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APPLICATIONS OF FABRIC FILTERS TO ASPHALT PLAN

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APPLICATIONS OF FABRIC FILTERS TO ASPHALT PLANTS

I. INTRODUCTION

The National Asphalt Paving Association estimates that there are approximately 5,000 plants in the U. S. today which provide over 90% of the asphalt road paving materials consumed annually. The asphalt paving market has more than quadrupled in the last thirty years to over 300 M ton/yr. Because of the nature of their product, plants tend to be within ∿ 20 miles of sites they service. Cold weather in many parts of the U. S. limits plant operations to an average of only about 8.5 mo/yr and the size of asphalt plants varies from 20 to > 200 ton/hr. While the asphalt mixing process is straightforward, particulate emissions will vary widely from plant-to-plant depending on the materials processed and on equipment design and operation. If this industry did not have some form of particulate control, emissions could run several million ton/yr. In the last ten years, the asphalt industry has made significant reductions in emissions (> 80%) primarily through improved control techniques. This paper discusses the effect of process steps on emissions and the use of high-efficiency collectors to minimize them.

II. OPERATING CHARACTERISTICS WHICH AFFECT EMISSIONS

Some latitude exists in the operation of an asphalt plant and, by carefully monitoring the process, plant operators can adjust settings to minimize emissions.

(A) Process Description

A typical batch or continuous mix asphalt plant (Figure 1) consists of a three-step process:

1. Sizing of aggregate mix.

2. Drying of aggregate.

3. Mixing aggregate with hot liquid asphaltic material.

A paving mixture will vary widely in aggregate size distribution depending on the application and specification of the purchaser. Typically, three to five different sizes of rock are metered onto a continuous conveyor belt which carries the mixture to a rotary drum dryer. Aggregates used include gravel (24%), sand (33%), stone (18%), limestone (20%), slag (3%) and miscellaneous (2%). The dryers are designed to remove moisture and then heat the rock to achieve a uniform coating when mixed with the asphalt. The rotary dryer is the major source of particulate emissions in an asphalt plant. Dryers are either oil (66%) or gas (34%) fired and are operated with hot air flowing countercurrent to the aggregate flow. The hot, dry aggregate is next conveyed from the dryer to a batch mixer where it is combined with the hot liquid asphalt for immediate use.

Drum mixer plants, of which there are about 400 in operation, are discussed later.

(B) Dryer Operation

Most asphalt plants operate intermittently--starting and stopping numerous times as they match production to demand. This can pose special problems to emission control devices if care is not taken to maintain temperature. Many units today are fully automated so that an operator can adjust the feed composition, dryer rate, drying temperature and burner operation from a central control room. Here also, the performance of the emission control system should be carefully monitored since it interacts with the dryer variables. Ideally, the dryer should be operated to achieve the desired level of dryness in the aggregate with a minimum of temperature surges and excess air. A 25% excess air level and an exiting gas temperature of 250°-300°F typically provides optimum fuel efficiency. As the aggregate is fed into the dryer, it is tumbled through the hot combustion gas which dries the aggregate. Along with the moisture, fine particulate is carried off by the exhaust gases. The entrained dust will vary greatly in particulate concentration and size depending on the feed composition but, typically, 30-40% of dust emitted will have a particle size < 20 μm and 10% < 5 μm. A 100 ton/hr unit may emit as much as 2-8 ton/hr of particle. Flights which lift and tumble the rock away from the dryer walls are placed in a dryer to improve the contact between the hot combustion gases and the aggregate. Although they increase the aggregate hold-up time (and, thus, the rotary drive motor power), they also improve drying efficiency. A proper combustion of flights, i.e., number and arrangement, will provide the best efficiency balance. However, by increasing gas-particulate contact, flights also increase particulate entrainment in the exiting gas stream and, thus, emission control load. The terminal settling velocity will determine the particle size distribution to be collected and the following equations apply.

Particle Size	Terminal Settling Velocity
1. (dp < 100 μm)	$V_t = \rho_p g dp^2/18\mu_f$
2. (100 < dp < 1000 μm)	$V_t = 0.2\rho_p^{2/3} g^{2/3} dp/\rho_f^{1/3}\mu_f^{1/3}$
3. (1000 < μm dp)	$V_t = (3\rho_p g dp/\rho_f)^{1/2}$

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V_t = settling velocity = ft/sec

ρ_p = particle density = lb/ft^3

ρ_f = gas density = lb/ft^3

g = acceleration due to gravity = ft/sec^2

dp = particle diameter in equations is in ft

μ_f = fluid viscosity, lb/ft-sec

By solving the equations for particle diameter with a known exit velocity, an estimate can be made of the minimum diameter that could settle in the dryer. For example, from an 8' diameter drum, exhausting 30,000 acfm at 300°F, the exiting velocity is 597 ft/min. Solving the equations above gives a 321 μm (∿ 1/80th of an inch) particle as being the minimum size that could settle out. Smaller particles would be carried out with the exhaust gases. Anything which increases exiting gas velocity (i.e., high moisture in rock, over firing, increased excess air) will increase particulate emissions.

The drum exhaust temperature is not only important for efficiency, but also for the prevention of corrosion and caking problems when a fabric collector is used for particulate collection. Low temperatures cause condensate to deposit on the bags and exhaust equipment, which leads to caking of the dust. Caking on the bags leads to an increase in pressure drop, a reduction in throughput, and higher energy costs. On the other hand, excessively high temperatures lead to shortened bag life (as discussed later).

Aside from particulate, a dryer emits a gas stream which contains air, water and combustion products. The composition of these emissions and their interaction with baghouses, the major type of control device, is of importance to Du Pont and the asphalt industry. The chemistry of the gas stream can influence the wear life of bags. As Nomex© aramid enjoys a high level of success and is used in almost all asphalt plant baghouses, Du Pont undertook a monitoring program to determine the composition of gas emissions and to assist the industry in improving cost and efficiency.

III. GAS STREAM MONITORING

A program was carried out by Du Pont, with the cooperation of baghouse users, to determine if there was an interaction between the dust in a dryer and SO_2 generated by the fuel combustion. Eight asphalt plants, representing a cross section of fuels and feed stocks, were monitored for SO_2 using a Du Pont 411 ultraviolet photoanalyzer. The results of those tests are shown in Table I. At seven of the eight sites, the measured SO_2 level was less than half that calculated from the amount of fuel burned. Presumably, the aggregate absorbs significant quantities of the SO_2 generated. In all seven sites, the dust pH is ≥ 7. Even those sites (#7 & #8, Table I) which use heavier oils (which usually contain higher amounts of sulfur) showed relatively low sulfur emissions. Therefore, only a small influence on bag life would be expected from the sulfur in the gas stream and confirms trade experience.

It is interesting to note the high level of excess air present in all systems. Apparently, most units, because of cyclic nature of their operation, are not able to carefully balance the burner firing against inlet load. Consequently, efficiency suffers.

IV. BAGHOUSE VS SCRUBBER

Early asphalt plants used cyclones to collect dryer emissions, but the efficiency of cyclones was inadequate. This is shown by the following separation data:

Cyclone Separation Effectiveness

Particle Diameter - μm	Collection Efficiency, %
larger than 30	99
10-30	60
5-10	5

Many plants, however, still employ cyclones to collect the larger particles (used as a sized filler). Current EPA standards set a 0.04 gr/dscf particulate emission limit. To meet this goal, a control technique with a

collection efficiency of at least 99+% of total emissions is needed (see Figure 2) and better than 96% of particles smaller than 5 μm must be collected. Only fabric filters and high-energy scrubbers are capable of meeting this goal.

Fabric filters collect dry particulate and allow for immediate reuse as a fine filler. Baghouses have been known to pay for themselves within three months, based on the value of the filler recovered. Scrubbers are sometimes used where high dirt content keeps the particulate collected from having any reuse value, but baghouses perform here as well.

(A) Performance Comparisons

Current industry estimates are that about 40% of the asphalt plants in the U. S. use fabric filters and ∿ 25% use scrubbers to collect emissions. This leaves ∿ 35% of existing plants still not meeting $\leq$ 0.04 gr/ft^3, which is the current federal emission code. Many older plants do not have to meet federal codes because they are "grandfathered" and have not had major modifications. For new installations, baghouses have enabled the industry to meet the new control laws since 1974. The reason for this is evident from a comparison of the two systems given in Table II. The high efficiency at any operating load and zero ground water discharge of a fabric filter are major advantages. Further, the collected particulate may be recycled to the mix and, thus, eliminate the cost of mineral fines. This gives a cash return from the control device (filler value $\cong$ \$7-9/ton). One consideration, high moisture in the gas stream, can lead to dew points, which cause blinding and corrosion. This condition is avoided by a proper design of the system. In summary, baghouses for particulate collection appear to be the preferred control technique with over 2200 installations. Of these, pulse jet type collectors are used throughout the industry because of their high air-to-cloth (a measure of throughput effectiveness, i.e., the cfm of air filtered per square foot of fabric surface) ratio, compact size, and ease of fabrication.

(B) Nomex Performance

Du Pont has developed fibers of Nomex to meet the fabric needs of the asphalt industry. Nomex provides (1) the high temperature operating (250°-400°F) capabilities desired to avoid dew points or blinding and (2) protection from temperature surges (∿ 500°F) needed in case of a feed stoppage. Combined with outstanding durability, oxidative stability and adequate chemical resistance, it has become the accepted fiber for this application. Bags of Nomex have demonstrated outstanding life and efficiency in countless installations. A life of 3-5 years is typical and as many as 8 years have been reported. Felts of scrim-reinforced Nomex (13-16 oz/yd^2) give the best balance of efficiency, durability and cost. Generally, for asphalt dryer applications, dust release is very good. However, singeing (flame treatment of the felt surface) is sometimes used to improve dust release.

V. DRUM MIXERS

Over the last several years, a new type of asphalt plant has been developed which is called a turbulent mass mixer (TMM). The TMM is being accepted rapidly with perhaps as many as 400 plants in service today.

(A) Characteristics

The system differs from a conventional plant in that the asphalt is injected directly into the dryer, thus eliminating a mixer. Unlike conventional rotary dryers, these units are co-current flow because of the asphalt injection (Figure 3). The hot asphalt (∿ 300°F) is sprayed on to the rock part-way through the dryer and, depending on the type of paving being produced, up to 5% asphalt is injected. The point of injection is important from a pollution as well as product consideration. If injected early, overheating may cause excessive amounts of hydrocarbons to be emitted from the asphalt; and, if injected late, inadequate coating may occur. At first, it was claimed that, with proper injection, the particulate emitted would be captured by the asphalt and no pollution control devices would be needed. However, this claim has proven to be wrong. Baghouses and scrubbers are both being used as control devices. Many of the operating guidelines employed by a conventional plant still apply (i.e., moderate excess air, exiting temperatures ∿ 300°F, etc).

(B) Monitoring Results

The emissions from a turbulent mass mixer plant were measured for SO_2 and a check was made of the dust for the presence of hydrocarbon (Table III). The results were essentially the same as those found in conventional plants, i.e., half of the SO_2 was absorbed by the dust (pH = 9.7). In addition, analysis of the particulate and condensed moisture showed only trace levels of hydrocarbons and no visible emissions ("blue haze") were observed. The collected particulate was also free flowing and showed no tendency to agglomerate. The pressure drop across the unit was 4-5 in. H_2O at about a 7/1 A/C ratio.

(C) Baghouse Applications

Approximately 100 baghouses have been successfully supplied to TMM plants and caking and blinding have been avoided by carefully controlling the asphalt injection operation. If blinding does occur, there are two things one might do to restore baghouse operation: (1) heat the unit to ∿400°F and pulse the bags for 3-4 hours. If that does not free the bags and bring the Δ P down, then (2) launder to remove the hydrocarbon deposits. One or two bags should be given an industrial dry cleaning or industrial washing before all are laundered to make certain they can be cleaned satisfactorily.

VI. FABRIC DEVELOPMENT (Shrinkable Nomex)

Current Nomex felts perform well in over 95% of the asphalt plant baghouses in service. However, an unusually fine, round, non-agglomerating dust is occasionally encountered which is very difficult to collect. In the past, the only options were to use heavier weight felts, reduced air-to-cloth ratio or a reverse air or shaker system (again at low air-to-cloth). All these options increased system and operating costs. For these problem areas, Du Pont is developing a new shrinkable Nomex fiber (SN) with filter characteristics even better than regular Nomex. It is processed to a felt in the same manner as conventional Nomex and then heat set at an elevated temperature above any subsequent use temperature. At

this temperature, the fibers shrink and interlock to give a strong, dense, stable felt structure. The strength is sufficiently high so that a reinforcing scrim is not required.

(A) Improved Efficiency

The SN felts, because of their tight, dense nature, collect the dust more on the surface and, thus, they are easier to clean and more efficient. Improved efficiency has been demonstrated in three field trials: (1) on an alumina dryer, (2) on a sintering operation and (3) on a clinker cooler.

(1) In the first test, the fabric collector was filtering an alumina dust which was round and had a low tendency to agglomerate. With 16 oz/yd^2 polyester bags, a leakage rate of 0.067 gr/cf (18.2 lb/day) was measured. A set of 16 oz/yd^2 shrinkable Nomex bags dramatically reduced emissions to 0.00145 gr/cf (0.4 lb/day) and an 18 oz/yd^2 set to 0.0005 (0.13 lb/day). No change in pressure drop or cleaning cycle was required.

(2) A baghouse, which was filtering emissions from a sintering furnace with conventional 16 oz/yd^2 Nomex, was emitting 0.03-0.05 gr/cf. After installing 16 oz/yd^2 SN bags, emissions were reduced by an order of magnitude to 0.002-0.003 gr/cf.

(3) In the third trial, lightweight (10 oz/yd^2) SN bags were placed in one compartment of a clinker cooler baghouse, which was functioning quite well with conventional T-450 Nomex bags. The leakage rate was measured in adjacent compartments and showed the 10 oz/yd^2 SN rate to be quite low and comparable to conventional 14 oz/yd^2 Nomex bags.

The field trials confirmed laboratory findings and show that:

- At equivalent weight, felts of shrinkable Nomex are significantly more efficient.
- For equivalent efficiency, lighter weight shrinkable Nomex felts can be used.

(B) Lighter Weight

In new or existing units where there are no problems with leakage, lighter weight SN bags can perform well. Bags of shrinkable Nomex (9-11 oz/yd^2) have been in service in a Florida asphalt plant for $\sim 1\frac{1}{2}$ years with no problems.

Shrinkable Nomex fiber has been introduced to the trade in development quantities for trade prove-out.

SUMMARY

The baghouse is best suited to the pollution control needs of the asphalt paving industry. It has demonstrated:

- High efficiency.
- Low maintenance.
- No waste disposal problem (usable byproduct).
- Simplicity of operation.

The new turbulent mass mixer asphalt plants are growing steadily in number and may account for up to 50% of the new plants being built. These plants eliminate the need for a separate mixer, but still require emission controls and the standards can be met with a properly designed baghouse.

Gas stream analyses have shown that sulfur emissions are lower than predicted (we theorize because of absorption by the rock dust). This absorptive action of the dust removes chemicals which could attack the Nomex bags. Bags of Nomex have long life due to durability, oxidative stability and good chemical resistance.

A new shrinkable Nomex fiber now offers the industry the opportunity to solve unique leakage problems, including the reduction in amount and size of particle control should Federal codes be further tightened.

Table I. Asphalt industry monitoring results.

Site	Fuel	Dryer Capacity T/Hr	Exiting Temperature °F	Gas Composition % CO_2	O_2	H_2O	SO_2 Conc, PPM Measured	Calculated	Dust pH	Excess Air %
1	#2 Oil & Natural Gas	200	160-210	1.4	17.5	-	5 .41	12	7.0	475
2	#2 Oil & Natural Gas	-	150-230	2.2	16.7	-	5 .127	18	7.0	388
3	#2 Oil	100	325-395	2.1	17.9	-	20 .41	49	11.2	548
4	#2 Oil	150	195	2.2	17.1	8.1	10 .12	52	9.3	416
5	#2 Oil	250	260	1.6	17.0	4.2	0	100	-	404
6	#2 Oil	150	305	4.5	15.0	11.7	10-25 (17.5) .46	38	9.7	212
7	#5 Oil	150	150-185	2.1	18.5	10.5	10 .06	171	10.8	672
8	#5 Oil	150	290-360	2.4	17.4	2.8	65-230 .70	214	6.9	459

.35 % Avg

65% retention

49 - 20 = 29/49 = 59%

52 - 10 = 42/52 = 81%

100%

5%

294/4 = 73%

Table II. Comparison of baghouse and scrubber systems.

	Baghouse	Scrubber
Efficiency, %	99+	90-98
Disposal Requirement	None	Pond for contaminated water
Dust Recycleable	Yes	No
Relative Initial Cost	1.25	1
Relative Operating Cost	1	1.5
Corrosion	No[a]	No[b]
Temperature Sensititivy	Yes	No

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(a) In a system properly designed to prevent dew point operation.

(b) Unless absorbed gases are not properly neutralized.

Table III. Monitoring of turbulent mass mixer asphalt plant.

Operating Conditions	
Capacity	100 T/D
Fuel	#2 Oil
Asphalt Temperature	315°F
Injection Rate	5%
Baghouse - Type	Plenum Pulse
- Temperature	305°F
- Bags	Nomex
- Pressure Drop	4-5 in H_2O
Gas Stream*	
SO_2	18 ppm (calc = 38 ppm)
CO_2	4-4.5%
O_2	14-15%
H_2O	12%
Dust - pH	9.7
Hydrocarbons	
Dust	Trace
Condensate	Trace
Excess Air	212%

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* Measurements made by Du Pont.

FIGURE I

CONVENTIONAL ASPHALT PAVING PROCESS

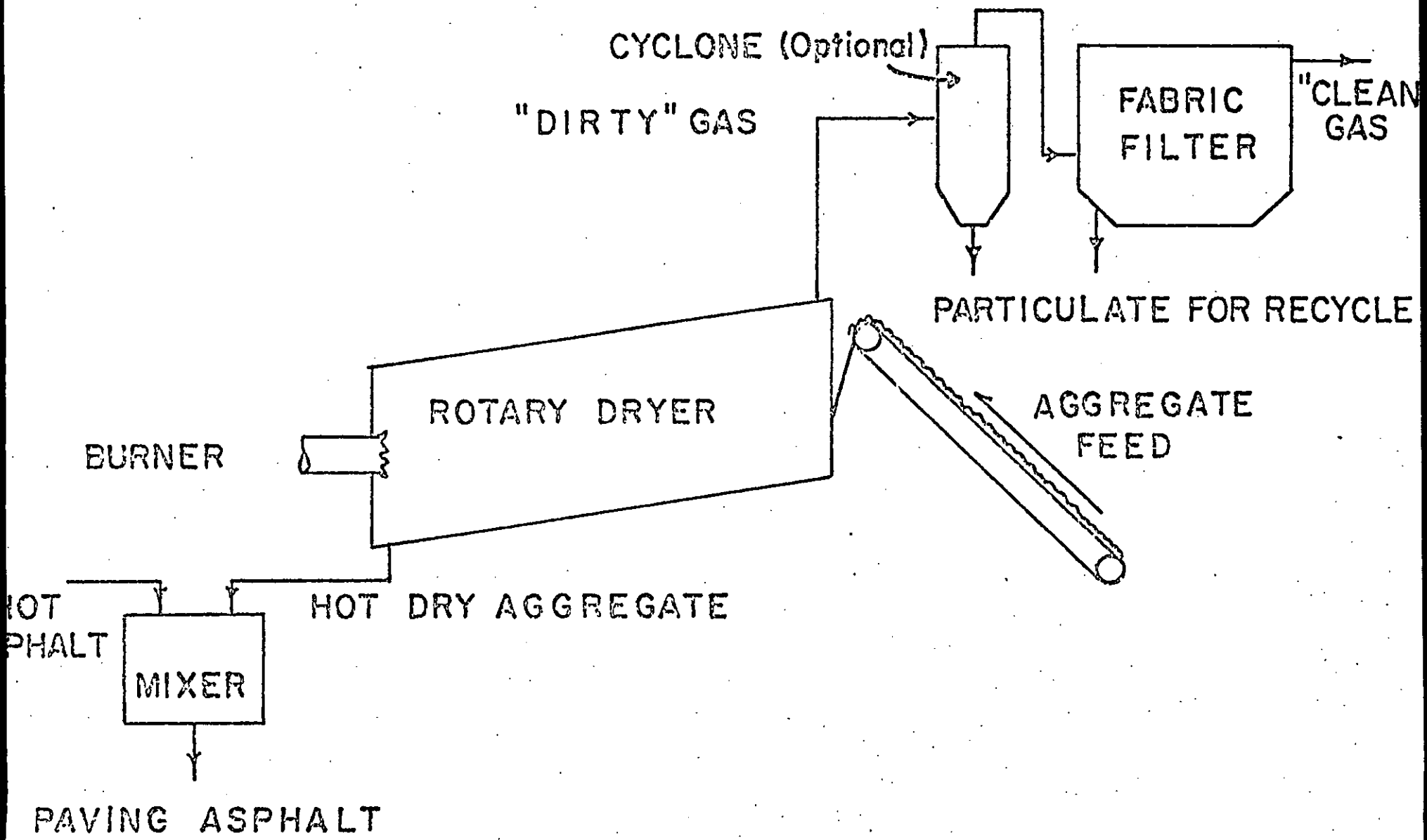


FIGURE I

CONVENTIONAL ASPHALT PAVING PROCESS

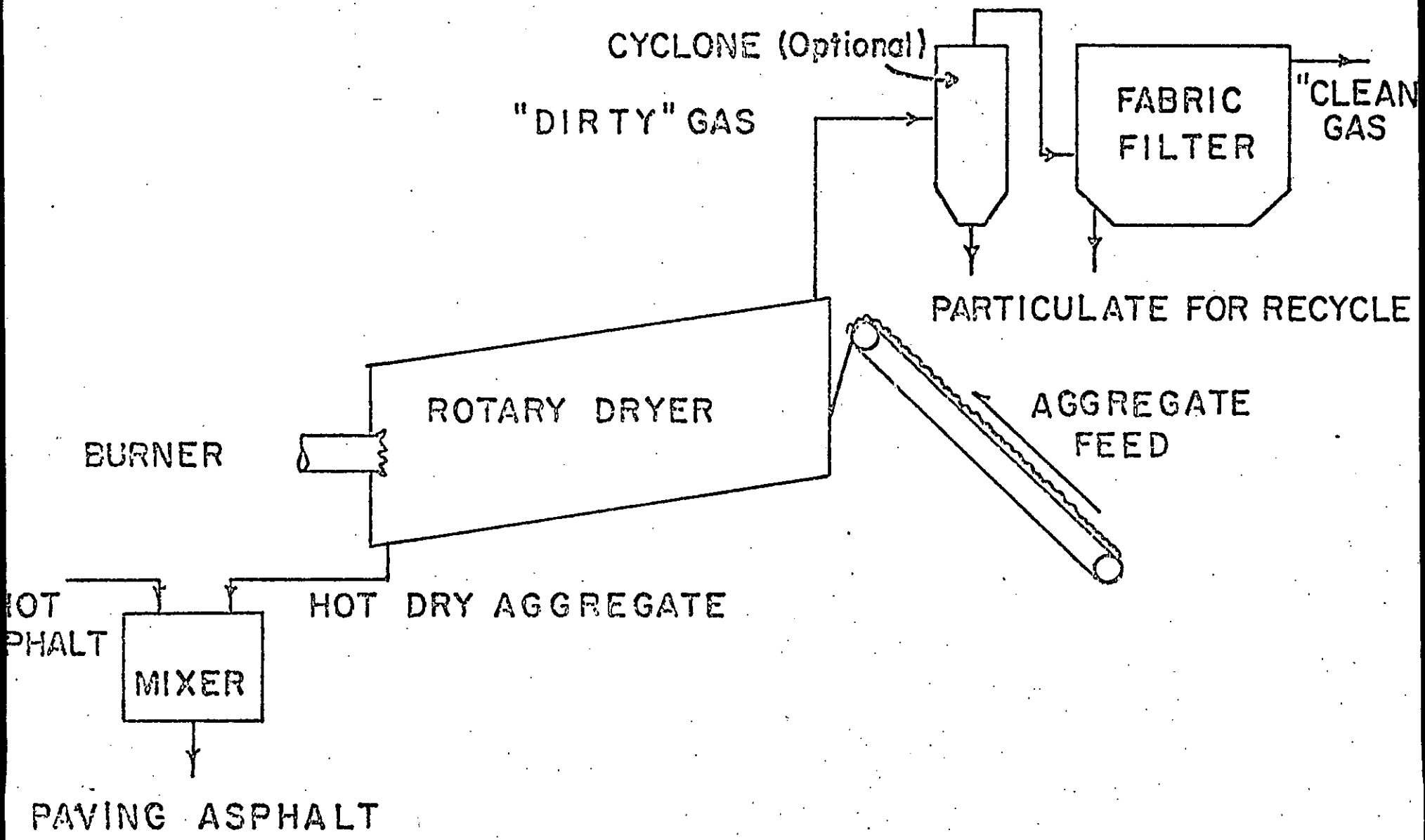


FIGURE 2

COLLECT EFFICIENCY REQUIRED TO MEET EPA LIMITS FOR ASPHALT DRYER

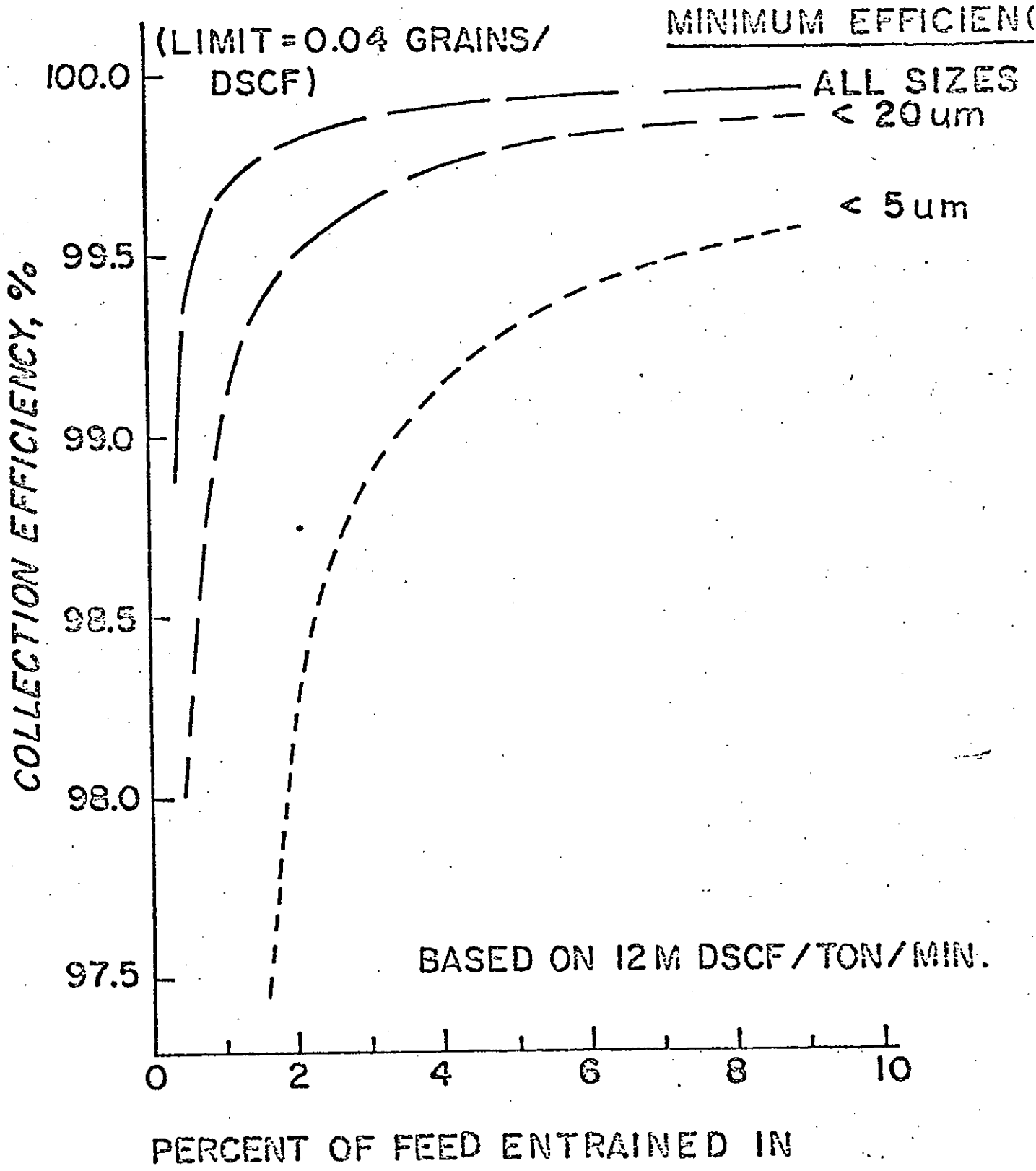
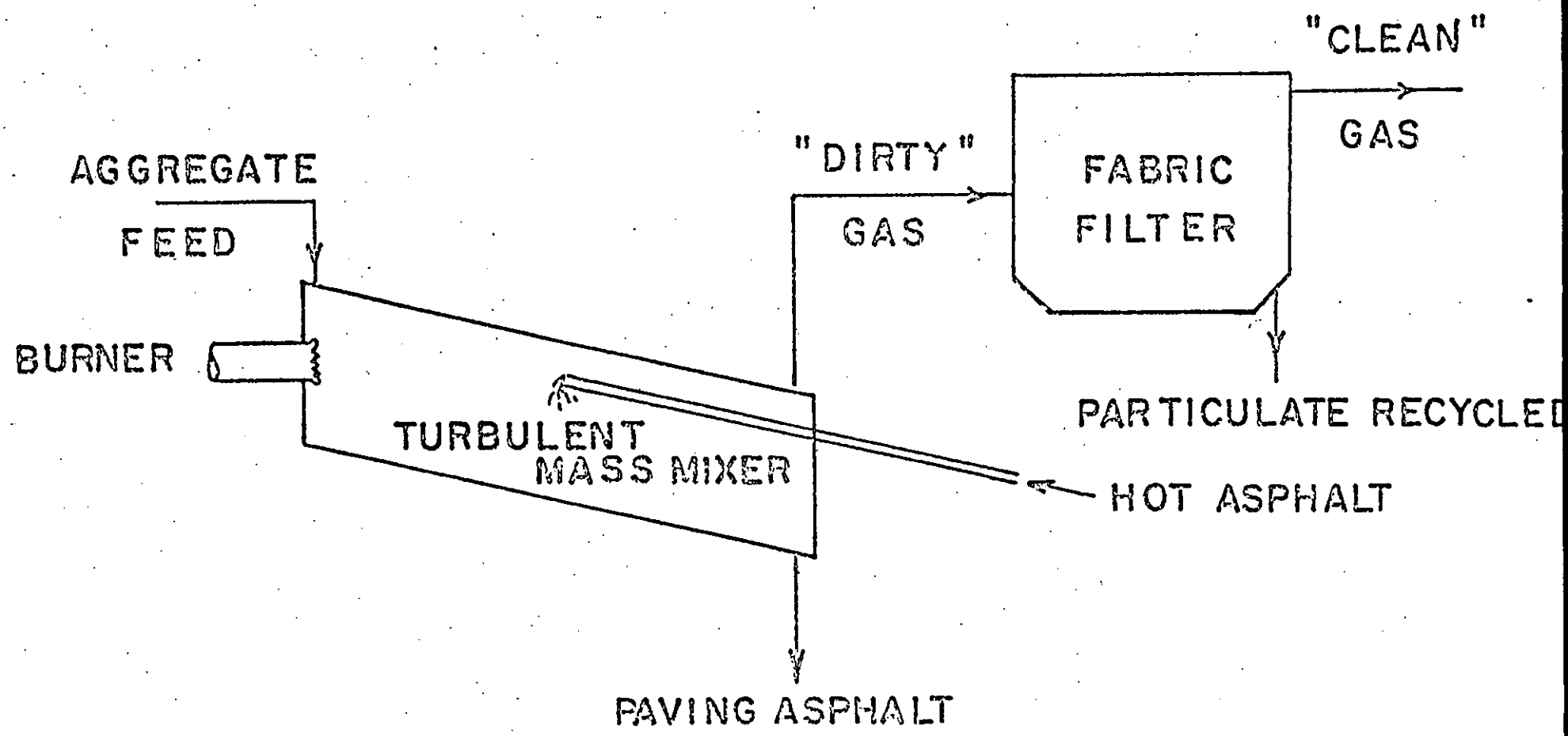


FIGURE 3

TURBULENT MASS MIXER ASPHALT PROCESS