Technical Paper T-119

DRYER DRUM MIXER

by J. Don Brock, PhD., P.E.

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INTRODUCTION

According to all predictions the American infrastructure will go through a total rebuilding program in the current decade. Returning our infrastructure to its once preeminent position will require new sewer systems, new drainage systems and re-establishing grades and drainage. An approximate 95% increase in traffic over the past fifteen years has led to a tremendous overload of the system. Thus, the bulk of new construction will be widening, maintenance, and upgrading of the systems. By the mid-nineties 50 to 70% of all asphalt mixes will likely contain one or more of the following recycle products:

- **Crushed concrete**
- **Recycled asphalt mixes**
- **Roofing shingles**
- **Oil contaminated soils**
- **Rubber**
- **Glass**

Also, the addition of additives such as lime and anti-strip will be necessary.

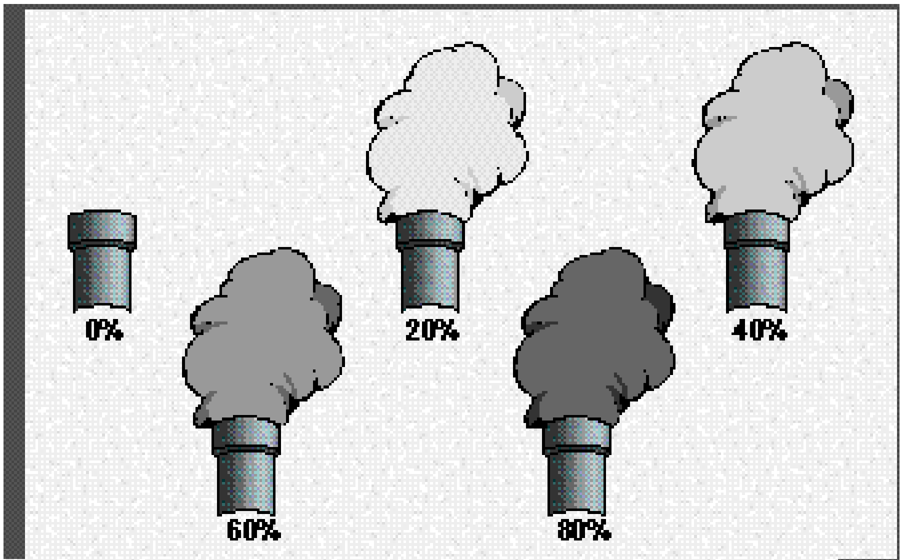
During this decade further shortages of crude oil may occur and lead to a variations in asphalt products available for new mixes and recycling.

Asphalt in recycle material is harder than in new asphalt mix because of aging that occurs while it is part of the old road surface. But the quality of new mix incorporating large percentages of recycle asphalt and various other recycle products will have to be equal to that of virgin mix. Both the old and new liquid asphalt will have to be distributed uniformly throughout the mix. This will require making mixes 20 to 30° F hotter than usual to produce a mix viscosity that will allow compaction to desired densities.

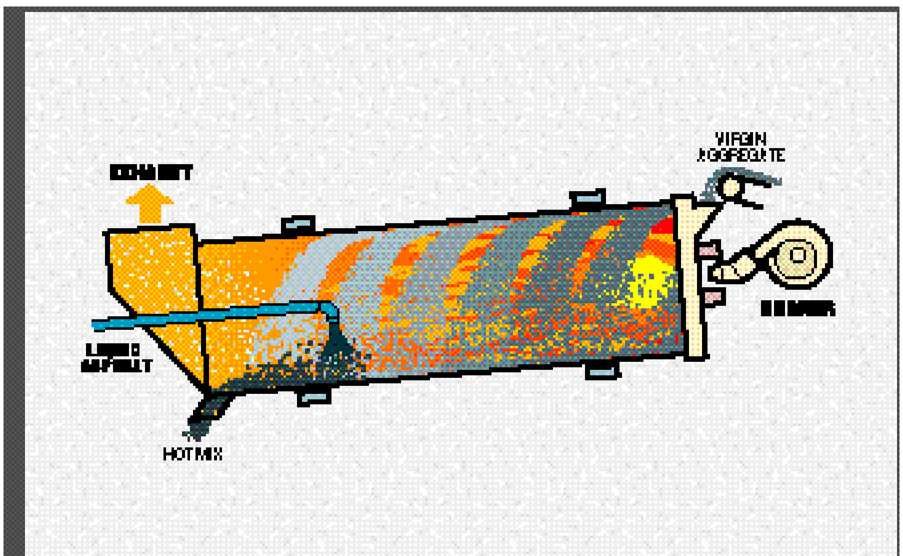
Even though mixes using various recycled products must be run hotter, environmental codes will require that the asphalt facilities operate absolutely clean. Even though the national code allows 20% opacity **(Figure 1)**, more and more state and local codes require zero opacity. The code is the same for all mixes, no matter how much recycle is used or the type of mix.

In order to obtain zoning and permits for a facility, its emissions must not only be invisible, but it must be odor-free and must run quietly. Over the many years since the introduction of the Clean Air Act in 1973, enforcement of codes has not been uniform. But enforcement will become much more uniform. And even those facilities in remote areas will be required to meet more stringent codes in the future.

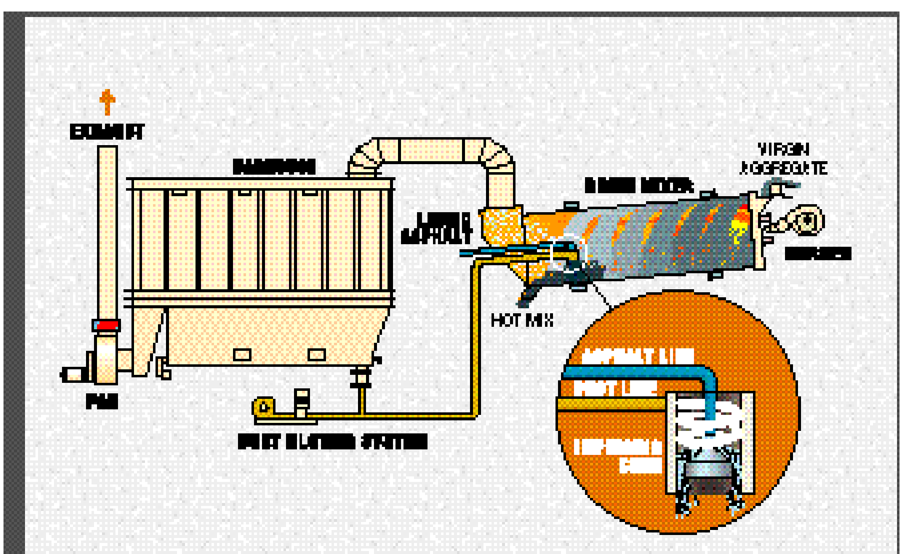
To be competitive in an increasingly competitive market, asphalt facilities will have to run higher production, have lower operating costs, and be easier to maintain. Last, but not least, the facilities must produce mix of the highest quality. The mix must have minimum segregation, excellent mixing of both the recycle and virgin materials, complete coating, and uniform film thickness.



OPACITY GUIDE F1



ORIGINAL PARALLEL-FLOW DRUM MIXER F2



DRUM MIXER WITH BAGHOUSE F3

BACKGROUND

Over the years asphalt plant manufacturers have designed equipment to meet the needs of the industry. Since needs change continually, equipment is continually changing.

In the ’50s and ’60s batch type asphalt plants were common. They did an excellent job producing quality mixes. But the late ’60s and early ’70s brought air pollution requirements. Most batch plants had production restricted by additional air pollution equipment. As a result, batch plants become larger and more difficult to move.

The early ’70s brought the invention of surge and storage bins. This, plus the availability of electronic controls, led to the introduction of drum mix plants. They operated as continuous mix plants. They were simpler. And they could be much more portable **(Figure 2)**. It was believed that they would eliminate bulky air pollution equipment.

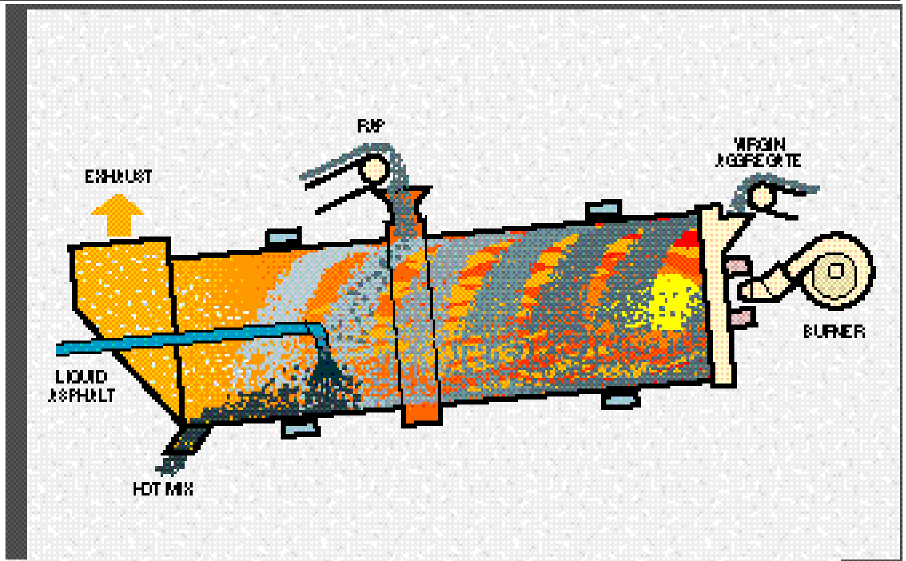
In 1973 the Clean Air Act was passed. It required all asphalt plants to have emissions of less than 20% opacity. It mandated particulate grain loading of less than 0.04 grains/dry standard cubic foot. Emissions from early drum mixer plants were much less than from batch plants. But the drum mixers (without collection equipment) still could not meet requirements of the new Clean Air Act. Consequently, wet washers and baghouses were added to the drum mixers. This, unfortunately, reduced their portability. **(Figure 3)**.

Due to shortages and high prices of crude oils in the late '70s recycling again became economically feasible. Drum mixers readily lent themselves to the introduction of recycle. It simply required cutting holes in the shell of the drum so the recycle material could be introduced into a cooler zone, downstream from the hot gases of the burner. **(Figure 4)**.

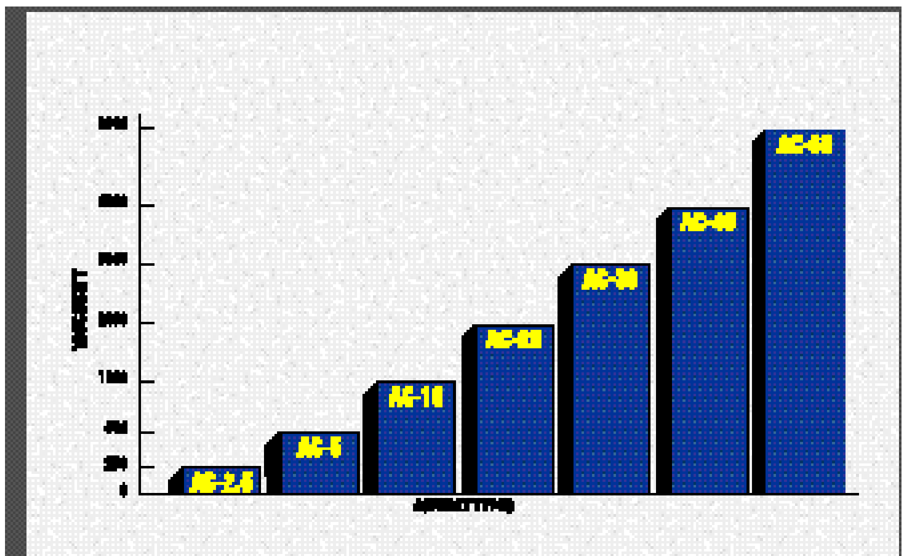
Concurrent with the oil shortages, crude oils from all over the world began to enter the United States. Variations in the crude oils led to variations in the hardness in the asphalts **(Figure 5)**. Recycle materials contained harder asphalt, which needed to be used with softer virgin asphalt. Often, however, softer materials were not available. And that led to cutting back the harder asphalt with lighter oils to artificially soften it.

Development of the milling machine made more recycled material available. It facilitated the removal of varying amounts of the road for leveling, for maintaining clearances of underpasses, and for eliminating dead weight on bridges. Each year the percentage of recycle mix increased. And each year the air pollution codes became stricter. This led to a problem caused by distillation, an inherent problem in the basic drum mixer.

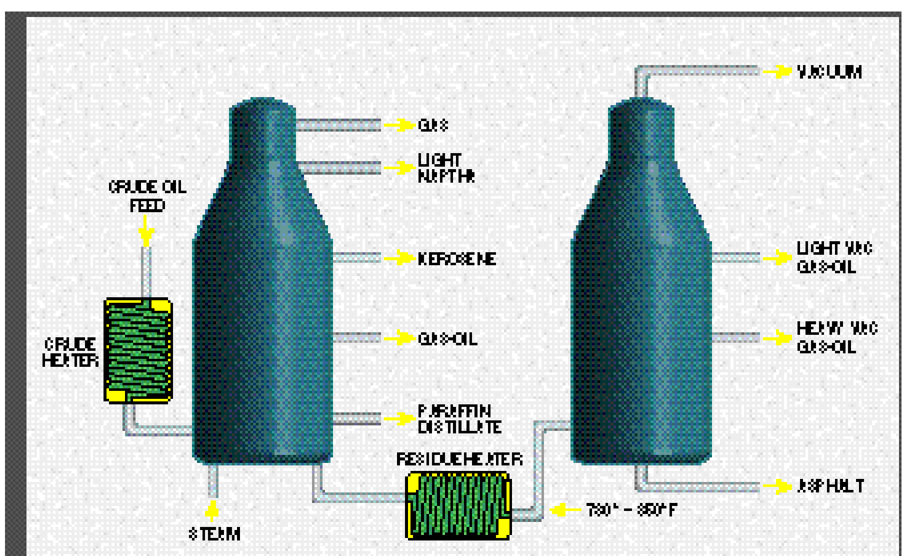
As shown in **Figure 6**, a refinery consists of one or more distillation columns. They distill crude oil at temperatures of 600–700° F and separate it into heavier and lighter fractions. Many years ago it was found that crude oil could be distilled at much lower temperatures (300° F) by injection of steam.



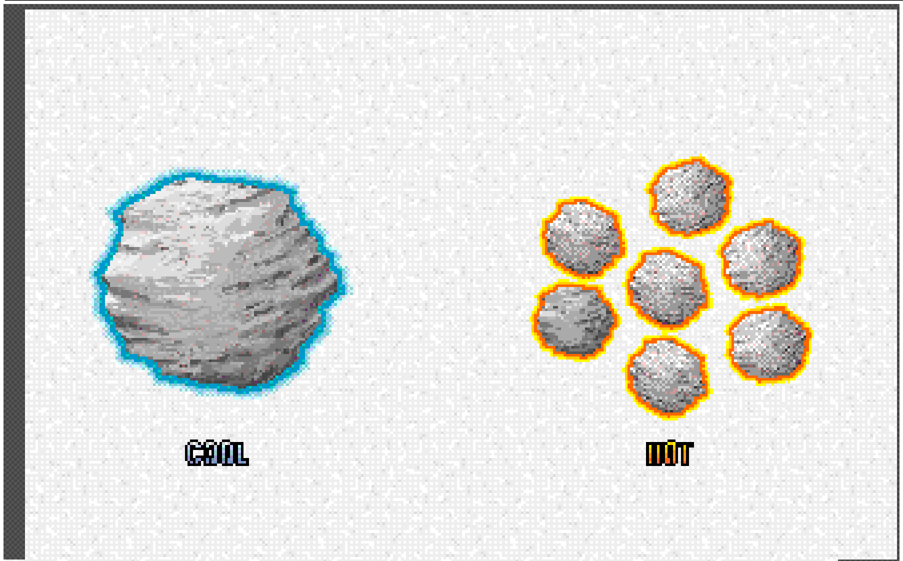
DRUM MIXER WITH CENTER INLET F4



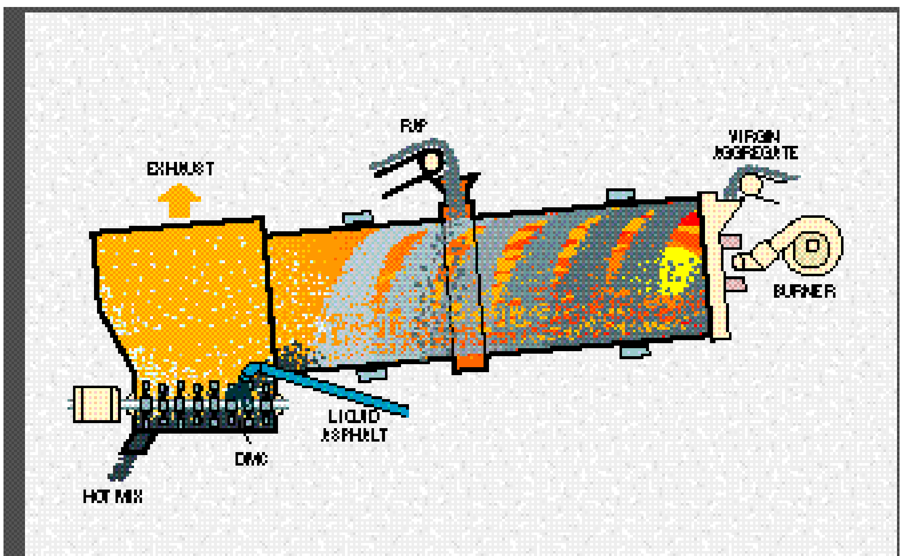
ASPHALT PRODUCED FROM VARIOUS CRUDE OILS F5



REFINERY FLOW DIAGRAM F6



SMALL PARTICLES HEAT UP FASTER F7



DRUM MIX COATER-I (DMC-I) F8

A drum mixer **(Figure 2)** is very similar to a refinery. The liquid asphalt is spread out as a thin film over many square feet of surface area in the mix. There it is exposed to temperatures in the gas stream of approximately 400 to 450° F.

The mix consists of large and small particles. The small particles have low mass and many of them are present. The small particles heat up quickly to the temperature of the gas stream as shown in **Figure 7.**

The gas stream contains exhaust gases and steam. The amount of steam depends upon the moisture in the aggregate. Higher moisture in the aggregate produces more steam. More steam produces more distillation, especially if the asphalt has been artificially softened with lighter fractions. These problems led to the need for a new generation of asphalt plants.

DRUM MIX COATER-I (DMC-I)

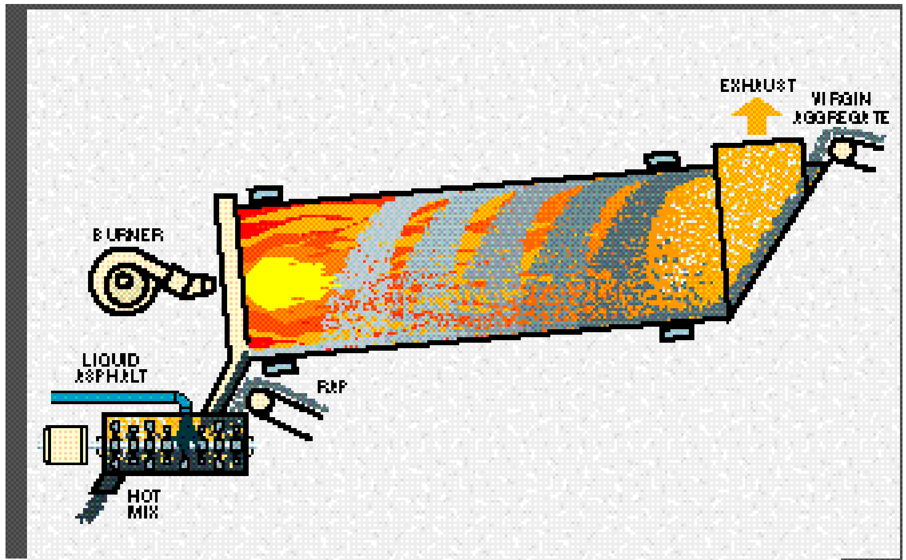
By the mid-1980s it became apparent that virgin asphalts should be introduced into the mix in a different way because they contain increased amounts of light oil. They needed to be removed from the gas stream to avoid exposure to hot gases or steam. This led to the development of the Drum Mix Coater-I plant shown in **Figure 8.** It had a parallel flow drum mixer in which the hot gases and aggregate move in the same direction. It also had a mixer or coater at the discharge end of the drum.

This plant produced an excellent product using recycle. The recycle entered into the center of the drum where it mixed with hot virgin aggregate. The old asphalt in the recycle melted, partly coating the virgin aggregate prior to introduction of virgin liquid asphalt near the end of the drum. This ensured that both virgin and recycle liquid asphalt was placed on both the virgin and recycle aggregate, resulting in an excellent homogeneous mix. But as air pollution codes became stricter, inherent problems of these plants and drum mixers became apparent:

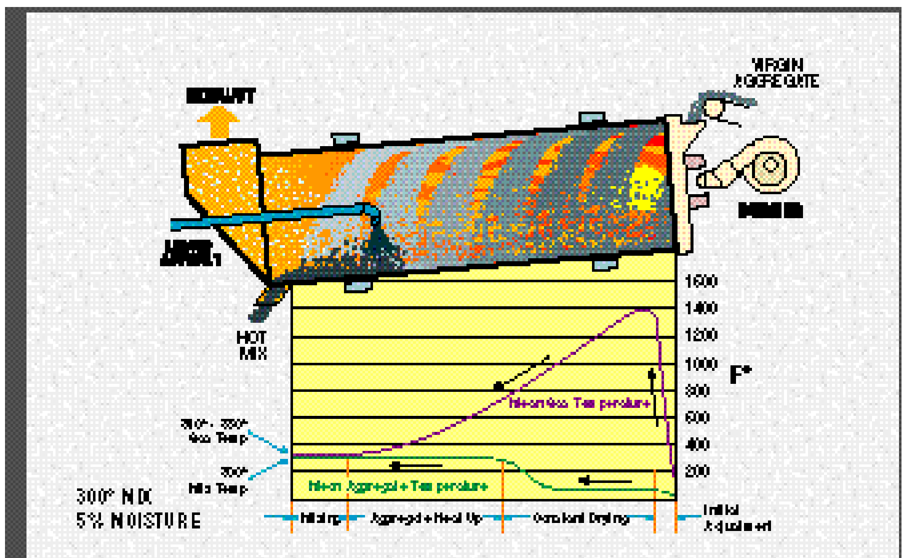
1. These plants ran much higher stack temperatures than those with the counterflow dryer previously used with batch plants. (Operators accepted this because the plants gave higher production rates.) The higher rates were obtained by running higher gas flows than previously used on counterflow dryers with batch plants.

2. The plants were very sensitive to mix temperatures. Running recycle often required increasing mix temperature by 10 to 30° F. But increasing mix temperature made the plants smoke.

3. Smoking or opacity increased as higher percentages (above 30%) of RAP were used. It was found that even 30 year old recycle still contained varying fractions of light oil. If the original asphalt was cut back with a light oil similar to a motor oil, or with a heat transfer oil, it remained in the material throughout the period it was on the road. Moreover, oil spilled from automobiles and trucks added to the oil in the pavement and showed up when it was used as recycle. Visible emissions that began to occur as higher percentages of recycle were used led to the development of the Drum Mix Coater-II.



DRUM MIX COATER-II (DMC-II) F9

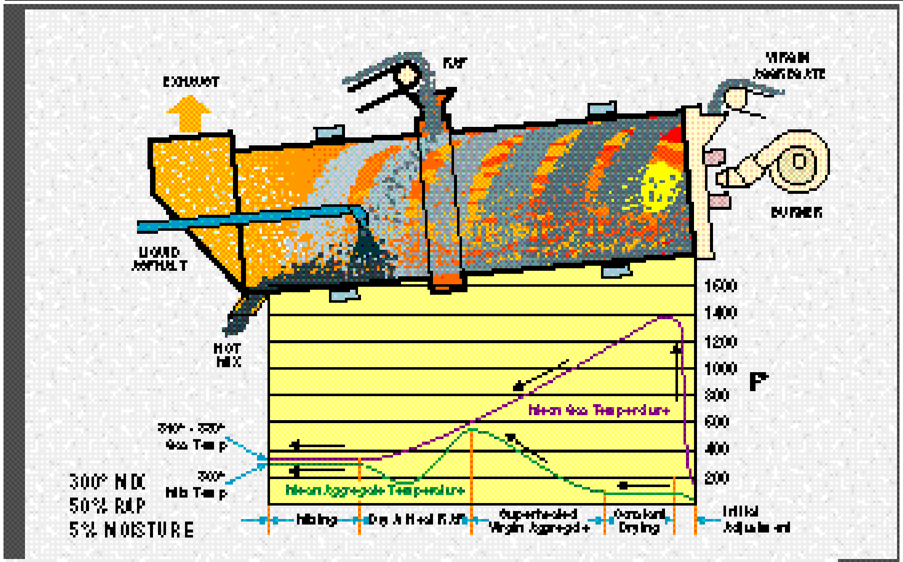


TEMPERATURE PROFILE OF DRUM MIXER F10

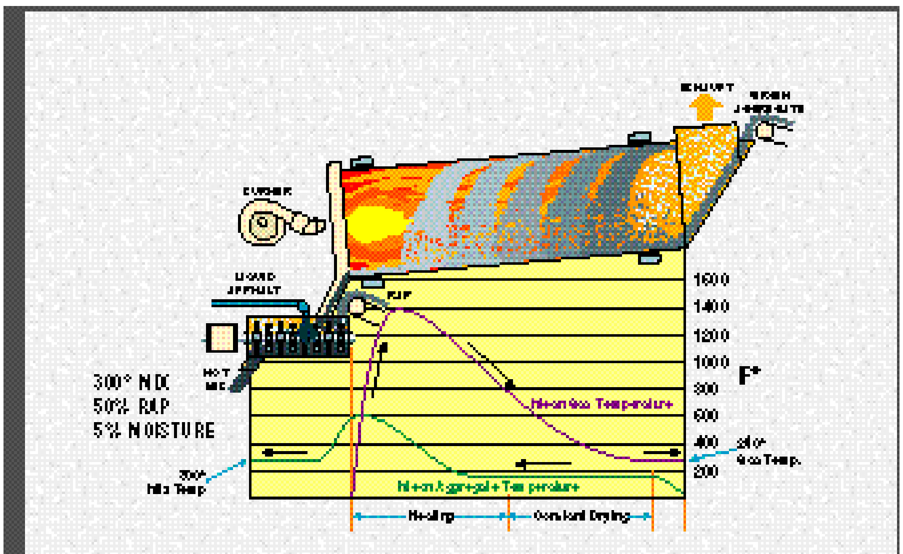
DRUM MIX COATER-II (DMC-II)

Figure 9 shows a diagram of the Drum Mix Coater-II. The DMC-II uses a counterflow dryer instead of the parallel flow dryer used in either the original drum mixer or a Drum Mix Coater-I.

In the original drum mixer the hot gases and the aggregate move in the same direction within the drum as shown in **Figure 10**. And when it produces a 300° F mix, the lowest obtainable exit gas temperature at the exhaust of the drum is 300°



TEMPERATURE PROFILE OF DRUM MIXER WITH CENTER INLET F11



TEMPERATURE PROFILE OF DMC-II F12

F, regardless of drum length. Even in today's most efficient and modern parallel-flow drum mixers, this temperature reaches 310 to 330° F.

Figure 11 shows a temperature profile of the original parallel-flow drum mixer with a center inlet. The profile also applies to the Drum Mix Coater-I previously described. Flights were installed in the front of the drums to superheat the virgin aggregate to a temperature as high as possible while reducing gas This was done to reduce temperatures to which small and large recycle particles were exposed. It did improve the operation of both mixers when using recycle. But it did not totally eliminate steam distillation from recycle material. Steam distillation thwarted efforts to totally eliminate all visible emissions when 30% or more recycle material was used and virgin aggregate had moisture levels of 5% or higher.

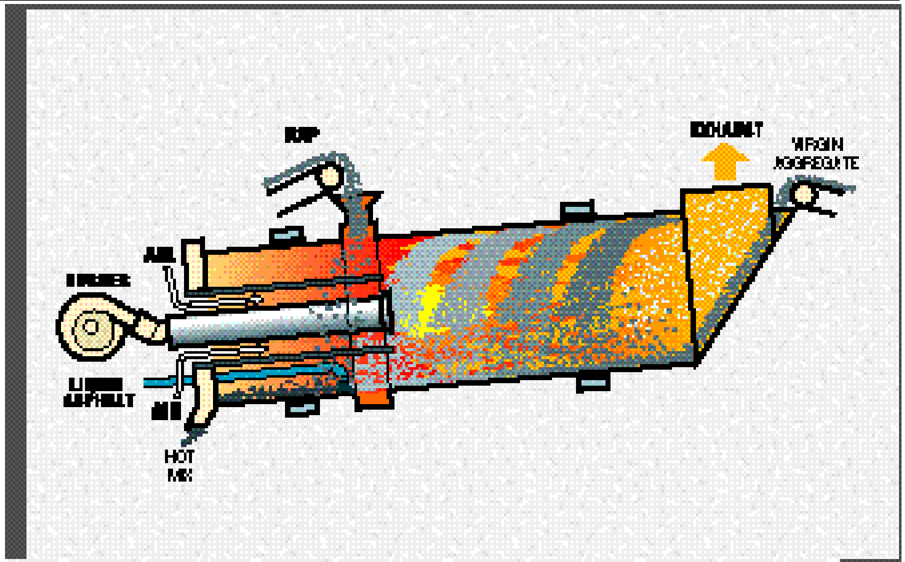
As shown in **Figure 9** and **12**, Drum Mix Coater-II has a counterflow dryer and uses a mixer at the discharge end of the dryer. And, as **Figure 12** shows, the virgin aggregate enters the end where gases are discharged. Consequently, the gases travel in one direction while the aggregate travels in the opposite direction. This design allows much lower exit gas temperatures to be achieved.

Exit gas temperatures as low as 180° F have been achieved using wet washers with this type of dryer. However, with baghouses, temperatures at the dryer exit are usually controlled at about 240° F. This prevents condensation of water or acids in the baghouse. When using natural gas or low sulphur fuel oils, exit temperatures can be lowered to 220° F. Lower temperatures allow higher production rates while using less fuel, a more efficient plant operation.

With the Drum Mix Coater-II recycle enters into the coater or mixing section **(Figure 12)**. The virgin aggregate is superheated. It, in turn, heats the recycle materials.

In the drum mixer **(Figure 11)** and DMC-I **(Figure 8)** approximately 90% of the recycle material heating is by the virgin aggregate and 10% by the hot gases. But in the Drum Mix Coater-II, 100% of the recycle heating is done by the virgin aggregate.

The major disadvantage of the Drum Mix Coater-II is the short mixing time in the coater. There is no mixing prior to the coater. The hot virgin liquid asphalt, virgin aggregate and cold recycle are injected at approximately the same point in the coater. Consequently, when high percentages of recycle material are used, the short mixing time produces a less homogeneous mixture. Newer versions of this plant with twin coaters allow introduction of recycle before the liquid is injected. This produces a product very similar to that of a Drum Mix Coater-I.



COUNTERFLOW DRUM MIXER WITH EMBEDDED BURNER F13

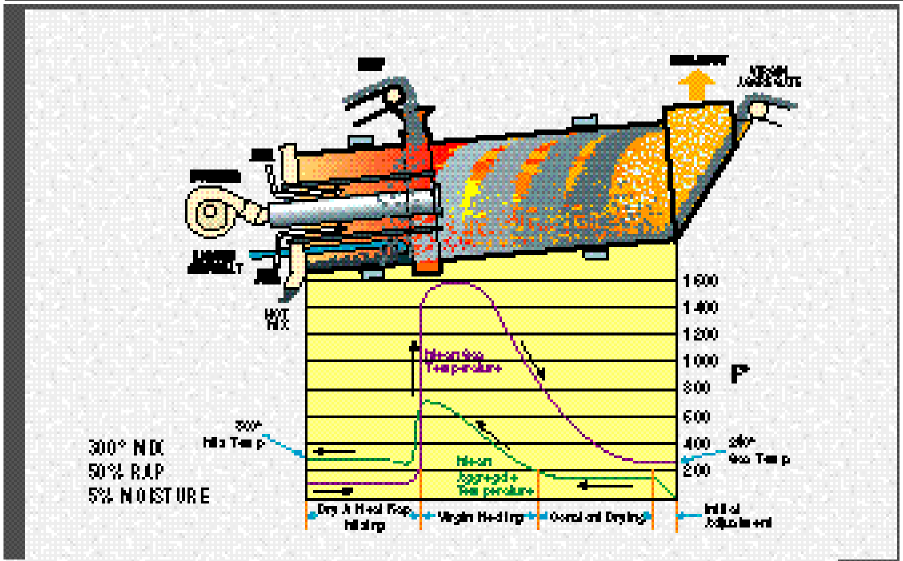
This type of plant has another disadvantage. Its drum shell gets very hot when superheating aggregate to 600–650° F. However, the shells can be air-cooled by various ingenious methods to eliminate this problem and increase efficiency.

NEWER DRUM MIXERS

By late 1986 it became apparent that a new type of plant would be needed in the ’90s. It should be capable of running high percentages or recycle. It needed to be capable of running high mix temperatures. It had to operate without polluting the atmosphere with odors or smoke (zero opacity would be required). This plant also needed to have an efficiency equal or greater than existing plants. It would have to readily use various recycle products to make a high-quality mix. These needs led to the eventual development of two new types of mixers:

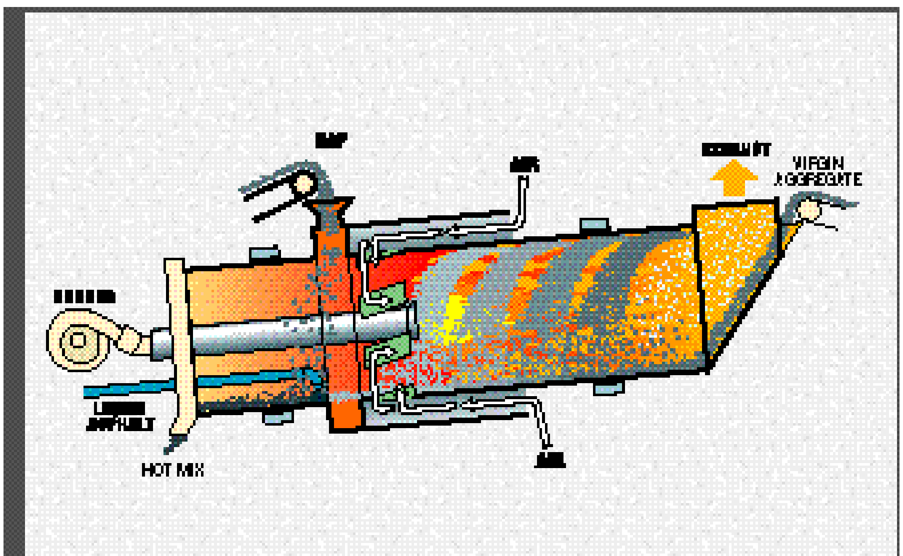
1. Double Barrel drum mixer
2. A counterflow mixer with an embedded burner

Figure 13 shows one version of a counterflow mixer with an embedded burner. **Figure 14** shows a profile of temperatures through the mixer. It uses a counterflow dryer to dry and superheat the aggregate. The burner is inserted approximately 14' into the drum. Recycle material is injected down-stream of the burner where



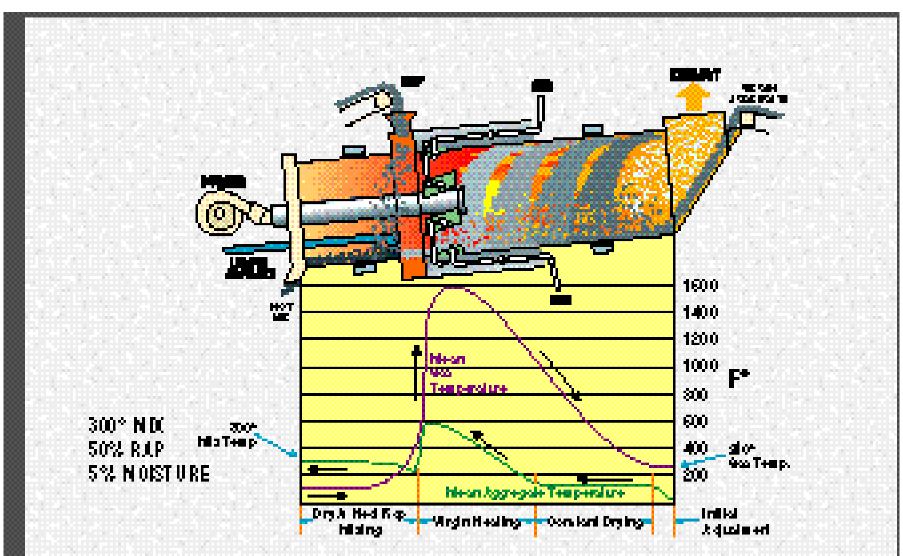
TEMPERATURE PROFILE OF COUNTERFLOW DRUM MIXER WITH EMBEDDED BURNER

F14



COUNTERFLOW DRUM MIXER WITH EMBEDDED BURNER AND AIR-COOLED SHELL

F15



TEMPERATURE PROFILE OF COUNTERFLOW DRUM MIXER WITH EMBEDDED BURNER AND AIR-COOLED SHELL

F16

it mixes with the hot virgin aggregate and virgin liquid asphalt.

But this plant has disadvantages. It has high shell temperatures and a short mixing time for recycle and virgin materials. Moreover, it is difficult to maintain because key components on the burner are not accessible.

Figure 15 shows the same type of counterflow mixer with an air cooled shell and air injection holes adjacent to the burner. **Figure 16** shows a profile of temperatures through the mixer. Secondary air for the burner is pulled through the injection holes, eliminating two disadvantages of the mixer shown in **Figure 13.**

Pulling secondary air through a outer shell cools the drum and preheats the air for combustion. The preheated secondary air increases plant efficiency approximately 4% in continuous operation and up to 8% for stop and start operations. The holes give access to key components of the burner for maintenance.

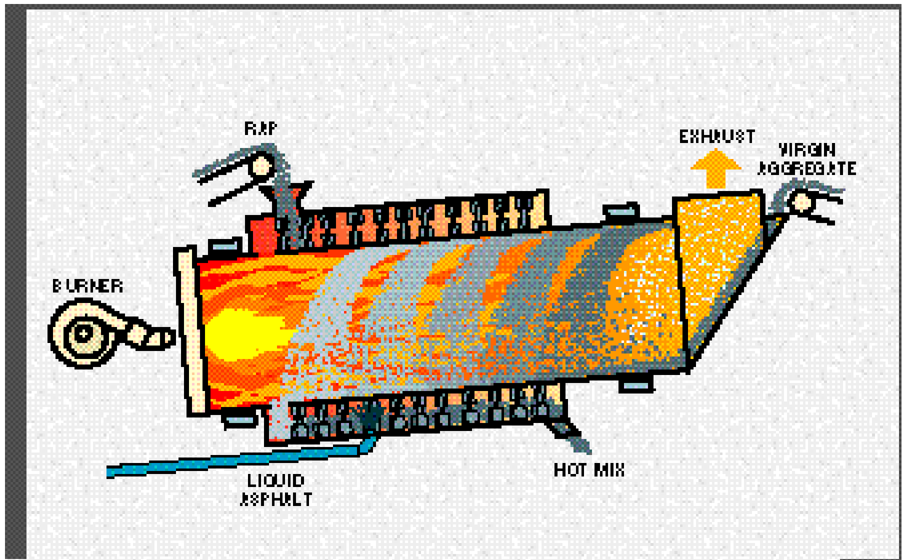
Figure 17 shows a revolutionary new type of mixer using a combination counterflow dryer and drum mixer. It is the Double Barrel® mixer. The mixer uses an enlarged coater, comparable to the one on Drum Mix Coater-II (Figure 9). The shell of the drum serves as the shaft of the coater. This results in a coater 10 to 12' in diameter, giving an extremely large mixing area.

Figure 18 shows a temperature profile of the Double Barrel drum mixer. Virgin aggregates are dried in the inner drum. They are superheated to

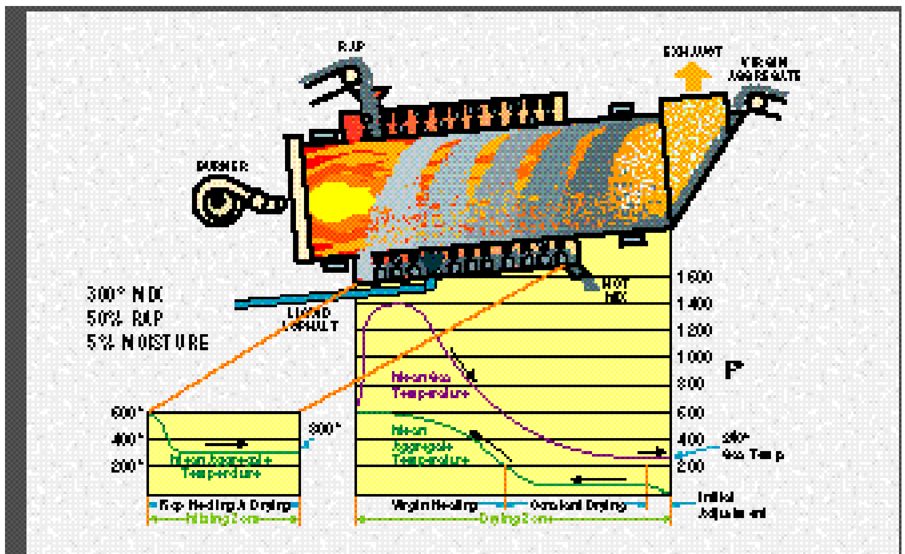
600°–650° F when running 50% recycle. After drying, the virgin aggregates drop through the wall of the inner drum into the outer drum. There it meets with the recycle material and the two are mixed. The super hot virgin aggregates melt the old asphalt in the recycle material and the old asphalt coats the virgin aggregates before fresh liquid asphalt is injected into the mix. Mixing time in this outer shell is 3/4 to 1 minute. The mix time is longer than usual, long enough to produce a very homogeneous, high-quality mix.

The outer shell of the drum does not rotate. Because of that it provides easy access for adding a variety of other recycle materials to the mix when needed or available. With this design, 90% of the heat for melting and drying the recycle comes from the virgin aggregate. The other 10% comes from the heat conducted through the inner shell and through the blending blades in the mixer section. Heat conducted through the inner shell to the mix keeps the shell from overheating. The outer shell of the Double Barrel stays at approximately 120° F at all times. All these factors produce a highly efficient mixer.

Any smoke or odor coming out of the mixing section is pulled back through holes in the inner drum. These are the same holes that pass the virgin aggregates into the outer shell. The pollutants go directly into the flame of the burner where they are consumed. As a result there are no odors and the stack has zero opacity. Moreover, virgin asphalt and recycle materials are not exposed to hot gases and steam produced by drying virgin aggregate in the inner shell. So, these gases and steam cannot distill light oils from the these materials.



DOUBLE BARREL® DRUM MIXER F17



TEMPERATURE PROFILE OF DOUBLE BARREL® DRUM MIXER F18

DRUM DIAMETER	PROCESS GASES THRU DRUM (CFM)	Percent of Moisture Removed and Gallons of Fuel per Ton										TOTAL EXHAUST THRU SYSTEM (CFM)
		3% 1.43	4% 1.60	5% 1.80	6% 2.05	7% 2.24	8% 2.45	9% 2.67	10% 2.90	11% 3.14	12% 3.38	
6'	28,000	253	211	179	153	137	123	111	100	91	83	33,600
7'	38,500	338	285	243	213	187	166	150	137	127	115	46,200
8'	50,000	443	380	317	274	243	216	195	179	164	150	60,000
9'	63,500	564	469	399	348	308	275	248	226	207	190	76,200
10'	78,500	696	574	496	432	380	339	306	280	255	234	94,200

+ 50% EXCESS COMBUSTION AIR IN DRUM
+ 10% LEAKAGE THROUGH RAP INLET AND DISCHARGE CHUTE AND SEALS
+ 110 lbs./FT³ MATERIAL WEIGHT
+ 4% MOISTURE
+ 5.5% LIQUID ASPHALT

+ 300° F Mix with 310° F Stack

PRODUCTION RATES (TPH) PARALLEL-FLOW MIXERS AND COATERS F19

DRUM DIAMETER	PROCESS GASES THRU DRUM (CFM)	Percent of Moisture Removed and Gallons of Fuel per Ton										TOTAL EXHAUST THRU SYSTEM (CFM)
		3% 1.37	4% 1.56	5% 1.76	6% 1.96	7% 2.17	8% 2.38	9% 2.59	10% 2.82	11% 3.04	12% 3.27	
6'	28,000	260	220	187	162	143	129	115	105	97	89	33,600
7'	38,500	355	300	255	223	198	176	159	145	132	123	46,200
8'	50,000	467	390	334	288	257	230	207	188	172	158	60,000
9'	63,500	590	493	423	369	325	291	265	238	219	200	76,200
10'	78,500	730	610	523	465	403	360	325	295	270	299	94,200

+ 50% EXCESS COMBUSTION AIR IN DRUM
+ 20% LEAKAGE THROUGH SEALS AND DISCHARGE CHUTE AND TOWER FUGITIVE AIR
+ 110 lbs./FT³ MATERIAL WEIGHT

+ 300° F Mix with 240° F Stack

PRODUCTION RATES (TPH) OF COUNTERFLOW DRUM MIXERS F20

DRUM DIAMETER	PROCESS GASES THRU DRUM (CFM)	Percent of Moisture Removed and Gallons of Fuel per Ton										TOTAL EXHAUST THRU SYSTEM (CFM)
		3% 1.32	4% 1.51	5% 1.71	6% 1.90	7% 2.10	8% 2.30	9% 2.51	10% 2.72	11% 2.94	12% 3.17	
6'	28,000	287	239	205	178	157	140	127	115	105	97	33,800
7'	38,500	394	329	281	245	216	193	174	158	145	133	42,350
8'	50,000	512	427	365	318	280	251	226	205	188	173	60,000
9'	63,500	651	542	463	403	356	318	287	261	239	219	69,850
10'	78,500	804	670	573	499	440	393	355	322	295	271	86,350

+ 50% EXCESS COMBUSTION AIR IN DRUM
+ 10% LEAKAGE THROUGH RAP INLET AND DISCHARGE CHUTE AND SEALS
+ 110 lbs./FT³ MATERIAL WEIGHT
+ 4% MOISTURE
+ 5.5% LIQUID ASPHALT

+ 300° F Mix with 240° F Stack

PRODUCTION RATES (TPH) OF DOUBLE BARREL® DRUM MIXERS F21

As recycle material is heated in the outer drum or mixing chamber of the Double Barrel mixer, its moisture is driven off as steam. This produces an inert steam atmosphere in the mixing chamber, with practically no free oxygen. Thus, there is virtually no oxidation of the mix while in the mixing chamber. The unusally long mixing time in the outer chamber gives sufficient time for the recycle to melt prior to the injection of new liquid asphalt. All of these favorable conditions result in an extremely high quality, well-coated mix.

Figure 19 shows production rates for parallel-flow drum mixers with 6 to 10' diameters, a mix temperature of 300° F and a stack temperature of 310° F.

Figure 20 shows production rates for counterflow drum mixers without preheated secondary air or an air-cooled shell.

Figure 21 shows production rates for the counterflow Double Barrel mixer. It cools the shell while preheating secondary combustion air.

The Double Barrel mixer plant gives an important secondary benefit. It causes bags in the baghouse to have much longer life. Because no oil from a Double Barrel mixer reaches the baghouse, bags last 700,000 to 1,000,000 tons of mix.

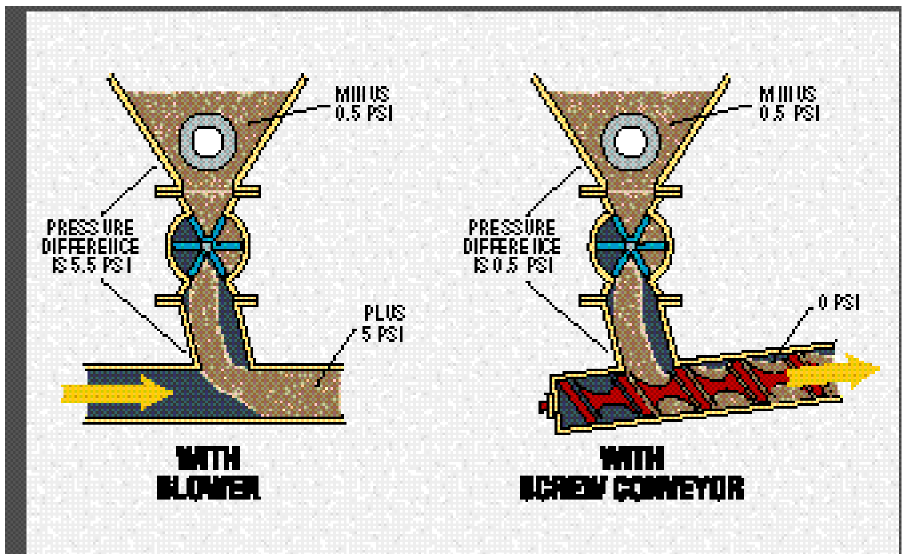
Conventional drum mixers strip light oils from the liquid asphalt. The oils coat the filter bags, shortening their life **(Figure 22)**. They may last for only 20,000 to 40,000 tons of mix when running recycle materials.

The Double Barrel mixer has another advantage over conventional drum mixers. On the Double Barrel mixer, fines are returned to the mixer from the baghouse via a rotary air lock and screw conveyor. The pressure drop between the baghouse and the Double Barrel mixer is very low. As a result, the airlock will last up to ten times longer than the air lock and blower system typically used on a conventional drum mixer. **(Figure 23.)**

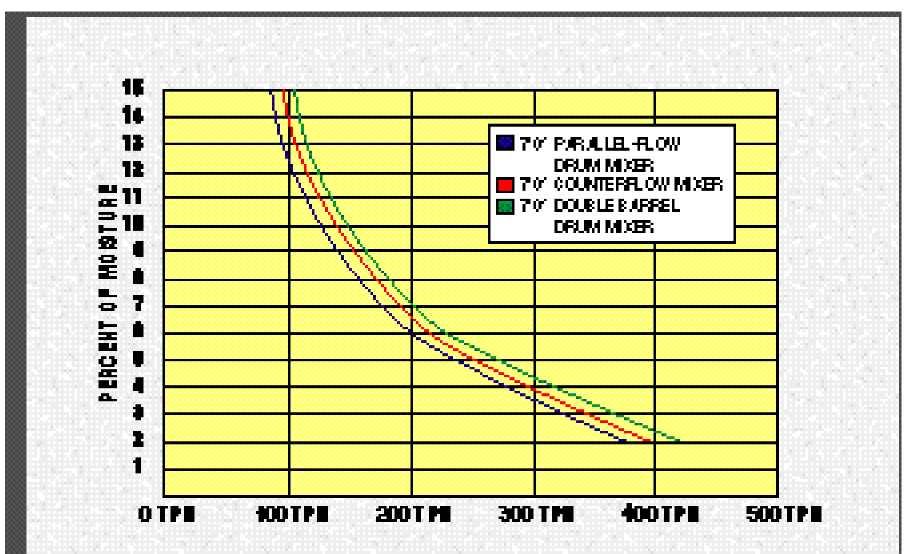
The counterflow dryer design provides lower stack temperatures. This allows higher production rates to be achieved as shown in **Figure 24**.

With the counterflow mixer design as shown in **Figure 13**, **Figure 15**, and **Figure 17**, flame efficiency is considerably higher. Aggregate is hot and dry by the time it reaches the flame. Consequently, it evaporates any droplets of unburned fuel thereby increasing combustion efficiency. In a parallel-flow mixer cold, wet aggregate showers through the flame and tends to smudge out the flame. This allows droplets of fuel to go unburned and produces much lower efficiency. (See **Figure 25**).

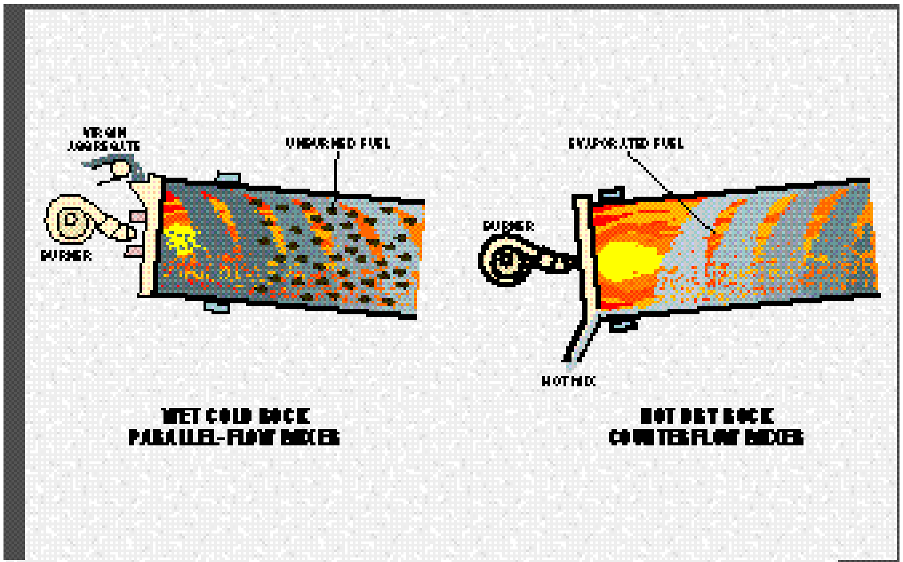
OIL SOAKED BAG F22



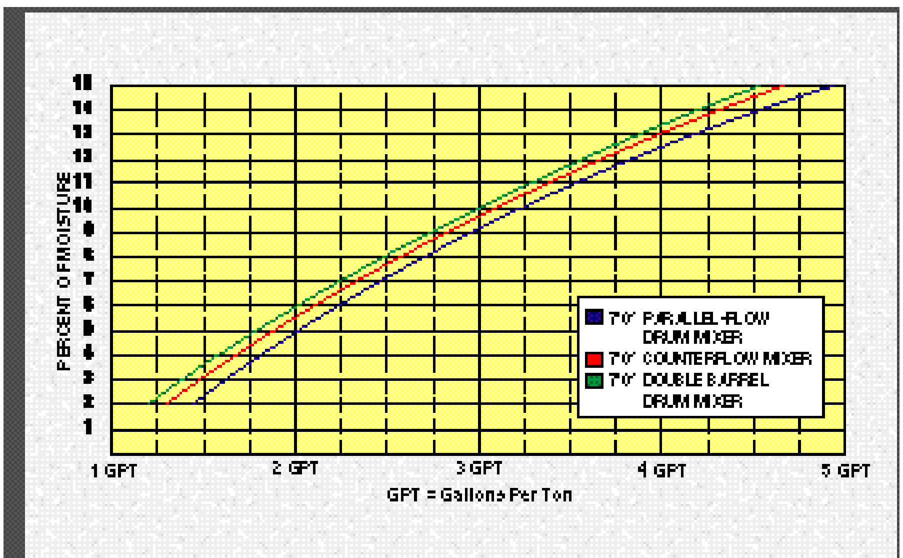
ROTARY AIR LOCK F23



PRODUCTION RATES (TPH) OF DRUM MIXERS F24



DRYER FLAME EFFICIENCY F25



FUEL SAVINGS (GPT) OF DRUM MIXERS F26

Figure 26 shows typical fuel usage for three types of drum mixers. Note that the Double Barrel mixer uses nearly 1/4 gallon less fuel per ton at 5% moisture. Accordingly, it burns approximately 36,000 gallons less fuel on a plant that runs 200,000 tons per year with average moisture of 5%. With an average moisture of 10% the Double Barrel saves slightly more than 1/4 gallon per ton, saving 65,000 gallons in a year. When using recycle materials the Double Barrel mixer gives even higher savings.

The revolutionary Double Barrel mixer meets the needs of the future. It can run up to 50% RAP without visible emissions. And it can use a variety of recycle materials. It operates more efficiently and has lower maintenance. It produces hotter mixes of highest-quality while meeting stringent federal and local air pollution codes.

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