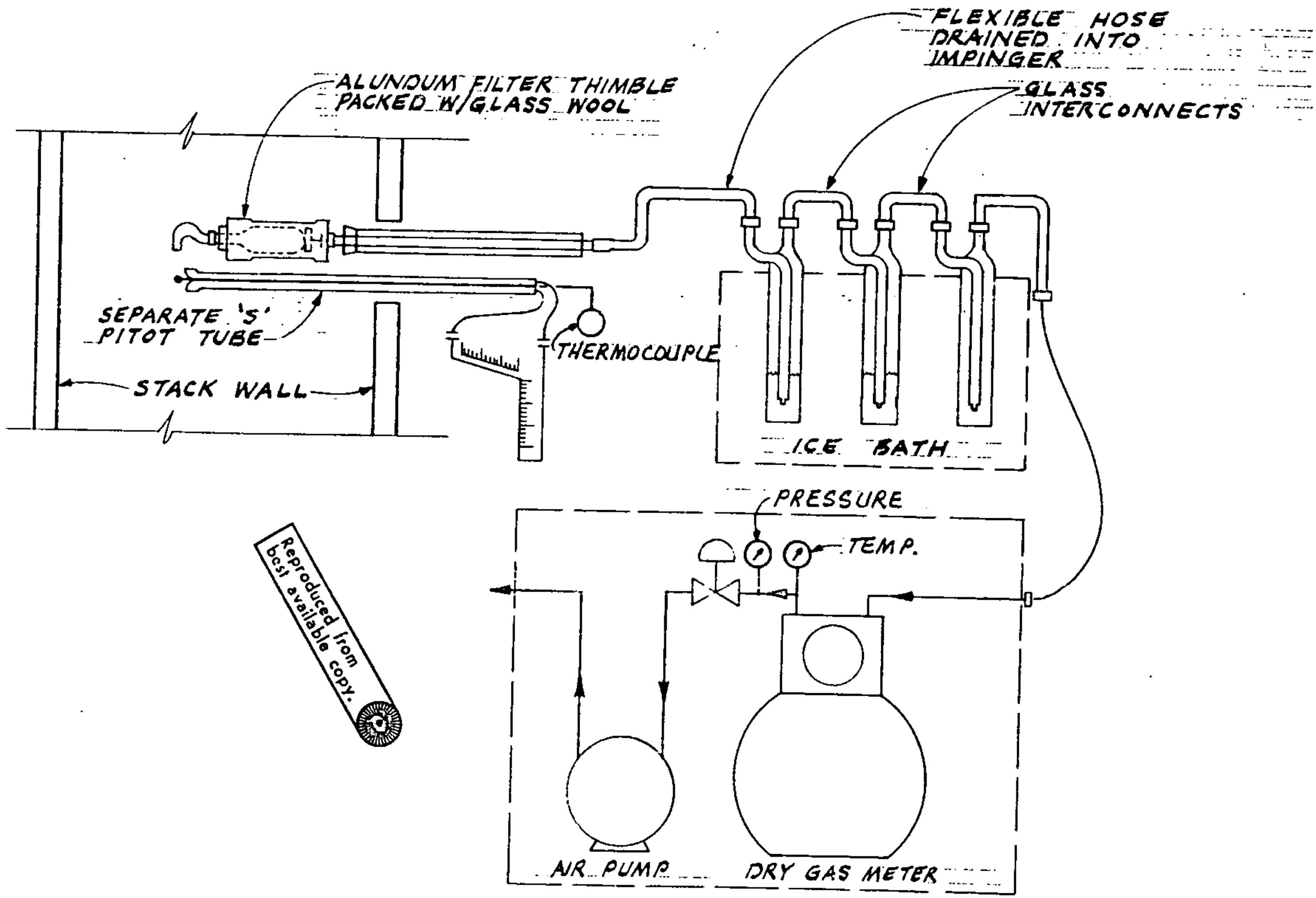
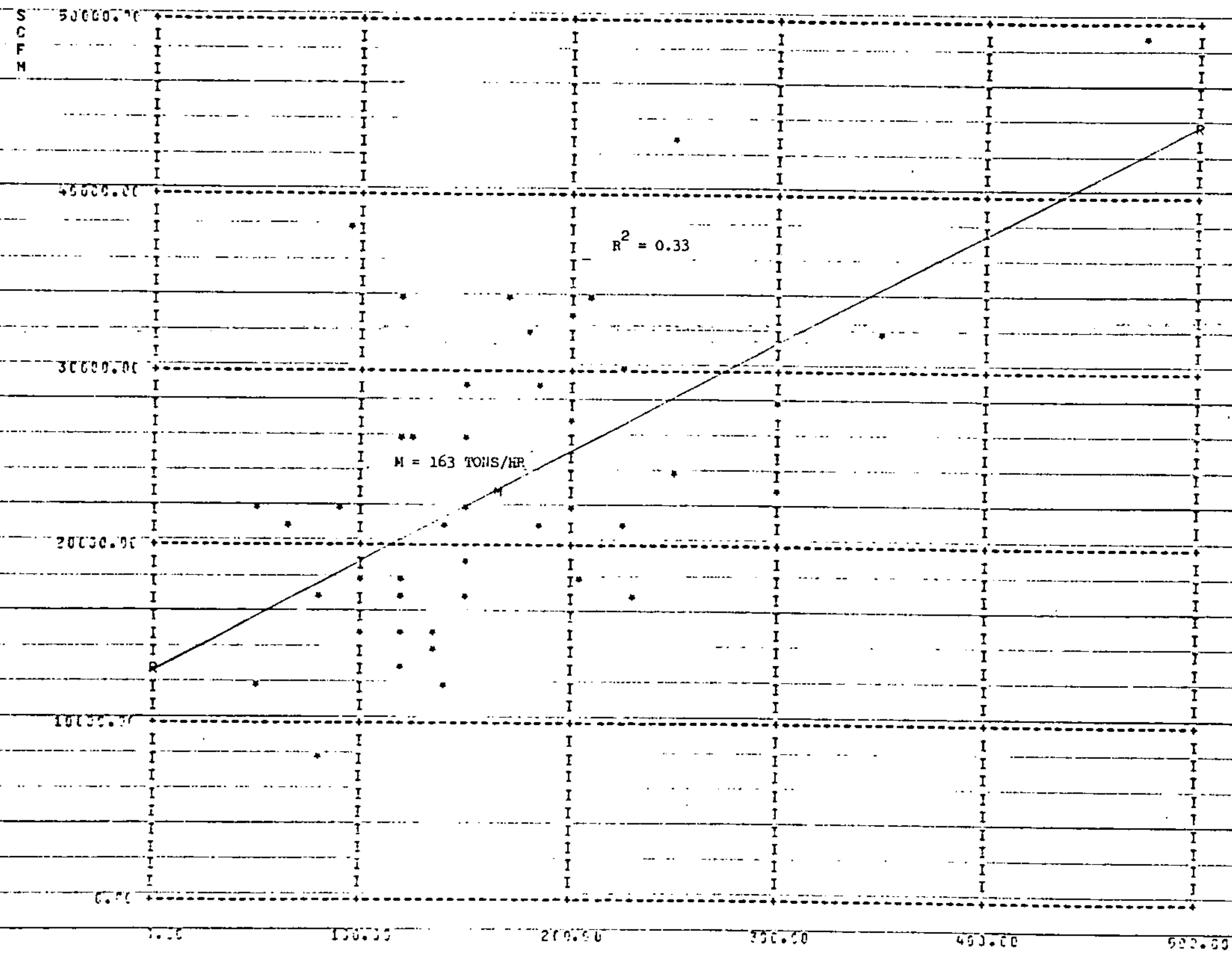


FIG. 12: LOS ANGELES(LA) STACK GAS SAMPLING TRAIN

THE VALUES AND GRAPH BELOW ARE THE REGRESSION WITH THE GREATEST EXPLAINED VARIATION.
REGRESS SCFM (DRY) ON PRODUCTION



CONNECT THE *R* AT MINIMUM OR MAXIMUM VALUE OF PRODUCTION WITH THE MEAN *M* TO OBTAIN REGRESSION LINE.

FIG. 13 – REGRESSION ANALYSIS OF SCFM ON PLANT PRODUCTION

TABLE AII- SUMMARY OF COMPARATIVE EMISSION SAMPLING WITH LA* AND EPA* TRAINS ON ASPHALTIC CONCRETE PLANTS

PARA-METER	PLANT NO. 1 - BAGHOUSE				PLANT NO. 2 - BAGHOUSE				PLANT NO. 3 - WET SCRUBBER				PLANT NO. 4 - BAGHOUSE				PLANT NO. 5 - BAGHOUSE			
	EPA		LA		EPA		LA		EPA		LA		EPA		LA		EPA		LA	
	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2
VOL_{STD}	66.85	63.17	82.19	79.47	42.49	41.32	60.73	59.44	27.63	27.47	24.60	22.61	25.37	19.59	42.52	39.61	25.06	24.86	40.33	37.97
M	32.10	31.46	29.50	30.00	33.22	32.76	32.87	32.17	6.31	9.04	4.09	7.14	16.68	16.49	15.15	18.55	25.21	26.47	23.66	26.11
Q_{os}	23,833	23,983	25,531	25,275	12,179	12,395	12,754	12,744	34,990	35,049	36,100	36,235	19,737	19,759	17,072	16,507	12,779	12,596	14,356	13,966
A_n	0.000341		0.000507		0.000341		0.000507		0.001364		0.000881		0.000 229	0.000 192	0.000507		0.000341		0.000507	
I	121.32	118.68	98.93	98.50	111.97	106.99	105.00	105.08	94.68	92.06	126.48	117.07	82.48	76.05	71.24	69.18	94.30	94.90	95.07	90.68
P_T	1017.3	652.3	2009.1	1899.9	204.8	182.5	352.6	328.1	78.7	87.8	47.7	58.2	192.3	167.4	459.1	490.4	208.0	234.8	368.8	433.5
C'	0.26	0.23	0.37	0.36	0.08	0.07	0.09	0.09	0.04	0.05	0.03	0.04	0.11	0.12	0.14	0.16	0.12	0.14	0.13	0.17
C'_{AVG}	0.245		0.365		0.075		0.09		0.045		0.035		0.115		0.15		0.13		0.15	

* LA (Los Angeles) and EPA (Environmental Protection Agency, Office of Air Programs) stack gas sampling trains were operated simultaneously on each plant.

BIBLIOGRAPHY

Aase, Glen D., "Dust Control of the Hot-Mix Asphalt Plants" - Unpublished Report June, 1961.

Barber-Greene Company, Bituminous Construction Handbook - Aurora, Illinois (1963).

Berg, Dave B. & Underwood, Lowell - "Dust Filter Reclaims 10,000 lb./hr. of Hot Asphalt Plant Aggregate". Chemical Processing 31 4, No. 47:66 (April 1963)

Danielson, J.A. Ed., Air Pollution Engineering Manual, National Center for Air Pollution Control. PHS Publication No. 999-AP-40, Cincinnati, Ohio, 1967.

Environmental Engineering, Inc. Asphalt Batch Plants. Report prepared for the EPA Contract No. CPA 70-142, Task Order No. 2. March 15, 1971.

Environmental Protection Agency "National Ambient Air Quality Standards - Part II". Federal Register 36:No. 7, 6687-6694 (April 7, 1971).

Environmental Protection Agency "National Primary & Secondary Ambient Air Quality Standards." Federal Register 36:No. 84, 8186-8194 (April 30, 1971).

Friedrich, H.E. "Air Pollution Control Practices & Criteria for Hot-Mix Asphalt Batch Plants" - Proceedings of 62nd APCA Convention - June 22-26, 1969 (APCA Paper No. 69-160).

Herod, Buren C., "NCSA's Dust Control Seminars Reflect Industry's Concern with Effective Measures". Pit and Quarry 61, No. 12:118-124 (June 1969)

Holton, John T., "Portable Filter Baghouses for Mobile Asphalt Plants." Filtration Engineering (Nov. 1969).

Ingels, R.M., Shaffer, N.R., and Danielson, J.A. "Control of Asphaltic Concrete Plants in Los Angeles County." JAPCA 10, No.1:29-37 (Feb. 1960).

Larson, Thomas D., Portland Cement & Asphalt Concretes - McGraw-Hill Book Co., New York, 1963 282pp.

Loquercio, Peter A. & Skinner, Charles F. (Environmental Pollution Control Systems Inc.). "Abating Pollution from Asphalt Mixing Plants Especially by Means of Baghouse." (Not yet published).

Lundberg, G.R. (Barber-Greene Co. Aurora, Illinois) "Summary of Dust Collection Systems in Asphalt Plants." Proceedings of the 10th Annual Convention of the National Bituminous Association, Feb. 3, 1965.

Modern Power and Engineering. "Asphalt Plant Beats Dust Problems". 63,No. 6:76-77, (June 1963)

National Asphalt Pavement Association, Environmental Pollution Control of Hot Mix Asphalt Plants - Information Series 27, 22pp.

National Asphalt Pavement Association - Correspondence to Office of Associate Commissioner, Air Pollution Control Office, EPA.

National Asphalt Pavement Association, Guide for Air Pollution Control of Hot-Mix Asphalt Plants, Information Series 17, 25 pp.

National Asphalt Pavement Association, Model Air Pollution Ordinance for Hot-Mix Asphalt Plants - Information Series 17A, 10pp.

National Oceanographic & Atmospheric Agency, "Crushed Glass Plus Asphalt Equals Glasphalt - A Sparkling New Pavement" - Pollution Abstracts (April 1971).

Perov, O.B. & Boris, D.M., Dust Discharged by Plants Producing "Cold Asphalt", and Its Effect on the Sanitary Conditions of Residential Localities (Translated from Russian)

Research Triangle Institute, "Asphalt Batching" Comprehensive Economics Cost Study of Air Pollution Control Costs for Selected Industries & Selected Regions. Sub Report I-7 Contract 22-69-79 Project OV-455 (June 26, 1965).

Research Triangle Institute, "Asphalt Batching Industry". Economic Cost Study of Air Pollution Control Costs for Selected Industries & Selected Regions, Appendix Q Contract 22-69-79 Project OV-455.

Roads & Streets; "Bay Collectors Meet Chicago Pollution Control". 12,No. 7:97-98 (July 1969)

Schell, T.W., "Cyclone/Scrubber System Quickly Eliminates Dust Problem." Rock Products 71 No. 7:66-68 (July 1968).

Shannon, Larry J. & Vandegrift, A. Eugene, "Particulate Pollution & Its Control" A publication by the Midwestern Research Institute.

Skinner, Charles F. (Skinner Engineering Company) "New Use for Baghouse Filter: Handling Hot Effluent". Plant Engineering. June 26, 1969 pp. 57-59

VonLehmden, D.J., Hangebranck, R.P. & Mecker, J.E. "Polynuclear Hydrocarbon Emissions from Selected Industrial Processes". JAPCA 15, No. 7:66-68

Vandegrift, A.E., Shannon, L.S., Sullee, E.E., Gorman, P.G. & Park, W.R. - "Particulate Air Pollution in the United States" JAPCA 21, No. 6:321-328 (June, 1971).

Weimer, Dr. Ing. Peter "Dust Removal from the Waste Gases of Preparation Plants for Bituminous Road - Building Materials". Staub-Reinhalt-Luft 27, No. 7:9-22 (July 1967).

APPENDIX

TABLE AI - Summary of Emission Data

TABLE AII - Summary of Comparative Emission Data

List of Data Contributors & Sampling Procedures

Discussion on Comparative EPA-LA Emission Sampling

Atmospheric Emission Evaluation Reports

Plant #1

Plant #2

Plant #3

Plant #4

Plant #5

Clear-up & Analysis (EPA Train)

Clean-up & Analysis (LA Train)

Computer Program Equations and Term Definitions

Particle Size Data - Wet Scrubber Systems

By Mass

By Count

TABLE A1

SUMMARY OF PLANT EMISSIONS

PLANT*	CAPACITY	PROD. RATE	RAW MAT'L. (% PASS. 200 MESH)	GAS FLOW RATE	GAS VEL. IN DRYER	PRIMARY COLLECTION					SECONDARY COLLECTION				EFFICIENCY PERCENT BY WEIGHT	EMISSION FACTOR
						TYPE	INLET		OUTLET		TYPE	Water/Air or Air/Cloth	OUTLET			
							PMR	C'	PMR	C'			PMR	C'		
	TON/HR	TON/HR		SCFM	FT/MIN		#/HR.	gr/scf	#/HR	gr/scf			#/HR	gr/scf		LB PER TON PRODUCTION
JC-1	160	150'		17151	785	8 ft.ØCyclone	11423	87.4 81.7	2233 1909	13.1 12.6	Wet Cyclonic Scrubber	13 gal/mscf				
JC-2	150	150'		21872		Cyclone (long cone)					Low Energy Scrubber		390	2.07		2.60
JC-3	300	300		28405	850	36" Multiple Cyclones			515 448	2.2 1.8	Orifice Scrubber ΔP = 8.0	25 gal/mscf	59 67	0.24 0.27	89% 85%	0.20 0.22
JC-4	150	150'		29374	870	Triple large Ø Cyclone					Centrifugal Scrubber ΔP = 5.3"	12.5 gal/mscf	21 20	0.08 0.08		0.14 0.13
JC-5	150	150'		18567	480	Twin 8' Ø Cyclones	30619	193.4	3374	19.2	Scrubber	11 gal/mscf				
JC-6	120	120'		14966	605						Scrubber ΔP = 8"		132 128	0.97 1.06		1.10 1.07
JC-7	250	250'		43012	860	12 36" Ø Cyclones					Centrifugal	6 gal/mscf	105 110	0.28 0.30		0.42 0.44
JC-8	80	80'		17003	1130	Single Long Cone					Cyclonic Scrubber		31.7 25.4	0.22 0.17		0.40 0.32

' APPROXIMATED FROM PLANT CAPACITY

* See Data Contributor's List for key to symbols.

TABLE A1

SUMMARY OF PLANT EMISSIONS

PLANT *	CAPACITY	PROD. RATE	RAW MAT'L. % PASS. 200 MESH	GAS FLOW RATE	GAS VEL. IN DRYER	PRIMARY COLLECTION					SECONDARY COLLECTION				EFFICIENCY PERCENT BY WEIGHT	EMISSION FACTOR
						TYPE	INLET		OUTLET		TYPE	Water/ Air or Air/Cloth	OUTLET			
							PMR	C'	PMR	C'			PMR	C'		
	TON/HR	TON/HR		SCFM	FT/MIN		#/HR.	gr/scf	#/HR	gr/scf			#/HR	gr/scf		LB PER TON PRODUCTION
JC-9	120	120'		15404	590	10' Ø Long Cone & Multicone					Centrifugal		31.7 29.6	0.24 0.23		0.27 0.25
JC-10	80	80		7582	650	8' Ø Cyclone Multicone					Centrifugal Scrubber		8.9 8.5	0.13 0.13		0.11 0.11
JC-11	120	120		17433	850	Single Cyclone	16037 17572	217 228	525 910	3.5 6.1	Spray Tower		83 84	0.57 .55	84 91	0.69 0.70
JC-12	150	150'		26350	780	Twin Large Ø Short Cone Cyclones	14500 17200	64.2 76.1			Spray Tower		162 172	0.72 0.76		1.08 1.15
PSAPCA 1 (JC-12)	150 Same Plant as JC-12	150'		26350	780	Same as Above					Baghouse		10.5 11.9	0.05 0.05		0.07 0.08
FC-1	200	200	4.0%-200	22333		Cyclone			2974	18.4	Horizontal Spray Tower	5gal/mscf	72 52	0.33 0.30	97.5 98.3	0.36 0.26
FC-2	150	120		18086		Cyclone			1072 868	9.1 8.5	Spray Tower	6gal/mscf	28.5 42.1	0.14 0.21	97.4 95.1	0.24 0.35
FC-3	150	135		14300		Cyclone					Wet Cyclonic Scrubber (Low Energy)	12gal/mscf	164	1.34		1.21
FC-4	120	52		21900		Cyclone					Centrifugal Scrubbers	4gal/mscf	6.6 10.7 17.5	0.08 0.11		0.34
FC-5	50 (Portable)	50		12000		Cyclone			1845 1705	18.1 16.5	NONE					

TABLE A1 SUMMARY OF PLANT EMISSIONS

PLANT	CAPACITY	PROD. RATE	RAW MAT'L.	GAS FLOW RATE	GAS VEL. IN DRYER	PRIMARY COLLECTION					SECONDARY COLLECTION				EFFICIENCY % BY WEIGHT	EMISSION FACTOR
						TYPE	INLET PMR	INLET C'	OUTLET PMR	OUTLET C'	TYPE	Water/ Air or Air/Cloth	OUTLET PMR	OUTLET C'		
	TON/HR	TON/HR		SCFM	FT/MIN		#/HR.	gr/scf	#/HR	gr/scf			#/HR	gr/scf		LB. PER TON PRODUCTION.
FC-6	120	120		34050		Cyclone			2039	7.1	Wet Centrifugal Scrubber	4gal. mscf	86	0.29	95.8	0.72
FC-7	250	99		18033		Cyclone					Wet Cyclonic Scrubber	6gal. mscf	44.8 47.0 43.3	0.29 0.30 0.28		0.45 0.48 0.44
FC-8	105	90		21600							Spray Tower (Experimental)		311 372	1.67 2.04		3.45 4.13
FC-9	120	96		38100		Multiple Cyclone			168	0.52	NONE					
FC-10	150	120		25566		Cyclone	2500	11.1	865	3.5	Wet Cyclonic Scrubber Spray Tower	1gal. mscf	135	0.69	84.4	1.13
SBCD-1		118		26300							Wet Cyclonic Scrubber	6gal mscf	93.9	0.42		0.80
SBCD-2		140		21400							Spray Tower		24.7	0.13		0.18
SBCD-3		294		22500		3 Cyclones					Wet Centrifugal Scrubber		64.9	0.34		0.22
SBCD-4		343		31704							Spray Tower	6 gal mscf	67.3	0.25		0.20
CCAPC-1	150	120	Crushed Rock	18000		Cyclone					Scrubber W/2 Centrifugal Collectors	19gal mscf	44.4	0.29		0.37
CCAPC-2	200	200	Crushed Rock	26700		Twin Cyclones In Parallel					3 Centrifugal Collectors in Series	15gal mscf	9.9	0.04		0.05

36

TABLE A1 SUMMARY OF PLANT EMISSIONS

PLANT	CAPACITY	PROD. RATE	RAW MAT'L.	GAS FLOW RATE	GAS VEL. IN DRYER	PRIMARY COLLECTION TYPE	PRIMARY INLET PMR	PRIMARY INLET C'	PRIMARY OUTLET PMR	PRIMARY OUTLET C'	SECONDARY COLLECTION TYPE	Water/Air or Air/Cloth	SECONDARY OUTLET PMR	SECONDARY OUTLET C'	EFFICIENCY PERCENT BY WEIGHT	EMISSION FACTOR LB PER TON PRODUCTION
	TON/HR	TON/HR		SCFM	FT/MIN		#/HR.	gr/scf	#/HR	gr/scf			#/HR	gr/scf		
CCAP-3	120	120	Crushed Rock & Gravel	12550		Cyclone					Two Wet Cyclonic Scrubbers	24gal/mscf	21.0 23.5	0.17 0.25		0.18 0.20
CWAPA 70-3	500	475	6%-200	49300		Cyclone					Multiclone Wet Fan Orifice Scrubber	9gal/mscf	107	0.25		0.23
CWAPA 70-4	180	187 180	3.3%-200	28700		Two Multi-clone in Series					Spray Tower	7gal/mscf	62.5 88.5	0.25 0.37		0.34 0.49
CWAPA 70-5 (VFT-9) (JC-16)	120	120 130	8%-200	25566		Twin Cyclones					Centrifugal Scrubber	9gal/mscf	96.0 118.7	0.43 0.63		0.80 0.91
CWAPA 70-6	175	219 181		31850 33300		Cyclone					Centrifugal	10gal/mscf	78.3 76.2	0.30 0.27		0.36 0.42
CWAPA 70-7	140	130 150	2%-200	11700		Cyclone					Spray Tower	34gal/mscf	24.7 23.0	0.23 0.25		0.19 0.15
CWAPA 70-8 (VFT-8) (JC-15)	200	210 215	4.6%-200	34.400		Twin Cyclone					Centrifugal Scrubber	11gal/mscf	11.3 11.6	0.03 0.03		0.05 0.05
CWAPA 70-9	75	67	9.9%-200	21200		Twin Cyclone					Spray Tower	19gal/mscf	10.1	0.06		0.15

TABLE A1 SUMMARY OF PLANT EMISSIONS

PLANT	CAPACITY TON/HR	PROD. RATE TON/HR	RAW MAT'L.	GAS FLOW RATE SCFM	GAS VEL. IN DRYER FT/MIN	PRIMARY COLLECTION TYPE	PRIMARY INLET PMR #/HR	PRIMARY INLET C' gr/scf	PRIMARY OUTLET PMR #/HR	PRIMARY OUTLET C' gr/scf	SECONDARY COLLECTION TYPE	Water/Air or Air/Cloth	SECONDARY OUTLET PMR #/HR	SECONDARY OUTLET C' gr/scf	EFFICIENCY PERCENT BY WEIGHT	EMISSION FACTOR LB PER TON PRODUCTION
CMI-1	225 Granite & Sand	225'		30400	1250	Cyclone			2135	8.2	Horizontal Spray Tower	5gal mscf	181	0.70	91.5	0.80
CMI-2	180 Limestone & Sand	180'		31500	1000	Cyclone			1715	6.3	Wet Centrifugal Scrubber	6gal mscf	63.0	0.23	96.3	0.35
CMI-3	100	100		10500	600	Multicone					Centrifugal Type Washer W/Wet Fan	5gal mscf 6gal mscf	14.1 5.9	0.16 0.19 0.07		0.14 0.06
VFT-1		225	6%-200	20833	880	Cyclone					Wet Centrifugal Washer W/ Wet Fan	8gal mscf	19.2 15.2 8.2	0.11 0.08 0.04		0.08 0.07 0.04
VFT-2		100	4%-200	15200	875	Cyclone					Baffled Spray Tower	3gal mscf	93.0 85.8	0.75 0.62		0.93 0.86 0.49
VFT-3		185		20500	870						Spray Tower	5gal mscf	91.5	0.52		
VFT-4		232	5%-200	16532	700	Cyclone					Spray Tower (No Recirc.)	27gal mscf	4.4 5.3	0.03 0.04		0.02 0.02
VFT-5		205	10%-200 5%-200 5%-200	18354	775	Cyclone					Spray Tower (No Recirc.)	29gal mscf	7.8 5.0 7.0	0.05 0.03 0.04		0.04 0.02 0.03
VFT-6 JC-13	275	250	5%-200	24125	650	Multicone					Baghouse	6.2 fpm	53.0 46.7 81.7 78.2	0.26 0.23 0.39 0.38		0.21 0.19 0.33 0.31

PLANT	CAPACITY	PROD. RATE	RAW MAT'L.	GAS FLOW RATE	GAS VEL. IN DRYER	PRIMARY COLLECTION					SECONDARY COLLECTION				EFFICIENCY	EMISSION FACTOR
						TYPE	INLET		OUTLET		TYPE	Water/Air or Air/Cloth	OUTLET			
							PMR	C'	PMR	C'			PMR	C'	% by weight	lb/ton product
	TON/HR	TON/HR		SCFM	FT/MIN		#/HR.	gr/scf	#/HR	gr/scf			#/HR	gr/scf		
VFT-7 JC-14	150	140	4%-200	12175	550	2 Cyclones in Parallel					Baghouse	7.3 fpm	8.2 7.5 0.0 9.4	0.08 0.07 0.10 0.09		0.06 0.05 0.07 0.07
VFT-8 JC-15 (CWAPA) (70-8)	220	170	10%-200	34400	875	2 Cyclones in Parallel					Centrifugal Washer	6 gal mscf	2.8 4.2 0.5 3.3	0.04 0.05 0.03 0.04		0.08 0.08 0.06 0.08
VFT-9 JC-16 (CWAPA) 70-5	145	125	3%-200	25566	1400	Cyclone					Baghouse	5.3 fpm	8.0 9.6 1.0 3.0	0.11 0.12 0.16 0.17		0.14 0.16 0.17 0.18
VFT-10 JC-17	120	135	6%-200	15200	875	Cyclone					Baghouse	6.7 fpm	3.6 5.3 6.6 9.9	0.12 0.14 0.14 0.17		0.10 0.11 0.12 0.15

TABLE AII- SUMMARY OF COMPARATIVE EMISSION SAMPLING WITH LA* AND EPA* TRAINS ON ASPHALTIC CONCRETE PLANTS

PARA-METER	PLANT NO. 1 - BAGHOUSE				PLANT NO. 2 - BAGHOUSE				PLANT NO. 3 - WET SCRUBBER			
	EPA		LA		EPA		LA		EPA		LA	
	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2
VOL_{STD}	66.85	63.17	82.19	79.47	42.49	41.32	60.73	59.44	27.63	27.47	24.60	22.61
M	32.10	31.46	29.50	30.00	33.22	32.76	32.87	32.17	6.31	9.04	4.09	7.14
Q_{os}	23,833	23,983	25,531	25,275	12,179	12,395	12,754	12,744	34,990	35,049	36,100	36,235
A_n	0.000341		0.000507		0.000341		0.000507		0.001364		0.000881	
I	121.32	118.68	98.93	98.50	111.97	106.99	105.00	105.06	94.68	92.06	126.48	117.07
P_T	1017.3	852.3	2009.1	1899.9	204.8	182.5	352.6	328.1	78.7	87.8	47.7	58.2
C	0.26	0.23	0.37	0.36	0.08	0.07	0.09	0.09	0.04	0.05	0.03	0.04
C_{AVG}	0.245		0.365		0.075		0.09		0.045		0.035	

PARA-METER	PLANT NO. 4 - BAGHOUSE				PLANT NO. 5 - BAGHOUSE			
	EPA		LA		EPA		LA	
	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2	RUN #1	RUN #2
VOL_{STD}	25.37	19.59	42.52	39.61	25.06	24.86	40.33	37.97
M	16.68	16.49	15.15	18.55	25.21	26.47	23.66	26.11
Q_{os}	19,737	19,759	17,072	16,507	12,779	12,596	14,356	13,966
A_n	0.000229	0.000192	0.000507		0.000341		0.000507	
I	82.48	76.05	71.24	69.18	94.30	94.90	95.07	90.68
P_T	192.3	167.4	459.1	490.4	208.0	234.8	368.8	433.5
C	0.11	0.12	0.14	0.16	0.12	0.14	0.13	0.17
C_{AVG}	0.115		0.15		0.13		0.15	

* LA (Los Angeles) and EPA (Environmental Protection Agency, Office of Air Programs) stack gas sampling trains were operated simultaneously on each plant.

DATA CONTRIBUTORS AND RESPECTIVE EVALUATION EQUIPMENT DESCRIPTION

Data was submitted for this study by several organizations and was collected by various sampling trains. Appreciation is also expressed to the following organizations.

Crim Engineering (Ref. JC)
3826 Woodland Avenue North
Seattle, Washington
(Sampling Train described in Appendix of Report)

Puget Sound Air Pollution Control Agency (Ref. PSAPCA)
410 West Harrison
Seattle, Washington 98119

The "PSAPCA" sampling train consisted in series of a 0.125 - 0.50 inch diameter nozzle, close-coupled, high-efficiency glass-fiber filter, probe, rubber hose, an ice bath with the first two of three impingers filled with 100 mils of distilled water, a silica gel drying tube, rubber hose, dry gas meter, temperature and vacuum indicators, control valve, and pump.

A separate pitot tube traverse was taken prior to the sampling to determine flow rate and nozzle size. Total particulate consisted of the nozzle and filter catches.

Frank L. Cross Jr. (Ref. FC)
North 215 William Henry Apartments
Malvern, Pennsylvania 19355

The "FC" sampling train consisted in series of a 0.25 - 0.50 inch diameter nozzle, a close-coupled coarse alundum thimble holder, probe, rubber hose, an ice bath (two impingers with 100 mils of distilled water, rubber hose, dry gas meter, vacuum and temperature indicators, a control valve, and pump.

A separate pitot tube traverse was conducted prior to the sampling to determine flow rate and nozzle size. Total particulate included the nozzle and thimble catches.

San Bernadino County Air Pollution Control District (Ref. SBCD)
172 West Third Street
San Bernadino, California 92401

The SBCD sampling train consisted in series of a 8-10 mm nozzle, an ice bath with two impingers filled with 100 ml of distilled water in each, a probe, a third dry impinger with a thermometer inside, a thimble, Whatman paper thimble, a dry gas meter, temperature and vacuum indicators, a control valve, and a pump.

A separate pitot tube traverse was conducted prior to the sampling to determine flow rate and nozzle size. Total particulate consisted of the nozzle, probe, impinger and filter catches.

Clark County District Health Department (Ref. CCAPCD)
Air Pollution Control Division
P. O. Box 4426
Las Vegas, Nevada 89106

The "CCAPCD" sampling train consisted of the standard EPA sampling train described elsewhere in this report.

Columbia Willamette Air Pollution Authority (Ref. CWAPA)
1010 N.E. Couch Street
Portland, Oregon 97232

The "CWAPA" sampling train consisted of the same components as the EPA stack gas sampling train. The impingers were used prior to the filter and a flexible, unheated teflon-lined hose was used between the probe and impingers.

CMI Systems, Inc. (Ref. CMI)
P.O. Box 6249
Chattanooga, Tennessee 37401

The "CMI" sampling train was designed and manufacturered by <u>2000 Inc</u>. It consisted of a 0.125 to 0.5 inch diameter nozzle, particle size and total mass collection device (Ref."Stack head") probe, condenser, rubber hose, vacuum gauge, flow control valve, pump, thermometer, and flow meter. A separate pitot tube traverse was conducted prior to the sampling to determine flow rate and nozzle size. Total particulate included the nozzle and "stack head" catches.

Valentine, Fisher & Tomlinson (Ref. VF&T)
520 Lloyd Building
Seattle, Washington 98101

The "VFT" sampling train was identical to the EPA train described elsewhere in this report.

DISCUSSION ON COMPARATIVE EPA-L.A. EMISSION SAMPLING ON ASPHALTIC CONCRETE PLANTS

The L. A. train measured 37% more than the EPA train on emissions from baghouse control systems. The L. A. train measured 20% lower than the EPA train when sampling the wet scrubber system. Reasons for the difference may include:

A. The EPA glass fiber-filter mat adhered to the molded rubber-composition glass frit filter backing that was used on the first two evaluations. These filter holders were not used on the last three evaluations.

B. The presence of moisture on the thimble and in the sampling hose between the probe and impingers of the L. A. train could have increased the collection efficiency of the thimble (a greater percentage of the total particulate was collected in the thimble on the wet scrubber systems) and the particulate hang-up in the hose. The hose was not cleaned out on evaluations after the first evaluation because it was determined on the first evaluation that the amount collected in the hose was less than 1% of the total particulate.

C. The L. A. train sampling head was inserted nozzle up to the far side of the stack and allowed to remain for a number of minutes which could have allowed particulate deposition inside the nozzle.

D. The coarse glass frit of the EPA train may have collected materials passing through the glass fiber mat. The glass frit was rinsed with water and acetone during cleanup.

E. The presence of dust on the L. A. thimble may make it more hygroscopic and therefore add excessive moisture weight to the final thimble weight.

F. Both dry gas meters in the trains were calibrated and found to be comparable within 1%. A wet test meter was used as the standard for the calibration.

G. The average percent of the total particulate that was caught in the impinger section of each train was 6.67% for the EPA train and 18.0% for the L. A. train. If chemical reactions could take place in the impingers that would add to the total weight, the L. A. train could bias the sample higher than the EPA train.

H. A third Hi-Vol type stack gas sampling train was used between the two simultaneous EPA and L. A.runs that were taken on Plant #4. Three samples were taken by CWAPA and found to contain an average of 0.0934 grains per standard cubic foot of exhaust gas. These three samples are closer to the .115 grains per standard cubic foot value measured by the EPA train.

STACK GAS EVALUATION
AT
PLANT NO. 1-5

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR PROGRAMS
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
CONTRACT NO. 68-02-0076

Prepared by

VALENTINE, FISHER & TOMLINSON
Consulting Engineers
520 Lloyd Building
Seattle, Washington 98101
(206) 623-0717

AUTHORS

J.C. Crim - Crim Engineering
W.D. Snowden - Valentine, Fisher & Tomlinson

September 15, 1971

VALENTINE, FISHER & TOMLINSON

CONSULTING ENGINEERS

A.S.H.R.A.E., A.A.A.S., S.A.M.E., I.E.S.

520 LLOYD BUILDING • MAIN 3-0717

SEATTLE, WASHINGTON 98101

WM. M. VALENTINE, M.E.
ARTHUR K. FISHER, M.E.
GEORGE D. TOMLINSON, E.E.

ASSOCIATES:
WAYNE A. HANSON, M.E.
P. "CHIC" CICCHETTI
DOUGLAS W. PASCOE, E.E.
PHILIP W. WOODRUFF
DENNIS W. FINLAYSON
HENRY L. ROYCE, ILLUM.
THOMAS G. JOHNS, M.E.
WILLIAM T. McDONALD
DEAN A. HANNIG

PURPOSE

The purpose of this stack gas evaluation is to determine the concentration (grains per standard cubic foot) and the pollutant mass rate (pounds per hour) of the atmospheric emission from Asphaltic Concrete Plant #1.

Two different types of sampling trains were used simultaneously. The first train was designed by the Environmental Protection Agency. The second train was designed by the Los Angeles County Air Pollution Control District (See Figures 1 and 2).

SUMMARY

The concentration and pollutant mass rate measured by the EPA train for Runs 1 and 2 were 0.26 grains/scf and 0.23grains/scf and 53.0 lb/hr and 46.7 lb/hr respectively. The concentration and pollutant mass rate measured by the LA train for Runs 1 and 2 were 0.37 grains/scf and 0.36 grains/scf and 81.4lb/hr and 77.9 lb/hr respectively. The air to cloth ratio of the baghouse was 6.2 to 1 and 4.5% of the aggregate passed a #200 sieve.

It was found after the evaluation that openings existed between the air inlet and clean air outlet and that some bags were plugged. The openings were sealed and the plugged bags were restored to reduce stack opacity and possibly resample the plant. Following restoration, the stack opacity was judged to be excessive by EPA and the plant was not resampled.

The emissions are considered higher than well controlled baghouses. Comparability of sampling methods and quantizing the emission from a not unusually maintained baghouse system justified evaluation of this plant. Plant production rate during the evaluation was 330 tons per hour.

VALENTINE, FISHER & TOMLINSON
CONSULTING ENGINEERS
A.S.H.R.A.E., A.A.A.S., S.A.M.E., I.E.S.
520 LLOYD BUILDING • MAIN 3-0717
SEATTLE, WASHINGTON 98101

WM. M. VALENTINE, M. E.
ARTHUR K. FISHER, M. E.
GEORGE D. TOMLINSON, E. E.

ASSOCIATES:
WAYNE A. HANSON, M. E.
P. "CHIC" CICCHETTI
DOUGLAS W. PASCOE, E. E.
PHILIP W. WOODRUFF
DENNIS W. FINLAYSON
HENRY L. ROYCE, ILLUM.
THOMAS G. JOHNS, M.E.
WILLIAM T. McDONALD
DEAN A. HANNIG

PURPOSE

The purpose of this stack gas evaluation is to determine the concentration (grains per standard cubic foot) and the pollutant mass rate (pounds per hour) of the atmospheric emission from Asphaltic Concrete Plant #2.

Two different types of sampling trains were used simultaneously. The first train was designed by the Environmental Protection Agency. The second train was designed by the Los Angeles County Air Pollution Control District (See Figures 1 and 2).

SUMMARY

The concentration and pollutant mass rate measured by the EPA train for Runs 1 and 2 were 0.079 grains/scf and 0.070 grains/scf and 8.22 lb/hr and 7.48 lb/hr respectively. The concentration and pollutant mass rate measured by the LA train for Runs 1 and 2 were 0.091 grains/scf and 0.085 grains/scf and 9.92 lb/hr and 9.32 lb/hr respectively. The air to cloth ratio of the baghouse was 7.3 to 1 and 4% of the aggregate passed a #200 sieve.

VALENTINE, FISHER & TOMLINSON
CONSULTING ENGINEERS
A.S.H.R.A.E., A.A.A.S., S.A.M.E., I.E.S.
520 LLOYD BUILDING • MAIN 3-0717
SEATTLE, WASHINGTON 98101

WM. M. VALENTINE, M. E.
ARTHUR K. FISHER, M. E.
GEORGE D. TOMLINSON, E. E.

ASSOCIATES:
WAYNE A. HANSON, M. E.
P. "CHIC" CICCHETTI
DOUGLAS W. PASCOE, E. E.
PHILIP W. WOODRUFF
DENNIS W. FINLAYSON
HENRY L. ROYCE, ILLUM.
THOMAS G. JOHNS, M.E.
WILLIAM T. McDONALD
DEAN A. HANNIG

PURPOSE

The purpose of this stack gas evaluation is to determin. the concentration (grains per standard cubic foot) and the pollutant mass rate (pounds per hour) of the atmospheric emission from Asphaltic Concrete Plant #3.

Two different types of sampling trains were used simultaneously. The first train was designed by the Environmental Protection Agency. The second train was designed by the Los Angeles County Air Pollution Control District (See Figures 1 and 2).

SUMMARY

The concentration and pollutant mass rate measured by the EPA train for Runs 1 and 2 were 0.04 grains/scf and 0.05 grains/scf and 12.8 lb/hr and 14.2 lb/hr respectively. The concentration and pollutant mass rate measured by the LA train for Runs 1 and 2 were 0.034 grains/scf and 0.043 grains/scf and 10.5 lb/hr and 13.3 lb/hr respectively. The gallons to 1000 cfm ratio for this wet scrubber system was approximately 5 to 7 gallons per 1000 cfm and the static pressure drop across the system is approximately 2.5" water across the pre-conditioner and 2.5 across the stack mist eliminator for a total secondary control system pressure drop of 5.0" water.

VALENTINE, FISHER & TOMLINSON

CONSULTING ENGINEERS

A.S.H.R.A.E., A.A.A.S., S.A.M.E., I.E.S.

520 LLOYD BUILDING • MAIN 3-0717

SEATTLE, WASHINGTON 98101

WM. M. VALENTINE, M.E.
ARTHUR K. FISHER, M.E.
GEORGE D. TOMLINSON, E.E.

ASSOCIATES:
WAYNE A. HANSON, M.E.
P. "CHIC" CICCHETTI
DOUGLAS W. PASCOE, E.E.
PHILIP W. WOODRUFF
DENNIS W. FINLAYSON
HENRY L. ROYCE, ILLUM.
THOMAS G. JOHNS, M.E.
WILLIAM T. McDONALD
DEAN A. HANNIG

PURPOSE

The purpose of this stack gas evaluation is to determine the concentration (grains per standard cubic foot) and the pollutant mass rate (pounds per hour) of the atmospheric emission from Asphaltic Concrete Plant #4.

Two different types of sampling trains were used simultaneously. The first train was designed by the Environmental Protection Agency. The second train was designed by the Los Angeles County Air Pollution Control District (See Figures 1 and 2).

SUMMARY

The concentration and pollutant mass rate measured by the EPA train for Runs 1 and 2 were 0.12 grains/scf and 0.11 grains/scf and 19.6 lb/hr and 18.0 lb/hr respectively. The concentration and pollutant mass rate measured by the LA train for Runs 1 and 2 were 0.14 grains/scf and 0.16 grains/scf and 21.0 lb/hr and 22.9 lb/hr respectively. The air to cloth ratio of the baghouse was 5.3 to 1 and 3% of the aggregate passed a #200 sieve.

VALENTINE, FISHER & TOMLINSON
CONSULTING ENGINEERS
A.S.H.R.A.E., A.A.A.S., S.A.M.E., I.E.S.
520 LLOYD BUILDING • MAIN 3-0717
SEATTLE, WASHINGTON 98101

WM. M. VALENTINE, M.E.
ARTHUR K. FISHER, M.E.
GEORGE D. TOMLINSON, E.E.

ASSOCIATES:
WAYNE A. HANSON, M.E.
P. "CHIC" CICCHETTI
DOUGLAS W. PASCOE, E.E.
PHILIP W. WOODRUFF
DENNIS W. FINLAYSON
HENRY L. ROYCE, ILLUM.
THOMAS G. JOHNS, M.E.
WILLIAM T. McDONALD
DEAN A. HANNIG

PURPOSE

The purpose of this stack gas evaluation is to determine the concentration (grains per standard cubic foot) and the pollutant mass rate (pounds per hour) of the atmospheric emission from Asphaltic Concrete Plant #5.

Two different types of sampling trains were used simultaneously. The first train was designed by the Environmental Protection Agency. The second train was designed by the Los Angeles County Air Pollution Control District (See Figures 1 and 2).

SUMMARY

The concentration and pollutant mass rate measured by the EPA train for Runs 1 and 2 were 0.12 grains/scf and 0.14 grains/scf and 13.6 lb/hr and 15.31 lb/hr respectively. The concentration and pollutant mass rate measured by the LA train for Runs 1 and 2 were 0.13 grains/scf and 0.17 grains/scf and 16.6 lb/hr and 19.9 lb/hr respectively. The air to cloth ratio of the baghouse was 6.7 to 1 and 6% of the aggregate passed a #200 sieve.

PROCEDURE

To allow comparison of sampling procedures, two stack gas sampling trains were used simultaneously. One sampling train was designed by the Environment Protection Agency (EPA), Office of Air Programs and the other was designed very similar to the Los Angeles County Air Pollution Control District (LA). The trains sampled gases from ports 90° apart. The LA train was inserted to the far side of the stack, allowed to reach stack temperature, and sampling begun with traversing being toward the near side of the stack. The EPA train was inserted at the near side of the stack with traversing being toward the far side of the stack. Total elapsed sampling time for each run was the same.

The EPA sampling train did not use the cyclone since large diameter particulates were not expected. The equipment measures the stack gas velocity at the same time and traverse location that the sample is being collected. See Figure 1 for more details on the EPA particulate stack gas sampling train.

The stack velocity was calculated from velocity readings taken during sampling. The sample probe and filter were heated to 250°F. to insure that water did not condense on and plug the filter. An ice bath to cool the gas from the filter consisted of a bubbler with 100 milliliters of deionized-distilled water, an impinger with 100 milliliters of the same water, a dry bubbler, and a bubbler with a weighted amount of silica gel respectively.

Following the sampling, the true moisture content of the stack gas was obtained by measuring the amount of water that was added to the impinger, bubblers, and silica gel weight.

A schematic of the LA stack gas sampling train used for the evaluation is shown in Figure 2. The procedure followed in using the LA sampling train is detailed in the Los Angeles County APCD Source Testing Manual, 1963.

With the LA train, a velocity traverse was run prior to sampling using "S" type pitot tube. The average velocity was calculated and the flow rate through the sampling train was determined so that the probe nozzle velocity equaled the average stack velocity. The probe was then inserted into the stack and equal areas were sampled for a pre-determined length of time.

At the end of the traverse, the true moisture content of the stack was obtained by measuring the amount of water that was added to the impingers and silica gel weight. The alundum filter thimble was removed and dried, the impinger water evaporated, and the probe and impingers rinsed with water which was also evaporated to obtain the particulate weight.

Two sampling ports were located at 90° apart. See Figure 3 for more details on sampling port locations. The number of traverse points were determined by EPA specification for the EPA train and by the Los Angeles County Source Testing Manual for the LA train.

PROCEDURE (Continued:)

Plant #1 burned diesel oil to dry the aggregate. A stack analysis for Sulfur Dioxide indicated that some sulfur could be present in the fuel oil.

The fines recovery (primary) system utilized 24-12"Ø multiclones. The emission control (secondary) system consisted of a reverse flow pluse jet type baghouse using 7916 square feet of felt-type media. The air to cloth ratio was 6.2 to 1.0. During this evaluation an estimated 25% of the bags were inoperative. The effective air to cloth ratio could then be as high as 10.0 to 1.0.

The percent of the aggregate passing a #200 sieve was 4.5%. The plant production rate measured during this evaluation was 250 tons per hour.

PRECEDURE (Continued:)

Plant #2 burned natural gas to dry the aggregate. Diesel oil is utilized as a standby fuel during the winter when natural gas is unavailable.

The fines-recovery (primary) system consisted of two parallel cyclones with an 88" diameter, 40" long cylinder and 85" long cone. The emission control system consisted of a reverse flow-pulse-jet type baghouse using felt-type media. The air to cloth ratio is 7.3 to 1.0.

The percent of the aggregate passing a #200 sieve was 4%. The plant production rate was measured at 142 tons per hour.

PROCEDURE (Continued:)

Cyclonic flow was expected, observed and measured at the points where the sample was collected. A separate "S" type pitot tube was first used to measure the velocity of the stack gases. A velocity indicating a flow rate of over 150,000 acfm was recorded. The integral "S" type pitot tube (Pitobe) on the EPA train with the nozzle in place measured a velocity which indicated a flow rate of over 100,000 acfm. It is hypothesized that the presence of the buttonhook nozzle on the pitobe affects the velocity head reading in multidirectional flow stacks.

Velocity readings were taken in the longest available straight duct after twin long-cone cyclones and prior to the wet scrubber system. A more reasonable velocity was measured indicating a flow rate of around 50,000 acfm.

The fines-recovery (primary) and emission control system (secondary) for this plant include twin cyclones (98" Ø, 45" long cyclinder and 150" long cone). The emission control system consisted of a cyclonic pre-contactor, a wet fan, and a cyclonic stack mist eliminator. Total ΔP across the secondary is 5.0 inches of water. Water usage is judged to be 6 gal/Mcfm.

Plant production rate during the evaluation was measured at 173 tons per hour. Plant dryer capacity is higher than 173 tons per hour but the screening process limits production.

PROCEDURE (Continued:)

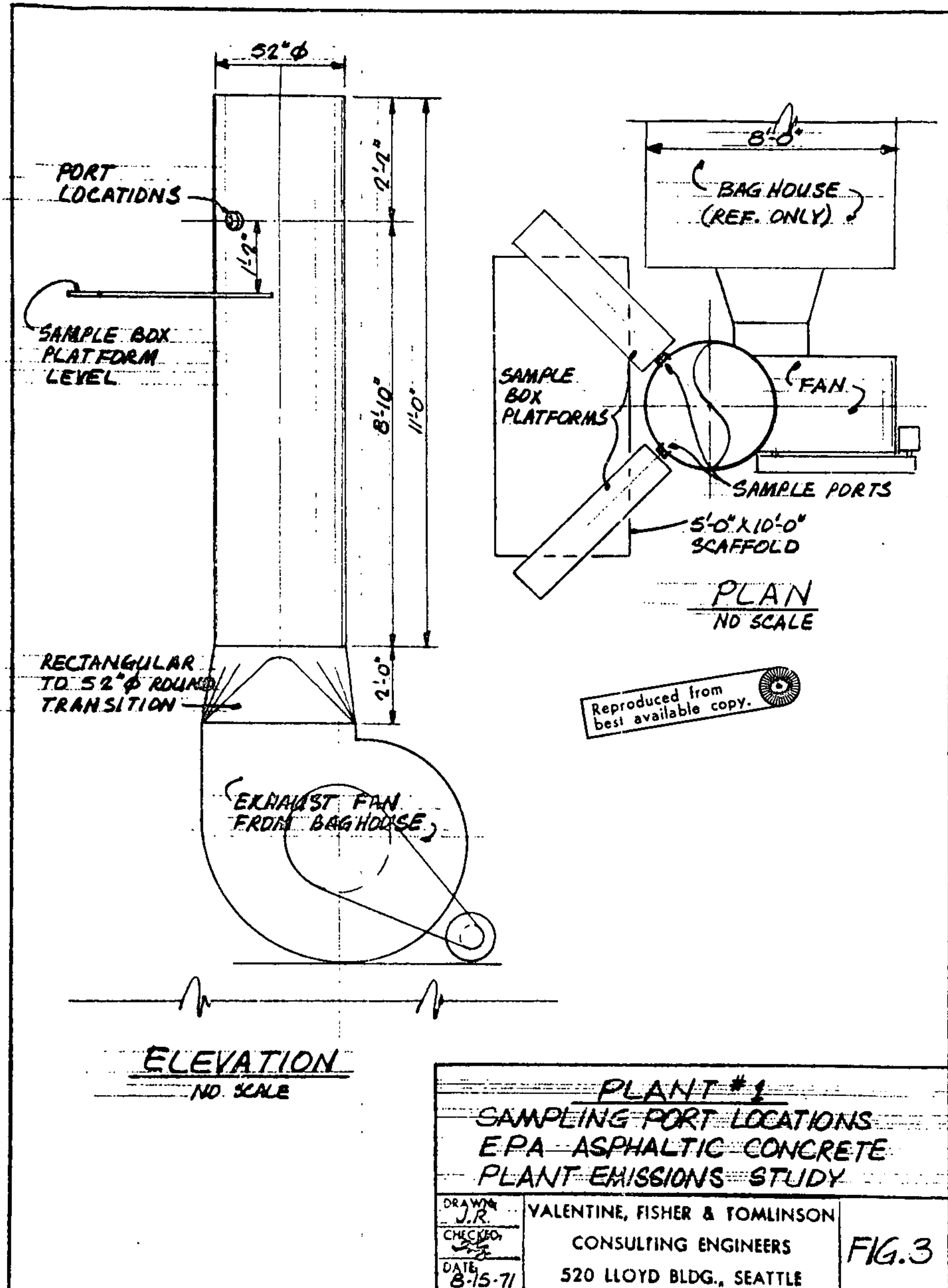
The fines-recovery (primary)system on plant #4 consists of two cyclones in parallel. The cylinder of the cyclones are 96" diameter and 58" long with a 156" long cone. The emission control (secondary) system consists of baghouse system with 5973 $feet^2$ of felt type filter media. The air to cloth ratio is 5.3 to 1.0.

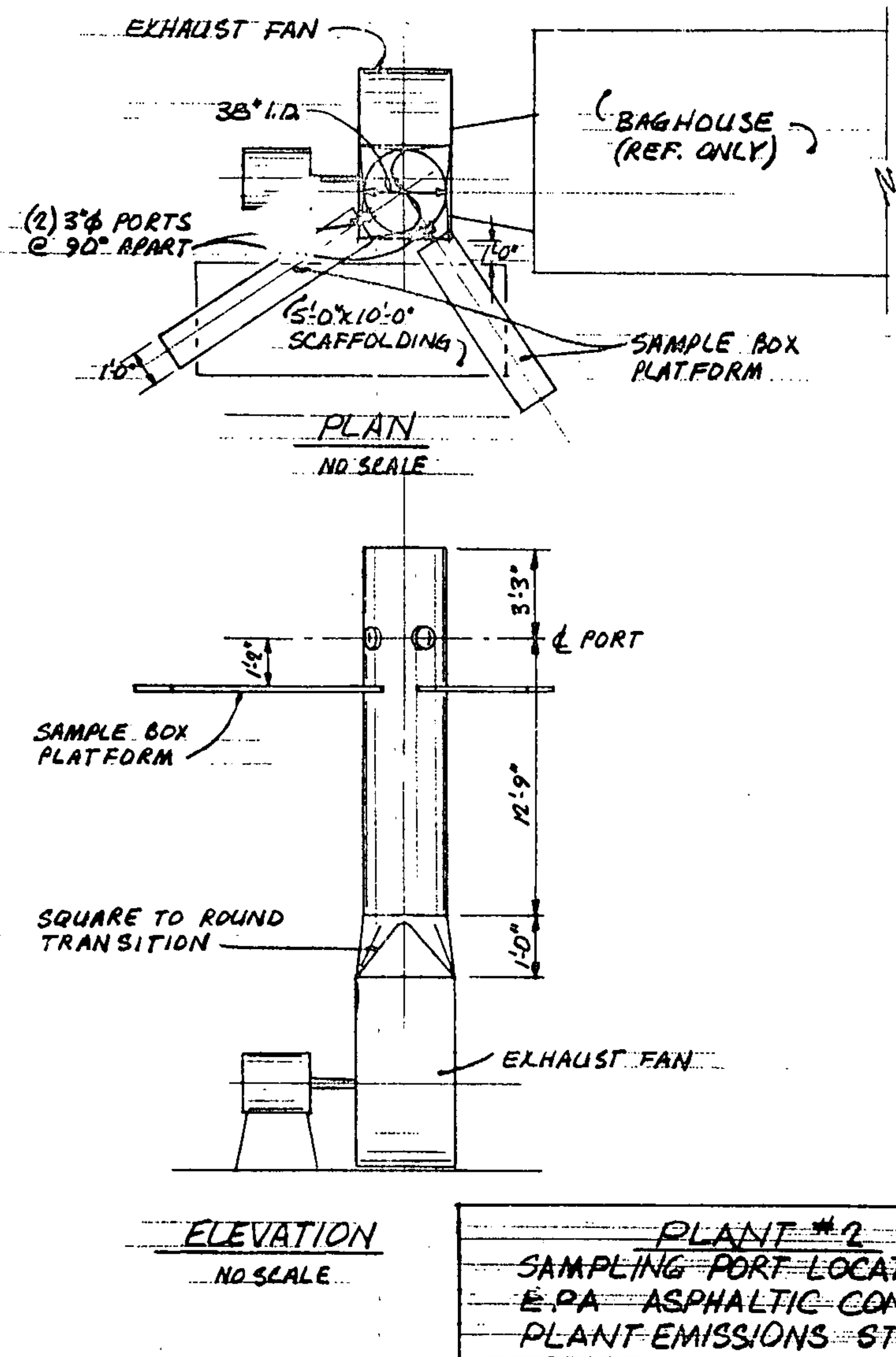
Diesel oil was burned to dry the aggregate. Three percent of the aggregate was found to be able to pass a #200 sieve. The plant production rate was found to be 133 tons per hour.

PROCEDURE (Continued:)

The fines recovery (primary) system on plant #5 consisted of two parallel cyclones. The cyclinder of the cyclone was 90" in diameter, 40" long and the cone was 82" long. The emission control (secondary) system consists of a baghouse with 3393 square feet of felt-type filter media. The air to cloth ratio is 6.7 to 1.0.

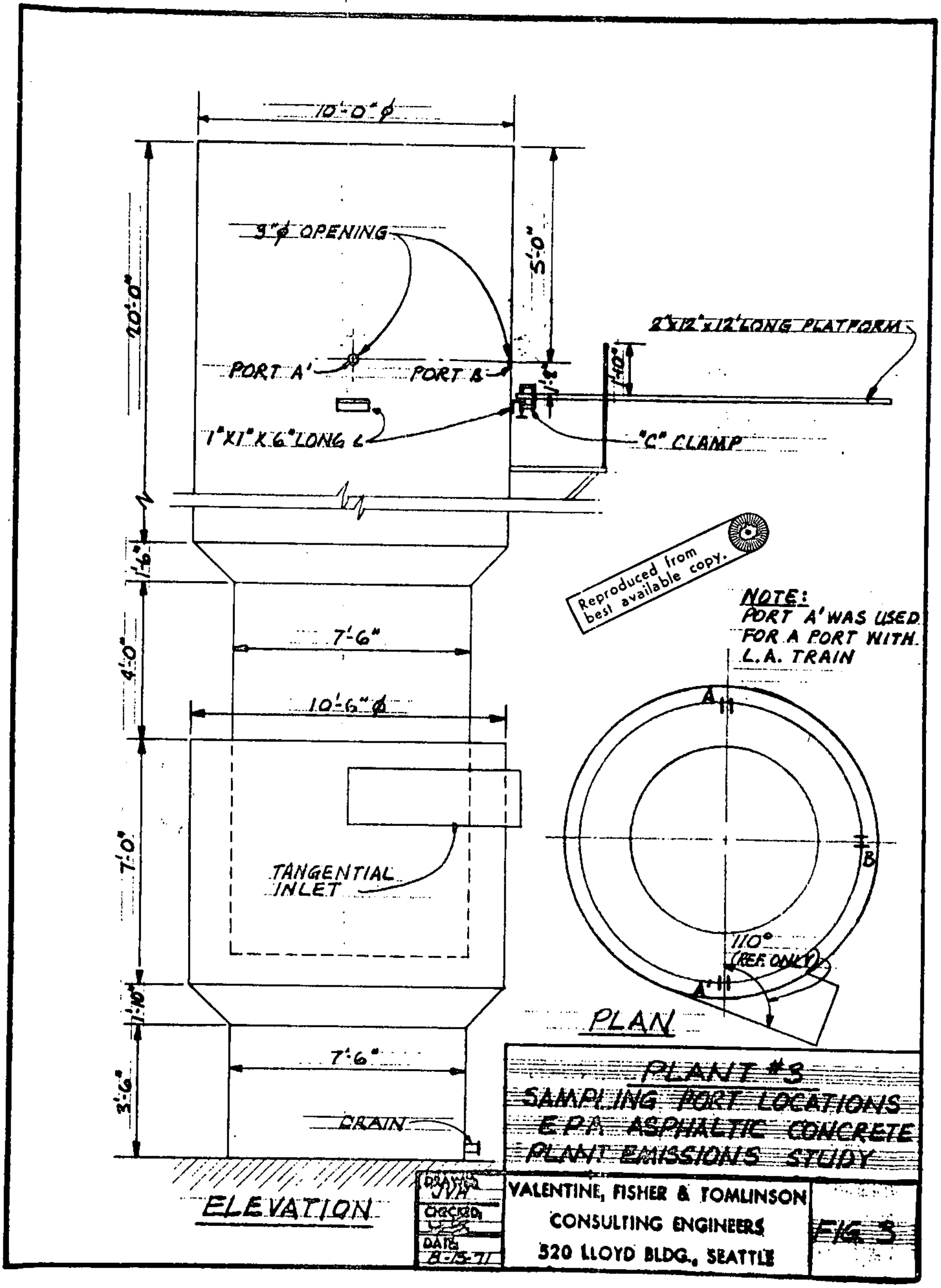
Natural gas was burned to dry the aggregate. Six percent of the aggregate was found to be able to pass a #200 sieve. The plant production rate was found to be 135 tons per hour.


52"Ø
PORT LOCATIONS
2'-2"
1'-2"
SAMPLE BOX PLATFORM LEVEL
8'-10"
11'-0"
RECTANGULAR TO 52"Ø ROUND TRANSITION
2'-0"
EXHAUST FAN FROM BAG HOUSE
ELEVATION
NO SCALE
8'-0"
BAG HOUSE (REF. ONLY)
SAMPLE BOX PLATFORMS
FAN
SAMPLE PORTS
5'-0" X 10'-0" SCAFFOLD
PLAN
NO SCALE
PLANT #1
SAMPLING PORT LOCATIONS
EPA ASPHALTIC CONCRETE
PLANT EMISSIONS STUDY
DRAWN J.R.
CHECKED
DATE 8-15-71
VALENTINE, FISHER & TOMLINSON
CONSULTING ENGINEERS
520 LLOYD BLDG., SEATTLE
FIG.3

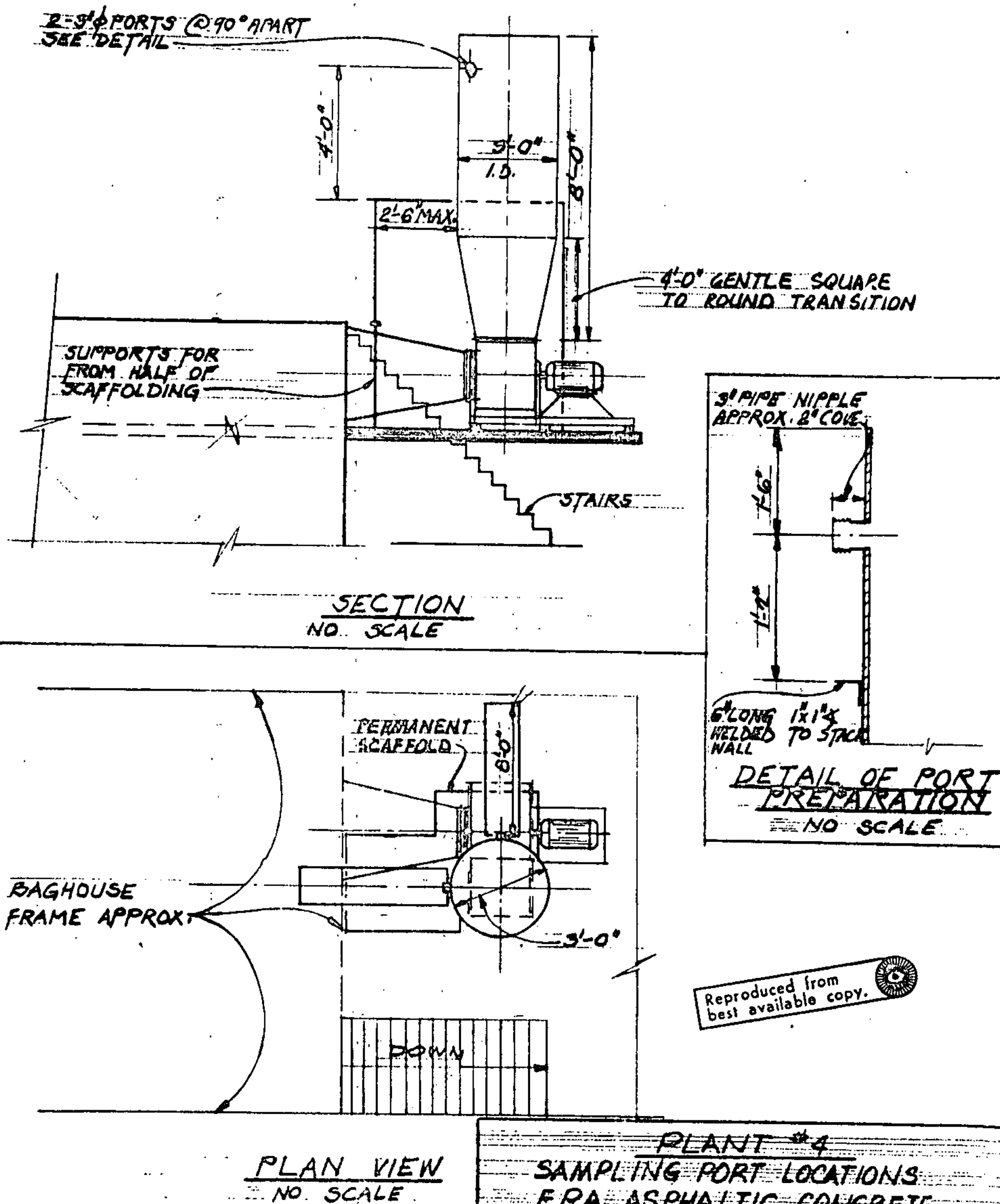


PLANT #2
SAMPLING PORT LOCATIONS
E.P.A. ASPHALTIC CONCRETE
PLANT EMISSIONS STUDY

DRAWN J.R.	VALENTINE, FISHER & TOMLINSON	FIG. 3
CHECKED	CONSULTING ENGINEERS	
DATE 8-15-71	520 LLOYD BLDG., SEATTLE	

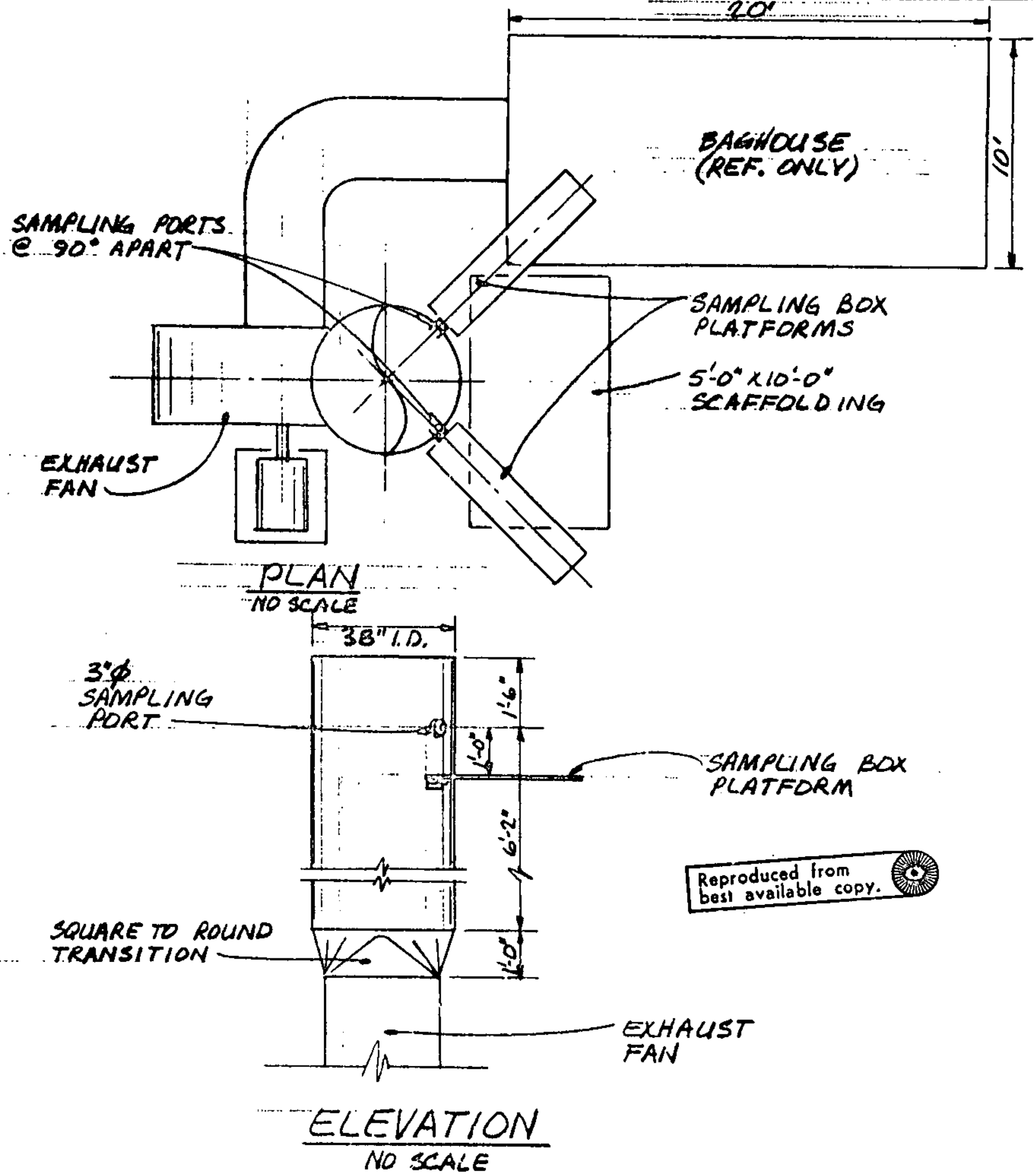

10'-0" ϕ
3" ϕ OPENING
5'-0"
20'-0"
2"x12"x12' LONG PLATFORM
1'-10"
PORT A'
PORT B
1'-8"
1"x1"x6" LONG L
"C" CLAMP
1'-6"
4'-0"
7'-6"
Reproduced from best available copy.
NOTE:
PORT A' WAS USED FOR A PORT WITH L.A. TRAIN
10'-6" ϕ
7'-0"
TANGENTIAL INLET
A
B
A'
110° (REF. ONLY)
PLAN
1'-10"
3'-6"
7'-6"
DRAIN
ELEVATION
PLANT #3
SAMPLING PORT LOCATIONS
EPA ASPHALTIC CONCRETE
PLANT EMISSIONS STUDY
DRAWN JVH
CHECKED
DATE 8-15-71
VALENTINE, FISHER & TOMLINSON
CONSULTING ENGINEERS
520 LLOYD BLDG., SEATTLE
FIG. 3

5858



PLANT #4
SAMPLING PORT LOCATIONS
EPA ASPHALTIC CONCRETE
PLANT EMISSIONS STUDY

DRAWN G.H.	VALENTINE, FISHER & TOMLINSON	FIG. 3
CHECKED	CONSULTING ENGINEERS	
DATE 8-15-71	520 LLOYD BLDG., SEATTLE	



PLANT #5
SAMPLING PORT LOCATIONS
EPA ASPHALTIC CONCRETE
PLANT EMISSIONS STUDY

DRAWN: J.R.	VALENTINE, FISHER & TOMLINSON	FIG. 3
CHECKED: [illegible]	CONSULTING ENGINEERS	
DATE: 8-15-71	520 LLOYD BLDG., SEATTLE	

VALENTINE, FISHER & TOMLINSON • CONSULTING ENGINEERS

COMPUTATION & DESIGNING SHEET

JOB NAME EMISSIONS FROM HOT MIX ASPHALT PLANTS — DATE July 22, 1971

PREPARED BY Wesley D. Snowden — PAGE 1 OF 4

SUBJECT Plant No. 1 - EPA Train   Run No. 1

71.22	VOL_M
29.99	P_M
530	T_{STD}
566	T_M
66.84613	VOL_{STD}
31.6	VOL_W
32.09800	M
0.67902	MF
29.43	W_D
25.76119	W_W
1.06008	C_D
29.90	P_{SN}
1.00032	C_S

	0.53	0.66	0.64	0.55 VH
	730	714	730	700 T_S
	19.66977	21.70806	21.61480	19.62141
	0.54	0.67	0.65	0.55 VH
	730	714	728	701 T_S
	19.85447	21.87189	21.75316	19.63542
	0.58	0.62	0.68	0.60
	730	714	727	702
	20.57668	21.03996	22.23420	20.52315
	0.57	0.57	0.70	0.60
	730	714	725	703
	20.39852	20.17374	22.52776	20.53777
	0.57	0.55	0.78	0.70
	730	713	725	705
	20.39852	19.80277	23.78024	22.21485
	0.56	0.60	0.76	0.72
	730	712	725	705
	20.21880	20.66681	23.47338	22.52956
0.41	0.52	0.55	0.77	0.76
720	731	712	725	705
17.18138	19.49666	19.78668	23.62731	23.14735
0.48	0.48	0.52	0.74	0.79
722	731	710	725	705
18.61612	18.73179	19.21457	23.16246	23.59978
0.51	0.51	0.54	0.51	0.81
725	732	706	715	705
19.22688	19.32149	19.52536	19.09581	23.89665
0.51	0.56	0.55	0.55	0.80
728	732	706	715	705
19.26862	20.24648	19.70532	19.83053	23.74868
0.52	0.60	0.53	0.66	
730	730	702	715	
19.48332	20.92644	19.28885	22.04994	

20.81276	K_a
0.84	C_p
53.76312	V_o
14.75	A_s
47580.36120	Q_o
530	T_{STD}
718	T_s
29.90	P_{SN}
23822.59458	Q_{OS}
718	T_s
530	T_{STD}
29.90	P_{SN}
100	T
0.000341	A_n
63.22678	V_n
121.72253	I
1017.30	P_T
0.23436	C_o
12	N
0.23436	C
47.87252	PMR_P
1017.30	P_T
14.75	A_s
100	T
0.000341	A_n
58.15423	PMR_{AR}
53.01342	PMR_{AVG}
0.25951	C_o'

VALENTINE, FISHER & TOMLINSON • CONSULTING ENGINEERS
COMPUTATION & DESIGNING SHEET

JOB NAME: EMISSIONS FROM HOT MIX ASPHALT PLANTS — DATE: July 26, 1971
PREPARED BY: Wesley D. Snowden — PAGE 2 OF 4
SUBJECT: Plant No. 1 - EPA Train — Run No. 2

67.36	VOL_M
29.86	P_M
530	T_{STD}
564	T_M
63.17235	VOL_{STD}
29.0	VOL_W
31.46200	M
0.68538	MF
29.58	W_D
25.93670	W_W
1.05648	C_D
29.76	P_{SN}
1.00234	C_S

0.63 / 725 / 21.37171
0.64 / 730 / 21.61480
0.64 / 730 / 21.61480
0.64 / 735 / 21.68870
0.60 / 735 / 21.60090
0.58 / 740 / 20.71714

0.68 / 735 / 22.35620
0.69 / 735 / 22.51999
0.75 / 735 / 23.47871
0.75 / 735 / 23.47871
0.75 / 735 / 23.47871
0.73 / 735 / 23.16354
0.78 / 735 / 23.94368
0.76 / 735 / 23.63472
0.45 / 740 / 18.24628
0.47 / 740 / 18.64939
0.55 / 740 / 20.17424

0.55 / 740 / 20.17424
0.53 / 740 / 19.80403
0.54 / 740 / 19.98999
0.56 / 739 / 20.34305
0.57 / 739 / 20.52388
0.55 / 738 / 20.14696
0.54 / 738 / 19.96296
0.54 / 737 / 19.94943
0.53 / 736 / 19.75044
0.52 / 736 / 19.56323
0.55 / 735 / 20.10593

0.58 VH / 734 T_s / 20.63298
0.61 VH / 735 T_s / 21.17427
0.64 / 736 / 21.70345
0.66 / 736 / 22.03996
0.72 / 737 / 23.03562
0.76 / 738 / 23.68290
0.79 / 736 / 24.11306
0.82 / 734 / 24.53324
0.82 / 732 / 24.49979
0.78 / 730 / 23.86210

0.48 / 740 / 18.84675
0.52 / 740 / 19.61631
0.60 / 740 / 21.07130
0.61 / 740 / 21.24617
0.62 / 720 / 21.17816

0.63 / 740 / 21.59166
0.52 / 740 / 19.61631
0.53 / 740 / 19.80403
0.58 / 735 / 20.64763
0.67 / 735 / 22.19121

21.38507	K_a
0.84	C_p
55.16504	V_o
14.75	A_s
48621.06040	Q_o
530	T_{STD}
776	T_s
29.75	P_{SN}
23962.79497	Q_{os}
776	T_s
530	T_{STD}
29.76	P_{SN}
96	T
0.000341	A_n
65.47214	V_n
118.68411	I
852.27	P_T
0.20776	C_o
12	N
0.20776	C
42.70642	PMR_P
852.27	P_T
14.75	A_s
96	T
0.000341	A_n
50.75634	PMR_{AR}
46.72838	PMR_{AVG}
0.22731	C_o'

VALENTINE, FISHER & TOMLINSON ● CONSULTING ENGINEERS

COMPUTATION & DESIGNING SHEET

JOB NAME EMISSIONS FROM HOT MIX ASPHALT PLANTS DATE July 22, 1971

PREPARED BY Wesley D. Snowden PAGE 3 OF 4

SUBJECT Plant No. 1 LA Train Run No. 1 (40°F Impinger Exit Temperature)

133.84	VOL_M
18.79	P_M
530	T_{STD}
542	T_M
82.19165	VOL_{STD}
34.40	VOL_W
29.50400	M
0.70496	MF
29.43	W_D
26.05769	W_W
1.05403	C_D
29.90	P_{SN}
1.00032	C_S

0.50	VH
710	T_S
18.84144	
0.65	VH
710	T_S
21.48255	
0.70	
710	
22.29349	
0.70	
710	
22.29349	
0.70	
712	
22.32487	
0.65	
712	
21.51276	

0.60	VH
715	T_S
20.71231	
0.65	VH
715	T_S
21.55806	
0.65	
715	
21.55806	
0.70	
715	
22.37165	
0.75	
715	
23.15707	
0.70	
715	
22.37165	

21.70646	K_a
0.83	C_p
55.00604	V_o
14.75	A_s
48752.91540	Q_o
530	T_{STD}
713	T_s
29.90	P_{SN}
25520.59907	Q_{os}
723	T_s
530	T_{STD}
29.90	P_{SN}
96	T
0.000507	A_n
54.45635	V_n
98.92954	I
2009.1	P_T
0.37643	C_o
10	N
0.37643	C
82.37145	PMR_P
2009.1	P_T
14.75	A_s
56	T
0.000507	A_n
80.46551	PMR_{AR}
81.41848	PMR_{AVG}
0.37205	C_o'

VALENTINE, FISHER & TOMLINSON ● CONSULTING ENGINEERS

COMPUTATION & DESIGNING SHEET

JOB NAME EMISSIONS FROM HOT MIX ASPHALT PLANTS DATE July 26, 1971

PREPARED BY Wesley D. Snowden PAGE 4 OF 4

SUBJECT Plant No. 1 - LA Train Run No. 2 (40°F Impinger Exit Temperature)

130•415 VOL_M
18•68 P_M
530 T_{STD}
543 T_M

79•47286 VOL_{STD}

34•07 VOL_W

30•00600 M

0•69994 MF
29•56 W_D

26•10530 W_W

1•05307 C_D
29•78 P_{SN}

1•00234 C_S

0•60 VH
715 T_S
20•71231

0•65 VH
715 T_S
21•55806

0•65
715
21•55806

0•70
715
22•37185

0•75
715
23•15707

0•70
715
22•37185

0•50 VH
710 T_S
18•84144

0•65 VH
710 T_S
21•48255

0•70
710
22•29349

0•70
710
22•29349

0•70
712
22•32487

0•65
712
21•51276

21•70648 K_a

0•63 C_p
55•14898 V_o
14•75 A_S

48806•84700 Q_o

530 T_{STD}
713 T_S
29•78 P_{SN}

25274•99099 Q_{os}

737 T_S
530 T_{STD}
29•78 P_{SN}
96 T
0•000507 A_n

54•71952 V_n
96•47598 I

1899•9 P_T
0•36615 C_o

12 N
0•36615 C

79•75305 PMR_p
1899•9 P_T
14•75 A_s
96 T
0•000507 A_n

76•09199 PMR_{AR}

77•92252 PMR_{AVG}

0•35968 C_o'

CLEAN-UP AND ANALYSIS (EPA TRAIN)

Clean-up was performed by first carefully removing the filter and placing it in a container marked "Run X, Container A." Reagent acetone and brushes were used to clean the nozzle, glass probe and cyclone. The acetone wash was placed in a container marked "Run X, Container B.". The volume of water in the impinger and bubblers was measured to the nearest 0.1 milliliters. The original volume of 200 milliliters was subtracted and the difference plus the water weight added to the silica gel was considered as the amount of water collected during the run. The water from the impinger and the water rinse of the impinger, bubblers and connectors were placed in one container marked "Run X, Container C." An acetone rinse of the impinger, bubblers and all connectors was performed and placed in a container marked "Run X, Container D." The silica gel was weighed within the bubbler before and after the run.

Analysis of the samples in each container was performed according to the following "Specification" or equivalent procedures:

Run X, Container A - Transfer the filter and any loose particulate from the sample container to a tared glass weighing dish and desiccate for 24 hours in a desiccator or constant humidity chamber containing a saturated solution of calcium chloride or its equivalent. Weigh to a constant weight and report the results to the nearest 0.1 milligram.

Run X, Container B - Measure the volume to the nearest 0.1 milliliter. Transfer acetone washings from container into a tared beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the result to the nearest 0.1 milligram.

Run X, Container C - Measure the volume to the nearest 0.1 milliliter. Extract organic particulate from the water solution with three 25 milliliter portions of chloroform and three 25 milliliter portions of ethyl ether. Combine the ether and chloroform extracts and transfer to a tared beaker. Evaporate until no solvent remains at about 70°F. This can be accomplished by blowing air that has been filtered through activated charcoal over the sample. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 milligram. After the extraction, evaporate the remaining water to dryness and report the results to the nearest 0.1 milligram.

Run X, Container D - Measure the volume to the nearest 0.1 milliliter. Transfer the acetone washings to a tared beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 milligram.

Blanks were taken on the acetone, ether, chloroform, and deionized water and subtracted from the respective sample volumes. The filter paper used was a Mine Safety Appliance 1106 BH, heat treated glass fiber mat.

CLEAN UP AND ANALYSIS (L.A. TRAIN)

Clean-up was performed immediately after collecting the sample in the field. The Alundum thimble was removed from the holder and placed in the thimble carrying case. The inside of the sampling nozzle and the gasket against which the timble was held during the test were both washed carefully into a field sample bottle. The bottle was marked with the timble number.

Any condensate that may have collected in the hose between the sampling probe and the impinger case was carefully shaken into the impingers. The impingers were then removed from the insulated case holding the ice bath and the olume of condensate measured. The condensate was put into a sample bottle and marked with the thimble number. Normally the entire set of impingers was changed after each sample.

In the laboratory the thimbles and contents were placed in an oven at 230° F. to 250° F. for four hours, cooled in a desiccator, allowed to reach laboratory humidity and then weight determined to the nearest 0.1 mg. The thimbles were held in 250 ml. beakers so the weight determination required two weighings. A similar procedure had been followed in preparing the clean thimbles for field sampling in order to determine their tare weight. The difference between the tare weight and the "dirty" weight is the weight of particulate collected by the thimble.

The condensate and the nozzles washings were placed in separate tared beakers and evaporated to dryness at 230° F. to 250° F. The beakers were placed in a desiccator to cool, then allowed to reach laboratory humidity and then weighed to the nearest 0.1 mg. The total of the particulate collected from these liquids and that collected in the thimble represents the total particulate collected during the test.

Blanks were taken from the deionized water that was used to initially load the impingers and to wash the nozzle. No weight was detected for the blanks during these tests.

PARTICULATE CONCENTRATION AND PMR CALCULATION TERMINOLOGY

VOL_m	= Dry gas meter volume @ meter temperature and pressure, dry - acf
P_m	= Dry gas meter pressure (recorded as inlet deflection accross orifice meter) - "Hg
T_m	= Dry gas meter temperature (average of inlet and outlet)
P_{STD}	= Standard atmospheric pressure (29.92" Hg)
T_{STD}	= Standard Temperature (520 or 530° R)
VOL_w	= Volume of water collected (expressed as vapor at standard temperature and pressure) - scf
M	= % water, calculated from amount the train collected in impinger, bubblers, and on silica gel
MF	= Mole fraction of dry gas
W_D	= Molecular weight of dry stack gas - lb/lb mole
W_W	= Molecular weight of wet stack gas - lb/lb mole
W_a	= Molecular weight of air - lb/lb mole
C_D	= Velocity correction coefficient for gas density
P_{SN}	= Stack pressure (static + barometric) - "Hg
C_S	= Velocity correction for stack pressure
VH_n	= Pitot tube pressure differential - "H_2O
V_o	= Stack velocity @ stack conditions - fps
Q_o	= Stack flow rate at stack conditions - acfm
T_s	= Average stack temperature
Q_{OS}	= Stack flow rate at standard conditions - scfm
T	= Time over which sample was collected - minutes
V_n	= Velocity of gases inside nozzle during sampling - fps
I	= % isokinetic (± 10% desirable)
C_O	= Particulate concentration - grains/scf
N	= % CO_2 by volume in stack (12 indicate no % CO_2 correction is to be made)

PARTICULATE CONCENTRATION AND PMR CALCULATION TERMINOLOGY

C	=	Particulate concentration corrected to 12% CO_2
PMR_P	=	Pollutant mass rate - "concentration method" - lb/hr
PMR_{AR}	=	Pollutant mass rate - "area ratio method" - lb/hr
PMR_{AVG}	=	Average pollutant mass rate - lb/hr
C'	=	Particulate concentration corrected for non-isokinetic sampling condition -grains/scf
P_T	=	Total Particulate collected by sampling train - mg
A_s	=	Area of Stack - FT^2
A_n	=	Area of Nozzle - FT^2

PARTICULATE CONCENTRATION & PMR CALCULATIONS

1. $VOL_{STD} = \frac{(VOL_m)\ (P_m)\ (T_{STD})}{(P_{STD}*)\ (T_m)}$

2. $M = \frac{(100)\ (VOL_w)}{VOL_{STD} + VOL_w}$

3. $MF = \frac{100 - M}{100}$

4. $W_w = (W_D)\ (MF) + 18\ (1-MF)$

5. $C_D = \sqrt{\frac{W_a*}{W_w}}$

6. $C_S = \sqrt{\frac{P_{STD}}{P_{SN}}}$

7. $K = \frac{\sum\sqrt{VH_n \times T_{S_n}}}{n}$

8. $V_o = 2.9\ (K_a)\ (C_p)\ (C_D)\ (C_S)$

9. $Q_o = (V_o)\ (A_S)\ (60)$

10. $Q_{OS} = \frac{Q_o\ (T_{STD})\ (P_{SN})\ (MF)}{(T_S)\ (P_{STD})}$

11. $V_n = \frac{(VOL_{STD})\ (P_{STD})(T_S)}{(MF)\ (T_{STD})\ (P_{SN})\ (T)\ (A_N)\ (60)}$

12. $I = (100)\ \frac{V_n}{V_o}$

13. $C_O = \frac{P_T}{VOL_{STD}}\ (0.0154)$

14. $C = \frac{C_O\ (12\%)}{N}$

15. $PMR_p = (C_O)\ (Q_{OS})\ (0.008571)$

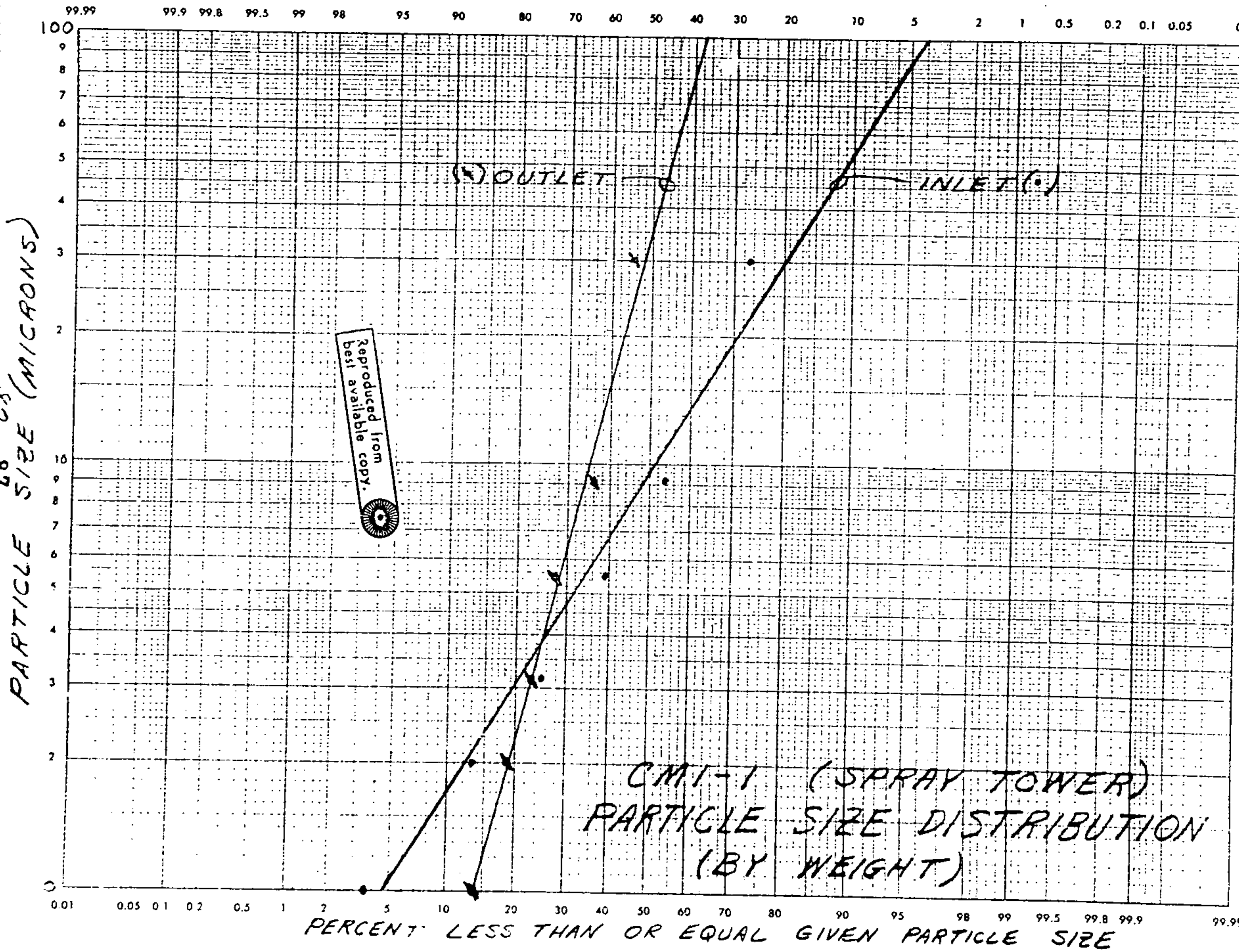
16. $PMR_{AR} = \frac{P_T}{T}\ \frac{A_s}{A_n}\ (0.000132)$

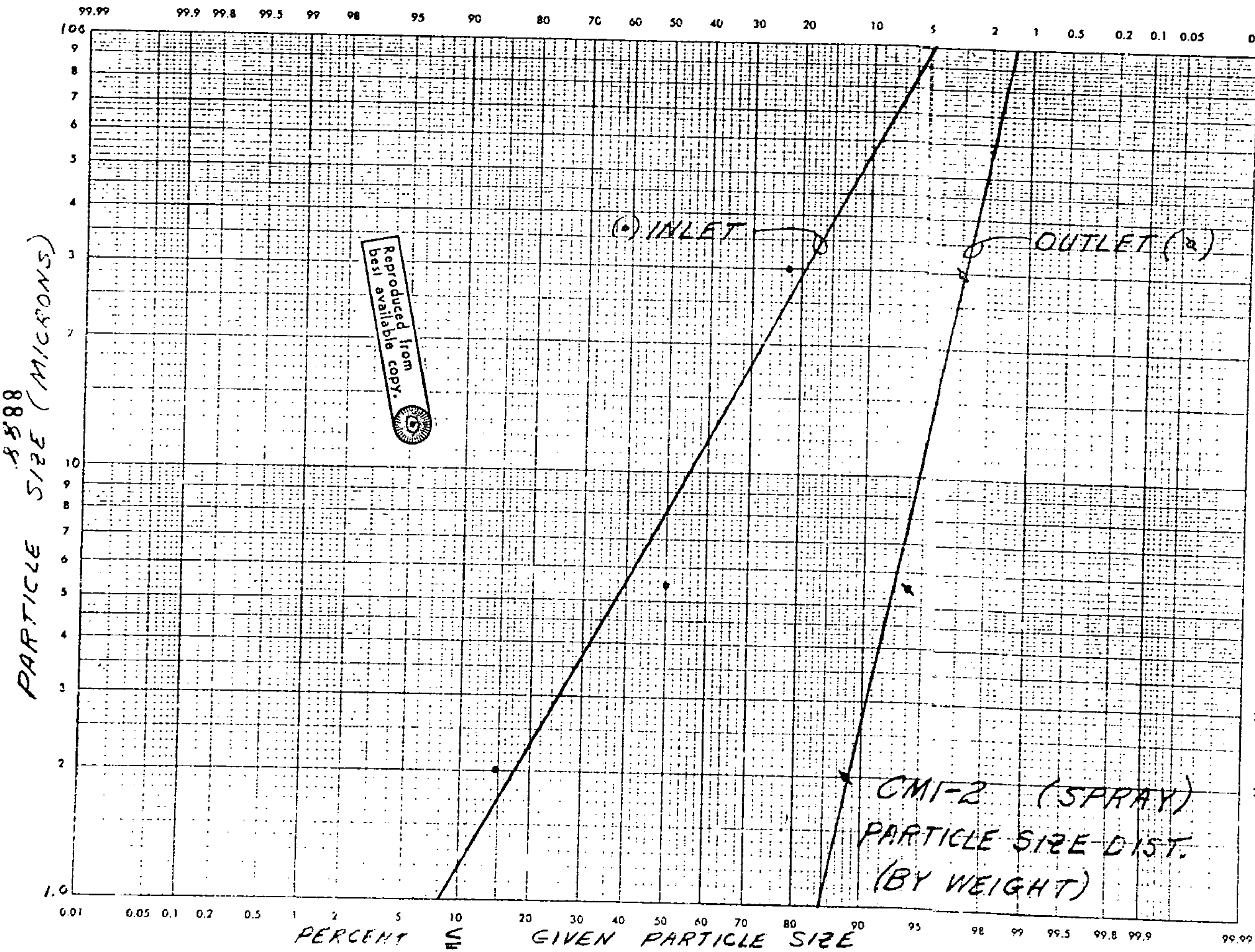
17. $PMR_{AVG} = \frac{PMR_p + PMR_{AR}}{2}$

18. $C' = \frac{PMR_{AVG}}{Q_{OSN}}\ (1400)$

* P_{STD} = 29.92" Hg.

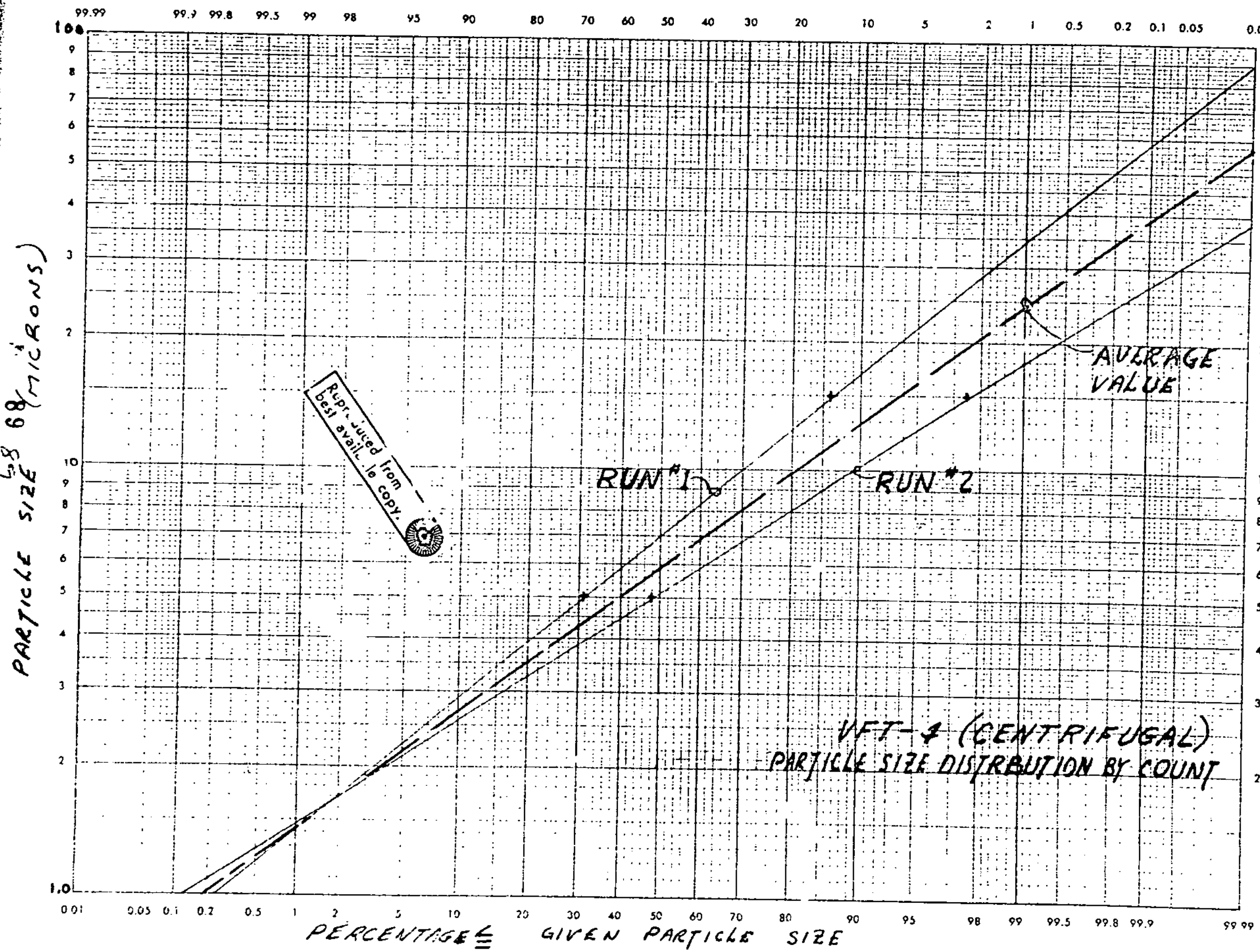
* W_a = 28.95 LB/LB MOLE

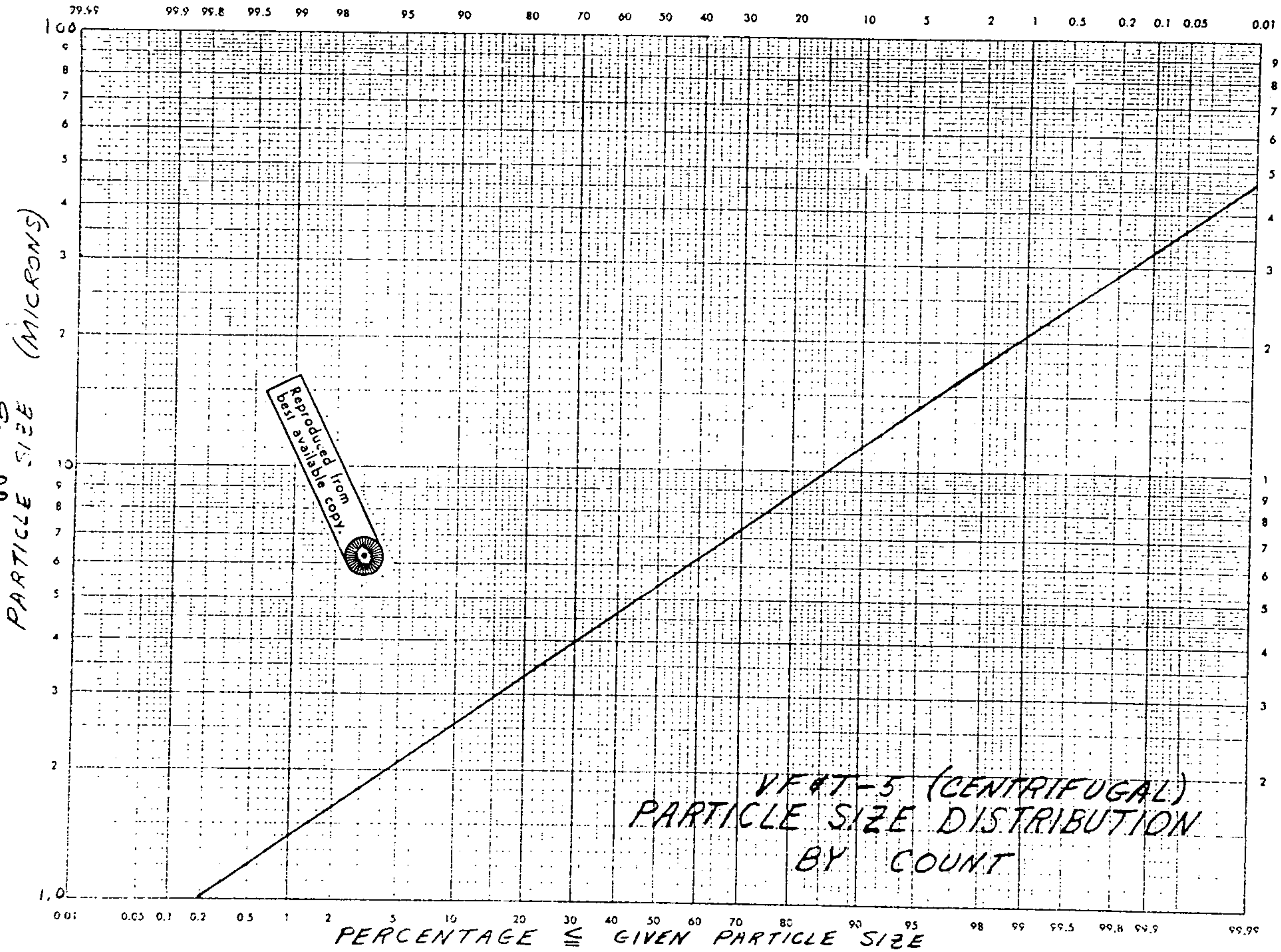

PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1015
CLEARPRINT CHARTS
LOGARITHMIC PROBABILITY
CMI-1 (SPRAY TOWER)
PARTICLE SIZE DISTRIBUTION
(BY WEIGHT)
(x) OUTLET
INLET (•)
PARTICLE SIZE (MICRONS)
PERCENT LESS THAN OR EQUAL GIVEN PARTICLE SIZE
Reproduced from best available copy.



INLET
OUTLET
CMI-2 (SPRAY)
PARTICLE SIZE DIST.
(BY WEIGHT)
PARTICLE SIZE (MICRONS)
PERCENT ≤ GIVEN PARTICLE SIZE
Reproduced from best available copy.

8888


VFT-4 (CENTRIFUGAL)
PARTICLE SIZE DISTRIBUTION BY COUNT
AVERAGE VALUE
RUN #1
RUN #2
PARTICLE SIZE (MICRONS)
PERCENTAGE ≦ GIVEN PARTICLE SIZE
Reproduced from best available copy.


VF#T-5 (CENTRIFUGAL)
PARTICLE SIZE DISTRIBUTION
BY COUNT
PARTICLE SIZE (MICRONS)
PERCENTAGE ≤ GIVEN PARTICLE SIZE
Reproduced from best available copy.