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DRUM MIX PLANTS— EQUIPMENT AND OPERATIONS

by

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Maghsoud Tahmoressi

Research Report Number 440-1F

Evaluation and Training Related to
Drum Mix Plants

Research Project 3-6-85-440

conducted for

Texas
State Department of Highways and Public Transportation

in cooperation with the
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by the

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Bureau of Engineering Research
The University of Texas at Austin

November 1986

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There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new and useful improvement thereof, or any variety of plant which is or may be patentable under the patent laws of the United States of America or any foreign country.

PREFACE

This is the first and final report dealing with the theory of the operations and suggested guidelines for proper operation of typical drum mix plants. Included is a brief description of batch and continuous plants. Drum mix plant discussion is subdivided into discussion of cold feed system, asphalt cement supply system, plant calibration, drum mixer, storage silos, and air pollution control equipment. Due to wide variation between plants manufactured by different manufacturers, the discussions are limited to general descriptions covering typical drum mix plants.

The authors wish to acknowledge the assistance received from various individuals and organizations. Support of Texas State Department of Highways and Public Transportation and Federal Highway Administration is acknowledged. To various drum mix plant manufacturers which provided some of the information for this report, appreciation is extended.

Thomas W. Kennedy
James A. Scherocman
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November 1986

LIST OF REPORTS

Report No. 440-1F, "Drum Mix Plants--Equipment and Operations," by Thomas W. Kennedy, James A. Scherocman, and Maghsoud Tahmoressi. Summarizes the theory of drum mix plant operations and describes procedures for proper operation of typical drum mix plant components.

ABSTRACT

This report contains a summary of the theory of drum mix plant operations and describes the procedures for proper operation of typical drum mix plant components.

Key Words: drum mixer, cold feed, cold feed elevators, dryer drum, flights, burner, silo, air pollution control

SUMMARY

The use of drum mix plants in asphalt paving industry has gained wide spread acceptance; however, there are still problems which are associated with use of drum mix plants. It is believed that most of these problems arise from improper use of drum mix plants. Drum mix plants can produce uniform asphalt mixtures when operated properly. This report summarizes some basic theories involved in the operation of drum mix plants and suggests guidelines for proper operation and inspection of drum mix plants.

IMPLEMENTATION STATEMENT

The guidelines and procedures contained in this report represent the current status of the knowledge pertaining to the operations of drum mix plants. This report can be used as a manual for training of highway department inspectors and other individuals.

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CHAPTER 1. INTRODUCTION

During the past 15 years use of drum mix plants, which are often incorrectly called dryer drum plants, has increased to the extent that approximately 95 percent of all new asphalt mixing plants are drum mixers. Batch plants are the remaining plants produced. Various studies have indicated that drum mix plants produce asphalt mixtures which are equal to those produced by conventional batch plants (Refs 1, 2, and 3). Nevertheless, there are many engineers and agencies which feel that drum mix plants cannot produce satisfactory mixtures. While there are inherent problems associated with both batch and drum mix plants, often there is a lack of understanding of how drum mix plants operate and how the operation differs relative to the operation of batch plants.

The purpose of this report is to provide detailed information related to the theory, equipment, and operations of drum mix plants. In this respect, the report can serve as a field manual as well as a backup document for formalized training courses, seminars, and short courses.

Chapter 2 contains a brief discussion of batch plants, continuous plants, and drum mix plants. Chapter 3 provides a brief but more complete discussion of the flow of materials through drum mix plants. Chapters 4 through 9 provide detailed information related to the cold feed system, asphalt cement supply system, plant calibration, drum mixer, storage silo, and air pollution control systems. The reference list provides a listing of the references reviewed, although not necessarily cited in the report.

CHAPTER 2. ASPHALT PLANTS

The purpose or function of an asphalt mix plant is to blend together aggregates and binder, normally asphalt cement, to produce a hot mixed homogeneous asphalt paving mixture. The aggregate can be a single material or can be a combination of coarse and fine particles with or without mineral filler. In addition to asphalt cement, the binder can also be a cutback asphalt, asphalt emulsion, or one of a number of synthetic binders. Various additives, either liquid, solid, or powdered materials, can also be incorporated into the mixture.

Three types of plants are currently in use in the United States. These are: (1) batch plants, (2) continuous mix plants, and (3) drum mix plants. Each type of plant fulfills the same ultimate purpose; however, the operation and flow of the various materials through these plants are different. The asphalt mixtures produced, however, should be identical, regardless of the type of plant used to manufacture it.

A brief review is provided below of the flow of materials and operation of batch plants, continuous mix plants, and drum mix plants. A more detailed presentation concerning drum mix plants is provided in Chapter 3.

BATCH PLANTS

The asphalt concrete batch plant (Fig 2.1) consists of a number of major components, as shown in Figure 2.2.

The first major component is the cold feed bins where the aggregates, at ambient temperature, are temporarily stored before processing. Closely associated are the collecting (feeder and gathering) conveyors beneath each cold feed bin and the incline or charging conveyor which carries the combined aggregates to the dryer.

The second component is the aggregate dryer where moisture is removed from the aggregates and the aggregates are heated to the proper mixing temperature. The hot, dry aggregates are then carried to the top of the batch plant tower by means of a hot elevator.

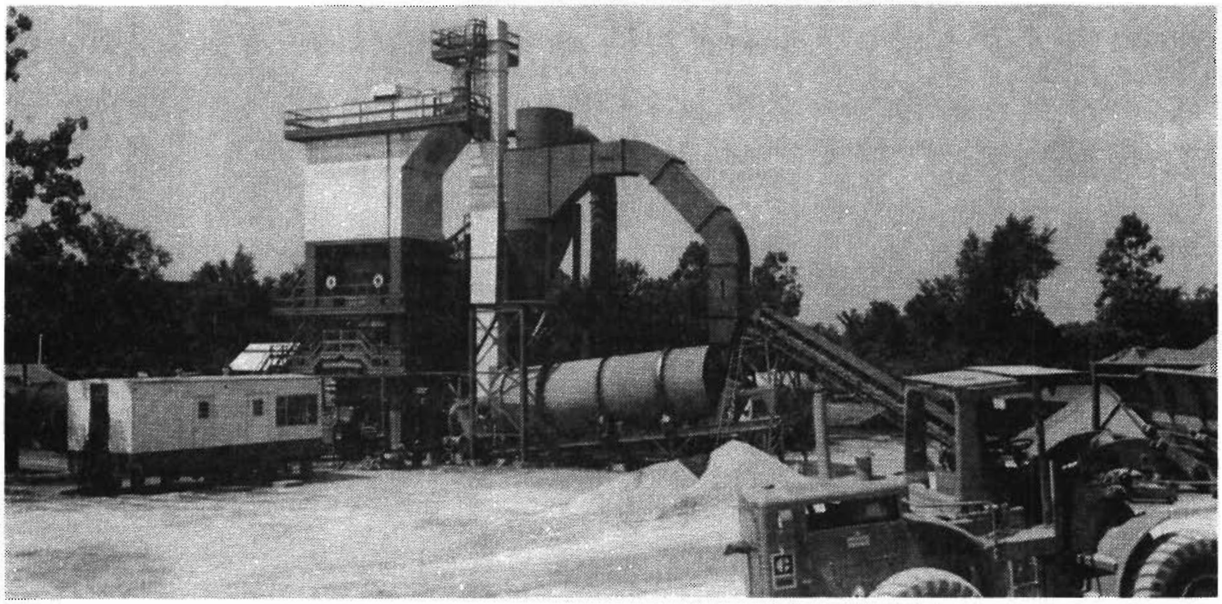

Figure 2.1. A typical batch plant (Ref 4)

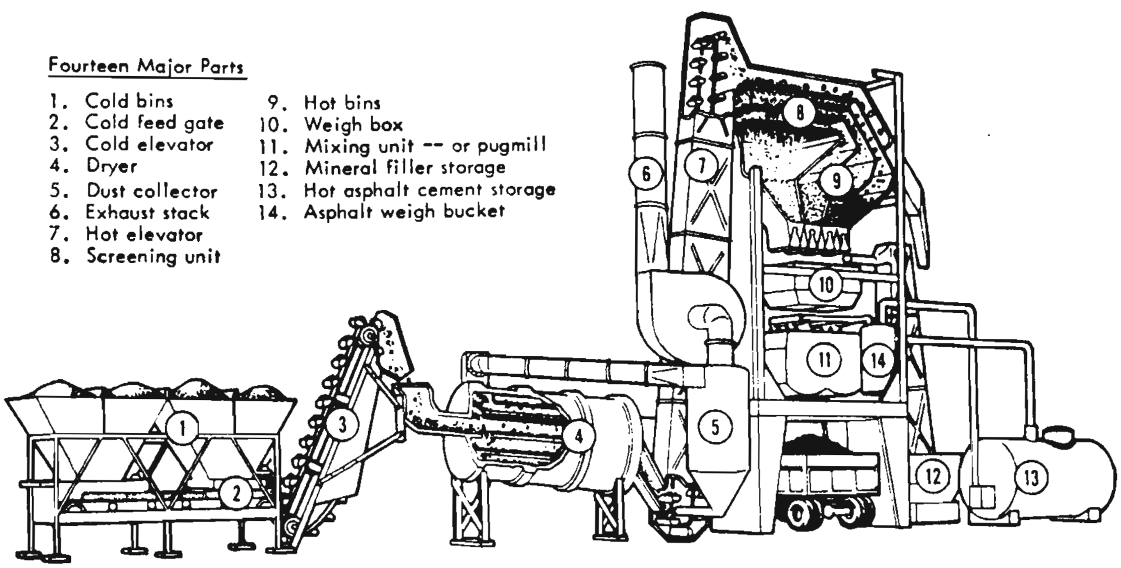

Figure 2.2. Major components of a batch plant (Ref 5)

At the top of the plant, the material is passed through a set of screens which divide the aggregate into several different sizes, typically four. The heated aggregates are then temporarily stored in the plant hot bins, located directly beneath the screen deck. From these bins, the various sizes are proportioned, by weight, into the weigh hopper or box. At the same time that the aggregate is being weighed, asphalt cement is pumped from a storage tank to the asphalt weigh bucket on the plant.

The correct blend of material is next dropped into the plant mixer, a twin-shaft pugmill. After the aggregate is introduced into the pugmill, the asphalt cement is sprayed into the mixing unit. The two materials are blended together by the shearing action of the pugmill blades or paddles. The completed mixture is then discharged from the plant, either into a haul truck or into a conveying device to temporary storage in a surge silo for subsequent delivery to the paving site.

If reclaimed asphalt concrete is being used to produce a recycled asphalt concrete mixture, the reclaimed material can be introduced into the plant at the following points: (1) at the bottom of the hot elevator, (2) into the hot bins, or (3) more commonly into the weigh hopper. In any case, the reclaimed material at ambient temperature is added to the new aggregate, which has been superheated, before the two different materials are dropped into the plant pugmill for mixing.

Due to environmental requirements, each batch plant is equipped with an air pollution control device. This equipment can consist of a dry collector, a wet collector, a fabric filter (baghouse), or a combination of devices. In some cases, the fines collected in the pollution control equipment are wasted; in other cases the dust is returned to the plant for incorporation into the mixture. Sometimes the dust is reintroduced into the bottom of the hot elevator. More often it is fed into the aggregate weigh hopper as mineral filler.

CONTINUOUS MIX PLANTS

A continuous mix asphalt concrete plant is shown in Figure 2.3 and the components and flow of material are graphically illustrated in Figure 2.4. The cold feed bins are the same as used with batch plants and include both

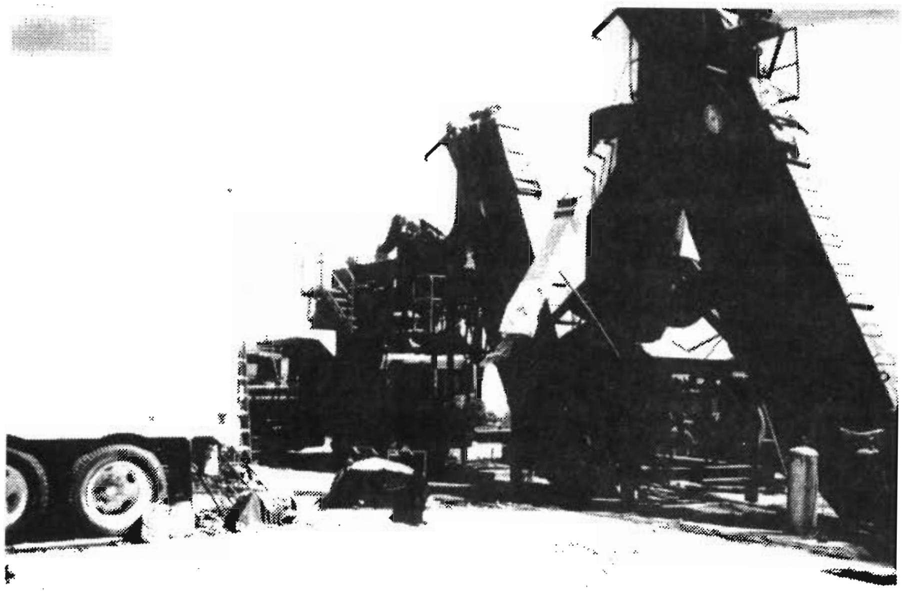

Figure 2.3. A typical continuous mix plant

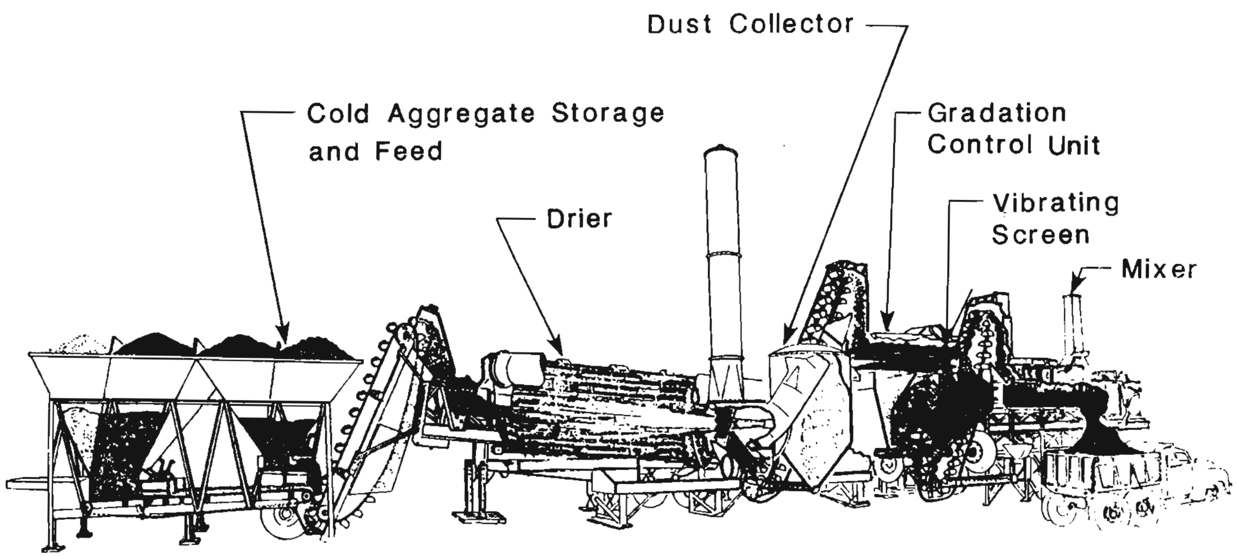

Figure 2.4. Major components of a continuous mix plant (Ref 6)

the gathering and charging conveyors. The aggregate dryer is the second component in the process. Here the moisture in the combined aggregates is removed as the material is heated from ambient temperature to the desired mixing temperature, which normally ranges from 270 to 300°F. The dried and heated aggregates are then conveyed up an inclined bucket elevator to the screen deck, which divides the aggregates into various sizes before mixing. The sized aggregates are then fed into the continuous mix pugmill for mixing.

The asphalt cement is held in the storage tank at a temperature of approximately 325 to 350°F and subsequently is pumped to the asphalt cement spray bars located above the pugmill. The asphalt binder, measured by volume, is then sprayed continuously over the aggregate. Mixing of the two materials occurs as the aggregates are moved toward the discharge end of the pugmill by the paddles. Mixing time can be increased or decreased by changing the retention time of the material in the pugmill by altering the setting of the pugmill end gate.

Because this is a continuous mixing process, a temporary holding hopper or bin must be provided to store the material until it can be discharged into a haul truck. This bin is typically located directly underneath the pugmill discharge and has a limited mixture capacity. The surge bin turns the continuous mix process into a truckload haul operation.

Continuous mix plants can produce recycled asphalt concrete mixtures by superheating the new aggregates in the dryer and adding the reclaimed material to the new material in the pugmill. A separate cold feed bin and charging conveyor can be used to introduce the reclaimed aggregate, by volume, into the mixing chamber.

For air pollution control purposes, the continuous mix plant can be equipped with dry collectors, wet collectors, or fabric filters. The captured fines can be wasted or returned to the plant pugmill if a dry collection system is utilized.

DRUM MIX PLANTS

The production of asphalt concrete mix in a drum mix plant (Fig 2.5) is also a continuous process. The coarse and fine aggregates are held in the cold feed bins at ambient temperature (Fig 2.6). The aggregates are

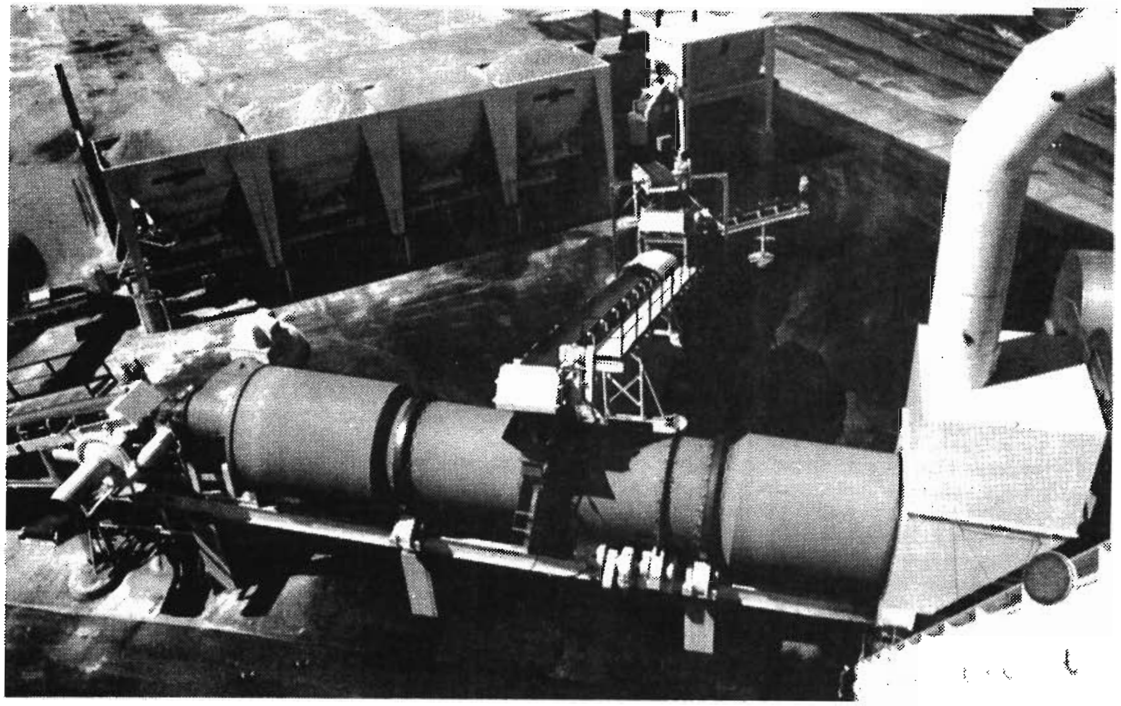

Figure 2.5. A typical drum mix plant (Ref 7)

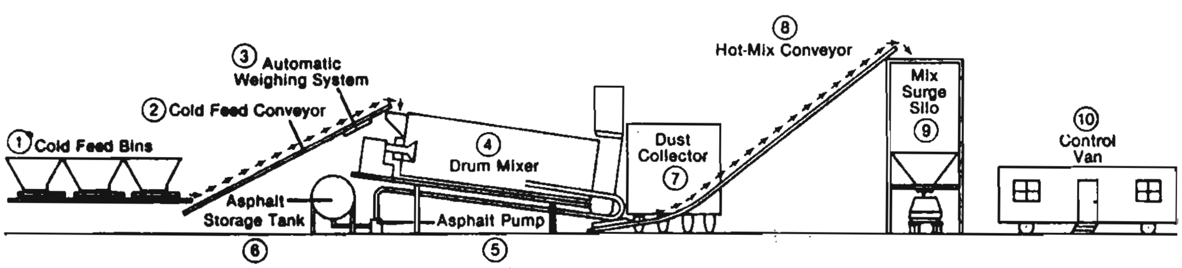

Figure 2.6. Major components of a drum mix plant (Ref 5)

proportioned out of the bins, carried by a charging conveyor over a weigh bridge system, and fed into the upper end of the drum mixer. Inside the drum, the aggregates are heated and dried, similar to the operation of a batch plant dryer. But in addition, the asphalt cement is added and the aggregates are coated with asphalt. The asphalt cement is supplied from a storage tank and pumped continuously into the drum mixer.

If reclaimed asphalt concrete material is used to produce a recycled mixture, this material is introduced into the drum at either (1) the upper end of the drum in combination with the new aggregate or (2) through its own entry port near the midpoint of the drum. The point of entry, in either case, is upstream or prior to the point at which the asphalt cement is injected. The actual location of asphalt cement introduction varies with different types (manufacturers) of drum mix plant.

Because it produces mix in a continuous operation, the drum mix plant must be equipped with a temporary holding bin or surge silo. The silo actually converts the flow from a steady discharge to a batch process (truckloads) for delivery to the laydown machine.

To control the amount of particulate carryout from the mixing process, the drum mix plant can be equipped with a variety of air pollution control systems which include (1) a dry collector, (2) a wet collector, or (3) a fabric filter (baghouse). For the dry collection processes, the collected fines can be returned to the mix, if desired.

CHAPTER 3. DRUM MIX PLANTS

The drum mix plant consists of a number of major components, which can be divided into three categories--those which handle the aggregates, those which control the asphalt cement binder, and those which process the blend of materials.

The aggregate handling system consists of the cold feed bins, gathering conveyors, charging conveyor, weigh bridge and belt speed sensor, mineral filler system, if any, and dust return system, if any. If reclaimed material is being fed into the plant, a separate cold feed system, i.e., cold feed bins, charging conveyor, and weigh bridge/belt speed systems, will be required on most drum mix plants in order to handle the additional aggregate flow.

The components to store and process the asphalt cement are relatively simple. First, a heated storage tank is necessary to hold the asphalt cement (binder) until it is needed. Second, a pump and meter are used to transfer the binder to the plant and to proportion the asphalt cement with respect to the amount of aggregate being introduced into the drum mixer. The pump must be able to be reversed in order to return unneeded asphalt cement to the storage tank whenever the plant operation is stopped.

The main component of the blending system is the drum mixer itself. Additional plant components involving the asphalt mixture include the hot mix charging conveyor, the hot mix surge silo, and the plant dust collection system. Also included is the control station where the flow of aggregates, asphalt cement, and asphalt concrete mix are monitored and regulated.

COLD FEED SYSTEM

The cold feed system can differ depending on whether only new aggregate is being used or new aggregates plus reclaimed material.

New Aggregate System

The cold feed bins are used to proportion the aggregates to obtain the correct aggregate gradation in the asphalt mixture. Because the drum mix plant operates on a continuous basis, and because there are no screens or hot bins in the system, whatever comes out of the cold feed bins ends up in the same proportion in the mix manufactured by the drum mixer. Thus the settings on the cold feed bins, both the gate openings and the speed of the transfer belt conveyors, must be correct to achieve the desired mixture gradation. The old cliche of "garbage in, garbage out" applies equally well to drum mix plants as to computers. If the cold feed is set incorrectly or if the gradations of the different coarse and fine aggregates vary considerably, the gradation of the final mix produced can also be out of specification.

Each cold feed bin operates on one of two methods. On older cold feed systems, the cold feed bins had variable gate openings. The amount of material discharged from a bin depended on the setting of the gate opening at the bottom of the bin. The conveyor underneath each bin typically operated at a constant speed. Thus the volume of aggregate transferred from a particular cold feed bin could be changed only within the limits that the bin gate openings could be changed.

With more modern cold feed systems, the gate opening at the bottom of the bin is constant, and the speed of the belt controls the amount of aggregate introduced into the mix. If only a small amount of material is needed from a particular bin to produce the desired aggregate gradation, then the speed of the conveyor belt under that bin is quite slow. If, on the other hand, the volume needed of a given coarse or fine aggregate in a cold feed bin is large, the speed of the conveyor belt will be increased to handle a greater amount of material. The constant opening, variable speed belt system is the most common cold feed operation utilized on most drum mix plants currently being manufactured.

The aggregate discharged from each cold feed bin and cold feed conveyor is deposited on a gathering conveyor which runs under all of the cold feed bins. On most plants, this conveyor is operated at a fixed speed, but on some plants, the speed can be varied. If more aggregate is needed as the plant production rate is increased, the speed of the individual cold feed bin conveyors is increased which places more materials on gathering conveyor. The reverse is true as the plant production rate is reduced.

The combination of aggregates produced from the cold feed bins and gathering conveyor is transferred to the charging conveyor. This can be done directly, from one conveyor belt to another, or the aggregate can be dropped through a scalping screen*. If quarry processed aggregates are used, it probably is not necessary to incorporate the scalping screen in the cold feed system. If bank run or pit run aggregates are used, it generally is desirable to process these aggregates through a scalping screen to remove any tree roots or other contaminants from the aggregates in order to keep the foreign materials from being introduced into the drum mixer.

The charging conveyor transfers the combined coarse and fine aggregates to the drum. It is equipped with two components to measure the amount of material entering the drum mixer. The first is the weigh bridge, which is an idler on the conveyor which acts as a load cell, determining the amount of material passing over the weigh bridge at a particular point in time. The second is the belt speed sensor which monitors the speed of the conveyor belt. These two measurements are combined in the plant computer system to determine the amount of aggregate, in terms of tons per hour, being introduced into the plant.

This aggregate feed ratio is the weight of the aggregate plus water passing over the weigh bridge. Since the asphalt cement content of the asphalt mixture is proportional to the dry weight of the combined aggregates, this wet weight must be converted by the computer system to a dry weight of the aggregate.

On many drum mix plants, the aggregates on the charging conveyor are dropped directly into the burner end of the drum mixer. The materials are discharged into a chute located above the drum and slide into the drum at its upper end. Some drum mix plants, however, are equipped with slinger conveyors which are located beneath the burner. The aggregates from the charging conveyor are transferred to the slinger conveyor and then carried into the drum. Depending on the speed of the slinger conveyor, the aggregates can be deposited directly in the front of the drum or can be flung part way down the drum, away from the burner flame.

* Scalping screens are required in Texas, Item 340 (Ref 8).

If mineral filler is needed in the mix, the material can be added in one of several places. In some cases, it is placed in one of the plant cold feed bins and fed into the plant as an additional aggregate component. The filler can also be fed from a silo onto the aggregate gathering conveyor and then into the drum. In each case the material must be placed between the layers of other aggregates on the cold feed conveyors to prevent blowing or dusting of the mineral filler which would occur if the filler were spread on top of the coarse and fine aggregates.

Many drum mix plants are equipped to feed the mineral filler into the rear end of the plant through a filler feed line or auger system. A silo is employed to hold the filler and a vane feeder is used to proportion the material into the conveying pipe. An air or pneumatic system blows the filler into the drum where it is coated with the asphalt cement before it drops into the bottom of the drum.

Reclaimed Material

The cold feed system used on a drum mix plant for reclaimed asphalt materials varies with the make, model, and age of the plant. On many of the original Boeing drum mix plants, the reclaimed material was fed into the burner end of the drum mixer in combination with the new coarse and fine aggregates. The same cold feed bin setup is employed for the reclaimed asphalt mixture as for the new material. One or more of the cold feed bins are dedicated to the reclaimed material and the remaining cold feed bins are used for the new aggregates.

With this system, each aggregate, new or reclaimed, coarse or fine, is proportioned from its own cold feed bin as needed to meet the final mix gradation. The gathering conveyor carries the combined new and reclaimed materials to the scalping screen and then to the charging conveyor. The material is then dropped into a top loading chute at the burner end of the plant or emptied onto a slinger conveyor under the burner for transport into the drum.

Currently most drum mix plant operations employ a split feed system to introduce the reclaimed material into the plant. Thus the entry of the reclaimed material is separated from the charging of the new coarse and fine aggregates. The new aggregates are conveyed into the burner end of the plant. The reclaimed asphalt material is fed into the drum through a rotary inlet system located at or near the midpoint of the drum.

Occasionally one or more of the normal cold feed bins will be used to hold the reclaimed material. In this case, however, the gathering conveyor is split, with one section conveying the new aggregates from their individual cold feed bins to the new aggregate charging conveyor and the other section carrying the reclaimed material in the opposite direction to a separate charging conveyor. As for the new material feed system, the reclaimed material gathering conveyor should feed its material through a scalping screen before placing the reclaimed material on the center inlet charging conveyor.

A separate cold feed bin or bins normally are employed to store the reclaimed material. These bins are usually more steep sided than the normal new aggregate cold feed bins and typically have slightly larger bottom openings to handle the reclaimed asphalt material more easily. The reclaimed material is fed out of the bins on a gathering conveyor, through a scalping screen, and onto the charging conveyor. The latter is equipped with a weigh bridge system to measure the wet weight of the reclaimed material being fed into the plant. This wet weight is automatically converted to the dry weight of the reclaimed material by the plant computer.

DRUM MIXER

New Aggregate-Asphalt Mixtures

The main component of a drum mix plant is the drum mixing unit itself. In the drum, the new aggregates are fed into the upper, burner end of the drum. The aggregates move down the drum by gravity as the drum rotates. As the aggregate is carried through the drum, the material is heated and the moisture is reduced. This occurs through heat transfer from the exhaust gases from the burner. These gases and the aggregates both travel in the same direction, from the upper end of the drum (aggregate inlet) to the lower end of the drum (mix discharge).

The drum mix plant thus operates on a parallel flow principle, i.e., the aggregates and heated air both move in the same direction inside the drum

(Fig 3.1). This parallel flow concept is in contrast to the counter flow process used in a conventional batch or continuous mix plant dryer (Fig 3.2). On a regular dryer, the aggregates move by gravity down the drum. The burner, however, is located at the discharge, or lower, end of the drum. The exhaust gases move upstream, opposite to the aggregate flow. Thus, on a batch plant dryer, a counter-flow drying process is employed while on a drum mix plant the aggregates and burner exhaust gases move in a parallel flow system.

As the aggregates move down the drum, they are tumbled by the flights or vanes located inside the drum (Fig 3.3) and the aggregates are dried and heated. As the exhaust gases move down the drum, in parallel with the aggregates, the heat is transferred to the aggregate. The initial temperature of the burner gases is over 2,500°F. By the time the gases exit the drum and enter the ductwork to the air pollution control system, the temperature of the gases should be reduced to approximately 300°F. At the upper end of the drum, the heating of the aggregates commences. Part way down the drum, when the temperature of the aggregates approaches the boiling point of water and stabilizes temporarily, moisture begins to be driven off from the aggregates' surfaces. When the aggregates have shed most of the moisture, the heating of the aggregate commences once again, reaching the preset discharge temperature at the lower end of the drum.

The veil or amount of aggregate placed in front of the burner flame and gases controls the efficiency of the heat exchange process. Within the capacity limits of each plant, the more aggregate in the drum, the more complete the heating and drying operation. To increase the efficiency of the drying process, the drum mixer can be modified to increase the dwell time of the aggregates in the drum. This increased retention time can be accomplished by increasing the number of flights in the drum, by using flights of different types and configurations, by reducing the slope or angle of the drum, by reducing the speed of rotation of the drum, and/or by placing internal restrictions or dams in the drum to retard the flow of aggregates.

The asphalt cement binder can be discharged into the drum through a pipe coming in from either the upper or lower end of the drum mixer. On some makes and models of plants, the asphalt cement injection pipe enters from the

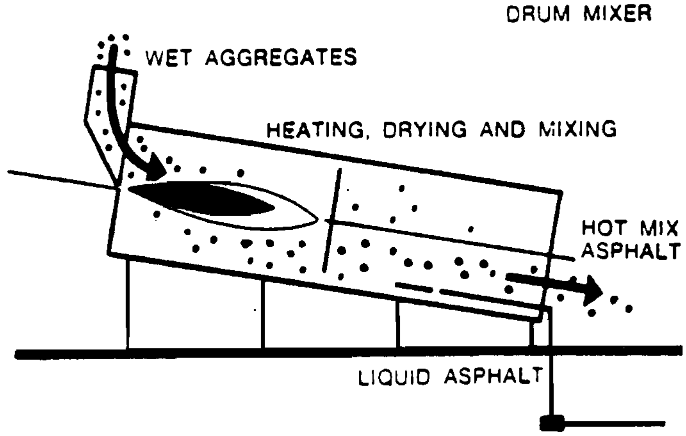

Figure 3.1. Parallel flow process of a drum mix plant (Ref 9)

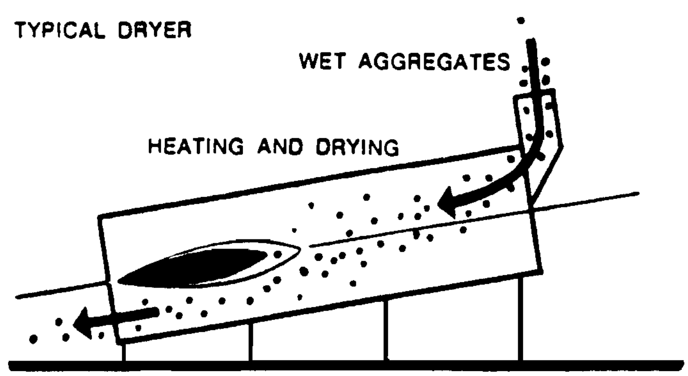

Figure 3.2. Counter flow process of a batch plant dryer (Ref 9)

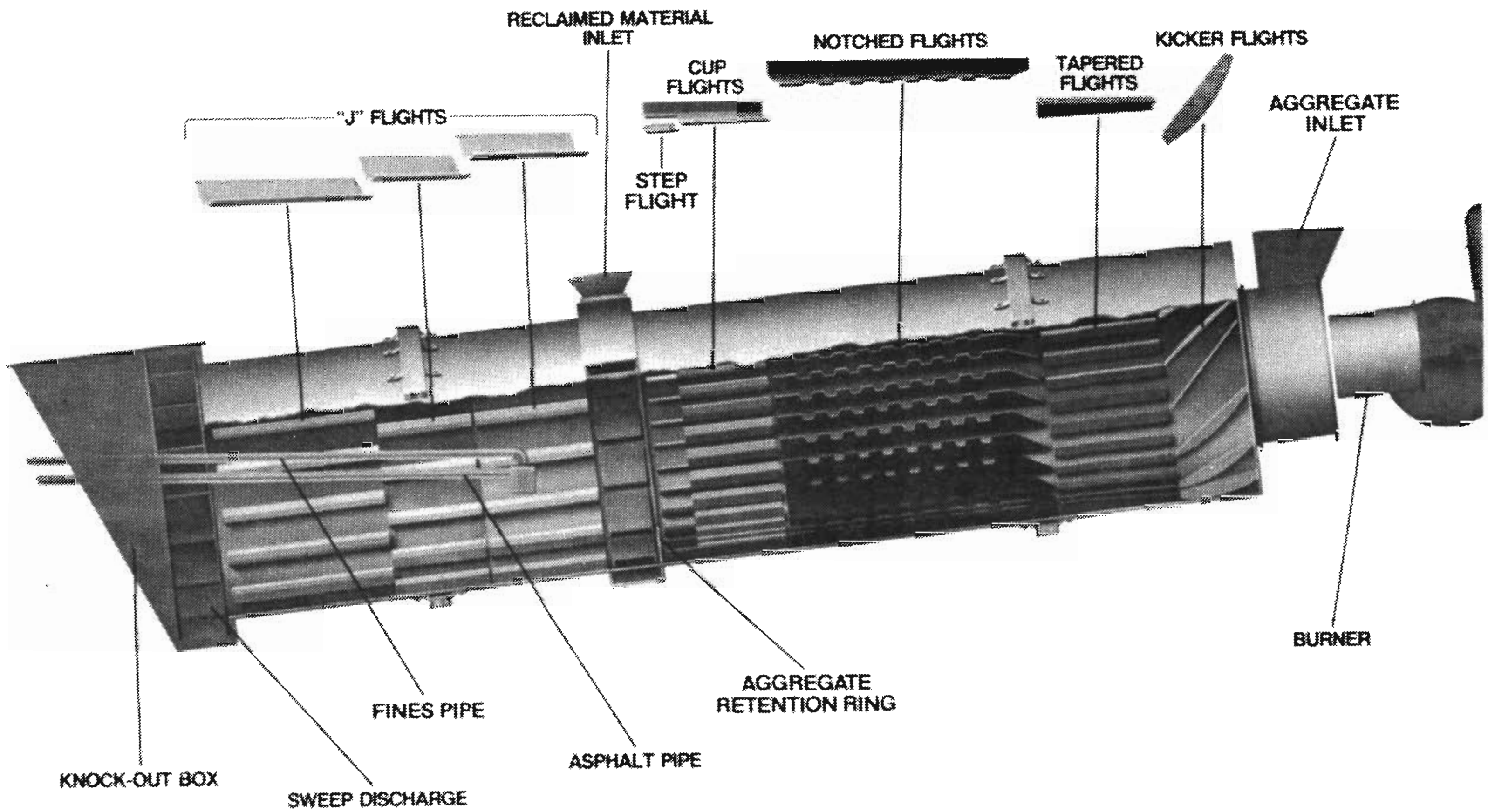

Figure 3.3. Flight configuration and locations inside a Barber-Greene drum mixer (Ref 10)

burner end of the drum, and the asphalt cement is added to the aggregates upstream of the drum midpoint. At this particular entry point, the binder may be exposed to the high temperatures of the burner gases.

In most drum mix plants, however, the asphalt cement is pumped into the drum through a pipe entering the drum from the discharge end. The length of the pipe inside the drum can be varied, but usually the asphalt cement is injected at a point approximately 30 to 40 percent of the way up the drum from the rear (60 to 70 percent down the length of the drum from the burner end). Once the asphalt cement is discharged, it comes in contact with available moisture, foams, and increases in volume. The foamed asphalt cement coats the new aggregates and any reclaimed material in the drum. The coating process usually takes place in a very short period of time. The asphalt coated materials are then heated to the proper temperature as they travel down the remaining length of the drum. The completed mixture is then discharged from the plant.

Recycled Mixtures

For recycled asphalt mixtures, the reclaimed material can be introduced into the drum at the burner end, together with the new aggregates. In this system, a heat diffusing device or heat shield (Fig 3.4) is sometimes used to reduce the immediate exposure of the asphalt coated reclaimed material to the hot exhaust gases. This is done to decrease the generation of hydrocarbon emissions (blue smoke) when the aged asphalt is subjected to the very high gas temperatures.

In most drum mix plants, however, the reclaimed material is fed into the plant through a separate entry port located near the middle of the drum length (Fig 3.5). By introducing the reclaimed mixture at this point, the asphalt coated material is exposed to exhaust gases which are at a lower temperature, thus lessening the amount of blue smoke generated. The reclaimed aggregates are partially protected from the exhaust gases by the new aggregates in the upper half of the drum.

In the midpoint entry system, the new aggregates are heated to a temperature above normal in the front end of the drum to facilitate the transfer of the heat to the reclaimed material. The superheated new aggregates and the

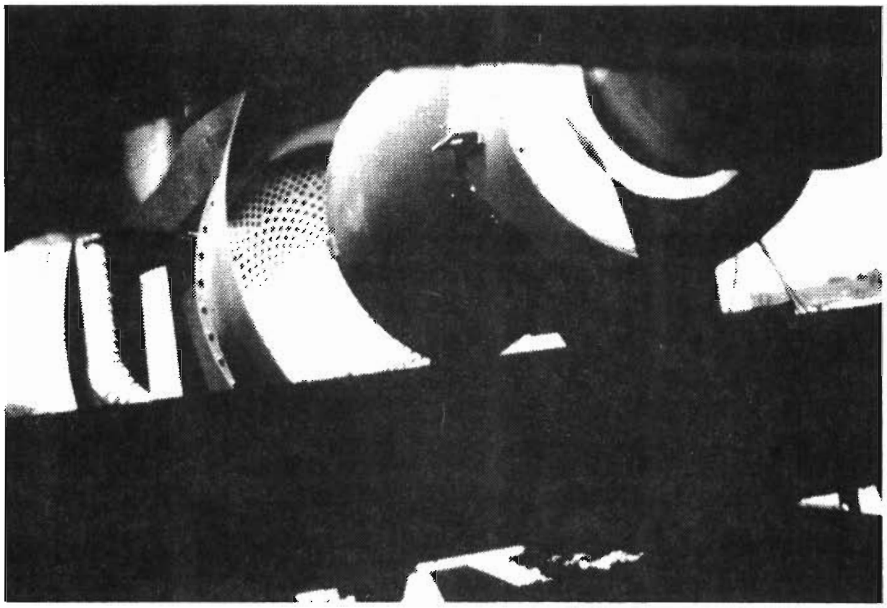

Figure 3.4. Burner end inlet for reclaimed material entry

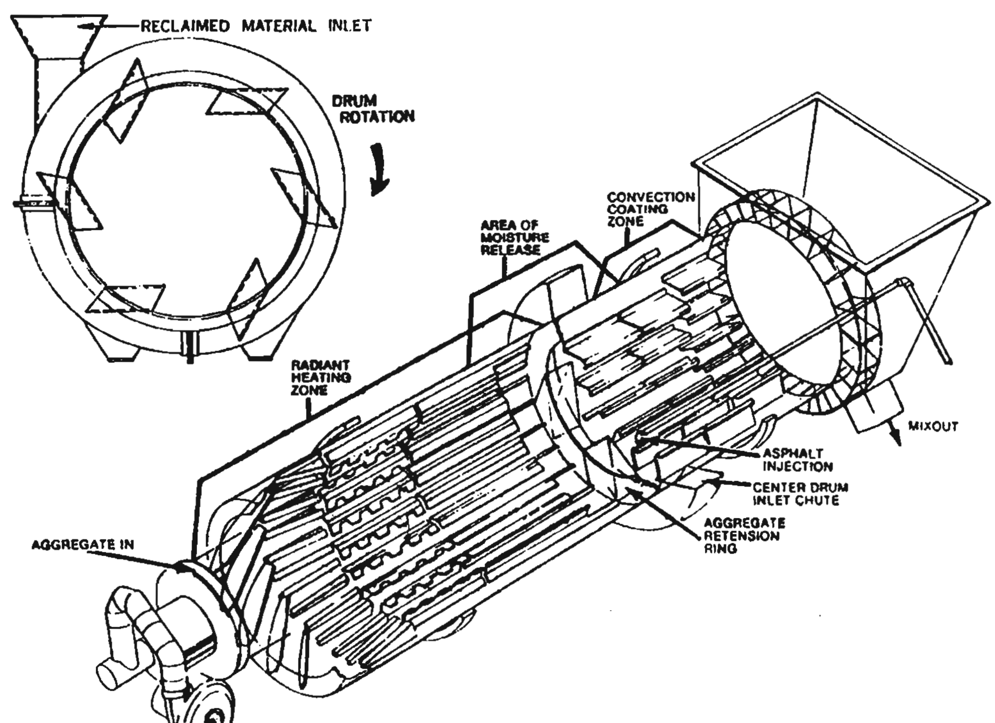

Figure 3.5. Center inlet for reclaimed material entry (Ref 11)

ambient temperature reclaimed aggregates are blended together in the lower half of the drum. The reclaimed material is thus heated both by exposure to the burner exhaust gases and by contact with the superheated new material. The asphalt cement is introduced in essentially the same manner as with new aggregate-asphalt mixtures.

ASPHALT CEMENT SUPPLY SYSTEM

The asphalt cement, received from the refinery by tank truck or railcar, is offloaded into a hot storage tank. The cement is stored at an elevated temperature, usually in the range of 300 to 350°F, until needed. Most storage tanks have the capability of circulating the asphalt cement within the tank or between tanks when the material is not being pumped to the drum mix plant.

Because the drum mix manufacturing process is a continuous one, the asphalt cement is pumped steadily to the plant. After passing through the pump, the binder moves through a valve or series of valves which proportion the correct amount of asphalt cement for the mixture, returning any excess material to the storage tank. The amount of asphalt cement fed to the plant is measured by a meter and is determined by the amount of aggregate (new aggregate or combined new and reclaimed material) measured by the weigh bridge on the charging conveyor. As the weight of aggregate being introduced into the plant changes, the computer controls automatically alter the volume of asphalt cement passing through the meter to the drum.

MIXTURE STORAGE SYSTEM*

The drum mix plant produces the asphalt concrete mix on a continuous basis. The transport of the mix to the laydown site, however, is a batch type process, i.e., truckload to truckload. Thus a temporary holding bin or surge silo is used to convert the continuous flow of material to a batch plant basis.

Several different types of conveying devices can be employed to carry the asphalt concrete from the discharge end of the drum mixer to the surge

* Texas requires a storage system, Item 340 (Ref 8).

silo. Bucket elevators, drag slat conveyors, and belt conveyors are the three most common means of transport. Each device has its own advantages and disadvantages. The means of carrying the mix is not as important as how the material is deposited from the conveying device into the top of the silo. Segregation problems can begin with the improper discharge of the asphalt cement mix into the surge bin.

A variety of methods are used to collect the asphalt concrete from the conveying device and drop the mix into the silo. Usually some type of batcher or "gob-hopper" is employed, with the mix being held temporarily until the hopper is filled. The asphalt concrete is then dropped as a mass into the silo. The bucket elevator, drag slat conveyor, or belt conveyor must place the mix into the center of the holding hopper, if used, or into the center of the silo. A "gob-hopper" must be situated to allow the discharged mix to fall into the center of the surge silo. This will reduce the tendency for the mix to build up on one side of the silo and then roll to the other side, causing segregation.

Most surge silos are round; however, a number of different shapes (rectangular, square, and elliptical) are being used. Most of the surge silos are insulated to reduce the amount of heat loss while the mix is in temporary storage. Some of the bins are completely heated while many have heat applied only to the cone of the silo. The silos are generally equipped with double gates at the bottom of the cone to control the rate of discharge of the asphalt mixture into the hauling vehicle.

In some cases it is possible to store the mix overnight or even for several days in the surge bin*. The silo must be well insulated and the amount of asphalt mixture held in the bin should approach the capacity of the silo, i.e., the silo should be full. If the storage is to be longer than overnight, an inert gas, such as nitrogen, can be charged into the top of the silo to purge the oxygen and reduce the rate of hardening of the mix. The mixture, which can be stored for minutes, hours, overnight, or several days, is then delivered to the trucks for transport to the paver.

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* Texas does not permit overnight storage without special permission - Item 340 (Ref 8).

AIR POLLUTION CONTROL SYSTEM

Two basic types of air pollution control systems, i.e., a wet process or a dry process, are used on most drum mix plants. The exhaust gases from the plant burner pick up particles of dust as the air moves through the drum. That dust laden air is carried out the rear end of the plant through ductwork and into an air pollution control device.

Wet Scrubber

If a wet scrubber system is employed, the dust laden exhaust gases are usually fed through a venturi where the speed of the gases is increased significantly. As the dirty air leaves the restricted space, water is sprayed on it. The speed of the air stream atomizes the water droplets and the dust particles collide with the minute droplets of water. The direction of the air is altered and it enters a cylindrical drum where the dust particles are separated from the exhaust gases by centrifugal force.

The moisture laden dust particles, being heavier, fall out of the air stream and drop to the bottom of the wet collector. The efficiency of the wet scrubber system depends on the size of the dust particles in the air stream, the speed of the dusty air, and the size and volume of the water droplets used in the spray system. A wet wash system must be properly maintained to function well. The water being sprayed should be clean and all the nozzles should be open and functioning.

The dirty water collected in the bottom of the scrubber is pumped to the waste water pond. The purpose of the pond is to allow the dust particles to settle out of the collector water. The settling pond must be of sufficient size to hold at least the volume of water that will be carried through the scrubber in a half day's production. This volume will usually allow enough time for the dust to settle out before the water is circulated back to the plant. A pond which is too small in area and depth will be filled with sediment and will cause dirty water to be fed back through the wet wash system, clogging the nozzles and reducing the efficiency of the scrubber.

Because it is a wet system, the dust collected by a wet scrubber must be wasted. The material cannot be fed back into the plant. Thus the gradation of the aggregate in an asphalt mixture produced in a drum mix plant, equipped with a wet wash system, will be somewhat different than that determined in the original mixture design since a portion of the fines will be missing.

Baghouse

A baghouse is really a fabric filter. The dust laden air passes through a cloth filter where the dust particles are caught and dropped out of the exhaust gas air stream. Many times an expansion chamber or knockout box is located at the end of the plant ductwork and at the front of the baghouse. The exhaust gases enter the expanded area and are slowed. The heavier dust particles decrease in speed enough to fall out of the air stream to the bottom of the house. The still dirty air then circulates through the chamber and around the numerous bags, which are filter cloth stretched over a wire frame. The air is pulled through the filter by the exhaust fan, depositing the dust particles on the outside of the bag.

If the dust coating on the filter cloth is too light, many fine dust particles will pass through the filter cloth and be carried up the plant stack into the environment. If the dust coating is too heavy, the exhaust fan is unable to pull enough air through the filter cloth, reducing the production capacity of the plant. In order to obtain the correct amount of dust coating on the bags, the bags are cleaned periodically. The cleaning is accomplished either by flexing or shaking the bags or by back flushing the bags with a blast of air. Only a few rows of bags in the fabric filter chamber are cleaned at one time, allowing the baghouse to continue to operate during the cleaning cycle.

The dust collected in the expansion chamber and the dust which is collected on the bags falls into one or more screw augers at the bottom of the baghouse. The collected fines can be wasted or can be returned to the drum mixer.

Generally, baghouse fines which are returned to the plant are fed into the lower portion of the drum through a fines pipe. They are typically conveyed pneumatically and exit the pipe downstream of the drum midpoint, but can also be carried back by an auger system. In some plants, the baghouse fines are deposited some distance in front of the asphalt cement injection point. Thus the dust is mixed with the aggregates before they are coated with the binder. In other plants, the dust is discharged into a mixing chamber where it is coated with asphalt cement before it comes in contact with the other aggregates. This latter system reduces the amount of baghouse fines which are reentrained into the exhaust gas air stream and carried back to the fabric filter.

The efficiency of the fabric filter in collecting the dust particles depends on many factors. The exhaust fan must be able to pull the air through the filter cloth. This is monitored by measuring the pressure drop across the bags--the change in pressure from the dirty side to the clean side of the house. Too little pressure drop means that dust particles will be pulled through the bags; too much pressure drop means that the bags are dirty and the plant is not operating efficiently.

SUMMARY

A modern drum mix plant consists of five major components: (1) cold feed aggregate bins and charging conveyor, (2) the asphalt cement supply system, (3) the drum mixer, (4) the hot mix surge silo, and (5) the air pollution control system. If reclaimed asphalt concrete materials are used, a second cold feed system may be employed on most plants.

The details of the operation of each of these major components are provided in the following chapters.

CHAPTER 4. COLD FEED SYSTEM

AGGREGATE STOCKPILES

Control of an asphalt concrete mixture begins with the stockpiles of aggregates which are to be processed through the drum mix plant and incorporated into the mix. Care should be taken to assure that the aggregates in the individual stockpiles are clean, separated, and not segregated. In contrast with an asphalt concrete batch plant, the drum mix plant does not contain a screen deck to separate the aggregates or a weigh hopper to recombine the various aggregate sizes. Thus, materials fed into the plant through the cold feed bins come out directly, and unaltered, in the final mixture.

It is important that the aggregates be stockpiled on a clean, dry, stable surface. The aggregates in the pile should not become contaminated with dust, mud, or grass. The piles should be free draining to allow the moisture content of the pile to be as low as possible. Excess moisture in the aggregates, particularly the fine aggregates (sand), increases the cost of drying the aggregates in the drum mixer and can reduce the production capacity of the plant. Thus it is essential that the moisture in the aggregate as received from the pit or quarry or subsequently added by rain be permitted to drain from the piles.

The stockpiles of the various aggregate sizes must be kept separated. The cold feed bins on the drum mix plant are calibrated to provide a specified amount of a different size aggregate from each bin. If the various aggregates are commingled in the stockpiles, a combination of sizes will occur in each cold feed bin. This blending of the aggregates will cause variations in the gradation of the final asphalt concrete mixture. Thus the stockpiles should be kept separate.

Segregation of the incoming aggregates is a major problem with all asphalt mixture manufacturing plants, both batch and drum. Aggregates of larger size, particularly when combined with smaller sizes of stone, have a tendency to roll down the face of a stockpile and collect at the bottom

(Fig 4.1). Thus, depending on how the stockpiles are handled, a slug of coarse material and then a batch of finer aggregate can be fed into the plant at various times. These changes in incoming aggregate gradation can cause severe problems in meeting a given job mix formula gradation in the final mix.

Stockpiles should be constructed in layers to prevent or minimize segregation (Fig 4.2). If trucks are used to carry the incoming aggregates to the plant site, each load should be dumped in a single pile (Fig 4.3). If room at the site is a problem, a front end loader can be employed to stack the coarse particles in layers. If the aggregates are delivered in rail cars, belt conveyors are usually used to unload the materials. Belt conveyors are also generally used to carry material from a pit or quarry to an on-site plant. When belts are used to convey coarse aggregate, the height of the piles must be limited in order to prevent the larger particles from tumbling down the sides of the pile and segregating (Fig 4.4). High piles with the conveyor dumping new material on the top of a conical shaped stockpile should not be permitted since severe segregation of the coarse materials can, and will, occur.

The aggregates in a stockpile should also be removed in layers to prevent segregation. If a front end loader is employed to feed the aggregates to the cold feed bins, the face of a large stockpile of aggregates, particularly coarse aggregates, should not be removed from the bottom up, which will cause the larger aggregates to roll down the face of the pile and gather at the bottom. If a tunnel system is used to feed the plant, care should be exercised in permitting a dozer to push the aggregates into the hopper at the tunnel opening. Crushing of the aggregates, as well as separation and segregation of the coarser materials, can occur.

If segregation does occur in a stockpile, the loader operator can mitigate the effects to a significant degree. By blending the coarser and finer areas in each stockpile <u>before</u> loading the aggregates in the cold feed bins, the loader operator can reduce the variations or changes in the incoming aggregate gradation. What should not be done is to feed one or two coarse loads of aggregate and then a couple of loads of fine material into a cold feed bin. Such variation will be directly reflected in the mix

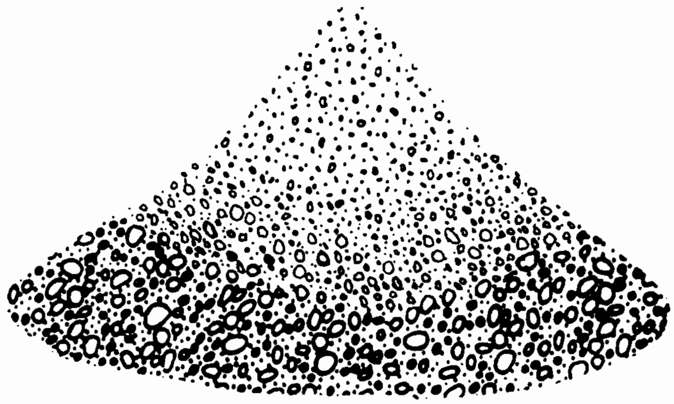

Figure 4.1. Segregation due to separation of coarse and fine aggregate (Ref 12)

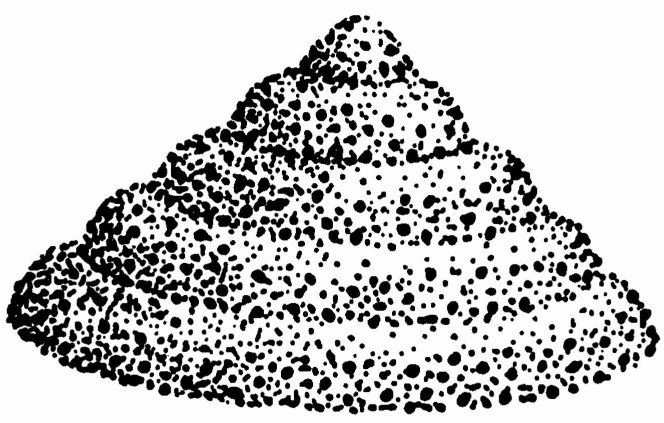

Figure 4.2. Stockpile in layers (Ref 12)

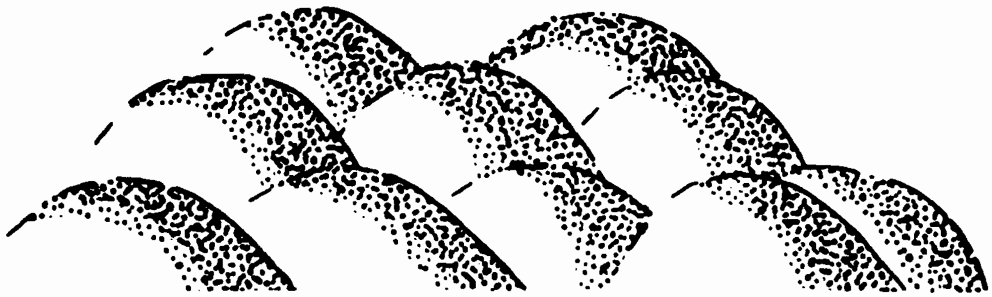

Figure 4.3. Stockpile in piles (Ref 12)

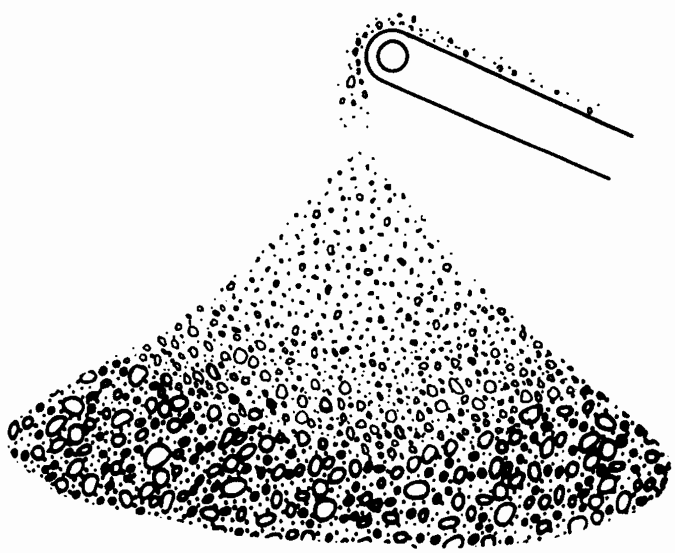

Figure 4.4. Improper stockpiling technique (Ref 13)

approach, however, is to prevent the segregation from occurring in the first place through proper stockpiling techniques.

COLD FEED SYSTEM

Cold Feed Bins

The flow of aggregates through a drum mix plant begins at the cold feed bins (Figs 4.5 and 4.6). The plant can be equipped with a single bin or with multiple bins to handle the new aggregates being used in the mix. In addition, if a recycled asphalt concrete mix is being manufactured, one or more reclaimed asphalt concrete cold feed bins will also be needed.

Most cold feed bins are rectangular in shape. The bins have sloping sides and a rectangular or trapezoidal opening at the bottom (Figs 4.7 and 4.8). The sides of the bins used for reclaimed asphalt mixtures are usually steeper than the sides of bins for the new aggregates. This reduces the tendency of the asphalt coated reclaimed material to hang up in the bin and bridge over the discharge opening.

Ideally, a bulkhead or divider should be used between cold feed bins (Figs 4.6 and 4.9). The width of each bin, depending on the capacity of the drum mixer and whether the plant is portable or stationary, is usually slightly wider than the bucket on a front end loader. If no dividers are used between the bins, the loader operator can overfill (Fig 4.10) a bin and allow the aggregates of one size to spill over into the aggregates in an adjacent bin. This combining of the aggregate sizes can cause variations in the mix gradation. Some plant manufacturers provide bulkheads on the cold feed bins; others do not. If bulkheads are not used to separate the aggregates between the various bins, they should be installed.

The cold feed bins are equipped with gates which can be set to provide a number of different openings. They are also provided with a variable speed conveyor belt beneath the bin (Fig 4.11). The quantity of the aggregate delivered from each bin is determined by the amount of the gate opening as well as the speed of the belt feeder. If a large volume of one particular aggregate is desired from a bin, the gate is set to provide a greater opening and/or the belt conveyor is increased in speed.

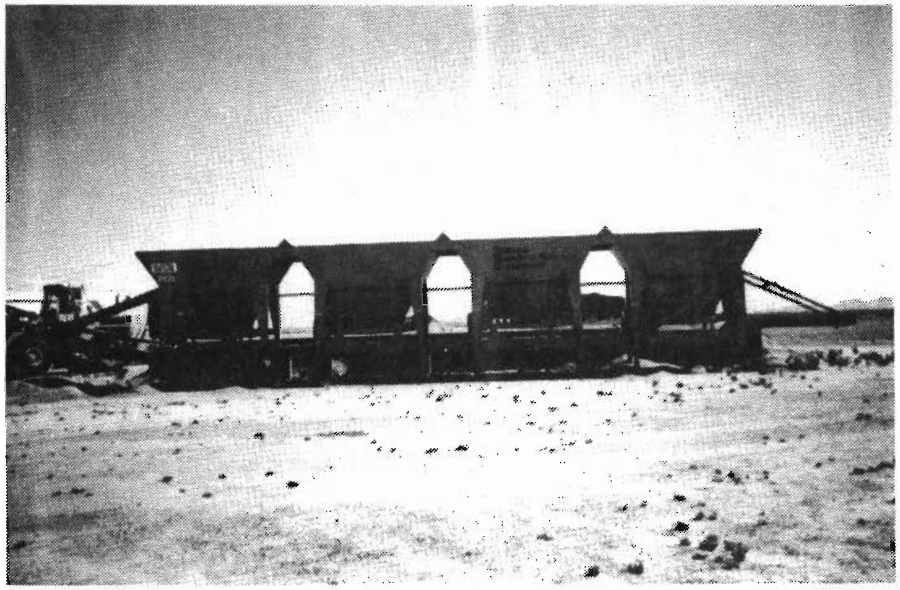

Figure 4.5. Cold feed bins

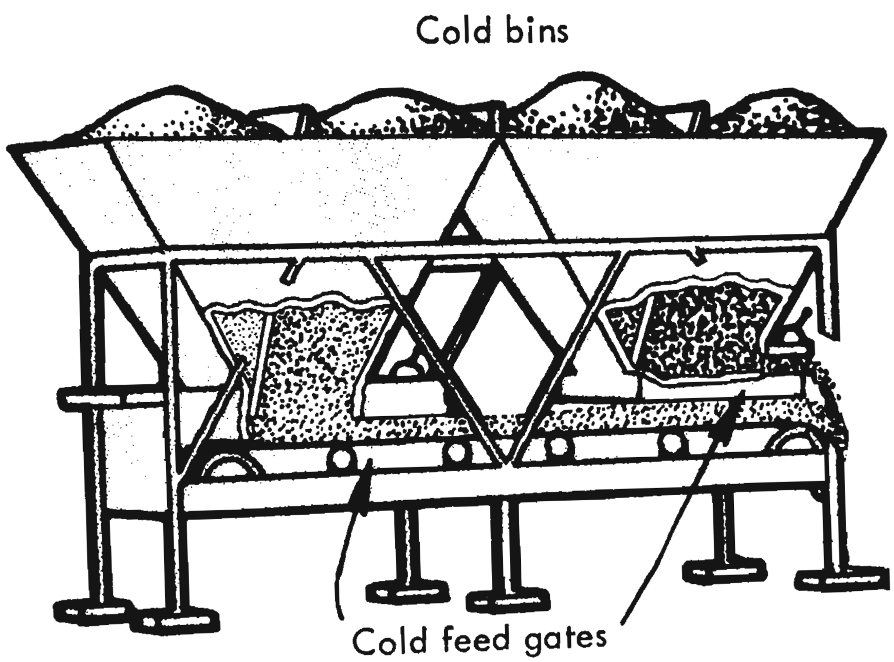

Figure 4.6. Schematic of cold feed bins (Ref 12)

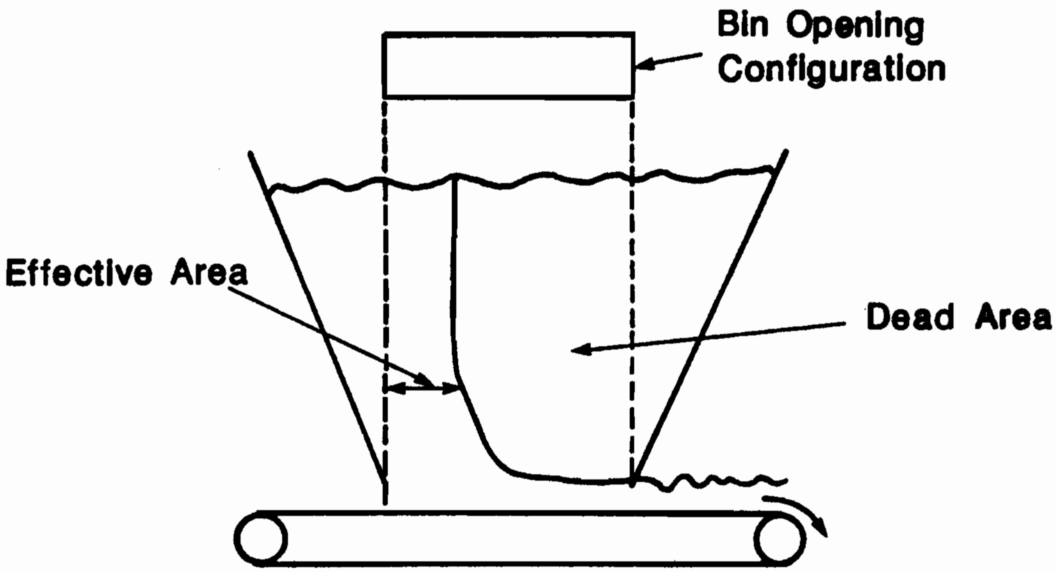

Figure 4.7. Cold feed bin with rectangular opening (Ref 14)

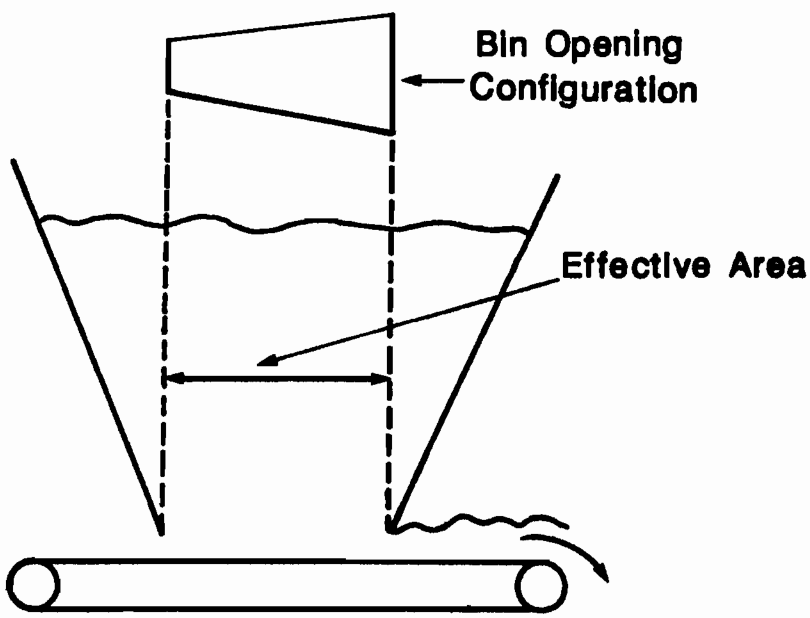

Figure 4.8. Cold feed bins with trapezoidal opening (Ref 14)

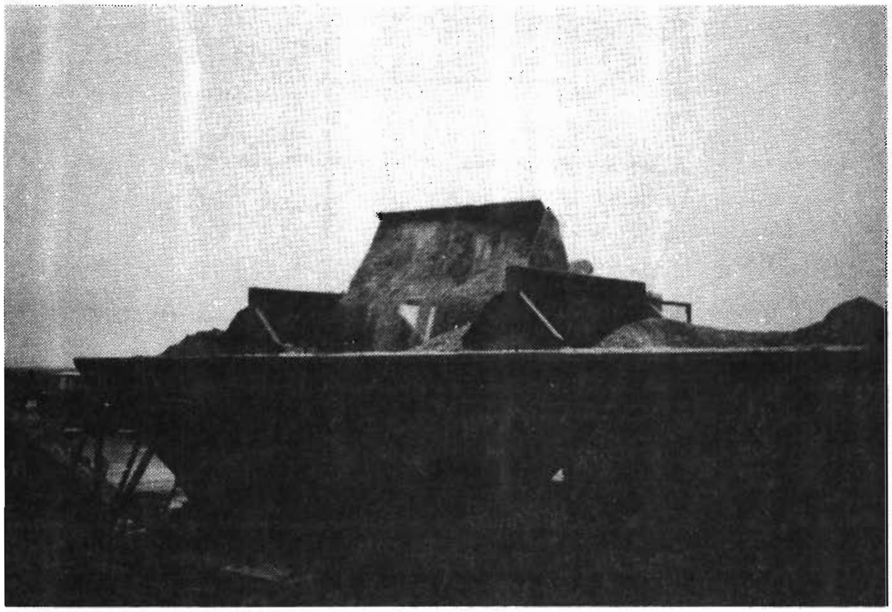

Figure 4.9. Cold feed bins with bulkhead between bins

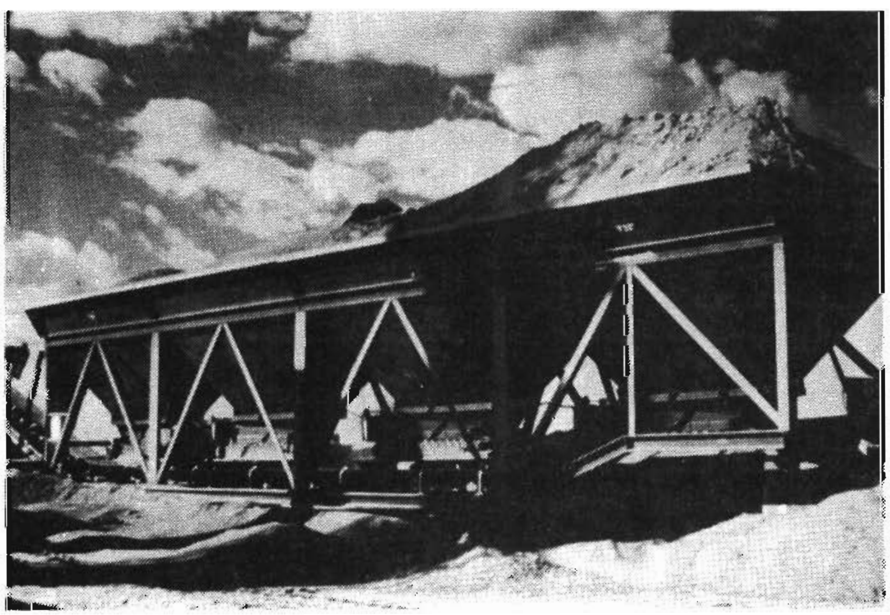

Figure 4.10. Overfilling cold feed bins

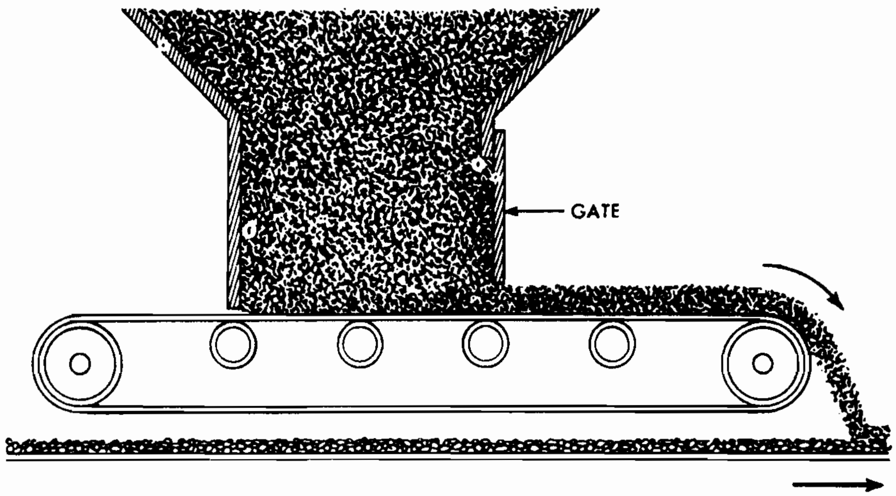

Figure 4.11. Feeder conveyor and gathering conveyor under a cold feed bin (Ref 5)

Feeder Conveyors

In years past, the conveyor belt (belt feeder) under each cold feed bin was run at a constant speed. To vary the quantity of aggregate fed from a bin, the gate opening had to be changed. Currently, for most asphalt plants, a constant gate opening on a bin is used and the belt speed is increased or decreased to draw the proper proportion of aggregate from the bin. The gate opening is typically set manually on each bin. This is done by raising or lowering the gate by a hand crank or wheel, or by unbolting, moving, and rebolting a sliding plate on one end of the hopper. Because the gate setting is usually done manually, the gate opening could be changed or incorrect without the plant operator being aware of it since there is no indication of gate opening on the plant control panel. Thus the gate setting should never be altered without the knowledge of the plant operator.

As the speed of the belt feeder under a bin is changed, the amount of aggregate discharged from the bin is also changed. Theoretically it is possible to withdraw material from the hopper using the full range of belt speed, from 0 percent to 100 percent of the maximum speed. It is desirable practice, however, to operate a belt feeder in the range of 20 to 80 percent of its maximum speed which still allows the plant operator to vary production rate to match haul truck availability or laydown conditions. If the bin opening is set so that the belt feeder is functioning near the upper or lower end of its speed range, the operator may not be able to change the plant production volume to any significant degree. Thus the gate on the cold feed bin should be set in a position to allow the feeder conveyor to run near the midpoint of its speed range.

> Example. Suppose a drum mix plant is rated at 400 tons per hour (at 5 percent moisture removal), but is actually producing mix at a rate of 300 tons per hour due to conditions at the paving site. The plant is thus operating at 75 percent of its rated capacity. Further suppose that one particular cold feed bin is supplying 30 percent of the aggregate needed for the mix, or 90 tons per hour of material (ignoring, for this example, the moisture in the aggregate and the asphalt cement in the mix). Further, the

gate on the cold feed bin is partly closed, so that the belt feeder conveyor is running at 85 percent of its maximum speed.

The plant operator receives word from the laydown superintendent that he can now place 400 tons of mix per hour. The operator increases the speed of all the conveyor belts proportionally to meet the increase in demand for mix. On the cold feed bin in question, however, increasing the output from 90 to 120 tons per hour is not possible because the speed of the belt feeder would have to be greater than 100 percent, which is impossible. Thus, by not operating in the middle of the belt speed range for each cold feed bin, the operator has lost the ability to easily alter the output of the drum mix plant to meet changing mixture needs.

In this example, the operator would have to increase the gate setting or size of the opening on the cold feed bin in order to discharge enough material to meet the new production requirements. In all too many cases the tendency is to run the feeder belt speed of the one cold feed bin at 100 percent and make up for the loss of aggregate from this bin by increasing slightly the amount of material drawn from the other cold feed bin by increasing the feeder belt speed under each of the remaining bins. This procedure obviously changes the gradation of the asphalt mixture being manufactured.

The speed setting of each belt feeder is displayed on the operator's console in the control trailer. The current speed is typically shown as a percentage of the maximum belt speed. If the feeder belt under a given cold feed bin is operating at a level under 20 percent or over 80 percent, the gate setting should be changed as soon as convenient to allow the belt to operate more nearly in the center of its speed range, for that particular production rate.

The speed setting for each individual belt feeder is set independently to allow the proper amount of aggregate to be pulled from each particular bin. Once determined, the speed of all the belt feeds is synchronized so that a change in the speed of one belt feeder is proportional to the change in the speed of all the other belt feeders. Thus if the production of the plant is increased from 250 to 350 tons per hour, for example, a change in the master control setting causes a corresponding proportional change in the speed of all the belt feed conveyors.

Gathering Conveyor

The aggregate deposited on each belt feeder is discharged onto a gathering conveyor located beneath all of the cold feed bins (Figs 4.12 and 4.13). In most cases, all the belt feeds are run in the same direction as the gathering conveyor. In some cases, particularly on portable plants, the last cold feed bin nearest the plant has the direction of the belt feeder reversed. The aggregate in that bin moves on its belt feeder in a direction opposite to the direction of the gathering conveyor. The direction of the belt feeder conveyor in relation to the gathering conveyor is primarily a function of the design of the cold feed bin system. It is important, however, that the material on each belt feeder be placed uniformly on the gathering belt conveyor.

Scalping Screens*

On plants which are handling bank run or pit run aggregates, it usually is desirable to insert a scalping screen or screens into the cold feed system at the end of the gathering conveyor (Figs 4.14 and 4.15). Bank or pit run aggregates often contain a variety of deleterious objects such as tree roots and vegetable matter, as well as oversize pieces of gravel. Thus the scalping screen can be put into the cold feed system at the discharge end of the gathering conveyor to remove all such large material. For quarry processed aggregates, it is not normally necessary to pass the aggregates through a scalping screen.

Most often the scalping screen is a single deck unit with only one screen cloth. The openings in the screen can either be square or slotted. The advantage of the use of the slotted screen is that a smaller screen area can be used to handle a given volume of material. On some portable drum mix

* Scaping screens are required in Texas (Ref 8).

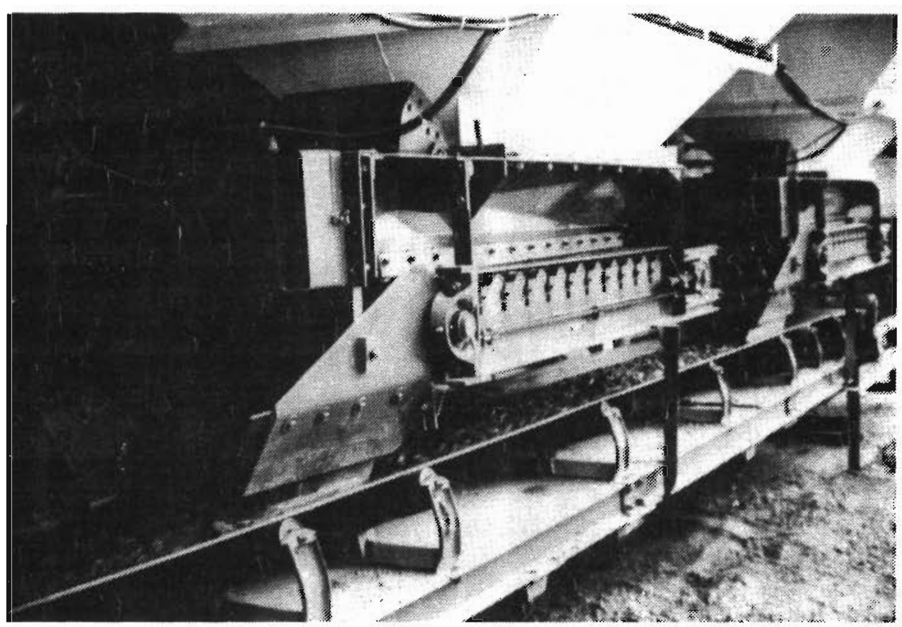

Figure 4.12. Location of a typical gathering conveyor

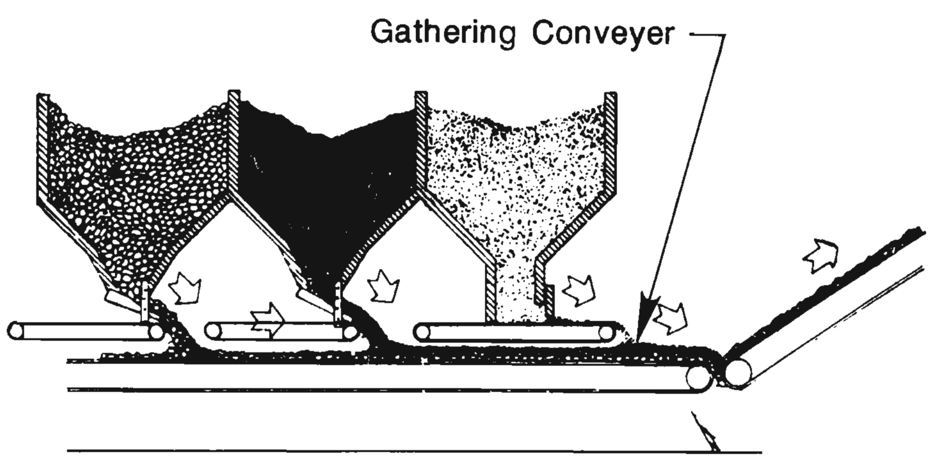

Figure 4.13. Gathering conveyor (Ref 5)

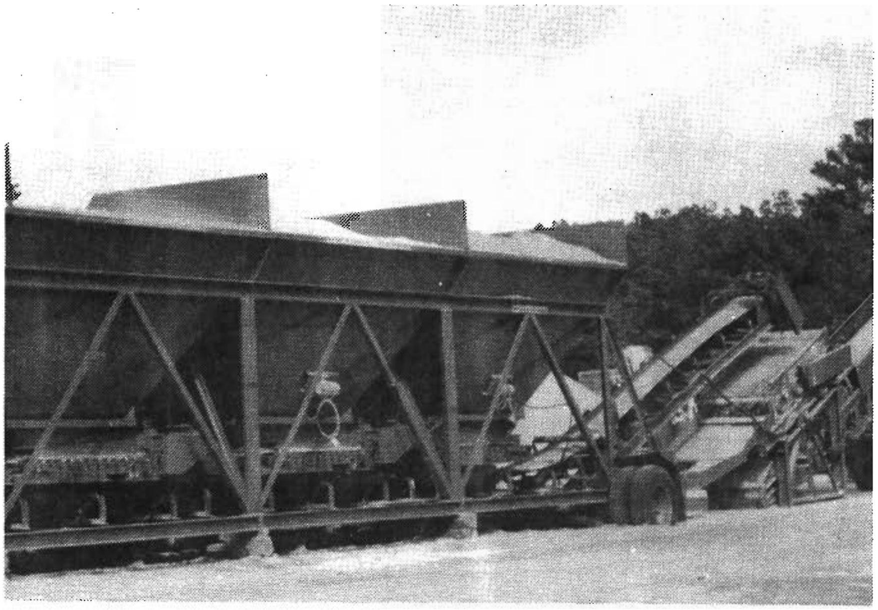

Figure 4.14. Scalping screen between gathering conveyor and incline conveyor (Ref 15)

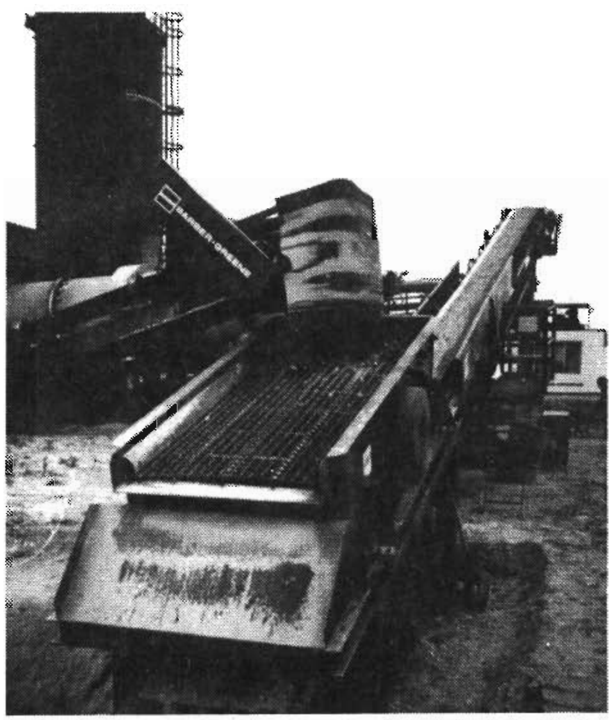

Figure 4.15. Scalping screen

plants, a two deck scalping screen is used which allows two different top size aggregates to be used without changing the screen cloth (Fig 4.16). If the top screen is being used and aggregate is caught on the bottom screen which needs to be included in the mix, a flip gate at the lower end of the second screen redirects the aggregate caught on the bottom screen back to the incline or charging conveyor and into the drum mixer. The flip gate can be either manually or automatically operated.

Some scalping screens are equipped with a bypass chute. This allows the aggregates on the gathering conveyor to be deposited directly on the incline conveyor without passing through the screen. This procedure is used when quarry processed aggregate is being fed to the drum mixer or when the scalping screen is plugged or broken. In the latter case, the scalping screen can be repaired without shutting down the whole plant.

In addition to a scalping screen at the end of the gathering conveyor, some cold feed bin systems include a small scalping screen under each cold feed bin (Fig 4.17). The aggregate from a particular bin falls off the belt feeder and onto the scalping screen. Properly sized material passes through the screen and onto the gathering conveyor. Oversize pieces are rolled down the screen into a reject chute which deposits the aggregates in a pile near the cold feed bins for subsequent disposal. The size of these individual scalping screens is quite small. If the screens become blinded or clogged, the proper amount of aggregate will not pass through the screen onto the charging conveyor, resulting in an incorrect proportioning of the aggregates and a variation in the gradation of the mixture. In addition, if a high proportion of aggregate is being drawn from one particular bin, the capacity of the scalping screen might not be enough to provide the necessary rate of feed. Thus the operation of such individual scalping screens should be monitored regularly.

Incline or Charging Conveyor

The combined coarse and fine aggregates are discharged from the gathering conveyor, through the scalping screen (if used), and onto the incline conveyor for transport to the drum mixer (Fig 4.18). The incline conveyor, or charging conveyor, carries the aggregate to a charging chute

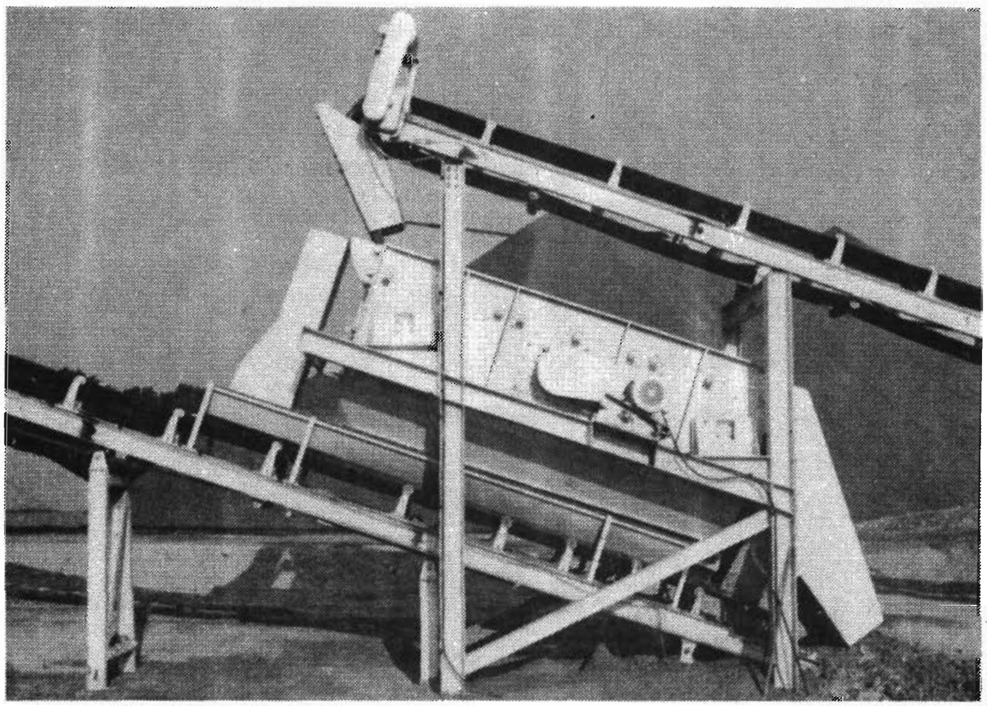

Figure 4.16. Inclined double deck scalping screen with bypass gates (Ref 16)

Figure 4.17. Individual scalpers under each feeder (Ref 17)

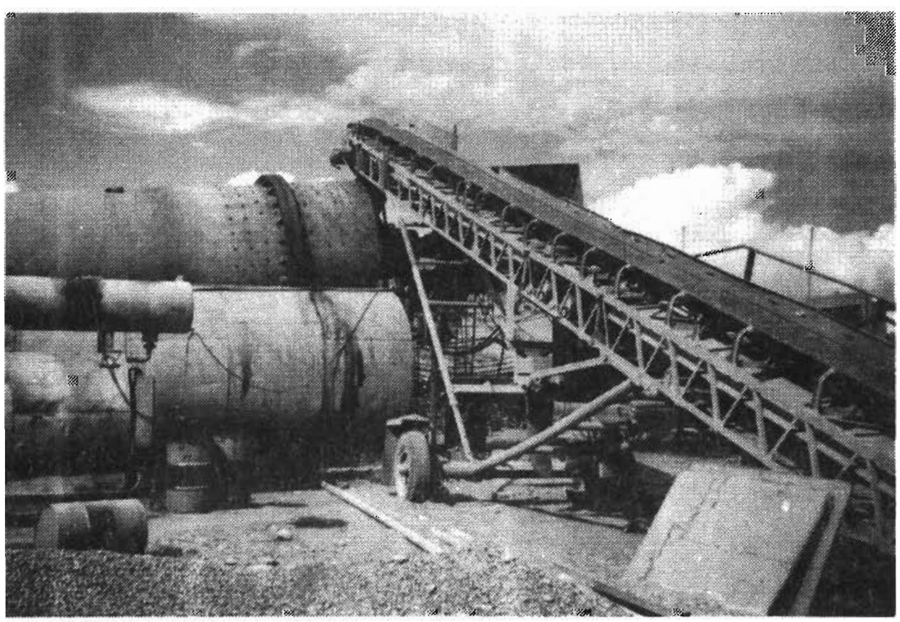

Figure 4.18. Inclined conveyor

above the burner on the drum or to a slinger conveyor under the burner. From one of these two entry points the aggregates are introduced into the mixing drum.

The incline conveyor contains a weigh bridge system which measures the amount of aggregate being fed to the drum mixer (Fig 4.19). The weigh bridge, or belt scale, determines the rate of flow of material over the moving belt at any given time. The incline conveyor operates at a constant speed, independent of the feeder conveyors or gathering conveyor. The weigh bridge itself is located near the midpoint of the charging conveyor, between the head and tail shaft pulleys.

A weigh idler is the heart of the weigh bridge (Fig 4.20). This idler is different from the fixed idlers on the conveyor frame. It is free to move and is attached to a load cell. As the aggregates pass over the weigh idler, the weight of the material at a given point of time is recorded as an electrical signal in the computer control system. The weight value, however, by itself is meaningless, because it covers only an instant of time. Thus the charging conveyor is also equipped with a belt speed sensor (Fig 4.21). This device, usually located on the belt take up pulley, is a tachometer which measures the actual speed of the conveyor belt.

The information from the weigh idler on the belt scale and from the belt speed sensor is combined to determine the actual weight of aggregate, in terms of tons per hour. This value is the wet weight of the aggregate, and includes the moisture in the aggregate. The wet weight of this material is converted to dry weight (without moisture) by the plant computer, using a manual input of the average moisture content in the combined coarse and fine aggregates.

To obtain an accurate belt speed reading, it is essential that the charging conveyor belt be tight. Any slippage of the belt over the speed sensor will result in an erroneous reading and an incorrect tonnage input value to the drum mixer. In addition, it is important that the incline conveyor be equipped with a scraper to clean off the belt as it revolves around the head and tail shaft pulleys.

If the aggregates being carried on the belt are relatively dry, all the aggregates that pass over the weigh bridge will enter the drum. If the

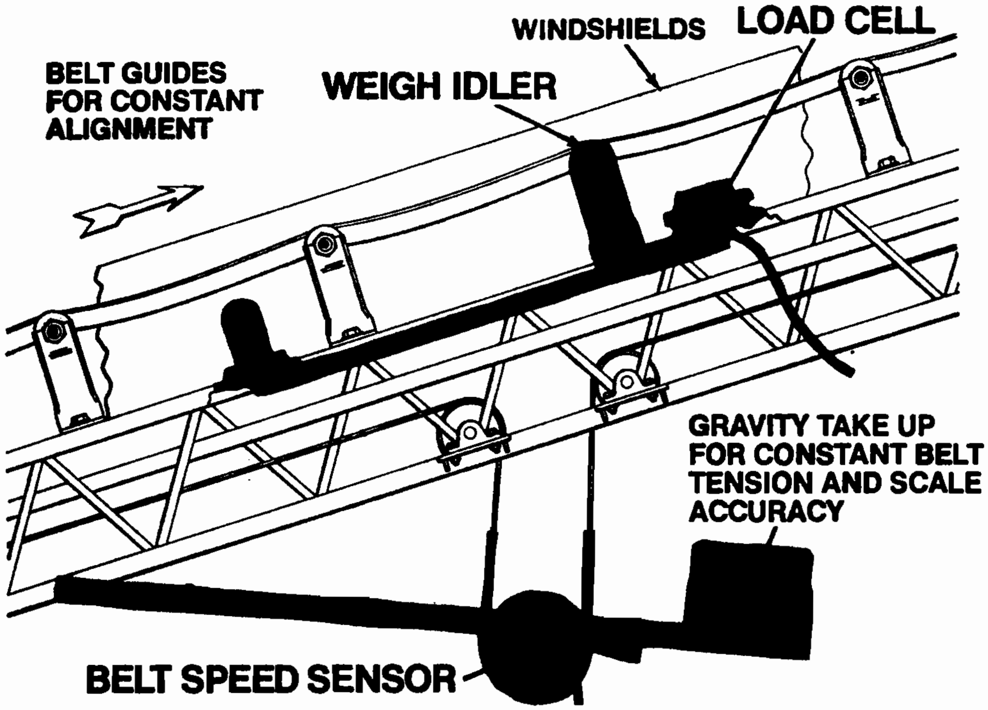

Figure 4.19. Weigh bridge system (Ref 18)

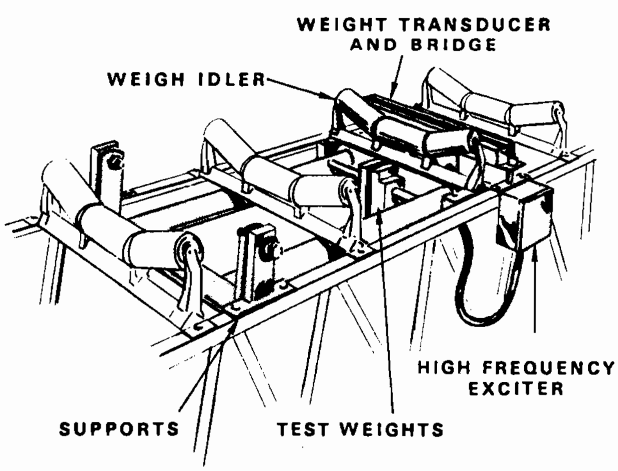

Figure 4.20. Continuous automatic belt weighing system (Ref 19)

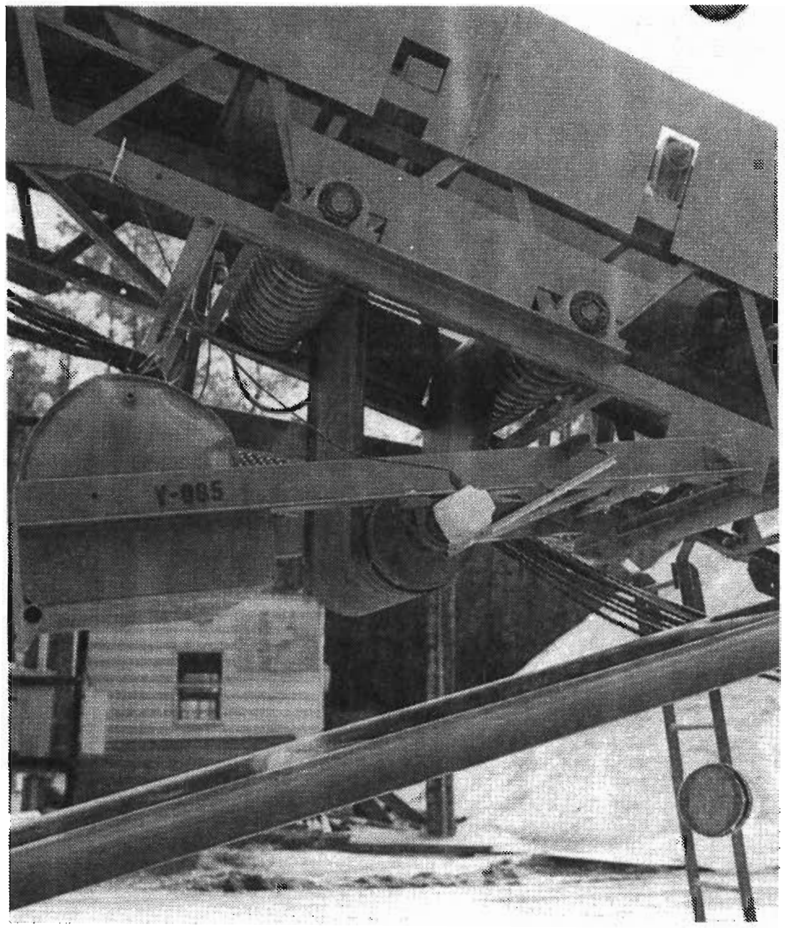

Figure 4.21. Belt speed sensor on belt takeup pulley (Ref 15)

moisture content of the aggregate is high, and if the fine aggregates are placed on the belt first, some aggregates may stick to the incline conveyor belt. This "extra" material will not be fed into the drum, but will remain on the belt. If not removed by a scraper block, the additional material will be continually weighed by the weigh bridge, creating a false weight reading. The computer will be told that more aggregates are entering the drum than actually are. This will cause additional asphalt cement to be pumped to the plant. Thus the belt scraper should be in place, cleaning the incline conveyor belt as it carries aggregates to the mixing drum.

The belt speed sensor can be mounted on the conveyor belt take up pulley. This device is essentially a gravity take up, used to keep the conveyor belt in tension (Fig 4.20). If the pulley weight is restricted from free movement, the belt speed determined by the sensor will be incorrect. The same is true if the belt is slipping as it passes over the pulley. Thus it is important that the conveyor belt be tight and not slipping in order to obtain an accurate belt speed reading.

Some incline conveyors are equipped with an air actuated take up system which is located on the tail shaft pulley and operates in a manner similar to the gravity take up system. Its purpose is to keep the conveyor belt tight. Thus the belt speed sensor still can measure the true velocity of the belt.

Individual Bin Weigh Bridges

On some plants, some of the individual cold feed bins will be equipped with weigh bridge systems located on the individual belt feeder conveyor. Thus instead of one weigh bridge on the incline or charging conveyor, multiple weigh bridge units are used. For this type of setup, the conveyor belt under each individual cold feed bin must be wider and longer than the feeder belt without the weigh bridge.

Usually a plant with individual cold feed weigh bridges will not have a weigh bridge installed on the last feeder conveyor closest to the drum mixer. Another weigh bridge is installed on the incline conveyor. This latter system provides data on the combined weight of all the aggregates, the same as the weigh bridge system on most drum mix plants.

The plant computer and controls are thus able to display the amount of aggregates being pulled from each cold feed bin. The amount of material delivered from the bins equipped with individual weigh bridges is read directly, after deducting the amount of moisture in each aggregate fraction. The volume of aggregates discharged from the last bin is determined by subtracting the amount of aggregate weighed by the individual feeders from the total aggregate weight measured by the weigh bridge located on the incline conveyor, adjusted for moisture content.

COLD FEED SYSTEM FOR RECYCLED MATERIAL

The cold feed system for handling recycled material is essentially the same as the conventional cold feed system with slight modification. If the drum mix plant is employed to produce a recycled asphalt concrete mixture, reclaimed asphalt concrete material must be fed into the plant. On most plants, this is done through the use of a separate cold feed bin setup (Fig 4.22). The bin or bins are similar to the cold feed bins used for new aggregates except that the sides of the reclaimed material bins are usually steeper. The steeper sides allow the asphalt coated aggregates to be more easily discharged from the bins. This is particularly important in hot weather when the reclaimed material can become sticky. The steeper sides reduce the tendency of the reclaimed material to bridge the opening at the bottom of the bin.

If a separate cold feed bin arrangement is used for the reclaimed material, the bin or bins are equipped with a variable speed belt conveyor under each bin. The bins are also provided with a gate which can be set at various openings. The reclaimed aggregates are deposited on the feeder conveyor and then transferred to a gathering conveyor. Most often, the asphalt coated aggregates are then passed through a scalping screen to remove any oversize pieces of asphalt mixture or deleterious material. Thus the handling of the reclaimed material is similar to the feeding of new aggregates.

After exiting the scalping screen, the reclaimed asphalt concrete is dropped onto the inclined conveyor for transport to the drum mixer. This conveyor is also equipped with a weigh bridge system which measures the

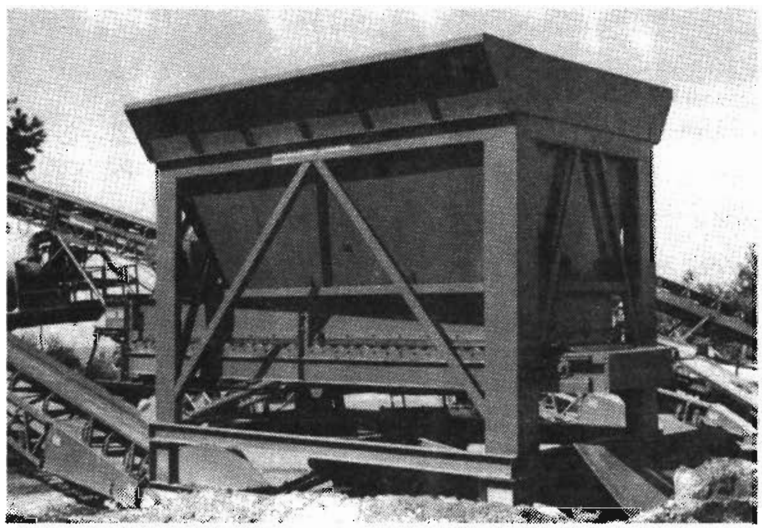

Figure 4.22. Reclaimed material hopper with steeper slides and larger feeder (Ref 10)

weight of the material passing over it as well as the speed of the belt itself. This weight, in tons per hour, includes the moisture in the reclaimed material. The moisture content value is manually input into the plant controls and the dry weight of the reclaimed material calculated by the plant computer. The information determined from the weigh bridge system on the reclaimed material incline conveyor is combined with the data from the new aggregate weigh bridge system to determine the plant output tonnage.

Some drum mix plants have the reclaimed asphalt concrete material cold feed bins combined with the new aggregate cold feed bins. The conventional bins are split, some holding new material and some reclaimed material (Figs 4.23 and 4.24). For one plant manufacturer, the new and reclaimed aggregates are both fed at the same time into the burner end of the drum mix plant. In this case, the reclaimed asphalt concrete is handled exactly like the new aggregates. It can be deposited underneath or on top of the new aggregates, depending on which cold feed bins are selected to hold the asphalt coated aggregates. The reclaimed material is often deposited on top of the new aggregate so that it can be exposed to a water spray when traveling up the incline conveyor.

When manufacturing recycled asphalt concrete mixtures, most drum mix plants use a split feed system to handle the reclaimed material. If a separate cold feed bin for the reclaimed asphalt concrete is not used, the material is placed in one or more of the conventional cold feed bins. The gathering conveyor under the bin or bins is modified, however, by dividing it into two different sections, each moving in a different direction (Fig 4.23). The gathering conveyor under the feeder belts for the new aggregates carries this material to a charging conveyor moving to the burner end of the drum mix plant. The gathering conveyor under the feeder belts for the reclaimed aggregates transports the reclaimed material to a separate incline conveyor which carries the asphalt coated aggregates to an inlet point near the midpoint of the drum mixer length.

As for the case where a completely separate cold feed bin system is used for the reclaimed material, a weigh bridge and belt speed sensor are employed to measure the amount of reclaimed material moving up the charging conveyor and into the drum. While using the split cold feed bin system to handle both

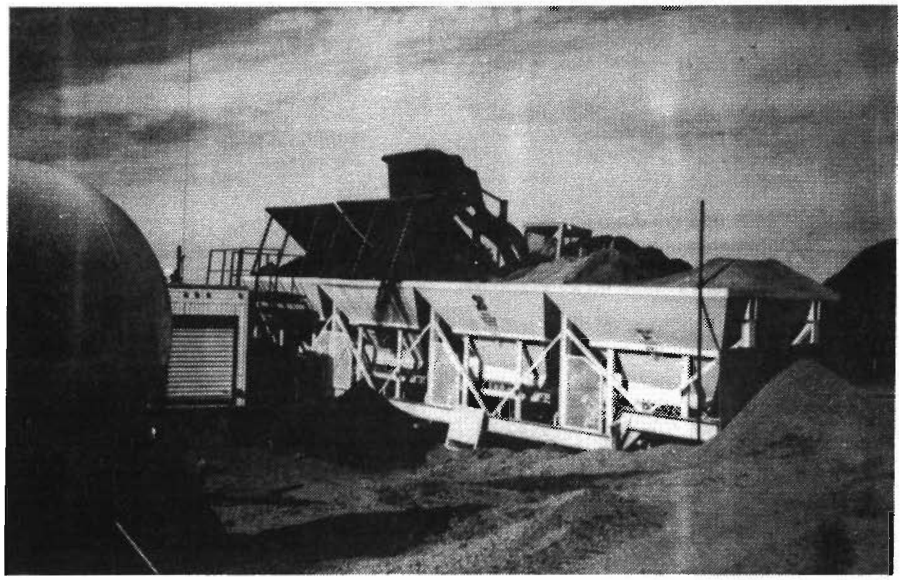

Figure 4.23. Combined new and reclaimed material cold feed bins

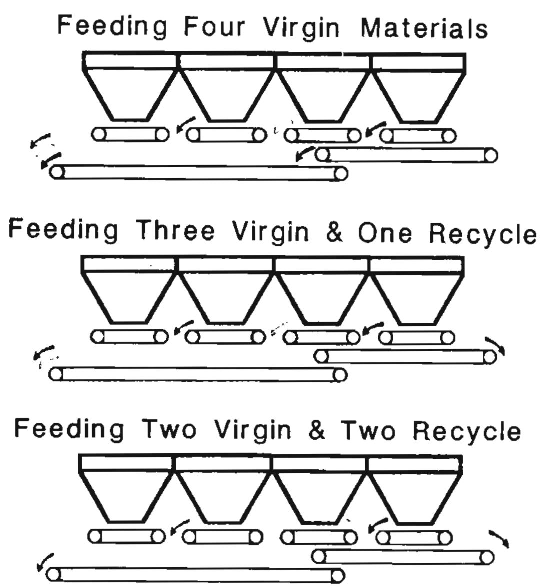

Figure 4.24. Conveyor under cold feed bins (Ref 20)

new and reclaimed aggregates saves the cost of a separate cold feed bin or bins for the reclaimed material, the chance of bridging the opening at the bottom of the bin increases because of the more shallow angle of the sides of the conventional cold feed bins.

CHAPTER 5. ASPHALT CEMENT SUPPLY SYSTEM

The asphalt cement supply system consists of storage tanks and a pump metering system.

STORAGE TANKS

Most asphalt cement storage tanks are heated with a hot oil system (Fig 5.1). A small burner is used to heat and maintain the temperature of the heating oil. The hot oil is circulated through a series of coils inside the asphalt cement storage tank (Fig 5.2). The heat is then transferred from the oil, through the coils, to the asphalt cement (Fig 5.3). This heat transfer process causes the asphalt cement to flow, causing new, lower temperature asphalt cement to come in contact with the heating coils. Thus the hot oil system maintains the proper temperature of the asphalt cement, generally in the range of 300°F to 350°F, depending on the grade and type of asphalt cement being used.

All storage tanks should be completely insulated and heated, and all the lines for both asphalt cement and heating oil should be jacketed to prevent loss of heat. The discharge line for the asphalt cement should be located near the bottom of the tank, as should the line used to fill the tank from the asphalt cement transport truck or rail car. The return line from the pump should be located so that the asphalt cement enters the tank at a level beneath the surface level of the asphalt cement stored in the tank and does not fall through the air (Fig 5.4).

If the drum mix plant is equipped with more than one asphalt cement storage tank, the capability normally exists to pump material from one tank to another. Thus the piping is available to circulate asphalt cement within one tank or from one tank to another. It is important that the plant operator be aware of which tank he is pulling material from, especially if more than one grade or type of asphalt cement is being stored in different tanks.

All asphalt cement storage tanks contain a "heel" of material at the bottom of the tank. This asphalt cement, located beneath the heating coils,

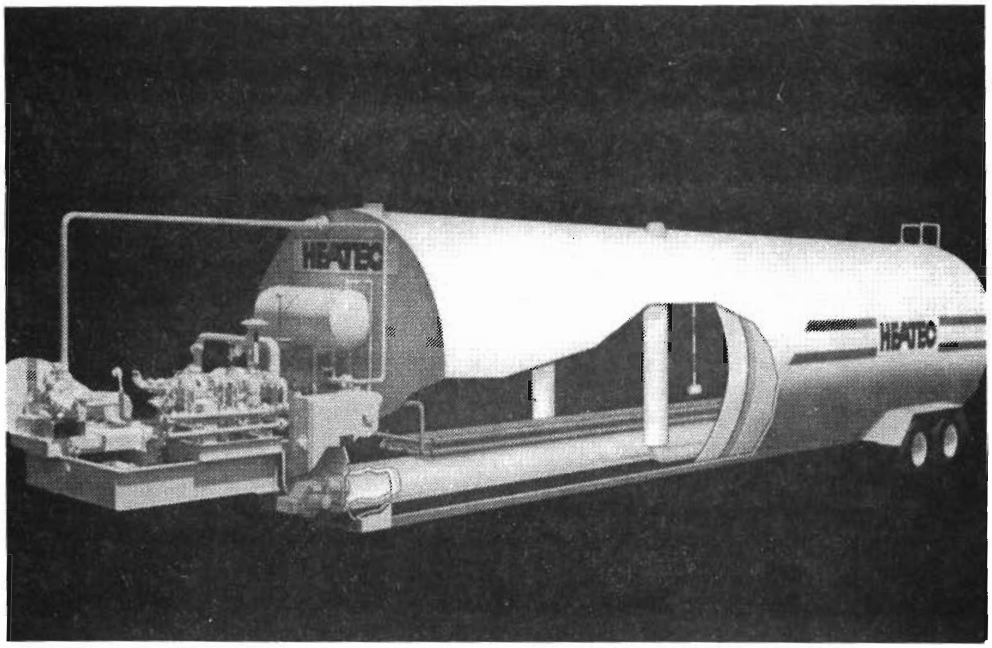

Figure 5.1. Asphalt cement storage tank (Ref 21)

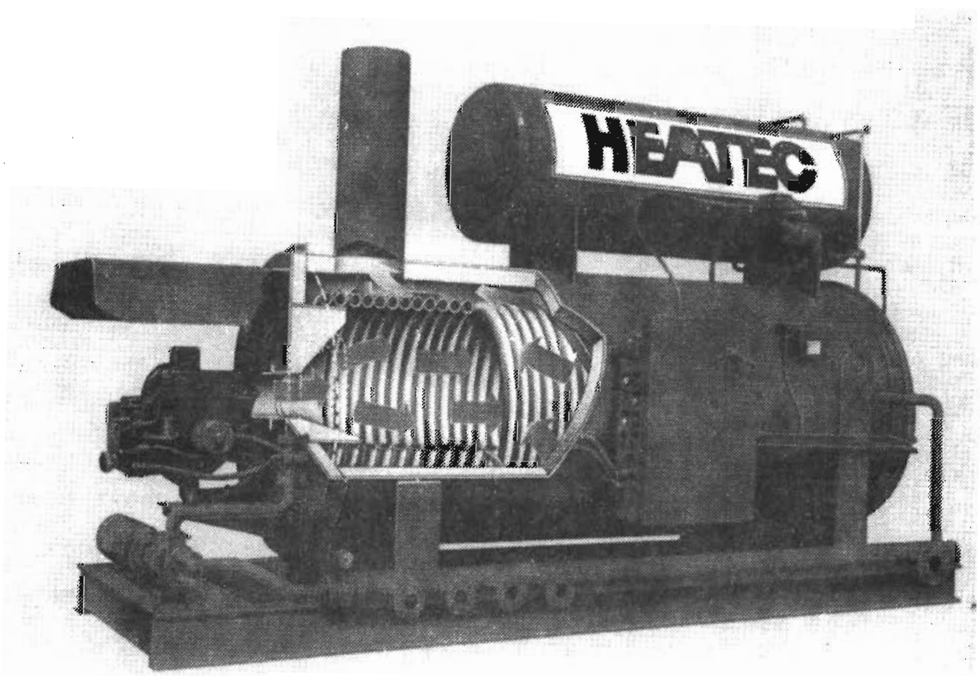

Figure 5.2. Asphalt cement storage tank with helical coil hot oil heater (Ref 21)

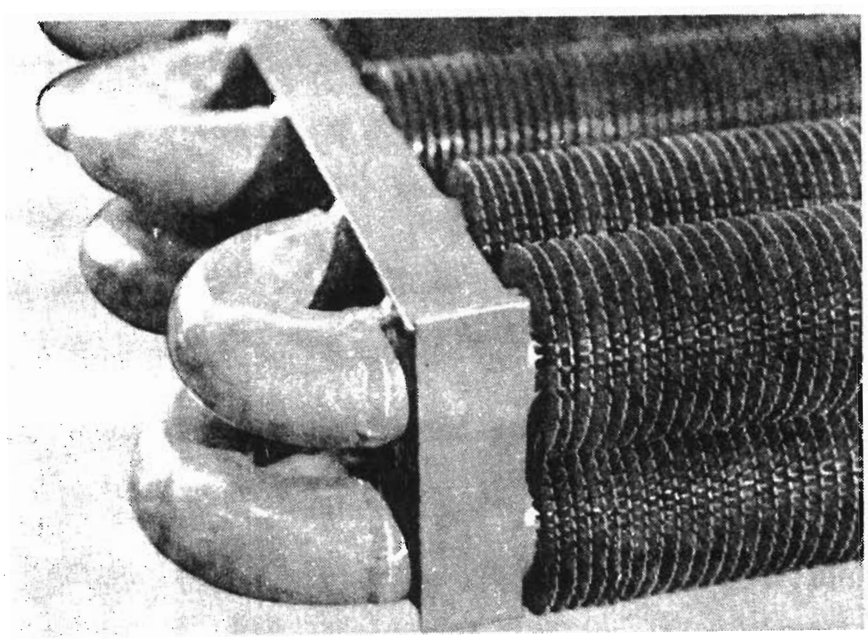

Figure 5.3. Heat transfer coils (Ref 21)

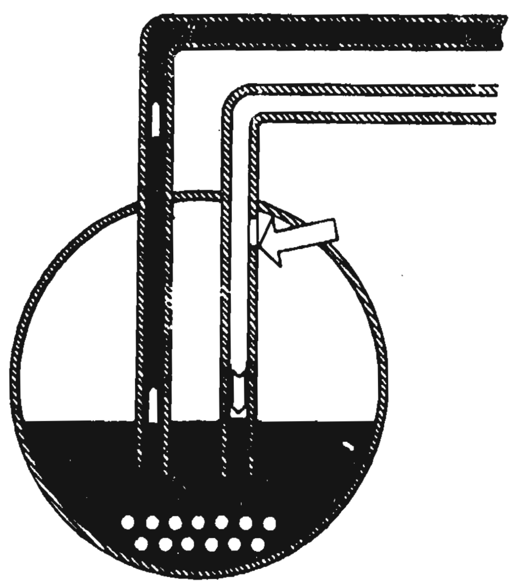

Figure 5.4. Asphalt return line (Ref 12)

does not circulate efficiently. The volume of material in the "heel" depends on the type and style of the storage tank, the location of the heating coils, and the amount of time since the tank was last cleaned. It is recognized, however, that some asphalt cement will typically remain in the bottom of an "empty" tank.

The capacity of an asphalt cement storage tank can be calculated from its diameter and length measurements. The amount of material in the tank at any particular time can be determined by measuring the depth of the asphalt cement using a tank stick. The stick or rod is marked in inches and is lowered into the tank through a port in the top of the tank. The stick is passed through the asphalt cement until it touches the bottom of the tank. As the rod is withdrawn from the tank, the level of the asphalt cement, in inches, is easily noted. A calibration chart, supplied with the tank by the manufacturer, is used to convert the depth of asphalt cement to volume.

It must be remembered that asphalt cement expands slightly when heated. Thus the volume of asphalt cement at 325°F will be somewhat greater than its volume at 275°F. This latter volume will be more than the volume at 60°F. For standardization purposes, all asphalt cement volumes are measured at 60°F, using conversion charts which are based on the specific gravity of the asphalt cement (Ref 28). If the specific gravity of the asphalt cement and its temperature are known, the volume measure at the elevated temperature can be easily converted to the "standard" volume at 60°F.

PUMP AND METER SYSTEM

The asphalt cement is pulled from the storage tank by a pump (Figs 5.5 and 5.6). It is sent, in part, through a meter which measures the volume. The asphalt cement is then transported through a pipe to the drum mixer. It is also returned, in part, to the asphalt cement storage tank. The exact functioning of the pump and meter system depends on the type of system employed.

One system uses a variable volume pump driven by a constant speed electric motor. The amount of asphalt cement pulled from the storage tank is controlled by changing the volume of the pump. The volume needed at the pump is determined by the plant computer and is in proportion to the amount of

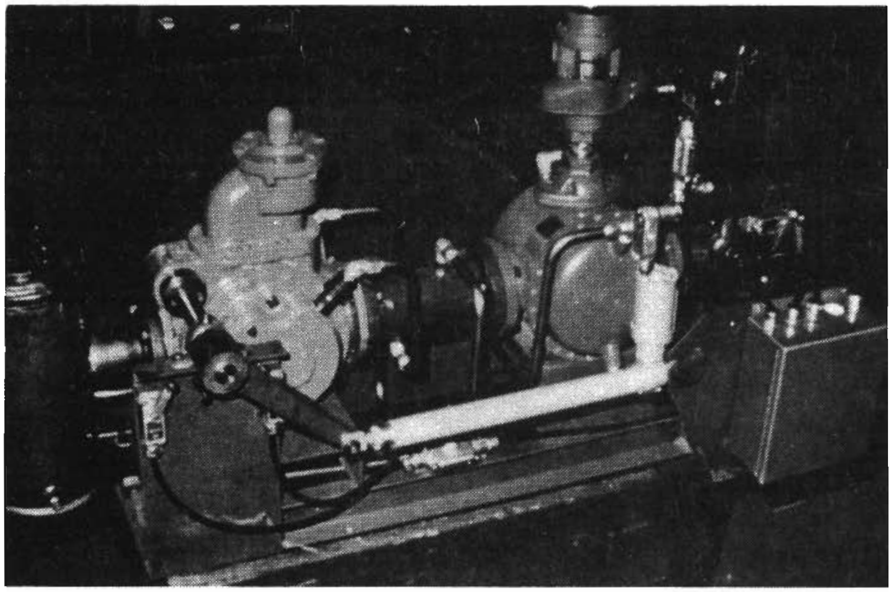

Figure 5.5. Typical asphalt pump

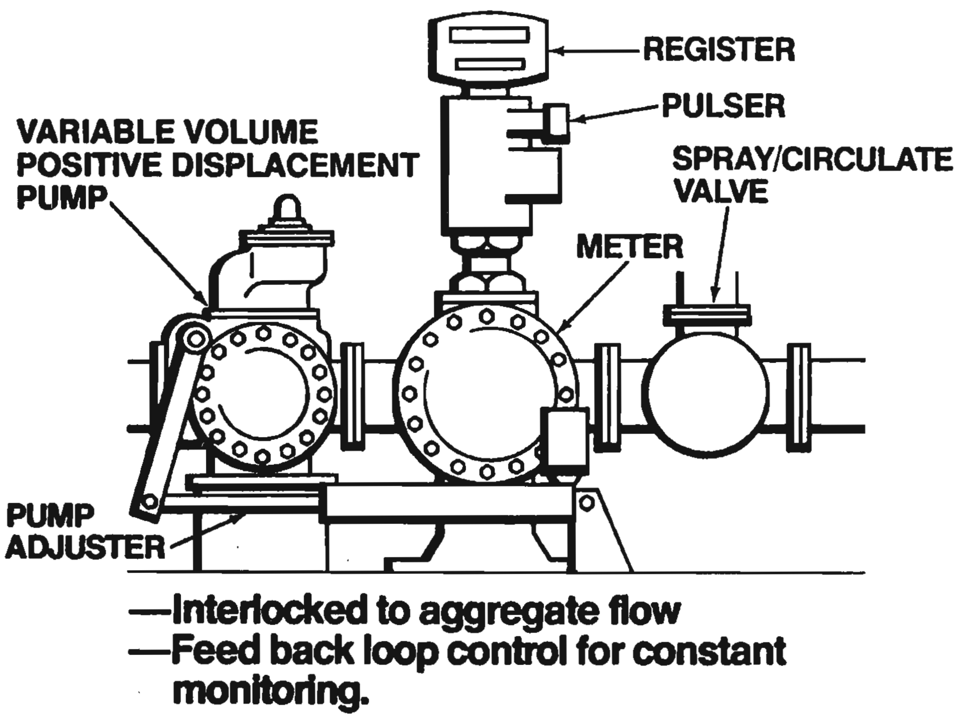

Figure 5.6. Schematic of asphalt pump system (Ref 18)

aggregate being fed into the drum mixer. As the amount of aggregate entering the plant increases, the volume of asphalt cement pulled through the pump also increases, and vice versa.

When the plant is not using asphalt cement, the material continually passes through the pump and meter and through a valve which is set to recirculate the asphalt cement to the storage tank instead of to the plant. The meter automatically puts the asphalt cement into the recirculate mode whenever the aggregate supply is shut down. During operation, the plant controls continually monitor the aggregate feed rate and proportion the variable volume pump accordingly.

A second system incorporates a fixed displacement pump driven by a hydraulic motor, which is in turn driven by a constant speed electric motor. A valve system is used to vary the rate of flow of the hydraulic fluid, thus controlling the quantity of asphalt cement delivered to the meter and then to the drum mixer. The amount of material sent to the plant is dependent on the aggregate feed rate, with the volume supplied increasing as the amount of aggregate charged into the drum mixer increases. A valve in the system downstream of the meter allows the asphalt cement to be recirculated back to the tank when not needed by the plant.

A third commonly used asphalt cement supply system consists of a constant volume pump driven by a constant speed electric motor. In this setup, the same volume of asphalt cement is pulled from the storage tank at all times. A proportioning valve is placed in the line between the pump and the asphalt cement meter. The position of the valve determines the volume of material sent through the meter. The proportioning valve sends some of the asphalt cement through the meter and the rest back through the recirculate line to the storage tank. The system also has a valve downstream of the meter which allows the asphalt cement sent through the meter to be recirculated to the tank. This valve is needed during the warm up period for the meter and during the calibration process. Again, the position of the proportioning valve is determined by the aggregate feed rate into the drum mixer.

The volume of asphalt cement moving through the meter changes with temperature. Some meters are set to measure the temperature of the asphalt cement moving through them and send the data together with the volume information to the plant computer. The specific gravity of the asphalt cement is set manually on the controls. The computer then calculates the volume of asphalt cement, at the standard temperature of 60°F, being fed to the plant.

On some meters, a temperature compensating device is installed directly on the meter stand itself. As the temperature of the asphalt cement changes, the meter senses the change and, based on the specific gravity of the asphalt cement, calculates the volume of asphalt cement at 60°F passing through the meter. This corrected volume is then sent to the plant console for display.

Regardless of the system employed, the asphalt pump system must be capable of changing the volume of asphalt cement sent through the meter in direct response to the demand of the aggregate supply. The response of the pump must be directly related to the change in the amount of material measured by the aggregate weigh bridge system. In addition, the volume of asphalt cement measured at any given temperature must be converted to the volume of asphalt cement at 60°F. At this standard reference temperature, the weight of the asphalt cement can be determined in terms of tons of material per hour, the same as for the aggregate feed rate. The total of the aggregate input (new aggregates, and reclaimed aggregates, if used) and the asphalt cement weight provides the production rate for the drum mixer, in tons of asphalt concrete per hour.

CHAPTER 6. PLANT CALIBRATION

For all drum mix plants, it is necessary to calibrate both the aggregates and the asphalt cement feed rates (Figs 6.1 and 6.2). This should be done periodically to assure that the amount of material processed through the plant is correct. The calibration process should be carried out whenever the plant is relocated. It should also be done whenever the plant has been shut down for a relatively long period of time, such as a month or more or over the winter layoff period. Finally, the plant should be recalibrated whenever there is reason to believe that some aspect of the system is operating erratically, such as wide variations in the aggregate gradation or the asphalt cement content.

Because of the differences in the aggregate weigh bridge systems employed by the various plant manufacturers, it is difficult to discuss all the small variations which can occur in the calibration procedure. The following comments, therefore, are general in nature but should be applicable to most drum mix plants. The plant operation and calibration manual for each particular make and model of drum mixer should be consulted for the exact calibration process to be used on an individual plant.

A NOTE OF CAUTION

The calibration procedures outlined require the use of a truck scale to measure the amount of aggregate which passes over the belt scale or the amount of asphalt cement which passes through the asphalt cement meter. It is usually assumed, often incorrectly, that the weight measured by the truck scale is totally accurate. In addition, the weight measured is often taken as an absolute value, without variation. These assumptions can cause a considerable amount of difficulty in calibrating the plant. Indeed, often the belt scale and asphalt cement meter are more accurate than the truck scale used for comparison purposes.

Scales are normally required to be accurate to a tolerance of ±0.5* percent of the weight being measured. Thus if 10 tons (20,000 pounds) of

* Texas requires a tolerance of ± 0.4 percent, Item 520 (Ref 8).

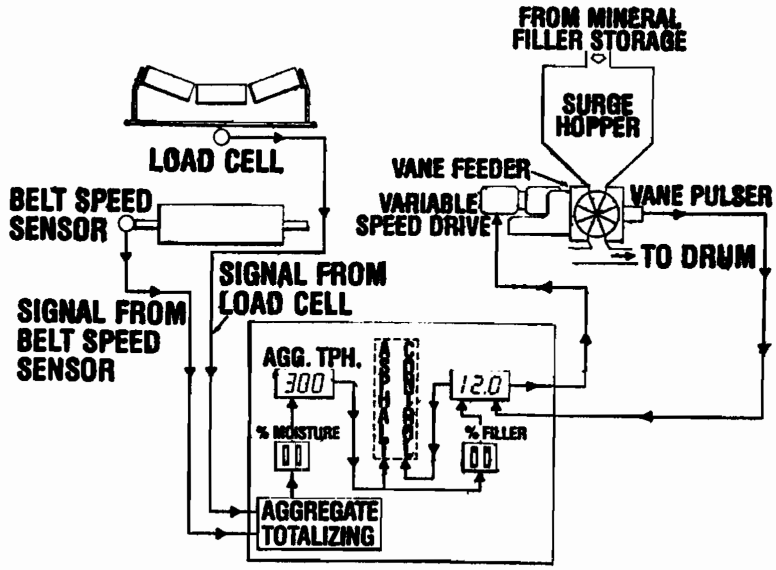

Figure 6.1. Schematic of aggregate feed system (Ref 18)

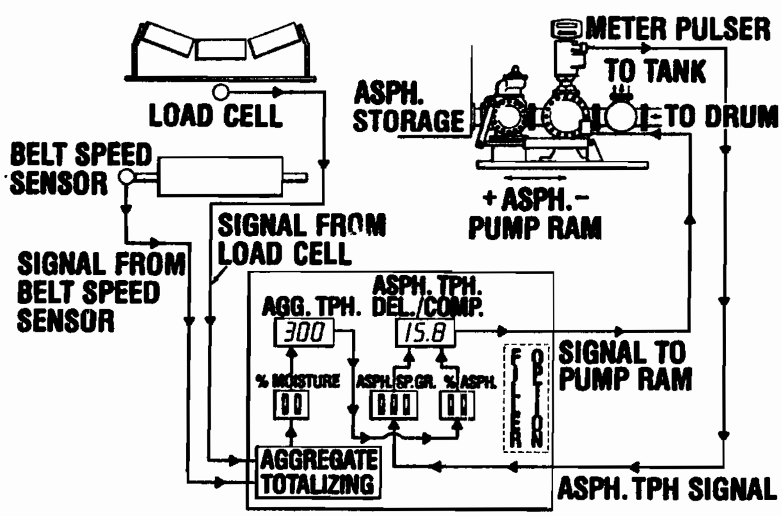

Figure 6.2. Schematic of asphalt feed system (Ref 18)

aggregates are being weighed, a scale in tolerance can read from 19,900 pounds to 20,100 pounds, a difference of 200 pounds. Any weight between the two end values is essentially correct. A belt scale or weigh bridge system also has an allowable tolerance of ±0.5 percent. When the amount of aggregate which passes over the weigh idler registers on the plant console as 20,000 pounds in a given period of time, the true value could be between 19,900 and 20,100 pounds.

If both the belt scale and the truck scale show 20,000 pounds of material delivered, everything is fine. If both readings are either 19,900 pounds or 20,100 pounds, again the numbers are accepted as correct and the calibration procedure accepted. The problem comes, however, when the belt scale reads on one end of the tolerance range and the truck scale reads on the other end of the same tolerance range. For example, if the true weight across the belt scale is 20,000 pounds, but the scale reading is 19,900 pounds, and if the true weight across the truck scale is the same true value of 20,000 pounds but the scale reading is 20,100 pounds, the difference between the two recorded readings is 200 pounds (20,100 - 19,900 pounds). This means that there is a 1.0 percent difference between the "correct" value of 20,100 pounds on the truck scale and the "out of spec" value of 19,900 pounds on the weigh bridge scale (200 ÷ 20,100 = 1.0%).

The conclusion from the above example is that the scale on the incline conveyor weigh bridge is inaccurate. This, however, is the wrong conclusion. Both scales are operating within the proper tolerance limits of ±0.5 percent. Thus the belt scale reading is really as accurate as the truck scale reading is. The incorrect conclusion comes from the fact that the value determined by the truck scale is taken as an absolute number, without tolerance. This assumption is simply not valid.

In order to meet the requirement for the belt scale value to be within ±0.5 percent of the truck scale reading, the accuracy of the weigh bridge scale would have to be ±0.25 percent instead of 0.5 percent (0.5 x 0.5 = 0.25). To continue the example, if the true weight is 20,000 pounds and the truck scale measured weight is 20,100 pounds, the incline conveyor weigh bridge must read between 20,000 and 20,200 pounds (±100 pounds from 20,100 pounds). To be assured that the belt scale reading would be within the value of 20,000 to 20,100 pounds, the average belt scale reading would need to be 20,050 pounds, or a difference of only 50 pounds from the supposedly correct truck scale value of 20,100 pounds. This 50 pound difference, over 20,100 pounds, is a tolerance value of only 0.25 percent. Thus the conveyor belt reading is penalized because the truck scale value is taken as an absolute value rather than a value which itself has an allowable variation of ±0.5 percent.

In order to overcome this improper conclusion concerning the accuracy of the conveyor weigh bridge reading, one of two courses of action can be pursued. First, the allowance tolerance on the belt scale reading can be increased to 1.0 percent if the truck scale reading is accepted as a single, "accurate" value. Thus the belt scale reading of 19,900 pounds would be judged to be within specs if the truck scale read 20,100 pounds. The true accuracy of the conveyor weigh bridge would still be only ±0.5 percent.

The second method is to allow for a ±0.5 percent tolerance value to the truck scale reading in determining the target value for the weigh bridge scale. Thus if the truck scale measured value is 20,100 pounds, the tolerance of ±0.5 percent would set an allowable target range of 20,000 to 20,200 pounds (± 100 pounds). If the true weight value was still 20,000 pounds but the belt scale reads 19,900 pounds (within the ±0.5 percent tolerance), the comparison of the belt scale value of 19,900 pounds and the lower limit of the truck scale weight range of 20,000 pounds would mean that the incline conveyor weigh bridge value would be judged to be acceptable [(20,000-19,000)/20,000 = 0.5%]. Thus the belt scale would not be unduly penalized because the allowable variance in the truck scale reading would be recognized and taken into account.

In summary, in calibrating either the belt scales or the asphalt cement meter on a drum mix asphalt plant, the comparison value determined through the use of a truck scale should be treated as a variable value rather than as an absolute and exactly correct number. This consideration will eliminate the usually incorrect conclusion that the accuracy of either the belt scale or the asphalt cement meter is suspect when both devices may be operating properly.

WEIGH BRIDGE CALIBRATION*

The weigh bridge system, located on the incline charging conveyor and/or on the individual cold feed bin feeder conveyor, determines the quantity of aggregates being delivered to the drum mixer. The input value of the aggregate feed in turn determines the amount of asphalt cement pumped to the plant. Thus the belt scale must be calibrated by comparing the weight measured by this scale with weight determined using a scale of known accuracy. Usually this latter device is a truck scale which has been checked and certified by the local "weights and measures" governmental agency.

Before any calibration is attempted, the conveyor belts on the drum mix plant should be operated for a minimum of 30 minutes in an empty condition. This warm-up period is important for several reasons. First, it allows the controls to heat up and stabilize at operating temperature. It also allows the conveyor belts to stretch and seat on the idlers. Thus the conveyors should be run for at least 1/2 hour before the calibration procedure is started. The warm-up period requirement is also valid for normal daily start-up operation.

In order to properly calibrate the weigh bridge scale, a number of items are needed: (a) a dump truck, (b) a certified truck scale, and (c) scale test weights. The calibration should not be carried out on windy or rainy days since these environmental conditions can affect the accuracy of the weight measurements. Normally the aggregate feed rate can be measured by passing the aggregates over the weigh bridge and through a diverter chute at the top of the incline conveyor and into the dump truck (Figs 6.3 and 6.4). If the drum mix plant is not equipped with a diverter chute, it may be necessary to pass the aggregates through the drum and surge silo and then into the truck.

The process of delivering the aggregates to be weighed directly to the truck from the top of the charging conveyor is the preferred and most accurate method. There is little chance to "lose" material from the conveyor if it is deposited in the truck through the diverter chute. If the aggregates

* The standard method used by Texas State Department of Highways and Public Transportation is Test Method Tex-920-K (Ref 22).

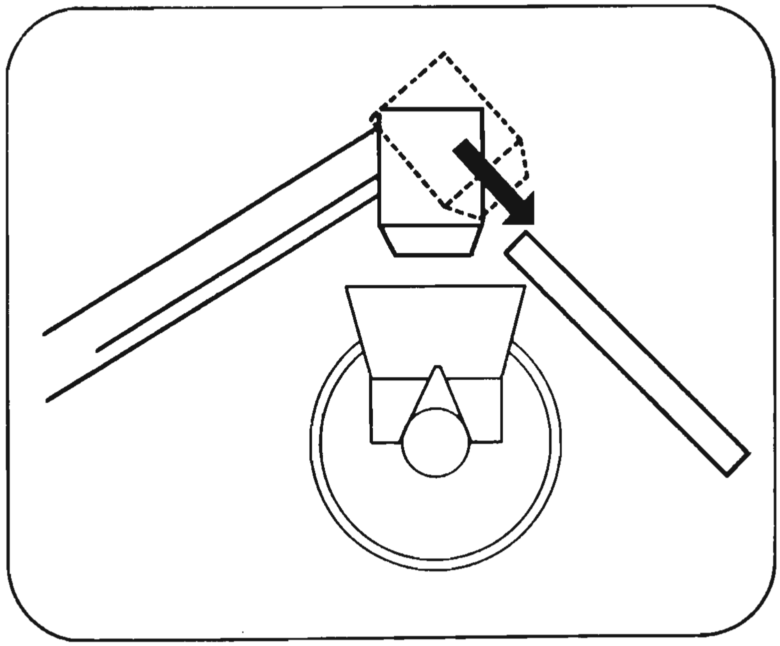

Figure 6.3. Schematic of calibration diversion chute (Ref 9)

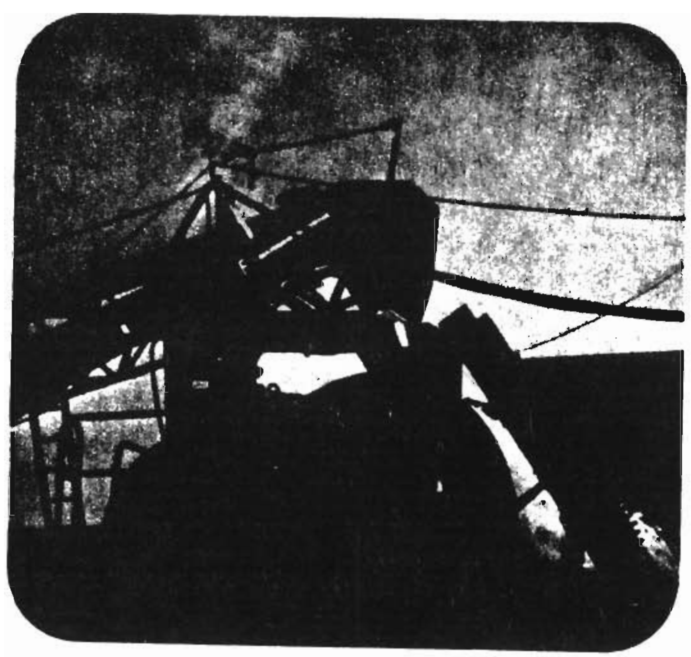

Figure 6.4. Calibration diversion chute

are passed through the plant, multiple opportunities exist for a small amount of aggregate to be retained inside the drum, in the conveying equipment between the drum and the silo, and in the surge silo itself. Each loss of material affects the accuracy of the comparison between the belt scale reading and the truck scale weight. Thus the aggregates should not be carried through the plant unless there is no means to divert the aggregates before entering the drum.

The calibration procedure commences with the nulling or zeroing of the belt scale. With the conveyor belt running, the plant controls for the weigh bridge are adjusted to indicate a zero weight on the weigh idler. Some minor variation in the zero reading, both plus and minus, may be recorded due to irregularities in the conveyor belt. But the average weight reading on the empty conveyor belt should be zero. Once the weigh bridge is nulled out (set to a zero weight), this adjustment control should not be changed again.

The empty truck used to collect the aggregates should be weighed on the certified truck scale. This tare weight should be kept as constant as possible during the calibration operation. The driver should either remain in, or out of, the truck at all weighings. Nothing should be done to increase or decrease the tare weight. Thus the truck engine should be shut off when the truck is stationary to keep the change in weight due to fuel consumption at a minimum. As a check, the tare weight should be measured again <u>after</u> the aggregates have been weighed and emptied from the truck bed. The average tare weight value should be used if the two weights are similar or an investigation should be made if the two readings differ by more than 0.5 percent.

Once the truck has been tared, the aggregates should be fed from one or more cold feed bins, across the individual belt feeders, onto the gathering conveyor, and then onto the charging or incline conveyor. At this time, the moisture content control should be set at zero percent. The rate of feed should be equal to the typical operating rate of the plant. Thus if the drum mixer is to be run at an average rate of 350 tons per hour, the initial weigh bridge calibration should be carried out at that operating rate. The aggregates should be passed over the weigh idler and then diverted into the waiting truck. As large a sample as feasible should be taken. If the truck is capable of holding 15 tons of material, a sample size approaching 15 tons should be used. All the aggregates passing over the belt scale should be deposited in the truck.

The amount of aggregate measured by the weigh bridge should be recorded and compared to the net weight of the material calculated from the truck weights. If the two values are within the required tolerance (see above discussion on allowable tolerances), the weigh bridge system is in calibration. If the two weights are out of tolerance, an adjustment needs to be made to the weigh bridge controls to move the weight measurement into compliance.

Most drum mix plants are equipped with a span control on the belt scale. Following the calibration instruction supplied by the plan manufacturer, the span control should be adjusted to a new setting, upward or downward, by a calculated percentage of the difference in the two readings. The cold feed bin feeder conveyors should then be started again and the aggregates passed over the weigh bridge and into the truck. If the truck aggregate weight and the belt scale weights are within tolerance, the initial calibration process is finished. If not, another adjustment is made in the span control setting and the procedure repeated once again.

Once the belt scale has been calibrated, the weigh bridge can be checked periodically by hanging test weights on the weigh idler. The test weights are used to simulate a load traversing the weigh idler. The charging conveyor is started once the test weights are in place. A stop watch is used to measure a period of time the incline conveyor is run, usually five to ten minutes. The value of the test weights multiplied by the time the conveyor is used to calculate the simulated number of tons per hour of material passing over the weigh bridge. This calculated value should be compared to the number shown on the plant console. Thus the test weights can be employed as a quick check for the weigh bridge calibration.

The test weights can also be used to verify the operation of the moisture content control on the plant. With the test weights in place, the moisture content value should be initially set at zero. This value should then be increased, indicating some moisture in the aggregate. The dry weight of the aggregates displayed on the console should decrease in proportion to the amount of moisture dialed in. For example, if the 0 percent moisture content feed rate is 350 tons per hour, a setting of 3 percent moisture on the dial should decrease the dry weight value shown by 3 percent, or to approximately 340 tons per hour.

COLD FEED CALIBRATION

Once the weigh bridge calculation is completed, the belt feeders under each cold feed bin must be calibrated. This is done by determining the amount of material delivered from a bin for different gate openings and different belt speeds. It is important, however, that the feeder conveyor operate within a range of 20 to 80 percent of its maximum speed. Ideally, the gate opening on each individual cold feed bin should be set so that the belt feeder will operate near the midpoint of its speed range under normal production circumstances.

To begin the calibration procedure, the maximum production rate to be run by the drum mixer should be determined. Next the relative proportion of each particular aggregate size for each cold feed bin is calculated. The percentage of each aggregate is then converted to a ton per hour rate. A gate setting is selected which from experience should provide enough material from a bin to meet the required maximum feed rate. For a given gate opening, three different belt speeds are used. These usually are 20, 50, and 80 percent of the maximum feeder belt rate, but other speed percentages can be used as long as they cover a range of values.

The moisture content setting for the aggregates is set at 0 percent and the feeder under one bin started. The aggregates from this bin are discharged onto the belt feeder running at the preselected calibration speed. The aggregates are delivered to the gathering conveyor and then to the incline conveyor. They are run over the weigh bridge on the charging conveyor and the amount of material delivered for each feeder conveyor belt speed determined from the plant computer system. The weight of material at a given belt speed is then plotted on a graph against the belt speed to determine the amount of aggregate to be drawn for a particular bin with a given gate opening at any feed belt speed (Fig 6.5).

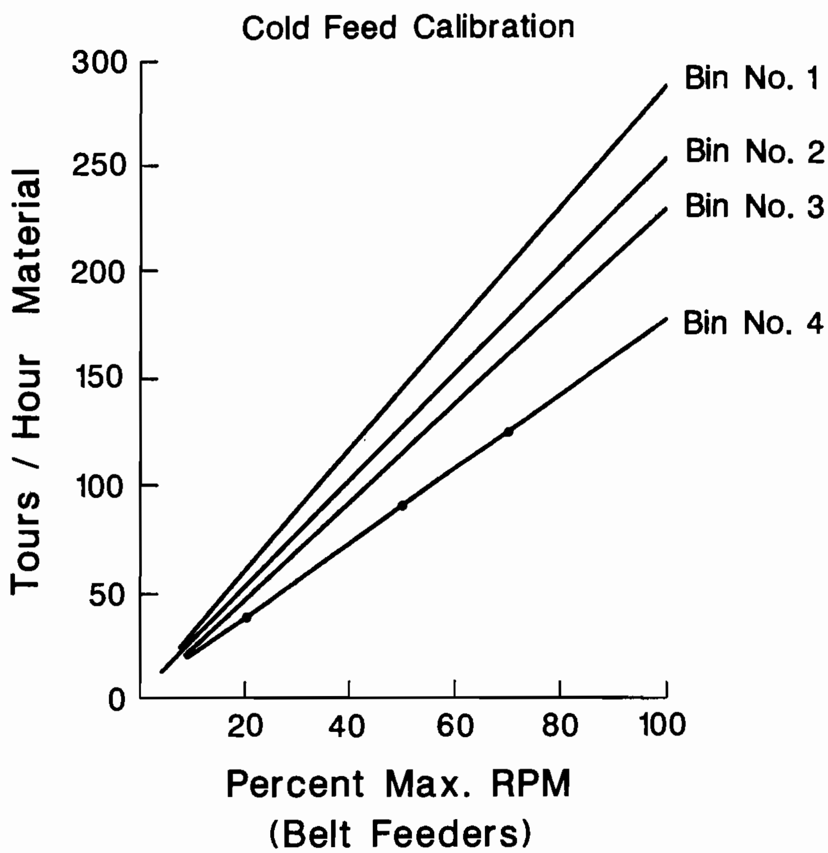

Figure 6.5. Example cold feed calibration plot (Ref 12)

From the graph, a belt speed setting is chosen that allows the proper amount of aggregate for that particular bin to be discharged to meet the required ton per hour rate. If the speed selected for the bin is too slow to be practical, a smaller gate opening should be selected and the calibration procedure repeated for the new gate setting at three different feeder belt speeds.

Because most drum mix plants are usually operated near their maximum capacity, at a given aggregate moisture content, it is good operating procedure to select a belt feeder speed at the upper end of the speed range, between 50 and 80 percent of the maximum belt speed. This will allow the plant operator to reduce the plant production rate without shutting the plant down because the belt feeder cannot run slowly enough to meet the lower production rate. Thus, given a choice of a belt speed of 40 percent at one gate setting and 70 percent at a smaller gate setting, the logical solution would be to choose the gate opening which allows the higher belt speed, not to exceed 80 percent of maximum.

Each cold feed bin is calibrated in the same manner. This includes calibration of the cold feed bin or bins holding the reclaimed material to be used in a recycled asphalt concrete mixture. For cold feed bins equipped with their own weigh idler and weigh bridge system, the cold feed bin would be calibrated using the same method as for the weigh bridge located on the incline conveyor rather than with the variable belt speed method outlined above.

ASPHALT CEMENT SUPPLY CALIBRATION*

In order to calibrate the asphalt cement supply system, an asphalt distributor truck is needed. It must be assured that the tank on the distributor is clean so that the asphalt cement can be pumped back into the asphalt cement storage tank. In addition, if the distributor has been used for either cutback asphalt or asphalt emulsion, those materials must be removed from the distributor tank to prevent the contamination of the asphalt

* The standard method used by Texas State Department of Highways and Public Transportation is Test Method Tex-921-K (Ref 22).

cement and foaming of the emulsified asphalt. The distributor tank should have enough capacity to hold at least 1,000 gallons of asphalt cement.

The tare weight of the distributor should be determined by running the truck over a certified scale. The asphalt pump and valve system should be able to be set so that the asphalt cement can be passed through the meter and then through a sample valve downstream of the meter. A line is then used to transport the asphalt cement to the distributor tank.

The asphalt cement should be initially circulated through the pump and meter and then back to the storage tank to bring the system up to the proper operating temperature. When the temperature has stabilized, the pump should be shut down and the valves set to allow the asphalt cement to enter the line to the distributor. Enough asphalt cement should be pumped into the line to just fill the line, without emptying any asphalt cement into the tank. The meter on the asphalt cement line should then be set to a zero reading. The pump is then activated once again and at least 1,000 gallons of asphalt cement is delivered to the distributor.

The asphalt pump is shut off and the meter reading determined. The pump is then reversed to pull back all the asphalt cement left in the line. The distributor is weighed and the net weight of the asphalt cement calculated. This value is compared to the weight reading on the computer console. The two readings should be within 0.5 percent of each other. If the asphalt meter reading and the net weight of the asphalt cement in the distributor are within 1.0 percent of each other, the meter value is probably accurate. Indeed, in most cases the asphalt cement reading is more exact than the truck scale supplied value.

AGGREGATE-ASPHALT CEMENT RATIO

The last function in the calibration procedure is to assure that the asphalt cement and the aggregate feeds are in proper proportion with each other (Fig 6.2). To accomplish this, the asphalt cement pump and meter system is put in the circulate mode, with the asphalt cement passing through the meter. Next the test weights are placed on the weigh idler on the incline conveyor, and the conveyor system warmed up for at least 30 minutes.

In this process, no actual aggregate is used, only the test weights to simulate the presence of material on the conveyor belt.

The asphalt content control is set on the console to any selected percentage. The amount of asphalt cement needed for the preset aggregate feed rate is calculated and compared to the actual rate of asphalt cement feed shown on the meter. If the values agree, the whole calibration procedure is completed. If the values are different, an adjustment should be made in the asphalt supply system, according to each particular plant manufacturer's requirements. Then the aggregate-asphalt cement ratio calibration procedure is repeated.

CHAPTER 7. DRUM MIXER

AGGREGATE ENTRY

The new aggregates to be incorporated into the asphalt mixture are discharged from their respective cold feed bins to their individual feeder conveyors, to the gathering conveyor under all the cold feed bins, and then (usually through a scalping screen) to the incline conveyor for delivery to the drum mixer. Upon reaching the end of the charging conveyor, the aggregates are typically introduced into the drum in one of two ways, through an inclined chute or on a slinger conveyor.

Inclined Chute

If the aggregates are carried on the incline conveyor to a point above the plant burner, the aggregates are fed into the drum by sliding down a sloped chute into the drum (Fig 7.1). The chute is angled to slide the aggregates toward the far end of the drum, away from the burner flame. The aggregate feed is by gravity, with the incoming material falling to the bottom of the drum.

Slinger Conveyor

On some drum mix plants, the new aggregates are deposited from the incline conveyor to an additional conveyor located beneath the plant burner. This belt, or slinger conveyor, transports the aggregates into the drum (Fig 7.2). On many plants, the speed of this conveyor can be varied, and thus the point at which the aggregates fall into the bottom of the drum can be altered within limits. The faster the speed of the slinger belt, the farther down the drum the aggregates are deposited. The slinger conveyor belt speed on one particular make of plant is usually increased when reclaimed aggregates are being jointly fed into the burner end of the drum with the new aggregates.

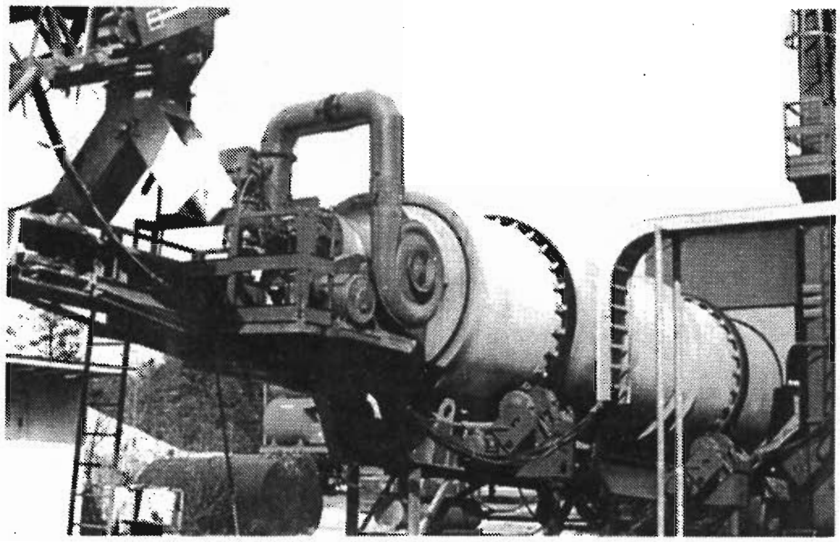

Figure 7.1. Introduction of aggregate into a drum mixer with an inclined chute (Ref 15)

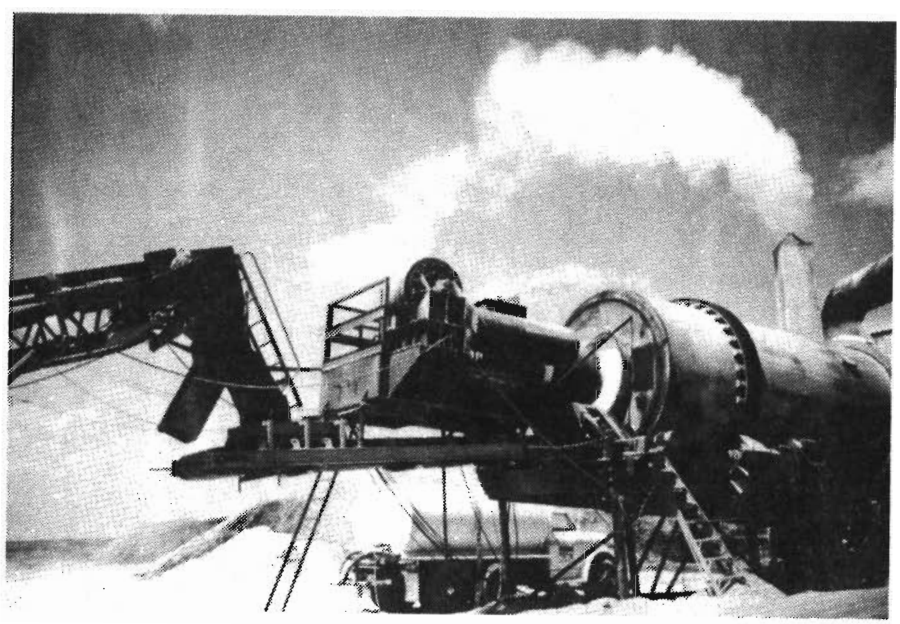

Figure 7.2. Introduction of aggregate into a drum mixer with a slinger belt

FLIGHT DESIGN

The aggregates fed into the burner end of the drum mix plant move down the length of the drum by gravity as the drum rotates. The time it takes for an individual aggregate particle to pass through the drum depends on many factors. Among these factors are: the length of the drum, the slope of the drum, the number and type of flights inside the drum, the speed of rotation of the drum, the size of the aggregate particles, and the production rate of the plant. In general, it takes about 3 to 4 minutes for the incoming aggregates to reach the discharge end of the drum mixer.

Flight design is an art, not a science. Each drum plant manufacturer uses a different pattern, shape, number, and location for the flights inside the drum. Each has reasons why a particular series of flights is needed to better heat and dry the aggregates in the drum. The flight design used yesterday by one given manufacturer is probably not the same as the flight design incorporated into a drum made today, and probably will not be similar to the design of the flights used on a drum mix plant produced tomorrow. Interestingly enough, with all the hundreds of variations in the flights used in the various drum mix plants, the aggregates do get heated and dried by all of the different flight configurations.

On a drum mix plant, the burner is located at the upper end of the drum, at the same location as the incoming new aggregates. Compared to the burner on an aggregate dryer where the flame is long and thin, the burner flame used on a drum mix plant is short and bushy and does not extend very far down the drum (Figs 7.3 and 7.4). The exhaust gases from the burner move in the same direction as the aggregates, a parallel flow process (Fig 3.1). This is in contrast with the operation of a batch plant dryer, which heats the aggregates using a counterflow principle in which the burner exhaust gases move in the opposite direction of the aggregate flow (Fig 3.2). This is because on a conventional dryer, the aggregates are introduced into the dryer at its upper end while the burner is located at the lower or discharge end of the dryer. In addition, the shape of the burner flame on the batch plant dryer is usually long and narrow and extends well up into the dryer shell.

Thus, the first flights (kicker flights) normally encountered inside a drum mixer are used to move the incoming aggregates away from the burner

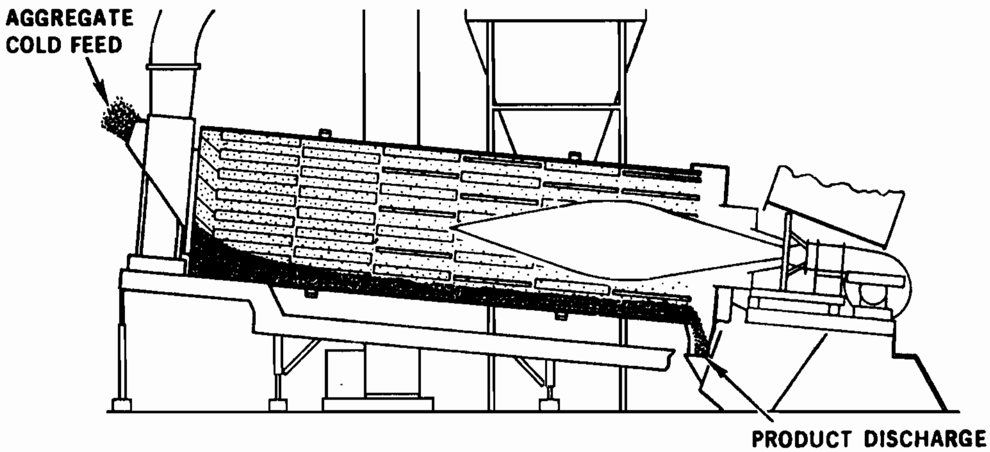

Figure 7.3. Aggregate drier showing long flame (Ref 23)

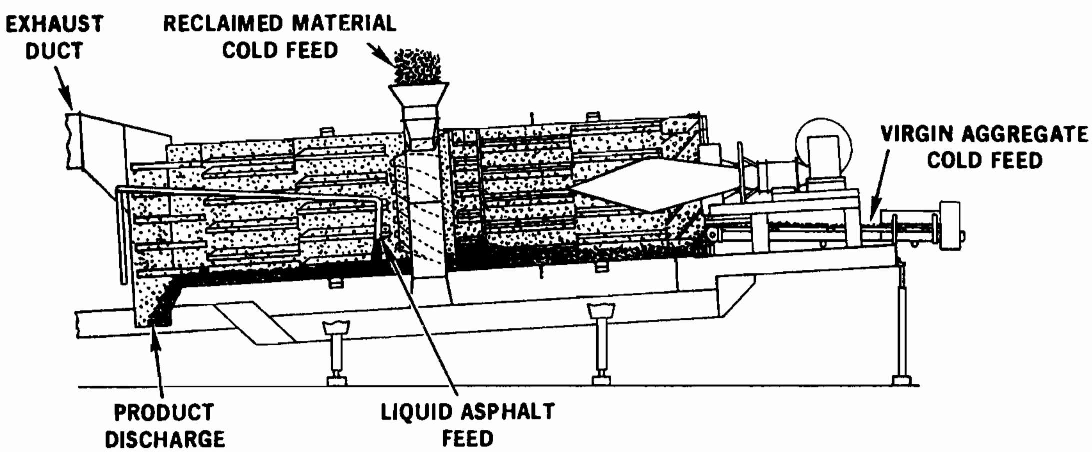

Figure 7.4. Drum mix recycle plant showing short, bushy flame (Ref 23)

flame and down the drum (Fig 7.5). This procedure allows the burner flame to expand in the front part of the drum and radiate its heat as quickly and completely as possible. These initial flights do not do any tumbling of the aggregates.

The next type of flights (cup, notched, and tapered flights in Fig 7.5) usually found inside most drums start to lift the aggregates from the bottom of the drum and begin the cascading action. Only a portion of the total aggregate volume is caught and tumbled, but by the time the quarter point in the drum length is reached, most of the aggregate particles are being lifted from the bottom of the drum and carried up and over the top of the drum. A number of different flight shapes are used by the various drum manufacturers, but the term "cup" flight provides a description of the typical configuration employed. The lifting or cup flights are used to build a veil of aggregates in front of the burner flame. The flights are designed so that some aggregates are dropped from the lifting flights across the whole drum circumference. This curtain of cascading aggregates is essentially used as a barrier for the burner exhaust gases so that the heat transfer process can take place.

The key to the heating and drying process with the aggregates is the density of the veil of material presented across the drum. The more complete the veil of aggregates, the more efficient the heat transfer process. It is important to assure that whatever flight design is used in the drum at this point, the cascading aggregates will be carried by the lifting flights in such a manner that some portions of the aggregates are tumbled through the exhaust gases at each point across the whole circumference of the drum.

Near the midpoint of the drum length some manufacturers have installed a number of different kinds of devices to retard the flow of the aggregates down the drum. In some cases a retention ring or "donut" is placed around the drum circumference. This ring or dam essentially reduces the diameter of the drum at this location. The aggregates moving downstream in the drum build up in front of the ring. This creates a heavier or denser veil of material as the aggregates are tumbled. Instead of a retention ring, some manufacturers install "kicker" flights which intercept the aggregates and turn them back upstream. These special flights are angled such that they

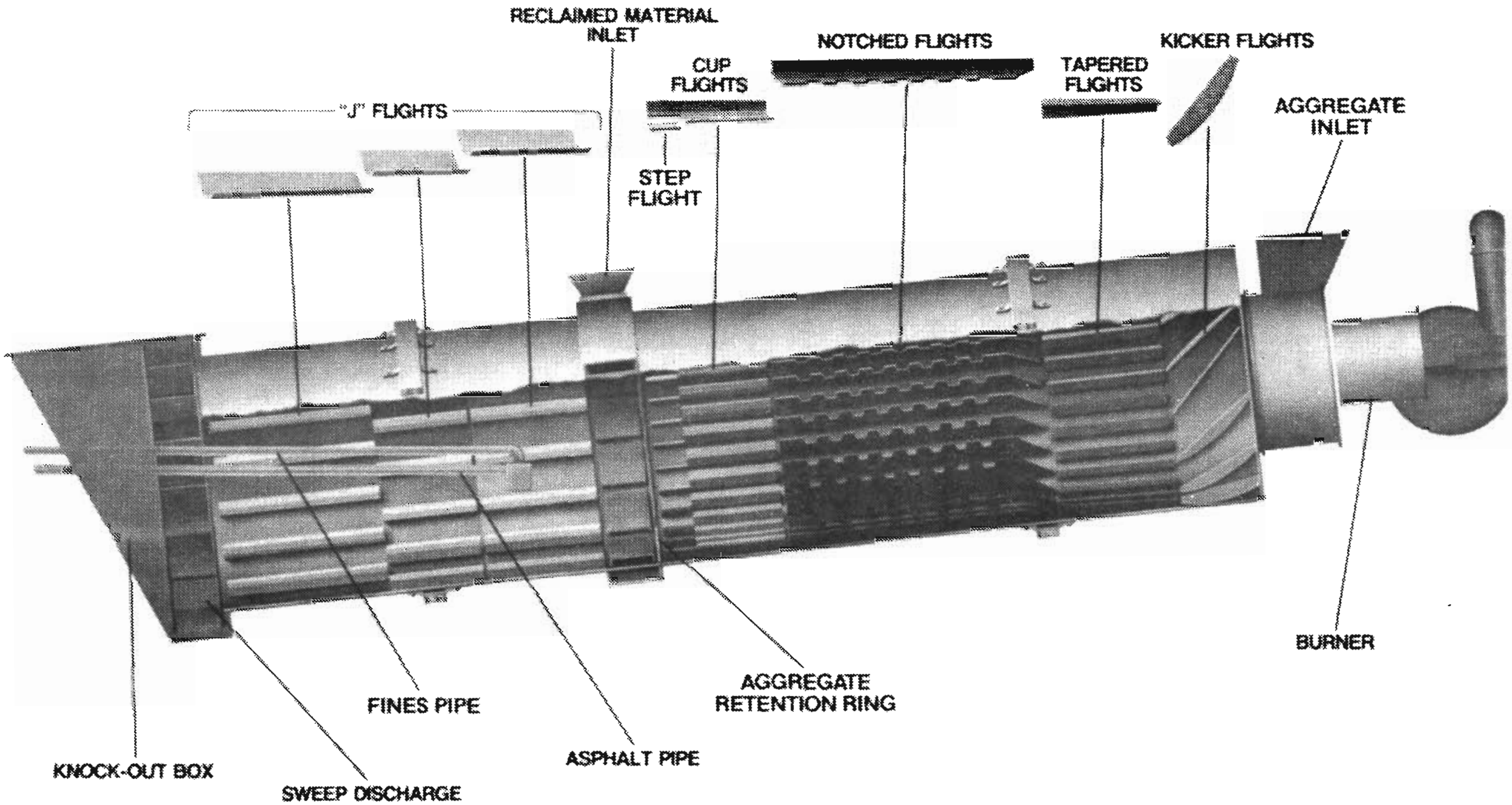

Figure 7.5. Flight configuration and locations inside a Barber-Greene drum mixer (Ref 10)

retard rather than enhance the flow of aggregates toward the discharge end of the drum. The reason for any of these types of devices is to assure a complete and heavy veil of aggregates near the drum midpoint to accomplish the transfer of heat from the burner gases to the aggregates.

On most drums, at some location just beyond the middle of the drum, the "mixing" type flights (J flights in Fig 7.5) are installed. These flights are used to tumble the aggregates and asphalt cement together. The mixing flights are basically used to allow the aggregate particles to be properly exposed to the foaming mass of asphalt cement. These flights also continue to allow the asphalt cement coated aggregate particles to cascade across the exhaust gas air stream to complete the heat transfer process and raise the mix temperature to the desired level for discharge.

A set of discharge flights is located at the end of the drum. The style and shape of these flights is chosen to change the direction of the mix moving down the drum. The exact shape and angle of the discharge flights depends on whether the asphalt mixture exits the drum from the side or the end. In any case, the discharge flights occupy only a small section of the drum length immediately in front of the discharge chute.

The above description of the types of flights inside a typical drum mixer is very general in nature. This is because there really is no such thing as a "standard" or uniform design. Thus it is impossible to accurately describe the exact tumbling process for the aggregates and the asphalt concrete mixture which occurs inside all drum mix plants. Figures 7.6 through 7.10 illustrate some additional typical flight designs and the flow of material through the drum.

BURNER SYSTEM

The burner on a drum mix plant also defies an easy or standardized discussion. In general, the purpose of the plant burner is to provide the necessary heat input to allow the aggregates to be heated and dried. Burners are sized in terms of output capacity by a Uniform Burner Rating Method, developed by the Bituminous and Aggregate Equipment Bureau of the Construction Industry Manufacturers Association (CIMA).

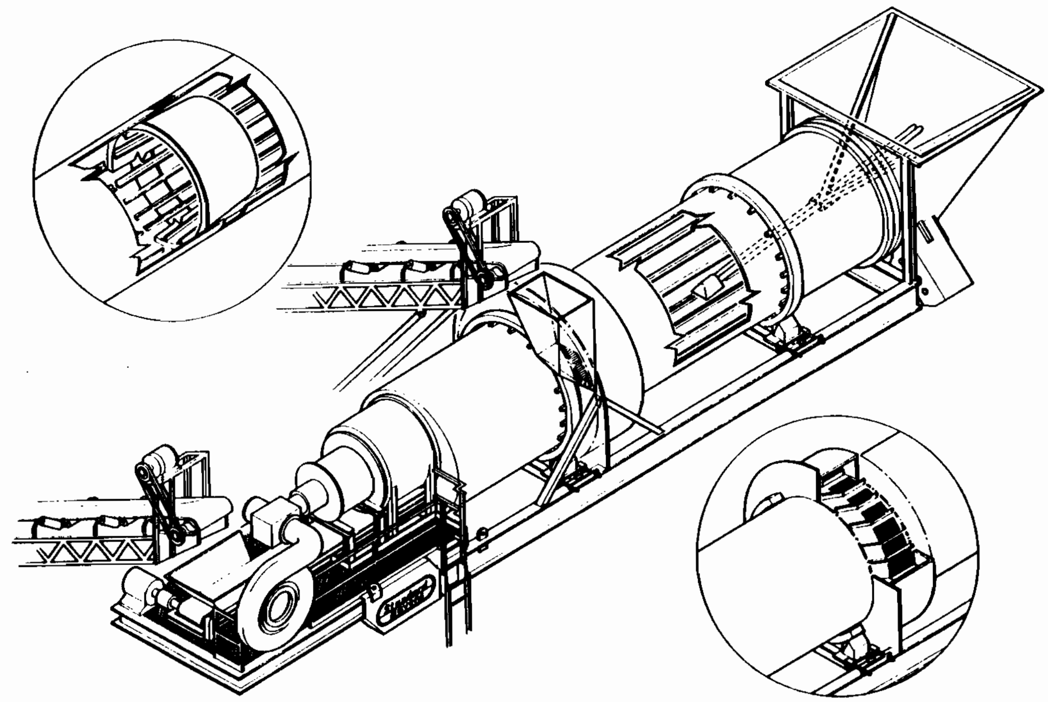

Figure 7.6. Cutaway views showing Standard Havens flights (Ref 24)

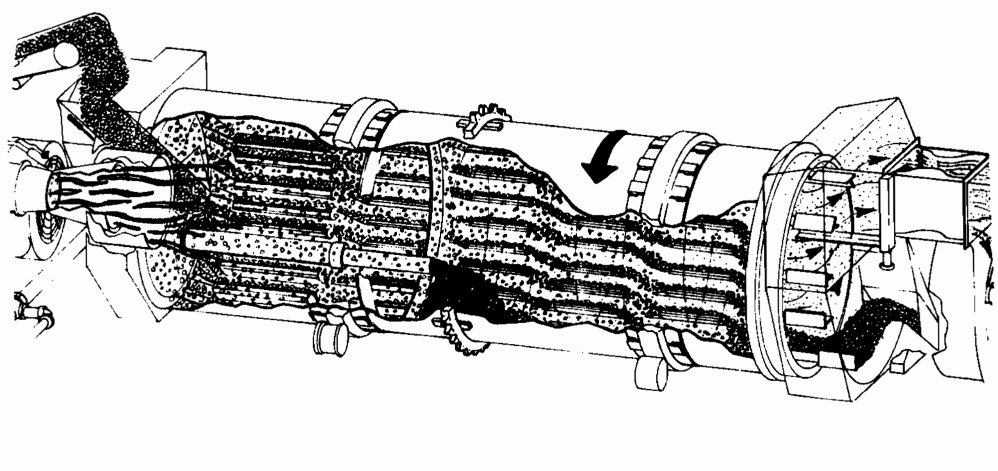

Figure 7.7. Flights and flow of material through Cedarapids drum (Ref 25)

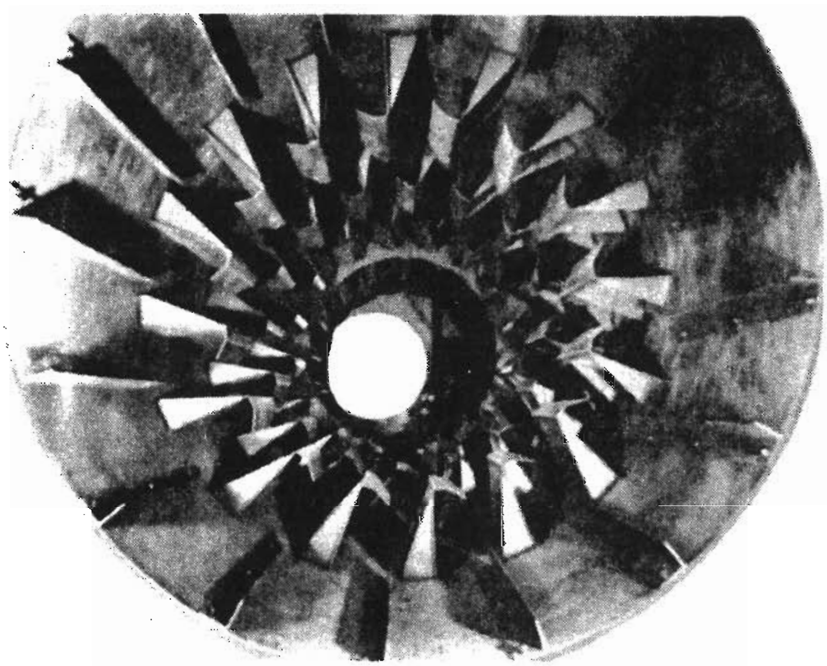

Figure 7.8. Cedarapids drum interior viewed from discharge end (Ref 25)

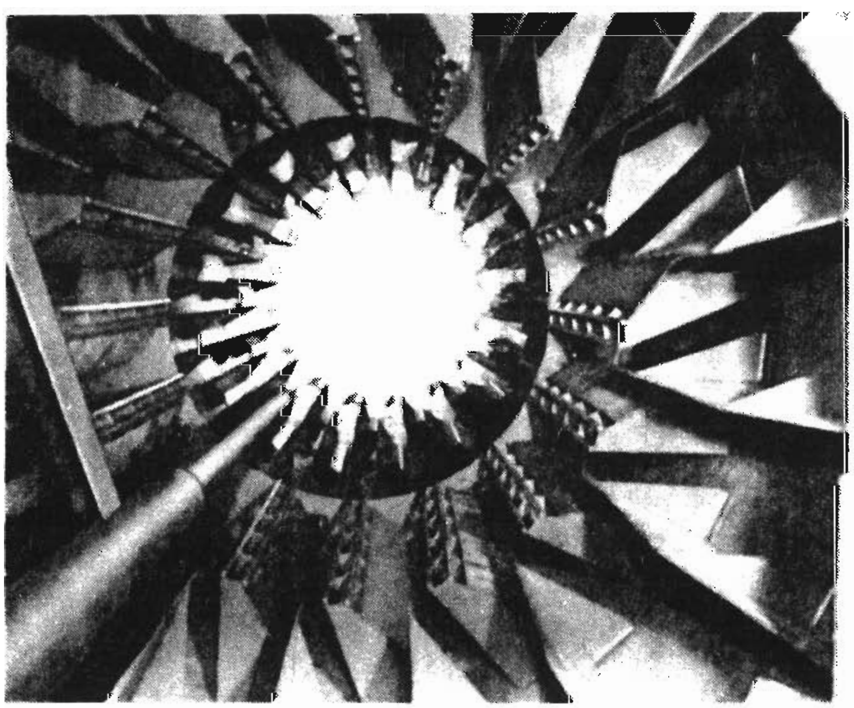

Figure 7.9. Cedarapids drum interior viewed from intake end (Ref 25)

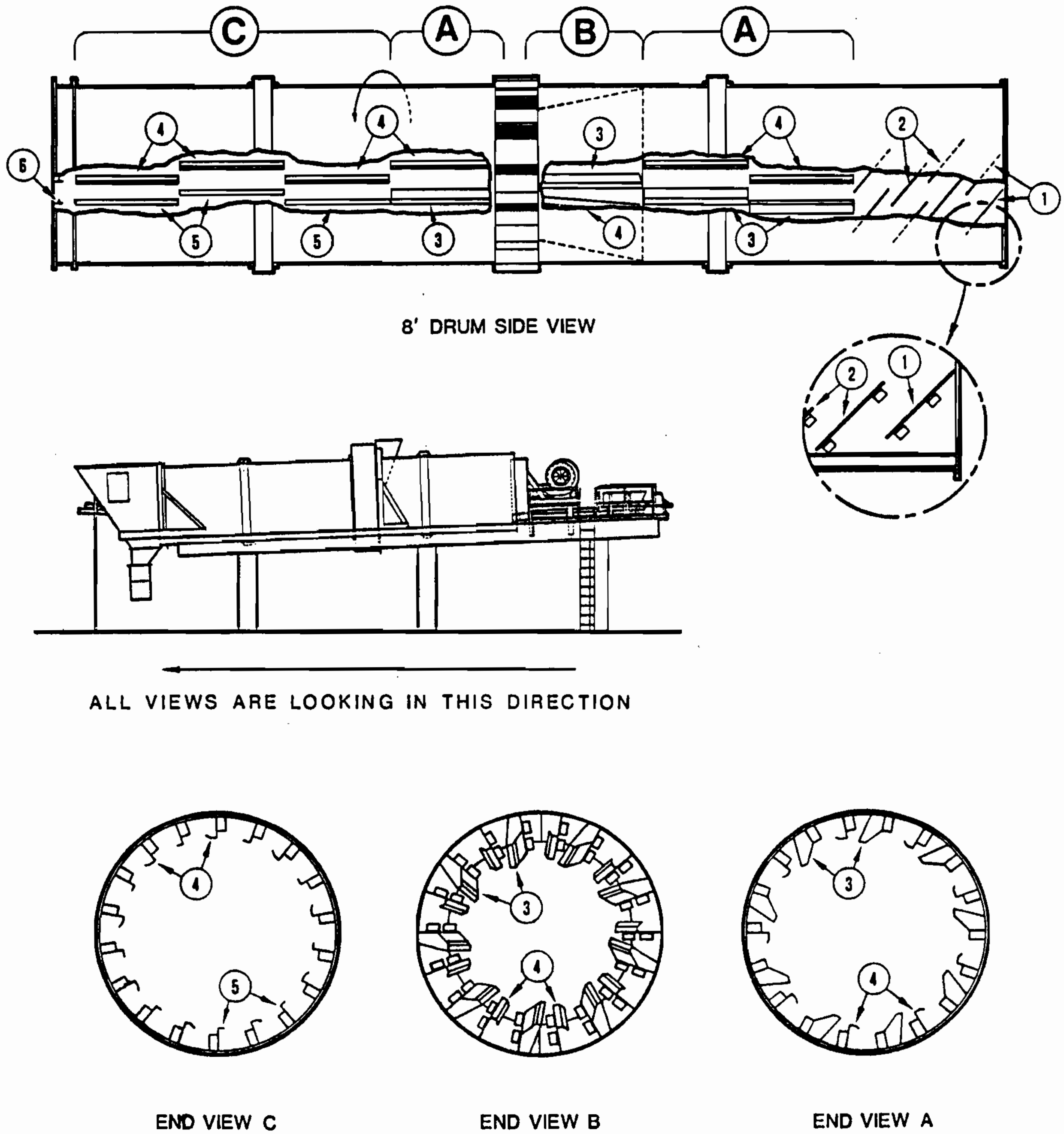

Figure 7.10. Standard Havens flight design (Ref 24)

The burner rating method employs eight different criteria to calculate an output value or "maximum" rating for a burner. These eight parameters are: (a) 25% excess air, (b) 5% leakage air, (c) 10% casing (shell) loss, (d) 350°F fan gas temperature, (e) 5% moisture removed from the aggregates, (f) 300°F asphalt concrete mix discharge temperature, (g) the use of #2 fuel oil for burning, and (h) an aggregate specific heat value of 0.2. The maximum amount of heat produced by the burner, in terms of Btu/hour is also dependent on the actual airflow through the drum, measured in cubic feet of air per minute.

Thus the ability of the burner to provide enough heat to properly heat and dry the aggregates is a function of the following variables: the volume of air moving through the drum, the mix discharge temperature, the stack temperature, the amount of available excess air, draft system leaks, and degree of combustion of the burner fuel. The maximum output for any particular burner can be read from the burner rating plate attached to each burner.

Fuel

A wide variety of fuels can be used to fire a burner on a drum mix plant. Some burners can be employed to burn several different fuels with only minor alterations in the burner settings and equipment. Other burners are only able to fire alternate fuels with more complete changes in the burner setup.

Three major types of fuel can be utilized in the drum mix plant burner. The first is gaseous fuels. This category includes both natural gas and vaporized LPG (liquid petroleum gas). The second type of fuel is the liquid materials. Some of the liquid fuels are propane, butane, LPG, fuel oil (#2), heavy fuel oil (#4-#6), waste oil, and slurried coal. The third category is solid fuel, which includes pulverized coal, pelletized biomass, and sewage sludge. Each of the above fuel types has its own particular heating benefits and disadvantages and economic considerations, all of which should be considered when a fuel choice is made.

Any of the above fuels may be used to fire the burner on the drum mix plant. It is important that the fuel selected be at the proper consistency for complete atomization at the time of combustion. No. 2 fuel oil, for example, will typically burn at ambient temperatures, without preheating. This is because its viscosity at most temperatures is less than 100 ssu (saybolt seconds universal). Heavy fuel oils, however, have viscosities which are above 100 ssu at normal ambient temperatures. Thus these fuels must be preheated before burning to lower the viscosity of the material and obtain complete combustion. Fuel oils which are too viscous will not burn properly, creating burner and mix problems.

The use of waste oils in plant burners has become more prevalent as the cost of conventional fuels has increased. Some waste oils, those which have been filtered and dewatered, burn well. Other waste fuels, contaminated with heavy metals and containing water, burn erratically and incompletely. The sound of the burner provides vital information as to the efficiency of the combustion process. A uniform, constant roar is a good sound. A coughing, sputtering, spitting burner is a sure sign of incomplete combustion.

Unburnt burner fuel can cause multiple difficulties. First, the fuel can coat the aggregates tumbling in front of the flame. This is evidenced by brown stains on the aggregate particles and a lack of asphalt cement coating on those aggregates. Second, the incomplete combustion reduces the amount of heat available to heat and dry the aggregates. In addition, the unburnt fuel can increase the costs of maintenance on the burner, clogging the nozzle, etc. Finally, the improper combustion process can allow unburnt fuel to enter the baghouse (if the plant is so equipped), coating and blinding the bags, thereby reducing the efficiency of the fabric filter to remove particulate matter from the stack gas discharge. In addition, such a coating on the fabric bags significantly increases the opportunity for a baghouse fire.

Burners

The burners used on most drum mix plants are hybrid burners. If the air used to burn the fuel is provided by a pressure blower, the burner is a forced draft unit (Fig 7.11). If air is pulled through the burner by an exhaust fan, the equipment is called an induced draft burner (Fig 7.12). On most drum mix plant burners, part of the air is forced through the burner.

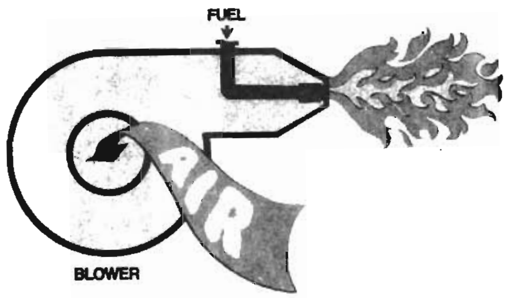

Figure 7.11. Forced air burner (Ref 26)

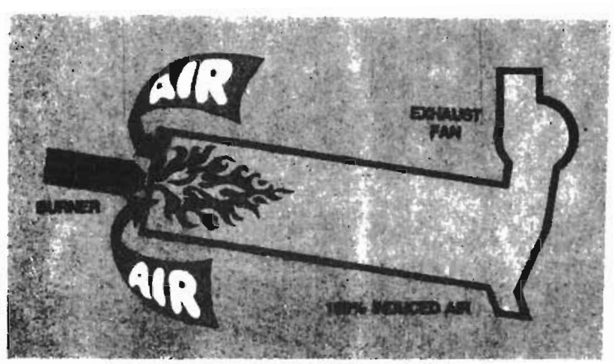

Figure 7.12. Induced Draft Burner (Ref 26)

This is called "primary" air. Part of the air is induced through the burner. This is called "secondary" air (Fig. 7.13).

A specific amount of air is needed to burn a specific amount of fuel. A lack of either air or fuel will reduce the burning rate. Usually the availability of air is the limiting factor. Typically, about 30 percent of the combustion air is primary air and 70 percent is secondary air. The exhaust fan, besides providing the induced air, must also handle the water vapor (steam) created in the drying process (Fig 7.14). Thus the exhaust fan volume (size) is usually the controlling device in the heating and drying procedure.

The burner includes an automatic control which alters the fuel input to maintain a constant mix discharge temperature. Thus the balance of fuel usage and air flow is actually only in balance when the burner is operating at capacity. When the burner is running at less than full capacity, more air than needed is pulled through the system and heated. On the other hand, when the moisture content of the aggregates is high, less fuel can be consumed since the exhaust volume is constant and steam and water vapor displace air in the exhaust gas stream.

The volume of air pulled through the drum is changed by the amount of air leakage. Any air entering the drum except at the burner reduces the efficiency of the combustion process. This leaked air, however, should not be confused with the "excess air" needed by the burner. The latter term refers to the amount of air in excess of that volume needed for complete combustion of the fuel. For most burners, up to 85 percent excess air might be needed to assure total burning of the fuel. As the amount of leaked air entering the drum increases, the efficiency of the heat transfer process is reduced because extra air is heated, reducing the amount of fuel which can be burned (keeping the total exhaust gas volume--product of combustion, water vapor or steam, and air--constant).

HEATING, DRYING, HEATING

The temperature of the burner flame exceeds 2,500°F. The temperature of the exhaust gases when they pass through the air pollution control equipment should be in the range of 300 to 350°F. Typical temperature profiles along

Figure 7.13. Combined forced and induced air burner (Ref 26)

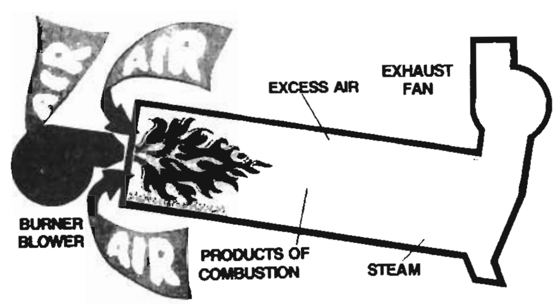

Figure 7.14. Burner products exhausted through the drum mixer (Ref 26)

the length of the drum are shown in Figures 7.15 and 7.16. The difference in the two temperatures represents the amount of heat that is used to dry and heat the aggregates inside the drum. The efficiency of the heating and drying process can be readily judged by the temperature of the exhaust gases going up the stack and the amount of moisture remaining in the asphalt concrete mixture.

Batch plant dryers were typically manufactured using a ratio of 4:1 for drum length versus drum diameter. A dryer that was 5 feet in diameter was usually 20 feet in length. Similarly, an 8 foot diameter dryer was normally made 32 feet long. Early drum mix plants used the same length to diameter ratio even though the heat transfer process was a parallel flow operation instead of a counterflow procedure. In recent years, there has been a trend toward the use of longer drums to better control and complete the heat transfer from the exhaust gases to the aggregates. This trend is also due in part to the use of drum mix plants to produce recycled asphalt concrete mixtures. Some drum mix plants manufactured lately use length to diameter ratios of 5:1 or even 6:1. Thus an 8 foot diameter drum mixer might be 40 to 48 feet in length.

The length of the drum is not particularly important if all the heat possible is removed from the exhaust gases and used to dry and heat the aggregate and mix. Perfect heat transfer would require that the mix discharge temperature and the stack temperature be equal. Excellent heat transfer (using all new aggregates with no reclaimed material) means that the stack temperature is within 20°F of the mix discharge temperature. Thus, if the mixture exits the drum at 280°F, and the exhaust gas temperature is under 300°F, the drum mixer is running very efficiently. If the stack temperature, however, is 360°F while the mix discharge temperature is still 280°F, the veil of aggregate inside the drum is incomplete and the drum is being operated very inefficiently.

Inside the drum, the temperature of the exhaust gases decreases as the gases move from the burner to the air pollution control ductwork. The rate of decrease depends on the amount of aggregate in the drum to intercept and cool those gases. As discussed in more detail in the section on recycling below, it is desirable to lower the temperature of the exhaust gas to about

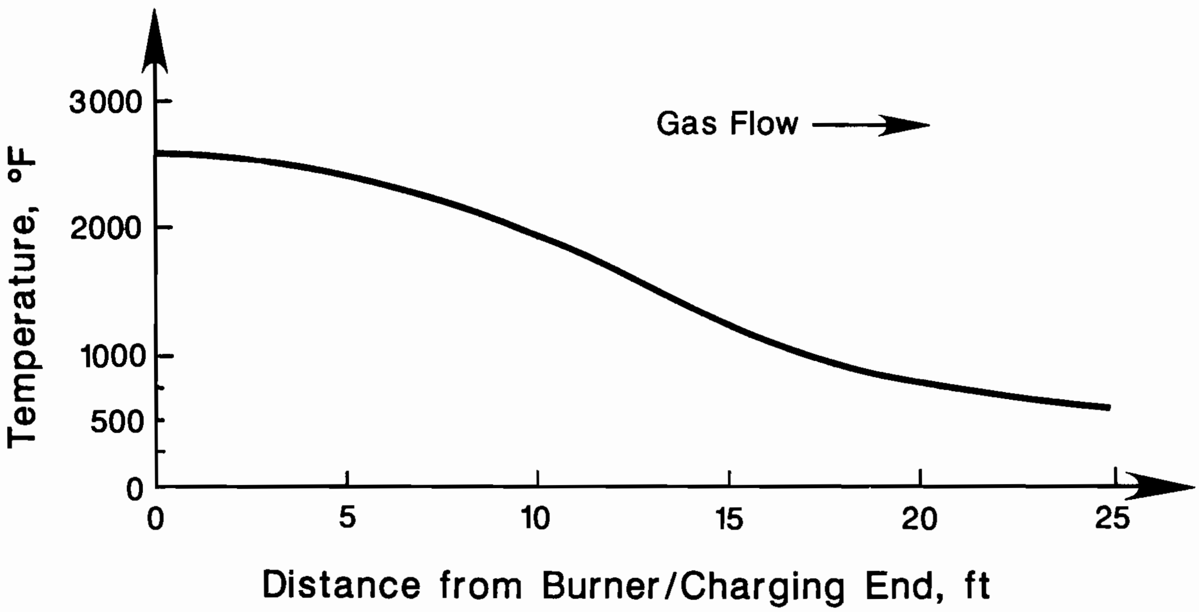

Figure 7.15. Typical temperature profile along the length of the drum (Ref 18)

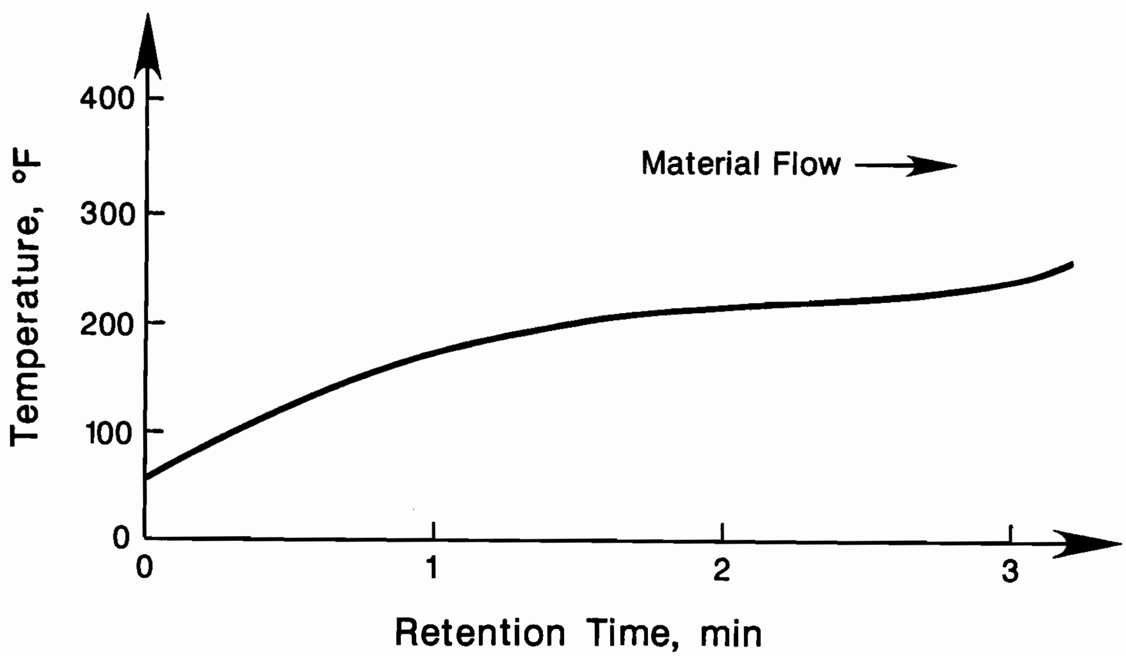

Figure 7.16. Aggregate temperature profile inside the drum (Ref 18)

800°F, or less, at the midpoint of the drum where the reclaimed material is introduced (in most plants). This keeps the old, aged asphalt cement around the reclaimed aggregate from vaporizing and turning into blue smoke coming out the plant stack.

In addition, another internal temperature control point is the location where the asphalt cement is injected into the drum. It is known that certain asphalt cements may contain a small amount of "light ends" or material which is volatile at elevated temperatures. The volume of the volatiles depends both on the source of the crude oil and the refining process used to produce the asphalt cement. If the temperature of the exhaust gases is below about 600°F at the place where the asphalt cement enters the drum, the volatiles or light ends will not be drawn off from the asphalt cement and no hydrocarbon emissions will result.

Thus in terms of heating the aggregate, it is desirable to reduce the temperature of the burner gases to about 800°F at the drum midlength and to less than 600°F at the asphalt cement injection point. Further, the temperature of these gases should be lowered to the same level as the mix discharge temperature when these gases exit the plant stack. This temperature reduction profile can be achieved only by keeping a complete, uniform veil of aggregate tumbling in the drum upstream of the drum midpoint (Fig 7.17).

As discussed previously, to control the density of the aggregate veil inside the drum, kicker flights, dams, donuts, or retention rings are often used to retard the flow of the aggregate down the drum. Another way to achieve the same effect is to lower the slope of the drum (Figs 7.18 through 7.20). The reduction in the angle of the drum itself causes the aggregate passing through the drum to take a longer time to reach the discharge end of the mixer. This increases the dwell time in the drum, providing more time for the aggregate to heat and dry. More importantly, the additional aggregate in the drum provides for a dense veil of material cascading around the circumference and thus better heat transfer.

Lowering the slope of the drum does not cause a change in the plant production rate. Although it takes somewhat longer for the first aggregate particles to leave the drum when the slope is reduced (from 3.5 minutes to

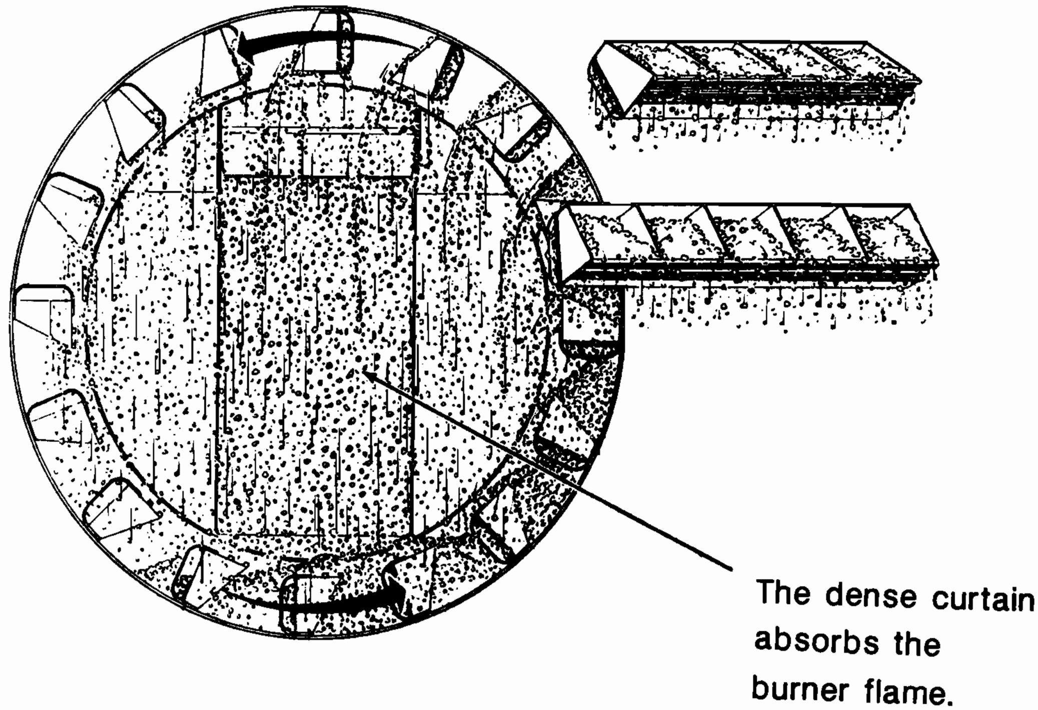

Figure 7.17. Aggregate veil (Ref 27)

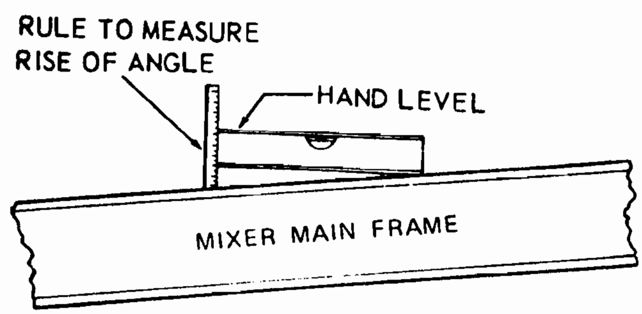

Figure 7.18. Measurement of drum slope (Ref 18)

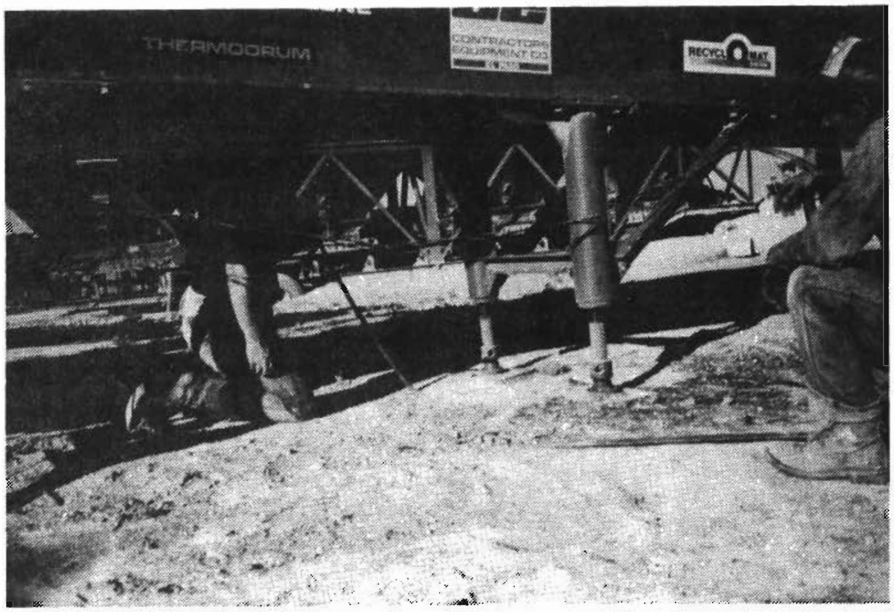

Figure 7.19. Changing slope of the drum

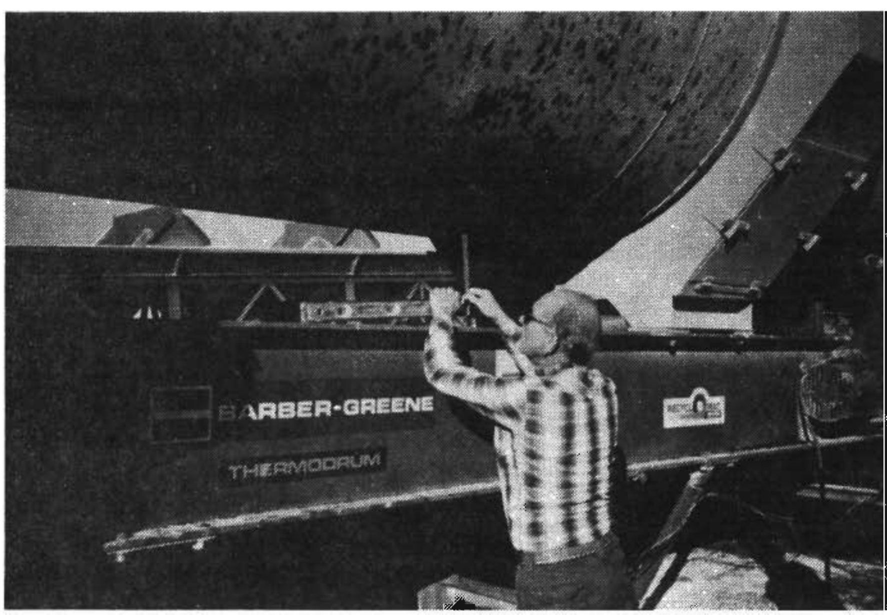

Figure 7.20. Changing slope of the drum

3.7 minutes, as an example), the actual plant mix rate remains constant in terms of tons per hour. Power requirements for the electric motors used to turn the drum are increased a little because of the extra weight of aggregate in the drum. The net result, however, is a better veil of aggregate, more complete heat transfer, and a reduction in the temperature of the exhaust gases at all locations in the drum.

One manufacturer has developed a drum mix plant which is not of constant diameter along its length. The drum is one diameter at both ends and a lesser diameter in the center or mid portion of the drum (Fig 7.21). The change in diameter in essence provides for development of a denser veil of aggregate in the drum. By squeezing the same volume of material that was tumbling in an 8-1/2 foot diameter drum, for example, into an area 7 feet in diameter, the veil of the aggregate is increased markedly. This rise in the aggregate density in turn significantly improves the efficiency of the heat transfer process. The velocity of the exhaust gases, however, is also increased.

While the exhaust gas temperature is being reduced as these gases move down the drum, the temperature of the aggregates is increasing as they move in a parallel direction (Figs 7.15 and 7.16). The heat transfer process takes place in three ways: (a) by convection--from the heat in the exhaust gas, (b) by conduction--from the temperature difference between one heated aggregate particle and another aggregate particle at a lower temperature, and (c) by radiation--from contact with the drum mixer flights and drum shell which have been heated by the burner gases.

The aggregates enter the drum at ambient temperature, usually between 40° and 110°F. The heating of this material begins as soon as the aggregates begin to be tumbled inside the drum by the flights. As the aggregates move along the drum length by gravity, they are heated. At some point in the drum, usually upstream of the drum midlength point, the temperature of the aggregates remains relatively constant at 180° to 200°F (Fig 7.16). Moisture in the aggregate particles starts to be driven off as the boiling point of water is reached. Because of the inert atmosphere and reduced oxygen content in the drum, the moisture is driven from the aggregate particles at a lower temperature than 212°F, the boiling temperature of water at sea level.

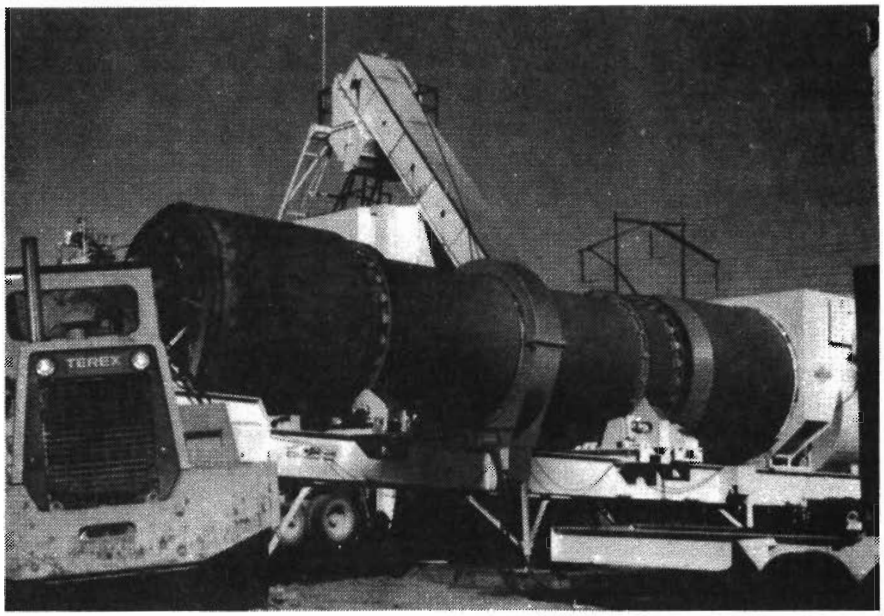

Figure 7.21. Variable diameter drum

The amount of time the aggregates temperature remains constant depends in part on the amount of moisture in the aggregate. The higher the amount of moisture in the incoming aggregate, the longer the time at a relatively constant aggregate temperature. The porosity of the aggregate also is a factor, with the more porous material taking longer to be relieved of its moisture. Finally, because of their lesser bulk and greater surface area, the fine aggregates (sand) in the drum mixer are typically heated more quickly than the coarse aggregates.

Once most of the moisture has been removed from the aggregates, their temperature begins to rise again. As the asphalt cement is added to the aggregate, coating occurs. The "mixing" flights continue to tumble the mix, continually exposing the material to the burner gases. The mix eventually reaches the required discharge temperature as it reaches the end of the drum. Thus the aggregate, as it proceeds down the drum, undergoes a heating, then a drying, and then another heating cycle.

The moisture content of the aggregate decreases gradually in the front portion of the drum. As the aggregate reaches the temperature needed to boil water under reduced pressure, the moisture content in the material is reduced rapidly. If the dwell time in the central section of the drum is long enough, the moisture content of the mix can be reduced to essentially zero. The liquid water in the aggregate is turned into vapor or steam and moves out of the drum together with the exhaust gas.

ASPHALT CEMENT INJECTION

On most drum mix plants, the asphalt cement is introduced in the drum through a pipe coming in from the rear of the drum (Fig 7.5). The pipe is connected directly to the asphalt cement pump and meter system. The size of the pipe used depends on the capacity of the plant, with 2 to 4 inch diameter line being typically used. In most cases the asphalt cement is merely dumped into the bottom of the drum. It is not normally sprayed or delivered through any type of nozzle.

On a few drum mix plants, depending on the manufacturer, the asphalt cement supply line enters the front of the drum, at the burner end. Again a straight discharge system is employed, with the asphalt cement emptied onto the bottom of the drum. The actual location of discharge varies widely, but for front end entry pipes, tends to be toward the midpoint of the drum length.

One advantage of early asphalt cement introduction is quick capture of the dust particles in the aggregate with the binder material. This action reduces the amount of particulate matter carryout by encapsulating the fines in the asphalt cement. Three disadvantages are present: (a) the asphalt cement can be hardened more by exposure to the higher temperature exhaust gases, (b) the production of light ends from certain asphalt cements can be increased because of the higher temperatures to which the binder is exposed, and (c) an increase in the moisture content in the mix can occur because the asphalt cement coats the aggregate particles before all the water in the material can be removed.

When the asphalt cement supply line enters from the rear of the drum, the discharge location can also be varied significantly. On many plants, the pipe extends upstream to a point about 40 percent from the rear end of the drum (60 percent of the length downstream from the burner). At this location, the moisture remaining in the aggregate causes some foaming of the asphalt cement. The aggregates pass through the expanded volume of the binder and the coating takes place. In a drum mix plant, coating rather than mixing may be the more appropriate term for the blending of the asphalt cement with the aggregates.

If the moisture content in the aggregates is still high at the place where the asphalt cement is injected, the coating of the aggregate particles may be delayed until more moisture is removed during the drying process. The asphalt cement foams due to the water and steam available, but the actual coating process may take place more toward the discharge end of the drum. If the moisture content of the incoming aggregates is very low, incomplete coating of the aggregates may occur. If water and steam available inside the drum are insufficient, foaming of the asphalt cement may be minimal. In this case, it may be necessary to add some water to the incoming aggregates on the incline conveyor to improve the coating of the asphalt cement on the aggregates in the mix.

If the asphalt cement being used contains a significant proportion of highly volatile material (more than 0.5 percent by weight), it may be advantageous to pull the asphalt cement supply line farther back toward the rear of the drum. This action reduces the exposure of the asphalt cement to the higher temperature exhaust gases. Thus the generation or release of the hydrocarbon volatiles is decreased. If the veil of aggregate farther up the drum is adequate, however, it should not be necessary to pull the asphalt cement line back. Further, the movement of the supply line can decrease the uniformity of the coating of the binder on the aggregates.

One drum mix plant manufacturer (Astec) has removed the asphalt cement injection line from the drum completely. Thus the plant is no longer truly a drum mixer, but a modern version of the old continuous mix plant. The aggregates are heated and dried in the drum, but exit uncoated. The aggregates are discharged into a single shaft inclined screw conveyor where the asphalt cement is sprayed on the aggregates (Figs 7.22 and 7.23). The mixing of the materials occurs as the aggregates and asphalt cement are pushed up the screw conveyor.

FINES FEED SYSTEM

Two types of aggregate fines can be fed into a drum mix plant, either individually or occasionally in combination with one another. The first kind is mineral filler and the second is baghouse fines. The equipment needed to handle each type of material is essentially the same. The primary differences between the various systems concern the degree of sophistication in the controls used to meter the materials.

If a mineral filler material, such as hydrated lime, portland cement, or limestone dust, is needed for the asphalt concrete job mix formula, the filler is usually delivered to the plant site by tank truck. The material is conveyed pneumatically from the haul truck to a storage silo. That silo is typically vertical, but can also be set in an inclined position. The mineral filler flows out of the silo by gravity.

A vane feeder system is located at the bottom of the silo (Fig 7.24). This feeder rotates in response to an input signal from the drum mix plant computer controls. The more filler needed in the mix, the more rapidly the

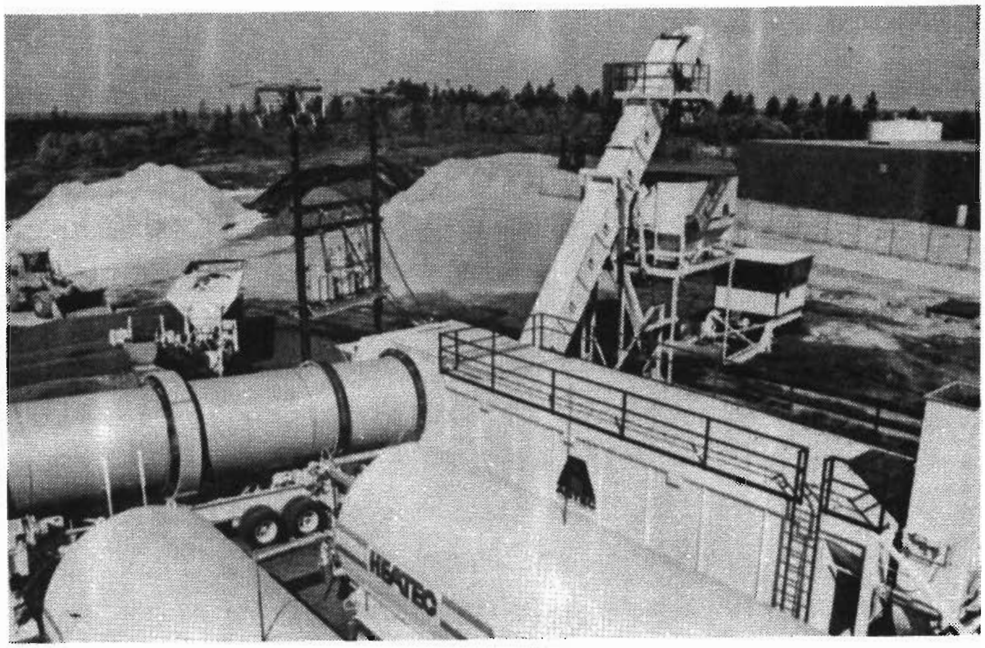

Figure 7.22. Astec "coater" plant (Ref 17)

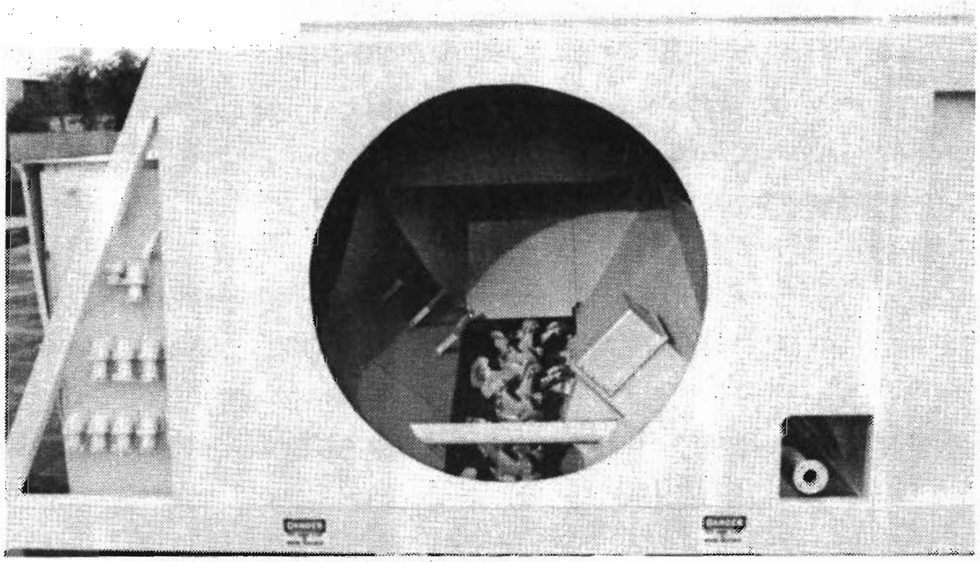

Figure 7.23. Coater auger in Astec plant (Ref 17)

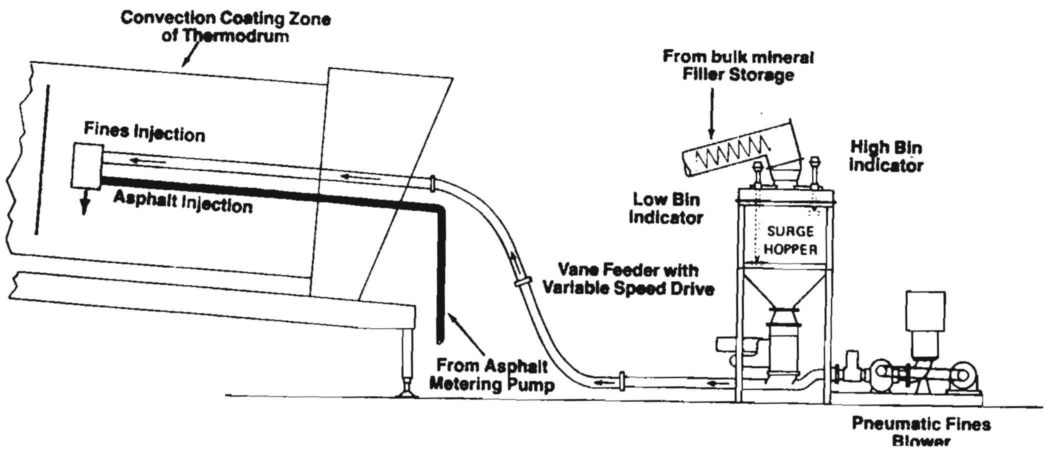

Figure 7.24. Pneumatic mineral filler system--for adding filler from bulk storage to thermodrum not equipped with fabric filter collector (Ref 18)

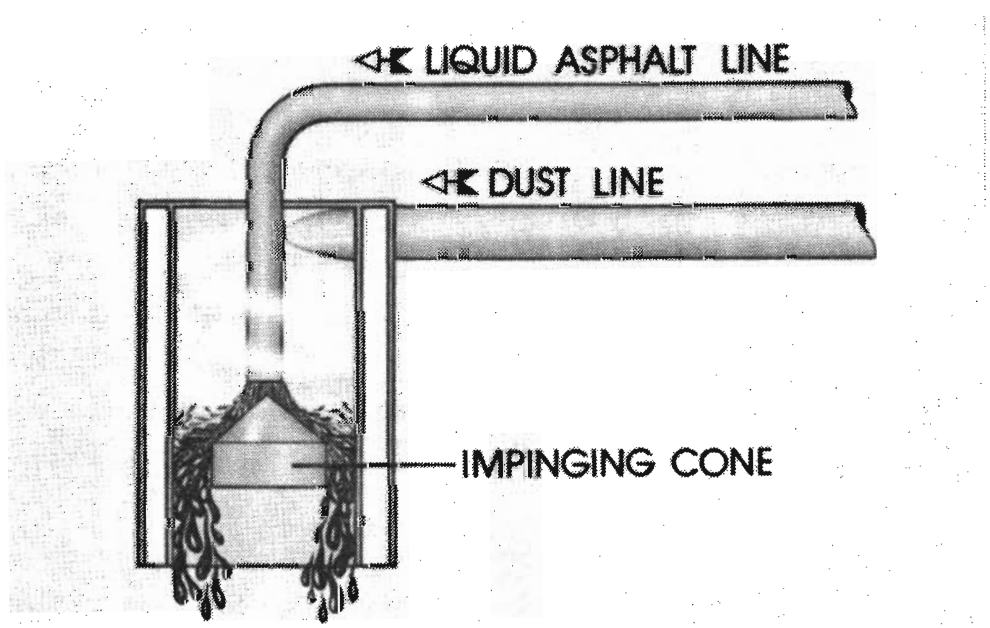

Figure 7.25. Asphalt cement-dust mixing box (Ref 17)

vane feeder turns. The feeder is normally equipped with an air system to keep the filler flowing uniformly into the vanes. The air keeps the mineral filler from packing into a tight mass above the feeder and bridging the opening to the vane feeder. If the flow of filler is restricted, the vane feeder will still rotate, but no material will be sent to the plant.

The vane feeder can be calibrated by weighing a given amount of filler into a suitable container. The plant controls are set to provide a certain amount of mineral filler per unit of time. The vane feeder is turned on and the filler allowed to flow through that equipment into the delivery pipe. The material in the pipe is diverted from the drum mixer to the container, which has been weighed empty. The time the vane feeder is operated is measured, the gross and net weight of the material in the container is determined, and the flow of the material in terms of tons per hour is calculated.

The mineral filler flow rate is measured at several different quantity settings on the controls. The calculated values are compared to the numbers shown on the computer output screen or dials. If the numbers are in agreement, the calibration procedure is complete. If the numbers disagree, the plant manufacturer's adjustment procedures should be followed. Once the adjustments are made, the mineral filler system should be calibrated once again.

Two items must be remembered. First, the pipe used to carry the mineral filler to the container being used for measurement should be full, both before and after the mineral filler starts to flow. This will provide for a constant volume of material to be delivered each time, without any filler being required to "fill up the pipeline itself." Second, the scale employed to weigh the empty and full container should be properly checked. This scale has a tolerance value around its true reading; that tolerance should be considered when comparing the weighed amount to the value shown on the computer console.

The mineral filler from the vane feeder enters the delivery pipe for transport to the drum mix plant. The material is conveyed pneumatically through the line and into the rear of the drum. Once inside the drum, the filler can be emptied in one of several ways. Sometimes it is merely discharged from the line into the aggregate at the bottom of the drum. Sometimes it is fed into a "mixing box" where it is coated with the asphalt cement before it is dropped into the drum (Fig 7.25).

If the mineral filler is discharged directly into the drum mixer, it can be emptied either upstream or downstream of the asphalt cement entry point. If the filler is placed into the drum upstream of the asphalt cement point, it is usually dropped directly on the aggregate tumbling around in the bottom of the drum. Because the filler is dry and of a very small particle size, it is easy for this material to be caught in the exhaust gas air stream. If this occurs, the filler can be carried out of the drum and into the air pollution control system without getting into the asphalt concrete mixture. Some portion of the filler will remain in the mix, but a major portion of the material, depending on drum operating conditions, can be lost from the drum mixer.

If the mineral filler is discharged from its feed pipe into the drum after (downstream) the asphalt cement has been fed into the drum mixer, a greater portion of the filler is usually captured in the foaming mass of asphalt cement and aggregate at the bottom of the drum. Because it comes into contact with the asphalt cement very quickly after exiting its charging pipe, the mineral filler has less chance of becoming airborne and being carried out of the drum. Thus a greater percentage of the mineral filler material will remain in the mix.

Some drum mix plants are equipped with a device which coats the mineral filler with the asphalt cement before the filler can be exposed to the exhaust gas air stream (Fig 7.25). In this case, the mineral filler and asphalt cement are emptied into the drum at the same position inside the drum. The "mixing box" prevents the burner exhaust gases from coming in contact with the filler until it is covered with the asphalt cement. Several different configurations for the mixing device exist. The most popular version allows the filler to swirl around inside the chamber and be sprayed with the asphalt cement before the combined materials fall out of the mixing device into the bottom of the drum. Once coated with asphalt cement, the mineral filler will be incorporated into the mix and not carried out of the drum by the exhaust gases.

If a baghouse, or fabric filter, is used as the air pollution control equipment on the plant, either all or a portion of the material captured in that device can be fed back into the drum mixer. The fines captured in the baghouse drop to the bottom of the house where they are collected in one or more troughs or channels. From the collection points, the baghouse fines are carried, usually by screw conveyor, through an air lock and then fed by air pressure through a pipe into the rear end of the drum mixer (Fig 7.26).

The baghouse fines are typically not metered, except as they pass through the air lock as they are returned to the drum. They flow as they are collected, on a continuous basis. Occasionally a surge of fine material will be carried into the baghouse, captured on the fabric filter bags, and dropped to the bottom of the unit. This slug of material is then carried back to the drum mixer. Typically this problem is minor and no metering of the baghouse fines is necessary. If, due to the plant operating characteristics, such surges of fines occur regularly, the baghouse fines should be fed into a surge bin for temporary storage. The collected material is then metered back into the plant using a vane feeder system, similar to that for mineral filler.

The line coming from the fabric filter usually enters the rear of the drum mixer and carries the baghouse fines material, under air pressure, into the drum. The material is discharged the same as mineral filler, either upstream or downstream of the asphalt cement entry point, or in conjunction with the asphalt cement through a "mixing box." The incorporation of these fines into the asphalt concrete mixture is the same as for the mineral filler material.

In a few instances, the job mix formula for the mixture being manufactured will require the addition of a mineral filler and the drum mix plant will be equipped with a fabric filter. In some cases, separate feed lines are used for the mineral filler and for the baghouse fines. Two pipes, in addition to the asphalt cement supply line, enter the drum mixer. Each empties into the drum, either at the same point or at slightly different positions. In most cases, the baghouse fines are delivered to a surge silo and are metered through a vane feeder into the supply pipe. The mineral filler, also in a silo, is fed through its own vane feeder into the same pipe

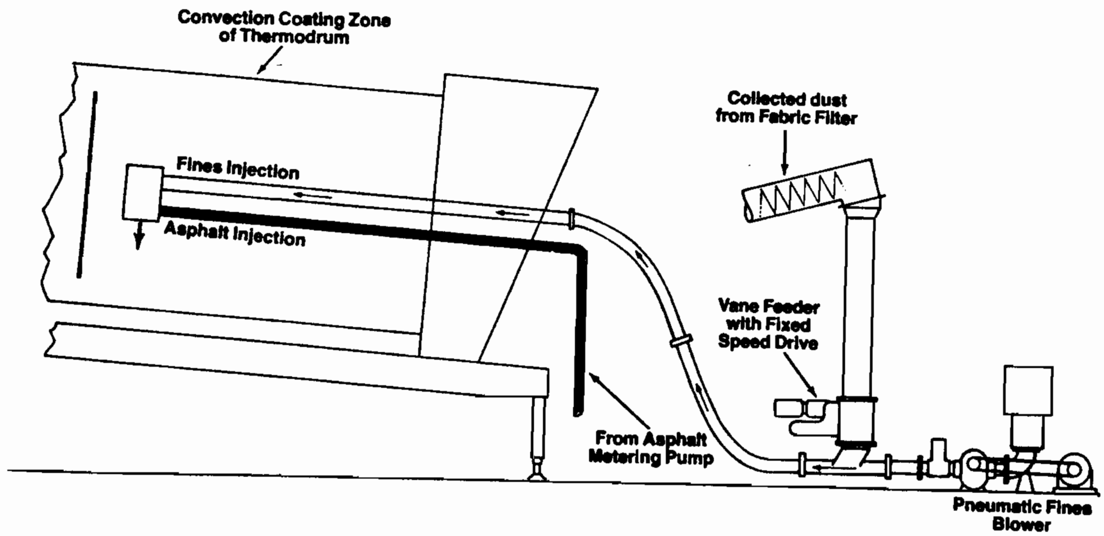

Figure 7.26. Pneumatic dust return from fabric filter collector back into thermodrum (Ref 18)

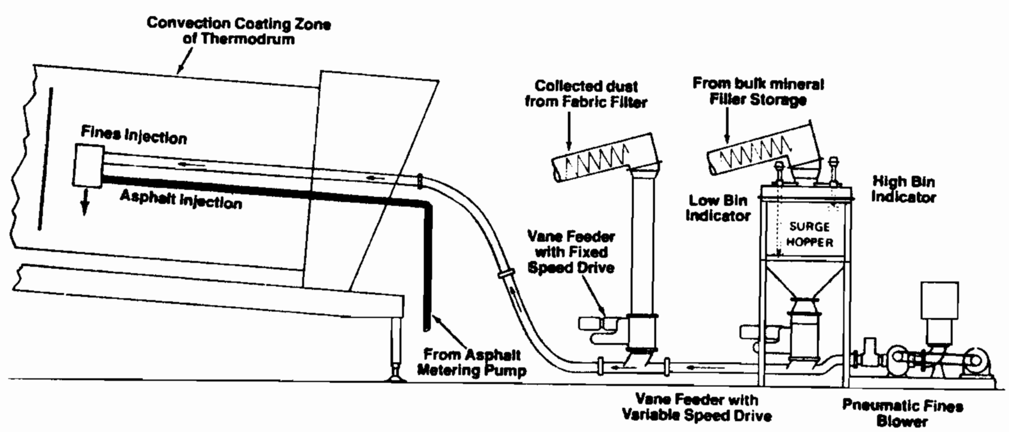

Figure 7.27. Combined pneumatic dust return and mineral filler system--for adding filler from bulk storage to thermodrum with fabric filter collector (Ref 18)

as the baghouse fines. Thus a common line is used to feed both the filler and fines to the drum mixer (Fig 7.27).

If a fabric filter, or baghouse, is used on the drum mix plant, the returned fines must be incorporated into the asphalt concrete mixture and not be allowed to recirculate back to the baghouse. This can only be accomplished by ensuring that the fines are kept out of direct contact with the high velocity exhaust gases and are coated with asphalt cement. If the fines are carried back to the baghouse, they will be caught and again returned to the drum mixer. Soon the baghouse will be overloaded with excessive fines since new material is continually being generated by the plant. The baghouse will quickly become plugged and cease operating properly. It is essential, therefore, that any mineral filler and/or baghouse fines be coated with asphalt cement and retained in the drum rather than being recirculated back to the fabric filter.

RECLAIMED MATERIAL/RECYCLING SYSTEMS

Drum mix plants can be used to efficiently and economically produce recycled asphalt concrete mixtures. In some plants, a single cold feed system is employed where both the new aggregates and the reclaimed aggregates are introduced into the drum mixer at the same position--at the burner end of the drum. In most plants, however, the feed of the two different materials is separated--the new aggregates are fed into the drum at the upper end of the drum and the reclaimed aggregates are charged into the drum at a midlength entry port. This split feed system keeps the reclaimed material out of direct contact with the burner flame and significantly reduces the opportunity for the production of blue smoke (hydrocarbon emissions) during the recycling process.

Single Feed

On drum mix plants where a single new aggregates/reclaimed aggregates cold feed system is used, the objective at the burner end of the drum is to protect the asphalt coated reclaimed material from direct contact with the burner flame. This must be done in order to reduce the volume of blue smoke generated. Several different procedures can be employed, either alone or in combination, to accomplish this task.

One method often employed is to spray water on the combined aggregates coming up the cold feed charging conveyor. The water spray, usually 1 to 4 percent, by weight of aggregate, "protects" the aggregates by placing a film of water on the aggregate particles. The water film temporarily reduces the exposure of the asphalt coating to the flame and exhaust gases until that film is evaporated from the aggregate's surface.

The degree of help that the water spray provides depends on many factors. The amount of moisture already in and on the reclaimed material is important. The amount of water applied and the location where it is sprayed should also be considered. If, for example, the reclaimed aggregates are placed first on the conveyor belt, underneath the new aggregates, the water spray cannot reach the asphalt coated particles. Thus, for the water to have any effect it should be applied to the reclaimed material directly. If, however, the amount of reclaimed material in the mix is high, the water still might not come in contact with most of the reclaimed material.

The type of entry of the aggregate into the drum also plays a part. If the combined material is fed through a chute above the burner, a series of flights is needed which are designed to push the aggregates downstream, away from the burner flame. If a slinger conveyor located beneath the burner is employed on the plant, the speed of that device should be set to fling the new and reclaimed aggregates part way down the drum rather than deposit the materials immediately in the front end of the drum. The farther away the asphalt-coated aggregates are kept from the burner flame, the less hydrocarbon emissions are generated.

On some plants, a heat shield or a diffuser is used to reduce the contact with the burner flame (Figs 3.4 and 7.28). This device, made of heat-resistant material, spreads the flame out around the circumference of the drum, decreasing the concentration of heat at any one point in the drum. The performance of the heat shield is dependent on its location inside the drum, the amount of reclaimed material in the mix, the moisture content of the new and the reclaimed aggregates, and the required mix discharge temperature.

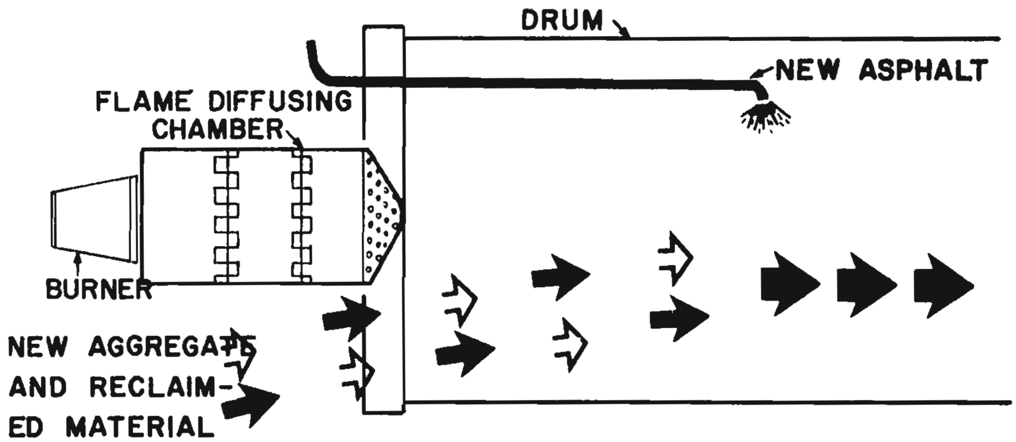

Figure 7.28. Flame diffused recycling (Ref 28)

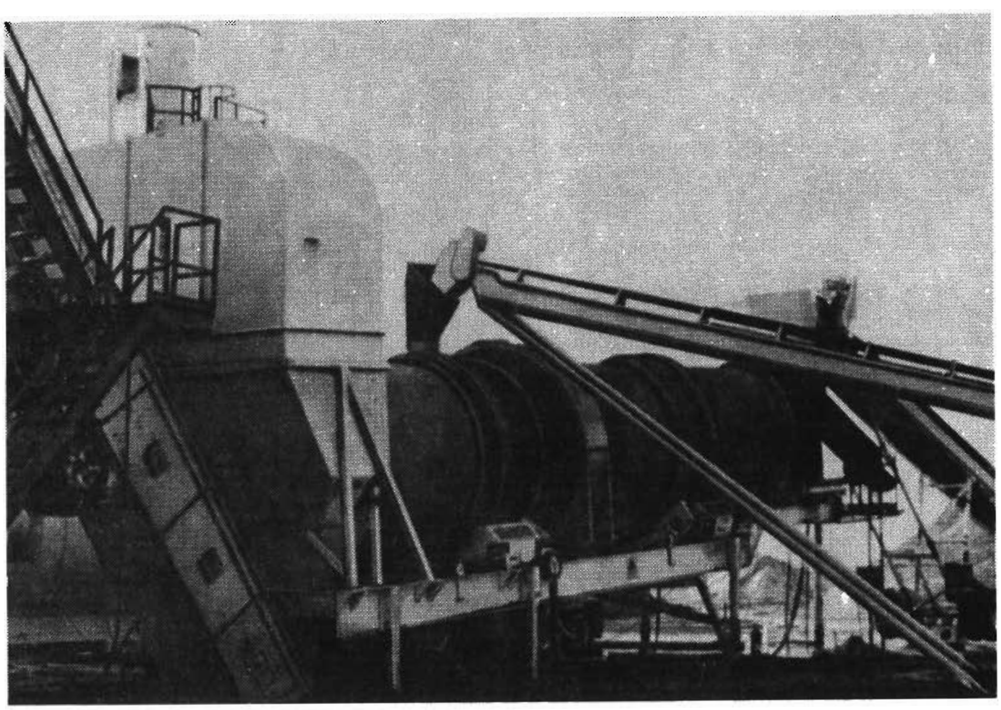

Figure 7.29. Mid-point entry of reclaimed material (Ref 16)

At high percentages of reclaimed material in a recycled mix produced in a single feed type drum mix plant, generation of blue smoke can be expected. The amount of the hydrocarbon emissions will increase as the volume of the asphalt coated material increases, as the moisture content in that incoming material decreases, as the mix discharge temperature increases, and if a heat shield is not used inside the drum. Because of the inherent air pollution control problems which exist when producing recycled asphalt concrete mixes using a single aggregate (combined new and reclaimed aggregates) feed entry point, the trend is to the use of a split feed aggregates entry system.

Split Feed

With the majority of the drum mix plants currently in use, the reclaimed aggregates are fed separately from the new, uncoated aggregates. The new material is delivered to the burner end of the drum mix plant in a conventional manner. The reclaimed aggregates, however, are usually held in a separate, free-standing cold feed bin or bins. This latter material is carried up to the plant on its own charging conveyor and weigh bridge system. The cold feed system employed is similar to that for the new aggregates--only the ultimate delivery point of the reclaimed material is different.

Each drum mix plant manufacturer has his own design for the intake system used to introduce the reclaimed material into the drum. In most cases, the inlet is located at the midpoint or just downstream from the center of the drum length (Figs 7.5 and 7.29). The drum has a series of ports or entry chutes cut into the shell to allow the reclaimed material to be introduced into the drum (Fig 7.6). The charging conveyor feeds the material into the rotary inlet and, as the drum turns, the reclaimed aggregates fall through the port holes and into the drum. In some cases, the particles are dragged from near the top of the drum shell through the air to the bottom of the drum. In most cases, however, the reclaimed material enters the drum near the bottom of the drum.

At the point that the reclaimed aggregates actually are placed inside the shell, the flights are often omitted for a short distance down the length of the drum. Thus the reclaimed material rests on top of the new, now partially heated and partially dried, aggregates for a short period of time.

Soon, however, the combined aggregates are picked up by the flights inside the drum and are tumbled together. This action continues the heating and drying of the new material and starts the heating and drying of the reclaimed material.

A number of different schemes are employed to try to reduce the temperature of the burner exhaust gases at the point where they come into contact with the asphalt coated reclaimed materials. It is believed that the asphalt cement coating will "vaporize" from the surface of the aggregate particles at temperatures in the range of 800°F to 1200°F. Thus, in order to prevent the generation of hydrocarbon emissions, the temperature of the burner gases needs to be reduced to something less than 1000°F at the location where the reclaimed aggregates enter the drum. This is accomplished primarily by assuring that a heavy veil of new aggregate is present in the drum immediately upstream of the reclaimed material entry point.

Because a portion of the aggregate used in the recycled asphalt cement mix is introduced at the midlength point on the drum, less aggregates are naturally fed into the drum at the upper or burner end. This means that a less dense veil of aggregate is obtained in the drum since less material is in the front of the drum at any time. Less heat transfer thus takes place between the exhaust gases and the aggregate particles because of the reduced mass of these particles inside the upper end of the drum. The temperature of the gases at the point they come in contact with the reclaimed material is therefore higher than it would be if the plant were being run using all new aggregates, at a given ton per hour production rate. Some means is needed, then, to transfer as much heat as possible from the exhaust gases to the new aggregates before the reclaimed material entry point is reached.

Most of the methods revolve around increasing the density of the new aggregates veil at a location immediately ahead of the center split feed point. In some cases a dam or donut is secured inside the drum, around its circumference. This ring forms a barrier to the flow of the new aggregates down the drum (Fig 3.3). The new material builds up in front of the dam until enough material is available to spill over the top of the ring and fall into the lower portion of the drum. The "excess" of material in front of the dam or donut becomes part of a heavier veil of material as it is tumbled inside the drum. The increased amount of aggregate allows for more heat transfer to be accomplished and thus reduces the temperature of the exhaust gases coming in contact with the reclaimed material.

The use of the ring or dam really only decreases the diameter of the drum at the shell midpoint. This restriction cannot be seen from the outside of the drum. Several plant producers are making the heat transfer technique much more obvious. Drums are available in the marketplace which vary in the diameter of the shell at different points along the drum length (Fig 7.21). The front portion of the drum, at the burner end, is larger in size than is the middle part of the shell. At the lower end, the drum diameter flares out again to the same dimension as the upper end. This change in diameter in effect creates a reduction in the drum volume. It thus increases the density of the new aggregate veil upstream of the reclaimed material entry point. Some drums are built without the second change in drum diameter. The upper portion of the drum is larger in diameter than the center part, but the drum diameter then remains constant to the discharge end of the shell.

Another way to increase the density of the new aggregates veil is to increase the number of flights inside the drum at the burner end of the drum. This greater amount of lifting action causes more aggregate to be tumbled at any particular time, increasing the density of the veil. Finally, the dwell time of the aggregate in the drum can be increased by lowering the slope of the drum. This, in effect, increases the amount of new aggregates in the drum thus causing a heavier aggregate veil and more complete heat transfer.

Some plant producers have gone to the use of longer drum lengths to allow for more time for the heat transfer process to take place. This method basically increases the volume of new aggregates in the upper portion of the drum, densifying the veil of material. Also, by changing the amount of time it takes for the material to flow through the drum, more complete heating and drying of the new aggregate particles occurs.

Normally, if only small amounts of reclaimed material are being incorporated into a recycled mix, e.g., less than 20 percent, minimal problems in terms of hydrocarbon emissions are usually encountered with the manufacturing process in a drum mix plant. As the percentage of old material becomes greater, however, and as less new aggregate is necessarily fed into the burner end of the plant, the potential for air pollution problems increases. When the amount of reclaimed material used exceeds 50 percent, by weight of mix, the possible production of blue smoke during the recycling process is significant. A combination of procedures, outlined above, is usually needed to assure adequate heat transfer from the exhaust gases to the new aggregates before the burner gases meet the reclaimed material. Except in unusual circumstances, a maximum of 70 percent reclaimed aggregates can be accommodated in the typical drum mix plant.

The reclaimed material is heated and dried in three ways. First, and most obviously, it is directly exposed to the high temperature exhaust gases. If the gases are less than about 1000°F when they come into contact with the asphalt covering on the reclaimed aggregate particles, little of the asphalt cement coating will be burned off or vaporized from the aggregate surface. The continued exposure to the gases as the combined new and reclaimed aggregates tumble together down the lower portion of the drum causes these materials to increase in temperature at the same time that the temperature of the exhaust gases is reduced. Thus heat is transferred from the hot air to the aggregate particles.

The second means of heat transfer is from the already partially heated new aggregates to the reclaimed material. When the reclaimed aggregates are dumped on top of the new material at the center entry port, the contact between the heated and the ambient temperature materials causes some heat to flow to the reclaimed material. This process continues as both materials travel together down the drum. Finally, the reclaimed material gains in temperature as it touches the heated drum flights and shell wall. As the materials are heated, moisture in the aggregate is driven off and the combined new and reclaimed particles are dried.

In many plants, the reclaimed aggregates enter, using the split feed system, only a short distance upstream of the asphalt cement injection location. This means that the combined materials (new and reclaimed) are coated with asphalt cement before the reclaimed aggregates are heated or dried to any significant degree. This early coating process usually causes some moisture to be trapped on the surface of the reclaimed material, under the new asphalt cement layer. Although much of this moisture is eventually removed as the materials flow down the drum, some residual moisture may remain in the recycled mix upon discharge from the drum.

Because of this potential problem, the asphalt cement injection point is pulled back toward the discharge end of the drum in some plants when recycled mix is being produced. This procedure allows more time for the reclaimed material to be heated and dried before the new asphalt binder is placed on it. Thus the moisture content in the mixture being manufactured is reduced. Ideally, the amount of residual moisture in a recycled asphalt concrete mixture should be the same as that in a mix produced using all new coarse and fine aggregates.

Production Rates

Asphalt concrete drum mix plants are typically rated in terms of the number of tons per hour of mix that can be produced. The manufacturing capacity is determined at an asphalt content of 5 percent. No mineral filler is assumed to be incorporated in the mix. The calculations are based on an incoming coarse and fine aggregate temperature of 60°F, a mix discharge temperature of 270°F, and an aggregate specific heat value of 0.2 Btu per pound per degree F. In addition, the atmospheric pressure is taken to be the same as at sea level. Any differences in the values of the above factors can cause a variation between the theoretical capacity of a given drum mix plant and its actual output quantity.

Plant capacities are affected by a number of other variables. Differences in operating techniques, atmospheric conditions, fuel type, and fuel Btu content will cause changes in production capacities. In addition, aggregate gradation will be a factor, with mixes containing a large percentage of coarse aggregates being more difficult to heat uniformly than mixes incorporating a balance of coarse and fine aggregate particles.

The moisture content of both the coarse and fine aggregates must be determined in order to calculate the average moisture content of the combined incoming aggregates. Since different rates of coarse and fine material are used in the mixes, the average moisture is typically somewhere between the amount of moisture in each of the two aggregate fractions. The moisture content of the fine aggregates is usually higher than that of the coarse aggregates. The weighted moisture content is thus a function of the amount of moisture in the coarse aggregates times the percentage of that material in the mix, plus the amount of moisture in the fine aggregates times the percentage of the latter material in the combined gradation.

If, for example, 60 percent of the asphalt concrete mix consists of coarse aggregates, then 40 percent of the mix is fine aggregates (assuming no mineral filler is used in the mix). If the moisture content of the coarse material is 3.0 percent and that of the fine particles is 8.0 percent, the average moisture content in the combined aggregates is calculated to be: (60% x 3.0%) + (40% x 8.0%) = (0.18) + (0.32) = 5.0%. If the amount of moisture in the fine aggregates was only 6.0 percent, the combined (average) moisture content of the cold feed materials would be: (60% x 3.0%) + (40% x 6.0%) = (0.18) + (0.24) = 4.2%.

The capacity of a drum mix plant, using all new aggregates, is primarily a function of the amount of moisture in the combined aggregates and the diameter of the mixing drum. As the average percentage of moisture in the aggregate increases, the capacity of a drum mixer of a given diameter decreases. At a constant average incoming moisture content, the production rate increases as the drum diameter increases. The theoretical relationship between average moisture content and drum diameter and the calculated drum mix plant production rate (at a mix discharge temperature of 270°F) is shown in Figure 7.30 for six different Barber-Greene drum mix plant models.

At an average moisture content of 5 percent, a drum mix plant having a diameter of 5 feet would have a theoretical production capacity of 100 tons per hour. If a drum 7 feet in diameter were employed, that plant's manufacturing rate would be 236 tons per hour. For a drum mixer 10 feet in diameter, the capacity would increase to 541 tons per hour, at 5 percent moisture removal. As the moisture content in the aggregate decreases, say from 5 percent to 3 percent, the production rate for a drum mixer that was 7 feet in diameter would increase to 336 tons per hour from 236 tph. If the aggregates were wet, with an average moisture content of 8 percent, for example, the same 7 ft. diameter plant would only be able to manufacture 163 tons of asphalt concrete mix per hour. As can be readily seen, the moisture

Nominal Drum Mixer Capacities[1]

	Normal Operating Range								
	% Surface Moisture Removed								
Model	2	3	4	5	6	7	8	9	10
DM-50 5X22	170 (178)	135 (142)	110 (116)	95 (100)	80 (84)	75 (79)	70 (74)	60 (63)	55 (58)
DM-55 6X24	265 (278)	210 (220)	170 (178)	150 (158)	130 (137)	115 (121)	110 (116)	95 (100)	85 (89)
DM-60 7X30	400 (420)	320 (336)	260 (273)	225 (236)	195 (205)	175 (184)	155 (163)	140 (147)	130 (137)
DM-66 8X32	515 (541)	410 (430)	335 (352)	290 (305)	250 (263)	225 (236)	200 (210)	185 (194)	165 (173)
DM-71 9X36	685 (719)	550 (578)	455 (478)	390 (410)	340 (357)	300 (315)	270 (284)	245 (257)	225 (236)
DM-75 10X40	910 (956)	725 (761)	600 (630)	515 (541)	450 (473)	400 (420)	360 (378)	325 (341)	300 (315)

1 Figures with no parentheses are aggregate drying capacities.

Figures in parentheses are mix production capacities calculated as: aggregate capacity + 5% asphalt (no mineral filler added).

Figure 7.30. Examples of effects of moisture content on plant production rate for six Barber-Green plants (Ref 29)

content of the aggregates can have a dramatic effect on the production capacity of a given diameter drum mix plant.

In the above illustrations, the mix discharge temperature was held constant at 270°F. This temperature, however, also affects the production rate of the plant. As the mix discharge temperature decreases, for a given aggregate moisture content and drum size, the volume of mix manufactured in the plant increases. In Figure 7.31, a Cedarapids drum mix plant which is 7.33 feet in diameter and 28 feet in length is shown producing mix at five different discharge temperatures. For a value of 5 percent moisture removal, the production rate will increase from 255 tons per hour at 300°F to 300 tons per hour at 250°F to 350 tons per hour at 200°F. When the moisture content on the incoming aggregates is relatively high, the production rate changes are not as great when the mix discharge temperature is lowered. At 8 percent average moisture content, for instance, the production capacity of the plant increases from 175 to 200 to 230 tons per hour as the mix discharge temperature decreases from 300° to 250° to 200°F, respectively.

For the manufacture of recycled asphalt concrete mixtures, the production rate is also a function of the volume of reclaimed material being fed into the drum mixer, for those plants which operate on a split feed system. For these plants, as the amount of reclaimed material delivered to the drum becomes greater than 50 percent of the total aggregate feed, the capacity of the plant is decreased as shown in Figure 7.32 for a Barber-Greene drum mix plant and various amounts of reclaimed material and different average moisture contents of the combined new and reclaimed materials.

Suppose a recycled mix is to be made up of 60 percent reclaimed material and 40 percent new aggregates, with the latter consisting of 25 percent coarse aggregates and 15 percent fine aggregates. Further assume that the moisture contents in the cold feed bins are 5 percent, 3 percent, and 8 percent, for the reclaimed, new coarse, and new fine aggregates, respectively. The weighted (average) moisture content of the combined materials can be calculated as: (60% x 5%) + (25% x 3%) + (15% x 8%) = (3.00) + (0.75) + (1.20) = 4.95%. This value is used as an input variable into the figure.

The ratio of reclaimed to new aggregates is also an input value. In this example, 60 percent reclaimed material and 40 percent new aggregates are

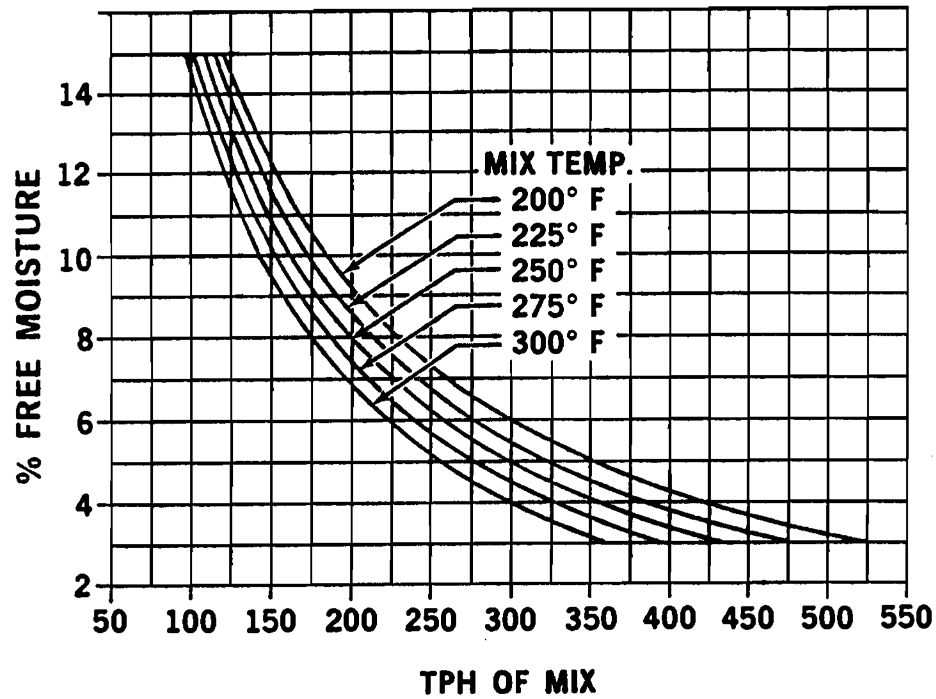

Figure 7.31. Capacity chart for Cedarapids drum mixers (Ref 30)

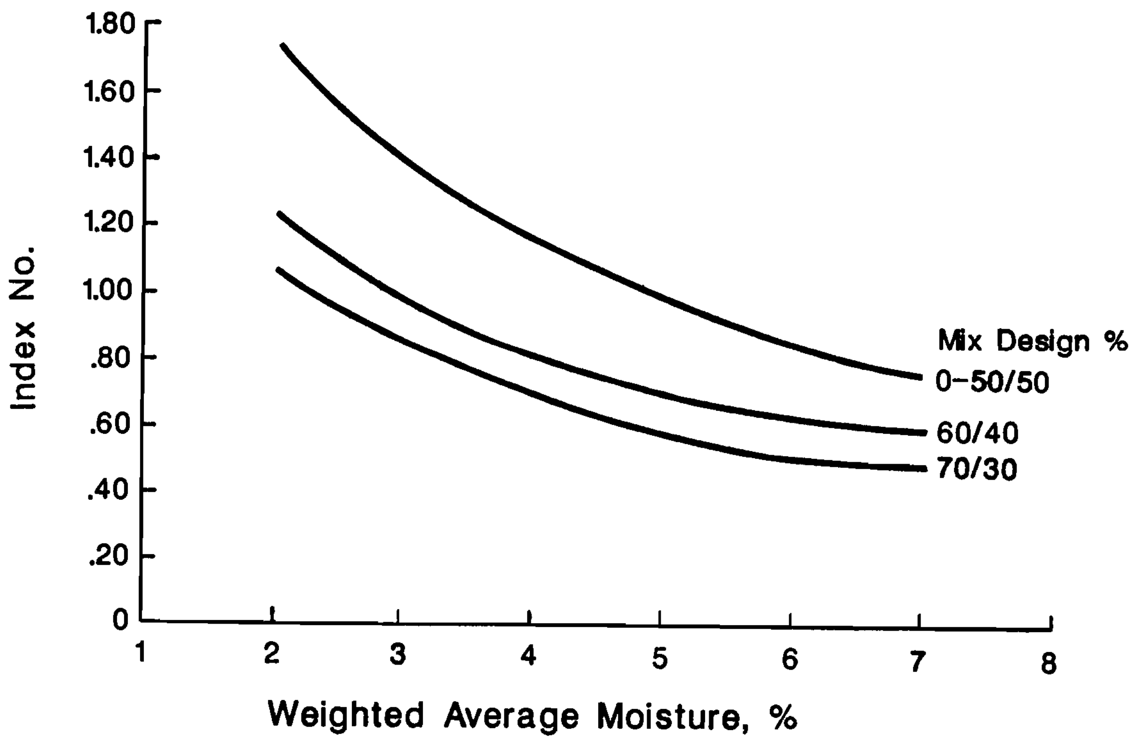

Figure 7.32. Capacity chart for Barber-Green recycling plants (Ref 31)

assumed for the recycled mix. For a 60/40 ratio, and at a weighted moisture content of 4.95 percent, the index number of 0.70 is obtained from the chart. This index value means that, in general, a drum mix plant could produce only 70 percent as much mix per hour, based on a 60/40 reclaimed/new aggregates blend, compared to the same plant producing mix using all new aggregates. Thus if the plant could manufacture 308 tons per hour (at 4.95 percent moisture removal) with 100 percent new material, it would theoretically be rated at 308 x 0.70 = 216 tons per hour using 60 percent reclaimed aggregates.

If the same plant was being operated at a ratio of 70 percent reclaimed to 30 percent new aggregates, and if the same weighted moisture content held for the combined aggregates, the rate of mix production would decrease. The index value for the example is 0.58, meaning that the production rate would only be 58 percent of that using all new aggregates. For the same drum mix plant, the amount of mix manufactured would be decreased from 308 tons per hour to 308 x 0.58 = 179 tons per hour. Thus, as the amount of reclaimed material used in the recycled mix increases above 50 percent, the amount of mix that can be manufactured in a drum mix plant is reduced.

PLANT EFFICIENCY

The purpose of a drum mix plant is to transfer heat from the burner flame and gases to the aggregates in order to heat and dry them. If perfect heat transfer could take place inside the drum, the temperature of the mix upon discharge from the plant would be equal to the temperature of the exhaust gases at the same point. This equilibrium point would mean that the heat transfer is in balance and that the drum mixer is running at maximum thermal efficiency.

In very few instances, however, does the mix discharge temperature equal the exhaust gas temperature. But if the veil of aggregates inside the drum is of the proper density, the exhaust gas temperature, measured at the plant stack, should be within 25°F above the temperature of the mix. Thus, if the mixture discharge temperature is 275°F, the stack temperature should ideally be less than 300°F. This small temperature differential implies that the drum mixer is operating efficiently. If the stack temperature is found to be more than 25°F above the mix temperature, it generally means that the heat transfer process inside the drum is not as complete as it should be, primarily due to the lack of a dense, complete veil of aggregates across the circumference of the drum. The degree of inefficiency of the heat transfer is evidenced by the temperature differential between the mix upon exiting the drum and the exhaust gases upon leaving the stack.

During the production of a recycled asphalt concrete mixture, the heat transfer between the burner gases and the new and reclaimed aggregates should be similar to that for a mixture using all new material if all materials are introduced into the burner end of the drum mixer. Thus, for this system, the exhaust gas temperature at the stack should be within the 25°F temperature difference if the plant is operating properly. If a split feed type plant is being employed, the difference in the two temperatures will typically be greater than 25°F, depending on the proportion of reclaimed material being introduced at the center inlet point. As a higher percentage of reclaimed aggregate is employed in the recycled mix, the temperature differential increases.

As the ratio of reclaimed material to new material becomes greater, from 20/80 to 40/60 to 60/40 (reclaimed/new), there is less and less new aggregate being delivered to the burner end of the drum mixer. This means less material inside the drum, for a given production rate, and a less dense veil of aggregates to intercept the exhaust gases moving down the drum. Thus, the heat transfer process is not as efficient inside the drum as when a greater volume of new aggregate is being used. In some instances, when more than 50 percent of the recycled mix consists of reclaimed material, the temperature of the exhaust gases can be more than 50°F above the mix discharge temperature.

The efficiency of the mixing operation, therefore, can be judged in part by observing the temperature differential which exists between the mix upon leaving the drum and the burner gases exiting the stack. Since both temperatures are recorded continuously and are displayed on the plant control consoles, this method of monitoring the plant production process is easy to accomplish. If the temperature differential is greater than it should be, an effort should be made to increase the density of the aggregate veil inside the drum, upstream of the reclaimed material entry port (if a split feed system is used) and upstream of the asphalt cement delivery point.

A second way to judge the efficiency of the drum mix plant operation is to observe the asphalt concrete mixture as it exits the drum and enters the delivery system to carry the material up to the surge silo. The appearance of the asphalt concrete material, whether it consists of all new aggregates or a blend of new and reclaimed aggregates, should be uniform across the width of the discharge chute. The color of the aggregate particles should be consistent and the larger aggregate pieces should be evenly distributed throughout the mixture.

If the drum mixer is not running efficiently, the veil of aggregates inside the drum will not be complete. On one side of the drum, depending on which direction the drum is turning, there will not be enough aggregate available to fully intercept the burner gases. In this area, the velocity of the gases remains high, allowing fine, dust sized particles to be picked up in the air stream and carried to the rear of the drum. As the exhaust gases change direction to enter the air pollution control system ductwork, the larger dust particles are deposited on one side of the drum. These uncoated particles are discharged on one side of the mixture as it exits the drum. A steady stream of light brown, uncoated, fine aggregate particles on one side of the asphalt concrete mix discharge chute thus provides an indication that the veil of aggregate inside the drum is incomplete.

If a dry, powdered additive such as hydrated lime is being added to the incoming cold aggregates at the burner end of the drum mixer, it is possible for that very fine material to be picked up in the exhaust gases shortly after it is charged into the plant. As long as the aggregate veil is proper, the fine dust will be trapped in the tumbling mass of aggregates and incorporated into the mix. If the aggregate veil is incomplete, however, the powdered material can be carried down one side of the rotating drum shell and then either transported into the air pollution control equipment or dropped into the bottom of the drum at the mix discharge point. The material will then be visible on one side of the asphalt concrete mixture as it exits the drum.

Typically a high stack temperature compared to the mix discharge temperature will be accompanied by a stream of light colored fines on one side of the mix discharge chute. Both of these phenomena are indications that the drum mixer is not operating as efficiently as it could and should be. The plant personnel should alter the production process to achieve a denser veil of aggregate in the drum. This can be accomplished in a variety of ways--by increasing the number of flights inside the drum, by installing a dam or ring inside the drum, by using "kicker" flights to retain the material in the drum longer, and by lowering the slope of the drum, also to increase the aggregate's dwell time. This was discussed in detail previously.

CHAPTER 8. SURGE BINS

BIN GEOMETRY

A drum mix plant operates on a continuous basis--aggregates are steadily withdrawn from the cold feed bins, continually carried up the charging conveyor, and constantly fed into the rotating drum. The aggregates move down the drum and exit from the drum in a continuous stream. The hauling vehicle, however, can only accept the manufactured mix on a batch basis, truckload by truckload. Thus a device is needed to convert the steady flow of material into a discontinuous flow. That piece of equipment is a surge bin.

Surge bins come in a variety of shapes. The majority of the silos currently employed are circular in cross section. Bins which are oval, elliptical, rectangular, and even square, are in use. The shape of the bin does not seem to have any significant effect on the ability of the silo to deliver mix to the haul truck uniformly, although there is some concern that mix can sometimes "hang up" in the corners on a square or rectangular bin. In addition, the diameter of the bin does not seem to be a factor in the amount of segregation of an asphalt concrete mix which can occur in the surge bin. The manner in which the bin is operated has a great effect on the uniformity of the mix delivered--greater than the geometry of the surge bin itself.

CONVEYING DEVICES

A variety of conveying devices are used to carry the asphalt concrete mix from the discharge chute on the drum mixer to the surge bin. The most popular equipment is the drag slat conveyor (Fig 8.1). In this system a continuous set of flights, connected together by a chain, pull the mix up an inclined metal chute. The amount of mix that can be carried by the drag slat depends on both the spacing between the slats and the height (or depth) of the individual flights themselves. On some drag slat conveyors, the speed of the conveyor can be altered to allow the capacity of the device to be more evenly matched to the output of the drum mixer.

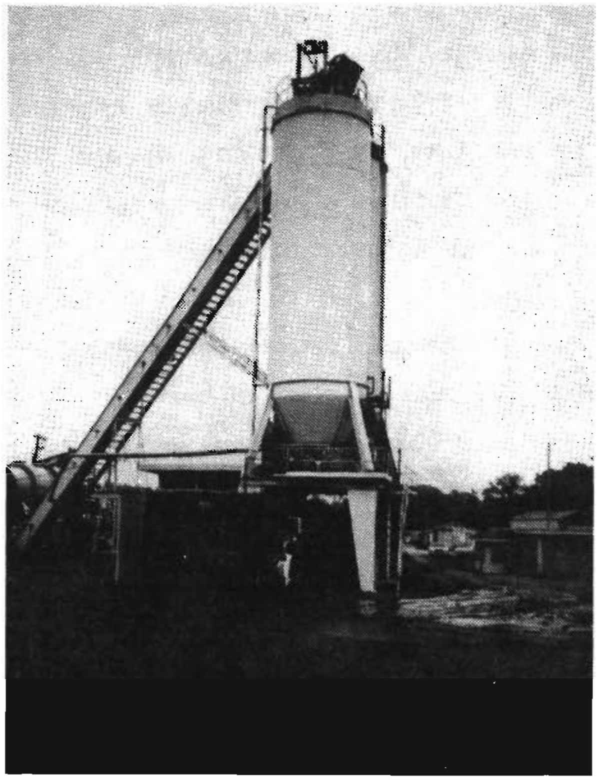

Figure 8.1. Drag slat conveyor

Belt conveyors can be used to deliver the finished mix to the surge silo (Fig 8.2). The belts are essentially the same as those that carry the incoming aggregates into the drum except they are able to withstand the increased temperature of the hot mixed material. Bucket elevators are also found on some plants (Fig 8.3). These devices are similar to the equipment used on batch type plants to carry the hot aggregate from the discharge end of the dryer to the top of the mixing tower.

The type of conveying equipment employed is not a major factor in the uniformity of the mix delivered to the surge bin. What makes a significant difference is the manner in which the mix exits from the device and enters the top of the surge bin.

TOP OF THE SILO

The asphalt concrete needs to be placed into the silo in a manner which minimizes the segregation of the material. Segregation most typically occurs in mixes which contain a big proportion of large aggregate and/or are gap graded. The actual separation of the large and small particles occurs when the asphalt concrete is placed in a conical pile and the bigger particles run down the side of the pile, collecting at the bottom edge. Segregation can also occur when all the mix is delivered to one side of the silo, allowing the coarser pieces to run all the way across the surge bin to the opposite wall. Prevention of segregation begins at the top of the silo.

In some of the early surge bins, the asphalt concrete material was transported to the top of the silo, either by slat conveyor, belt conveyor, or bucket elevator, and discharged into the silo. This method of delivery caused the large particles to be flung the farthest--against the far wall--and the smaller particles to be dropped with a shorter trajectory. To combat this problem, some manufacturers developed a series of baffles to capture and contain the asphalt concrete, dropping it into the center of the bin. Still other suppliers used a splitter system to divide the mix that was delivered to the device, thereby pushing a portion of the mix to each section of the silo. In general, the baffle and splitter systems reduced the segregation problem but did not always eliminate it.

Figure 8.2. Belt conveyor

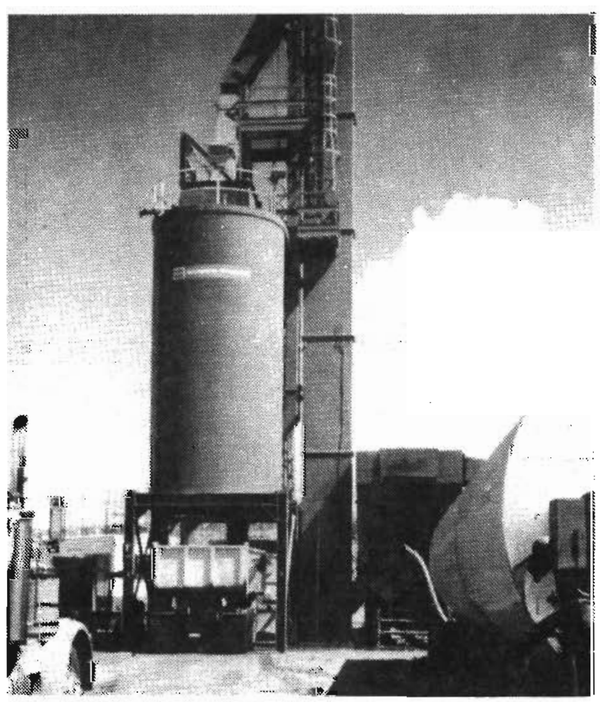

Figure 8.3. Bucket elevator

Most surge silos currently in use employ some form of temporary holding hopper or batcher at the top of the silo to momentarily store the mix being transported up the conveyor (Fig 8.4). This "gob" hopper collects the continuous flow of mix and then, when the hopper is nearly full and the hopper gates are opened, deposits the mix, in a mass, into the main part of the silo. The mass of mix hits the bottom of the silo (when empty) or the top of mix already in the silo. Upon contact, the mix spatters in all directions, uniformly, thereby minimizing segregation. The system functions well unless the surge bin is almost full. In the latter case, the mix, when released from the hopper, does not fall very far. When it quickly hits the mix already in the silo beneath the hopper, the falling mix lacks the momentum to spread out over the width of the bin. Thus a conical pile can be formed. This pile can be the beginning of a segregation problem as more mix is deposited on top of it. Most surge silos are equipped with high bin indicator warning systems which alert the plant operator to cut off the flow of incoming mix when the bin becomes too full.

The temporary batchers may not prevent a segregation problem if the asphalt concrete mix is delivered to it improperly. In many cases, the transporting devices place the mix all on one side of the hopper. This causes a small amount of rolling of the coarse aggregate in the batcher itself. It also causes the mix to be dropped off-center into the silo. Thus, even though the surge bin may be equipped with a batcher, the mix must be deposited uniformly into the center of the hopper and the mix must be delivered from the batcher into the center of the bin to prevent segregation of large stone size mixes or gap graded mixes.

All too often, the plant operator may leave the gates on the bottom of the batcher wide open. This completely defeats the purpose of the holding hopper, allowing the asphalt concrete mix to dribble into the silo in a continuous stream. In some cases, the batcher may be emptied more often than necessary, before it is completely full. This continual dumping of the hopper reduces the amount of material dropped into the silo and can enhance the amount of segregation which can develop.

Another means of introducing the mix into the silo is with a rotating spreader chute (Fig 8.5). This device turns around at the top of the silo,

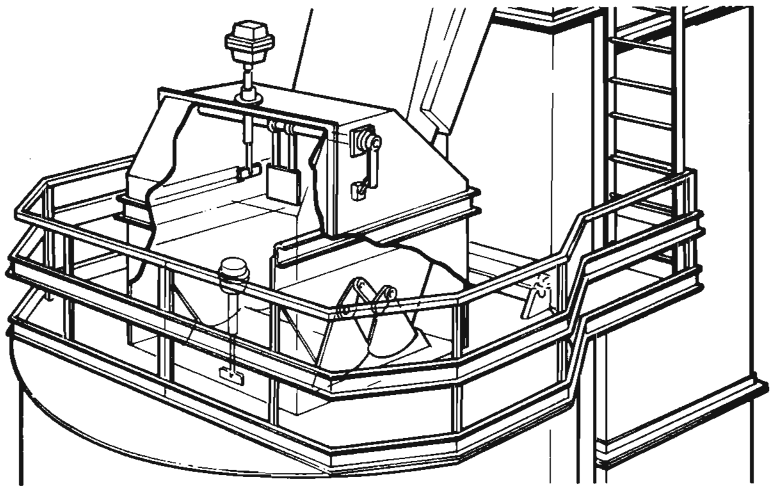

Figure 8.4. Silo loading batcher at top of silo (Ref 18)

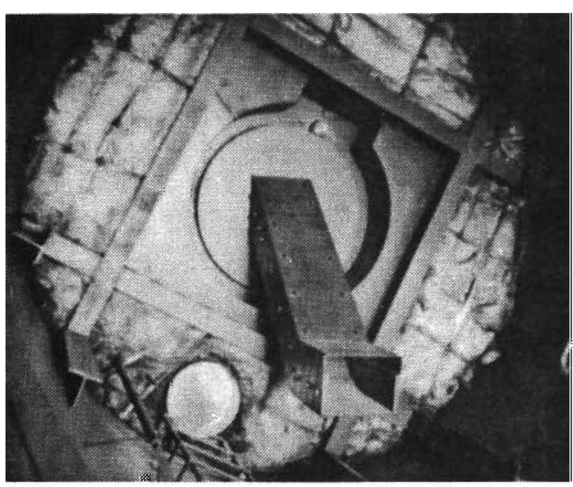

Figure 8.5. Roatating chute inside silo (Ref 32)

depositing the mix in a circle around the circumference of the silo. The flow of the asphalt concrete is continuous, but the development of conical piles of mix is minimized by spreading the material out over a wider surface area. Because the chute on the rotary spreader is subject to extensive abrasion from the mix, it must be checked periodically to assure that no holes have developed in the device. Depending on the location of the hole, mix can either be all deposited in the center of the silo or all around the outside circumference of the silo.

HEAT AND INSULATION

Most surge bins are insulated. The purpose of the insulation is to reduce the loss of heat from the mix as it temporarily resides in the bin. The type of insulating material and its thickness vary among the various manufacturers.

The cone on the surge bin is usually heated. This is done to prevent the mix from sticking to the wall of the cone and building up. The heat can be provided by electrical or hot oil systems. In some cases, the vertical walls on the silo are also heated. The heating is done to allow the mix to retain the desired temperature for an extended period of time. If the silo is to be used strictly as a surge bin, emptied of mix at the end of each production cycle, heating of the bin walls is usually unnecessary.

Occasionally it is necessary to retain an asphalt concrete mixture in the silo for a longer time period, such as overnight or over a weekend*. In most cases this can be quite successfully accomplished without undue hardening or temperature loss in the mix. A well insulated silo, however, is required. There is no strong evidence, on the other hand, that heating of the bin vertical walls is necessary. Mixes stored for several days in silos equipped with heated cones only have shown only minimal oxidation and temperature loss. The amount of hardening which occurs is related to the amount of mix in the silo. The large mass of mix in a full silo will age less than will a small volume of mix in a nearly empty silo. In addition, the amount

* Texas does not permit overnight storage without special permission - Item 340 (Ref 8)

of temperature loss in the stored mix will depend on a number of factors, including the initial mix temperature, the gradation of the material, and environmental conditions.

Asphalt concrete mixes can be stored for as long as two weeks when kept in a heated, air-tight silo. In this case, an inert gas system is employed to purge the silo of oxygen. The silo must be well sealed to prevent the movement of air into and through the mix. The bin, moreover, must be completely heated and very well insulated. Although mix can be stored for relatively long periods of time, it is rarely necessary to do so. Most silos, therefore, are used either as surge bins or periodically for overnight storage of the asphalt concrete material.

The mix held in a surge or storage bin should be tested to assure that it meets all the normal requirements for asphalt concrete materials delivered directly to the paving site. This testing should include measurement of the mix temperature upon discharge from the silo and the viscosity of the asphalt cement recovered from the mix. As long as the mixture meets these specifications, the length of time the material is held in the silo should not be restricted.

THE CONE AND LOADOUT

The bottom of the surge bin is shaped like a funnel (Fig 8.6). This section, or cone, is used to deliver the mix to the hauling vehicle. The angle of the cone varies between the different manufacturers, but usually is between 55° and 70°. This slope assures that the mix is deposited in a mass into the truck. The angle needs to be steep enough to assure that the larger aggregate particles do not roll into the center of the cone as the mix is drawn down, causing segregation.

The vast majority of the surge silos have low bin indicator systems which warn the plant operator when the level of mix in the bin approaches the top of the cone. By keeping the volume of mix in the silo above this minimum height, the development of segregation will be minimized. As very coarse mixes or gap graded mixes are pulled below the top of the cone, there can be a tendency for the largest aggregate particles to roll into the center of the crater.

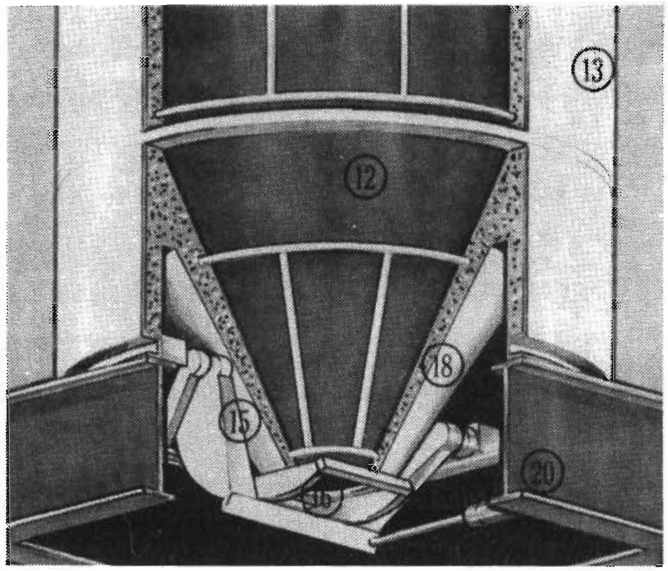

Figure 8.6. Cone at bottom of silo (Ref 33)

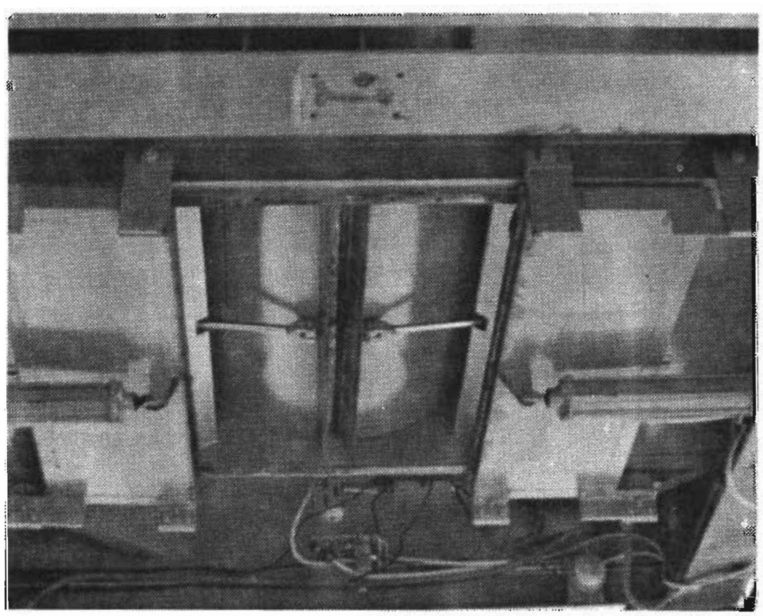

Figure 8.7. Silo gates at bottom of cone (Ref 34)

Just as it is important to deliver mix into the silo in a mass, it is also important to deposit the asphalt concrete in one mass into the haul truck. In this operation, it is necessary for the gates on the bottom of the silo, at the bottom of the cone, to be opened and closed quickly (Fig 8.7). It is also necessary for the gates to open completely so that the flow of mix is unrestricted. There is only one reason to cut off the flow of mix into the vehicle once that delivery has started--to divide the drops of mix into different sections of the truck.

If all the asphalt concrete is placed in the hauling vehicle in one drop from the silo, segregation of the larger aggregate particles can occur. If the mix is deposited into the center of the truckbed, the material will build up into a conical shaped pile. Because the growth of the pile will be restricted by the sides of the truck, the bigger aggregate particles will roll toward the front of the truckbed and also toward the rear of the truck. These pieces accumulate in both ends of the load and are then delivered into the hopper on the paver from the truckbed. The pockets of coarse material then appear in the mat behind the laydown machine at the end of every truckload of mix. In reality, some of the large aggregate pieces come from the end of one truckload and also from the beginning of the next truckload of mix.

This segregation problem can be eliminated by dividing the delivery of the asphalt concrete from the silo into multiple drops, each delivered to a different section of the bed of the hauling vehicle. If a tandem axle or triaxle dump truck is being utilized, about 40 percent of the total weight of the mix to be hauled should be loaded into the center of the front half of the truck (at the quarterpoint of the truck length). The truck should then be pulled forward so that the next 40 percent or so of the total load can be deposited into the center of the back half of the bed (at the three-quarter point of the truck length). The vehicle should then be moved again so that the remaining 20 percent of the mix can be dropped into the center of the bed, between the first two piles. If a semi-trailer is used to deliver the mix, the number of drops of material from the silo should be increased so as to distribute the mix along the length of the truckbed.

The objective of this delivery method is to minimize the distance that the coarser aggregate pieces can roll. This significantly reduces the chance for segregation in the mix. This procedure, however, requires that the truck driver remain in his vehicle during loading and that he reposition his truck under the silo periodically so that the asphalt concrete mix is spread more evenly on the truckbed. In any case, the truck should NOT be loaded in one drop of mix from the silo, even if the mix does not have a tendency to segregate. Multiple discharges are very beneficial in keeping the mix uniform for delivery to the paver.

The plant operator should quickly be able to determine the time it takes to deliver the proper amount of mix, per drop, into the haul vehicle. This can be done by timing the discharge of the mix and comparing the time to the weight of mix delivered. Because trucks are a variety of sizes, the time per drop of mix may well be different from truck to truck. But, after a little practice, the operator should be able to accurately judge, by time, the amount of material to be placed in each truckbed. This amount can also be confirmed visually by watching the height of the growing pile (or piles) of mix in the truck as the loading continues.

In any case, the loading operation should not be allowed to dribble mix into the haul vehicle. The gates on the silo should not be continually opened and closed to deliver only small amounts of mix to the truck. This problem occurs most frequently in plants where the surge bins are placed directly over the truck scales. Because the operator can quickly determine the amount of mix actually in the truckbed by observing the scale readout on his control console, the tendency is to load the vehicle right up to the legal limit. This is done by using multiple drops of small quantities of mix at the end of the main delivery. If the discharge of mix from the silo is timed, however, this procedure is unnecessary. By eliminating the practice, the potential for mix segregation is also reduced. In addition, a batching weigh hopper can be used under the silo to determine the amount of mix being loaded into the haul truck (Fig 8.8). This equipment eliminates the need for a truck scale.

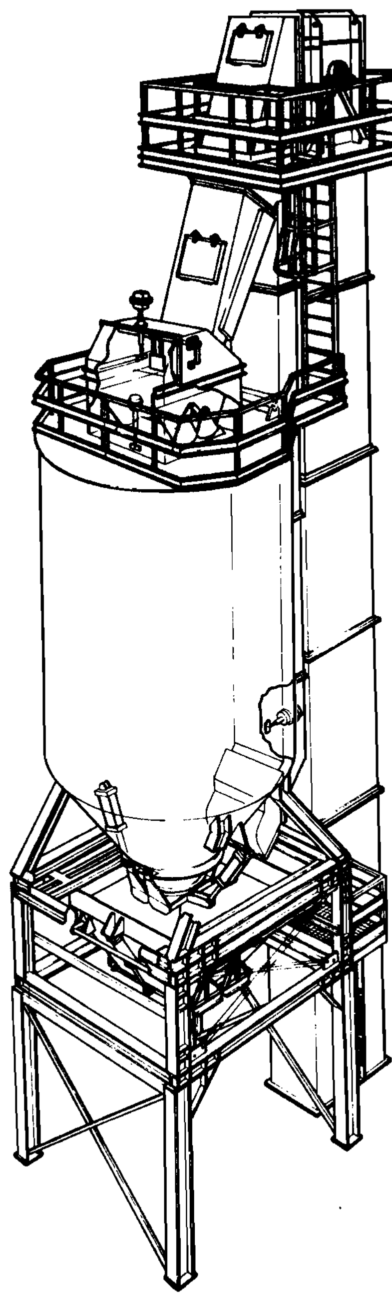

Figure 8.8. Silo weigh batcher (Ref 18)

SURGE BINS AND SEGREGATION*

Two types of segregation occur in an asphalt concrete mixture placed by an asphalt paver. The first is side-to-side segregation. In this instance, the larger aggregate pieces all appear on one side of the mix on the roadway. The second type of segregation is truckload-to-truckload. Here the coarser particles appear in the mat at the end of each load of mix. In each case, there is a definite pattern, either continuous or intermittent, to the segregation problem. Definition of the pattern helps determine the cause of the problem.

Side-to-Side. Side-to-side segregation generally occurs at the top of the silo. This pattern is an indication that the larger aggregates are being delivered to only one side of the surge bin. Instead of entering the center of the bin through a batcher or being uniformly distributed around the walls of the silo by a rotating spreader, the mix is being separated during its discharge from the transporting device into the bin. In some cases, the smaller aggregates are deposited in the middle of the bin and the bigger pieces are flung to one side. In other instances, all the mix is thrown to one side of the silo and the larger aggregate particles roll downhill to the opposite side of the silo.

If side-to-side segregation occurs in the mat, the direction of loading the haul trucks under the silo should be reversed for several truckloads of mix. Thus, if the trucks are usually filled when heading in an easterly direction under the silo, a few vehicles should be loaded when facing west. When these reversed truckloads are dumped into the paver, the pattern of segregation on one side of the lane should switch to the other side of the mat. This procedure will confirm that the segregation problem has its origin in the silo caused by the way the mix is being delivered into the bin by the drag slat conveyor, belt conveyor, or bucket elevator. Correction of the problem entails redirecting the flow of mix as it is deposited in the bin.

Truckload-to-Truckload. This type of segregation can be continuous--between every truckload, or discontinuous--occurring periodically in the mat at the end of some loads of mix. The causes of each pattern can be the same

* Segregation is considered in more detail in Reference 13.

or different. Asphalt concrete mixtures which contain a large amount of big aggregate will tend to segregate more readily than mixes which are made using a smaller top size material. Mixes which are gap or skip graded will separate more quickly than mixes which are uniformly graded from coarse to fine.

Mixes which are dribbled into the center of the silo in a continuous flow will form conical piles inside the bin, causing the larger particles to roll to the sides of the bin. As these pockets of coarse material are drawn down into the cone of the silo, they are funneled into a narrow space and are more concentrated. However, as long as the level of mix in the silo remains above the low bin indicator point, most of these particles are redistributed and segregation is not a major problem.

When the mix is drawn below the top of the cone on the silo, the larger pieces on the side roll into the center of the cone and are concentrated in one point. These pockets of large aggregate are then present as the mix is discharged into the haul truck. If the pattern of segregation is not constant on the roadway, one possible cause of the problem is that the plant operator is periodically, but not always, ignoring the low bin indicator point in the bin and delivering mix to the hauling vehicle even when the level of material in the silo is below the top of the cone. This situation is even more aggravated when the silo is run completely out of mix. If the pattern is consistent, the operator may be completely disregarding the low level warning point (it may be broken or turned off) and always loading the trucks with the level of mix in the silo beneath the top of the cone.

Even this cause of segregation can be reduced as a potential problem by loading the haul vehicle in at least three drops of mix from the silo to the truck. This lessens the distance that the large particles will roll in the bed, as explained above. Again it is pointed out that the segregation problem which is started inside the silo can be significantly enhanced by discharging the mix into the truck in only one drop from the surge bin. The larger aggregate pieces roll to the front of the bed and to the tailgate. The segregation that appears on the roadway, therefore, comes in part from the end of one load of material but also in part from the beginning of the next load.

Even though the mix is segregated in the hauling vehicle, the degree of segregation which appears in the asphalt concrete mat on the roadway can be reduced by a number of actions. First, the tailgate on the haul vehicle should not be pulled until the bed of the truck is raised enough to allow the mix in the bed to shift and slide against the tailgate. This permits a greater mass of material to be delivered at one time into the paver hopper, lessening the percentage of coarse pieces discharged into the hopper. Second, the hopper on the paver should be kept partially full between trucks. The mix should not be pulled out of the hopper to the point that the drag slats at the bottom of the hopper are visible. If the hopper is emptied between truckloads, the large aggregate particles will be deposited into the bottom of the hopper and will be pulled first through the paver and spread across the augers and then the mat. If some mix is left in the paver, the new load of material will be combined with this mix and the percentage of coarser particles in one spot in the mix reduced. Finally, the wings on the paver hopper should not be dumped between every truckload and should never be dumped into an empty hopper. The bigger aggregates tend to collect in the wings of the hopper. When the wings are dumped into the empty hopper, the segregation problem is enhanced.

Although mix segregation starts in the silo, it can be aggravated by the method in which the material is discharged into the haul truck and also by the way the asphalt concrete is delivered to the paver. Attention to the pattern of the segregation and to its continuity provides an indication as to the cause of the problem.

CHAPTER 9. AIR POLLUTION CONTROL

All drum mix plants have a small amount of dust carryout associated with their operation. Typically less dust becomes airborne inside a drum mixer than inside a conventional aggregate dryer on a batch type asphalt plant. It is still necessary, however, to provide control equipment to capture any particulate emissions which might otherwise be discharged from the drum mixer in order to meet the various federal and state air pollution codes.

Inside the drum, the aggregate particles are tumbled as the material is transported down the drum by the various types of flights. Some of these aggregates are very small in size--passing the number 50, 100, and 200 sieves (or 40, 80, and 200 sieves). Many of these very fine aggregates are initially free flowing. Others are attached by moisture to larger aggregate particles. As these latter particles move down the drum and are dried, some of these very fine aggregates drop off and become free flowing themselves. These very fine aggregates are then susceptible, because of their small size and light weight, to becoming entrapped in the exhaust gas airstream inside the drum. The small particles are thus carried into the plant ductwork and to the plant stack.

The airflow inside a drum mixer varies with a number of factors. The primary variable, however, is the diameter of the drum. The larger the drum diameter, the greater is the amount of air pulled through the drum, all other factors being constant. The size of the exhaust fan is also a consideration. The larger the fan, the more air pulled through the drum. Finally, the rotating speed of the fan is important--increasing the fan speed, within limits, increases the amount of airflow in the drum.

A minimum volume of air must move inside the drum mixer in order for the plant burner to operate properly. This volume is measured in CFM, or cubic feet per minute. For a small diameter drum mixer, the required air flow might be about 20,000 CFM. For a higher capacity plant, the needed airflow could range as great as 100,000 CFM. This is a great amount of air being pulled through the mixing unit each minute. The velocity of the air, in terms of feet per second, varies with the diameter of the drum and with the amount of aggregates inside the drum. The amount of dust carryout increases with the square of the drum gas velocity.

The more aggregates that exist inside the drum, the less the amount of particulate carryout. A complete veil of aggregates, across the whole top of the drum area, greatly reduces the amount of dust particles which can be captured in the burner exhaust gases. This is because the airborne dust collides with the larger aggregate particles as it is carried down the drum by the burner gases. The more aggregates in the drum, the less dust that is initially picked up in the airstream and the more fine particles which are knocked out of the air by coming in contact with the coarser aggregates.

The amount of dust carryout can also be significantly reduced in many cases by encapsulating the aggregates in the asphalt cement binder early in the heating-drying-heating cycle. In plants where the asphalt cement discharge point is well up toward the burner end of the drum, the coarse and fine aggregates are coated with the binder material while some of the very fine aggregates are still damp. Thus many of the fine particles, which might easily become airborne if they were drier and therefore lighter, can be covered with the asphalt cement before they become caught in the exhaust gases. Typically, with some minor exceptions, the amount of dust carryout increases as the asphalt cement injection line is positioned farther down the drum toward the discharge end of the drum.

The amount of dust carried into the plant air pollution control equipment is a function of many variables. The amount of very fine material in the incoming new aggregates is one factor. Another is the size, weight, and moisture content of the very fine aggregates. The same is true for the type and amount of the very fine particles present in the reclaimed aggregates if a recycled asphalt concrete mix is being manufactured. The operation of the plant is a major consideration, with the production rate (amount of material inside the drum) and location of the asphalt cement discharge pipe being significant variables. Within limits, therefore, the amount of dust carryout from a drum mix plant can vary widely, and can be altered with a change in the incoming aggregate characteristics and the production process.

DUST COLLECTORS

Since some dust particles will always escape from the asphalt concrete mix and be caught in the burner exhaust gas airstream, air pollution control equipment is needed on a drum mix asphalt plant. Three primary types of collectors can be employed, either singly or in combination with one another. These three types are: (a) dry collectors, (b) wet collectors, and (c) fabric filters.

In many air pollution control systems used on modern drum mix plants, a dry collector is used in conjunction with either a wet scrubber or a fabric filter (baghouse). The dry collector is sometimes referred to as the primary collector, although this is old terminology. The wet collector on the fabric filter is then called the secondary collector. The dry collector is used to remove the larger dust particles from the exhaust gas airstream. The wet scrubber or baghouse is then used to capture the very fine dust particles. In essence, the dry collector functions to decrease the dust loading on the "secondary" collector.

DRY COLLECTORS

Dry collectors, for the most part, are expansion chambers. The dust laden exhaust gases exit the rear of the drum mixer and are carried into the ductwork between the drum and the plant stack. For a given set of plant operating criteria (aggregate moisture content, production rate, drum slope, etc.), a given volume of air is pulled through the drum, from the burner end to the discharge end, by the exhaust fan (Figs 9.1 and 9.2). The velocity of that gas varies with the amount of area through which the air is moving. As the given volume of air, in terms of cubic feet per minute, is drawn out of the drum and into the metal ductwork, the velocity of the dust laden gas increases. This is due simply to the fact that the cross-sectional area of the ducts is considerably less than the area across the drum diameter. Thus the speed of gases increases in the restricted space for a given volume of air.

A dry collector is employed to significantly and quickly reduce the velocity of the burner gases after they exit the ductwork. It is essentially an expansion chamber with a greater cross-sectional area than the ductwork.

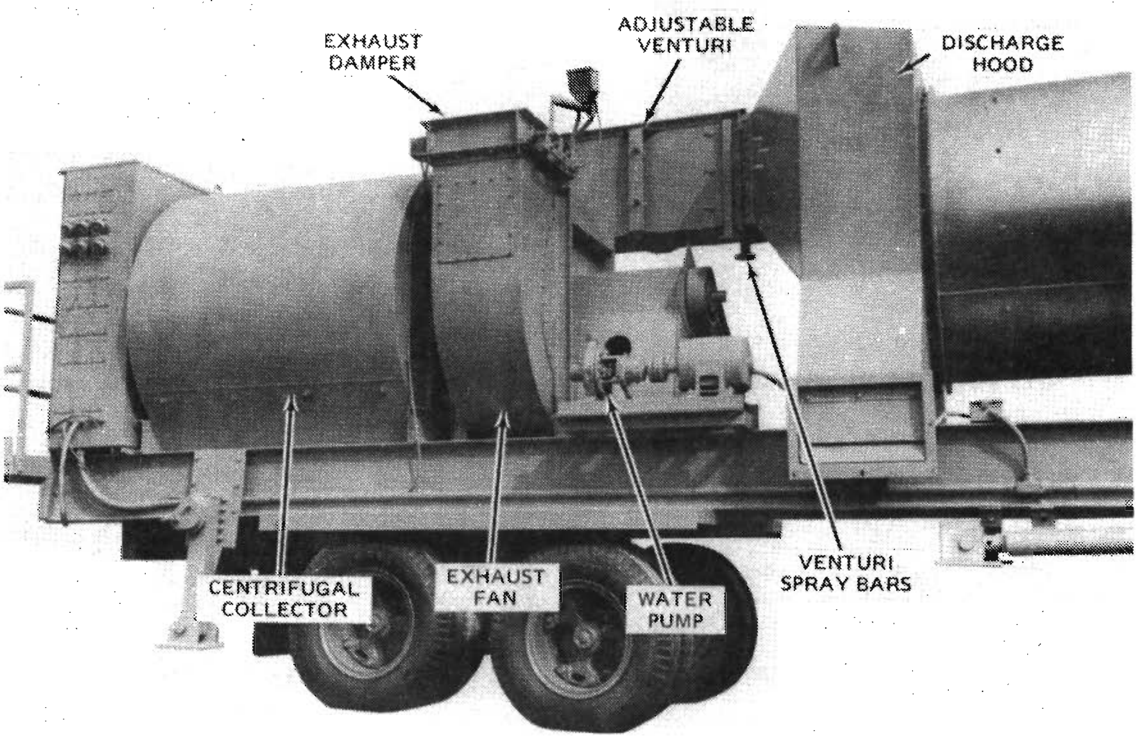

Figure 9.1. Exhaust fan or wet collector system (Ref 25)

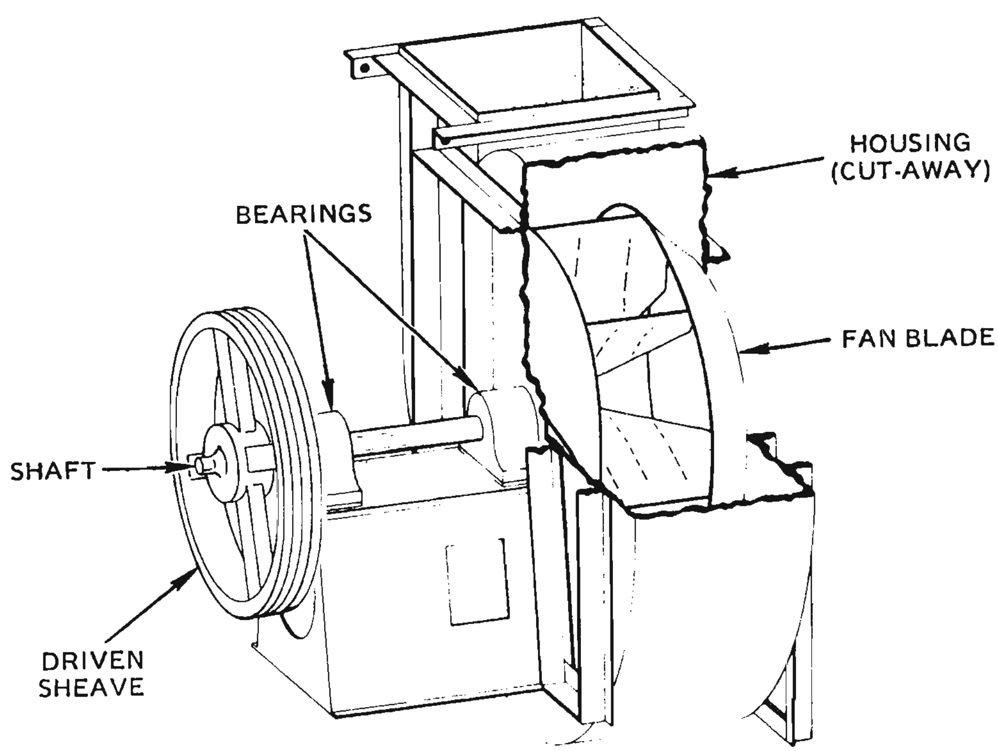

Figure 9.2. Cut-away view of exhaust fan assembly (Ref 25)

The chamber, also sometimes called a knockout box, allows the speed of the gases to decrease, causing in turn the largest and heaviest of the dust particles to fall out of the airstream. The size and amount of the dust which leaves the exhaust gases depends on the relative reduction in velocity of the gas as it enters and passes through the dry collector.

The larger, heavier dust particles slow down more quickly than do the smaller, lighter pieces. As these particles leave the airstream, they fall to the bottom of the dry collector. The bottom portion of the collector chamber is typically sloped to allow the material to be concentrated at a central point or along a trough. The dust particles which are caught can then either be wasted or returned to the drum mix plant.

Dry collectors can have an efficiency of 70 to 90 percent. This means that a dry collector can be used to remove a significant portion, but not all, of the dust found in the exhaust gases. When used in front of a wet collector, the dry collector reduces the amount of dust entering the wet scrubber. This decreases the volume of the sludge produced in the secondary collector. When used in conjunction with a fabric filter, the dry collector makes the baghouse more efficient by eliminating a major portion of the dust which would otherwise enter the equipment. In this case, the dry collector, or knockout box, is often built into the front of the housing for the fabric filter or bags.

WET COLLECTORS

Wet collectors work on the principle of wetting the dust particles which are entrapped in the burner exhaust gases (Fig 9.3). The water droplets hit the dust specks, causing them to fall out of the exhaust gas air stream. The combination of water and dust is then removed from the collector in the form of a watery sludge.

The dust laden burner gases are drawn from the drum mixer by the exhaust fan. After passing through the dry collector, if any, the gases are pulled into the wet collector ductwork. At one point, the gases pass through a narrowed opening, or venturi (Fig 9.4). As the air flow is concentrated in a small area, it is sprayed with water from multiple nozzles. The water spray

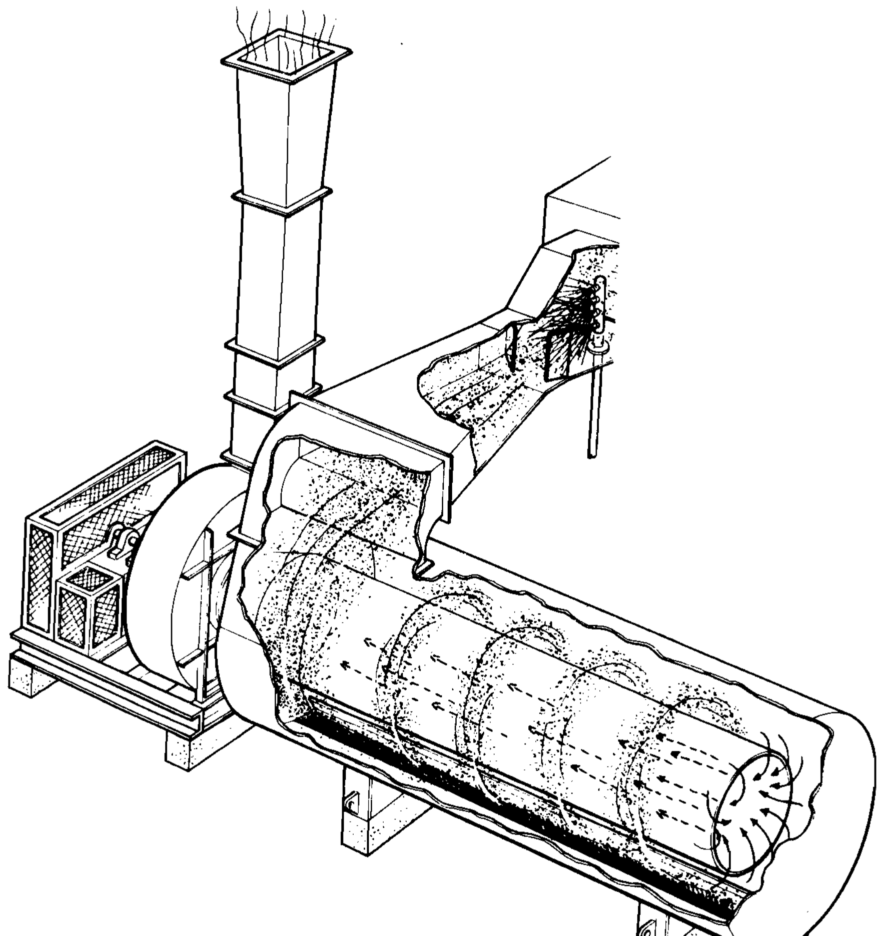

Figure 9.3 Wet collector (Ref 35)

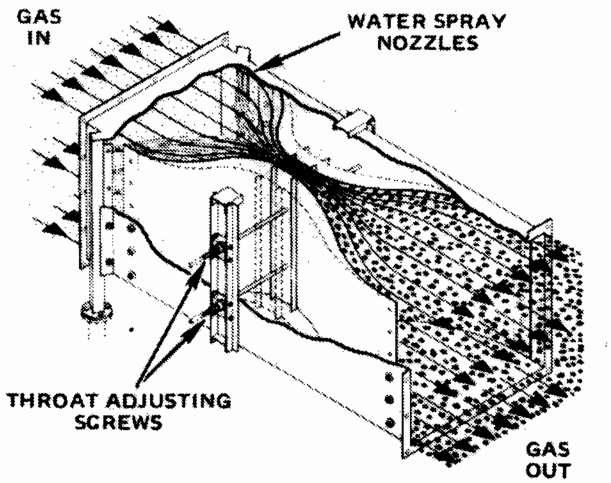

Figure 9.4. Venturi throat (Ref 25)

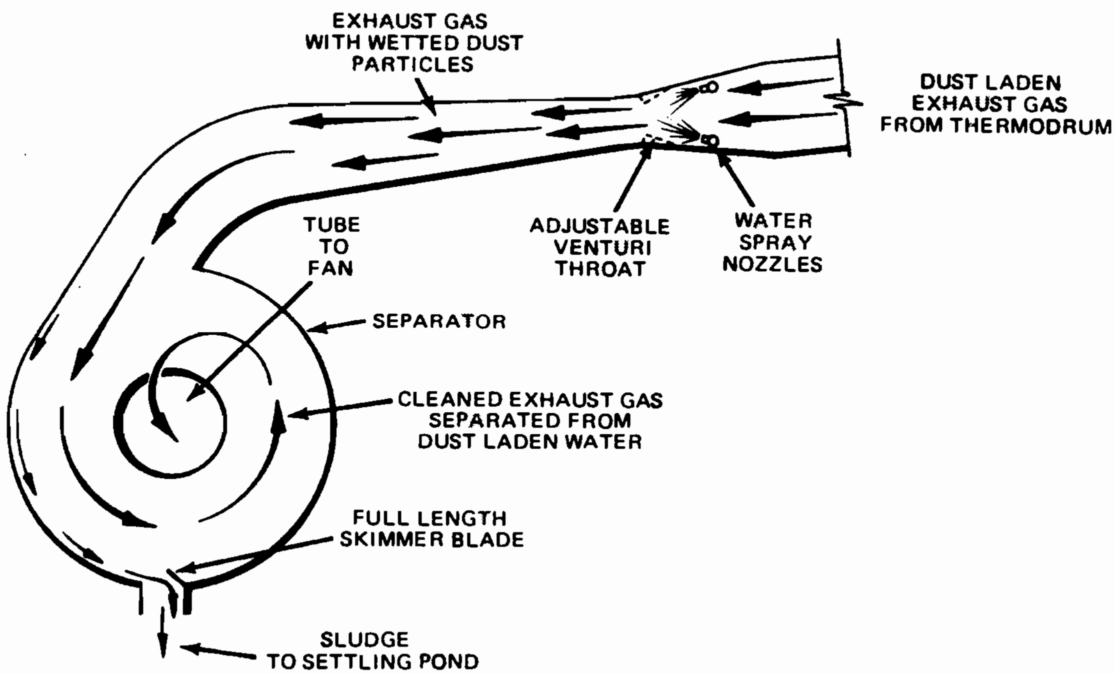

Figure 9.5. Circular motion of exhaust gases on a wet collector (Ref 35)

wets the dust particles. The exhaust gas and wet dust then move into the separator section of the collector.

In this part, the exhaust gases are sent into a circular motion around the circumference of the unit (Fig 9.5). The wetted dust particles, which are relatively heavy, are removed from the exhaust gases by centrifugal force. The particles fall into the bottom of the collector. The clean air continues to swirl around the collector until it reaches the end of the collector. The cleansed exhaust gases are then passed to the plant stack and to the atmosphere.

A wet scrubber system is usually 90 to 97 percent efficient in removing dust particles from the airstream. The efficiency rating is a function of the size and amount of the dust in the exhaust gases. It is also affected by the volume of water used to spray the particles. If all the nozzles in the scrubber are open and functioning, the wet collector will remove almost all of the dust particles drawn into it. If, however, some of the water spray nozzles are plugged, the efficiency of the wet collector will be reduced.

Another variable which affects the scrubber operation is the cleanliness of the water being used in the system. If the water being sprayed is free from sediment, the wet scrubber will function better than if the spray water is dirty. The amount of dirt in the water depends on the settling pond and water recirculation system used on the drum mix plant.

A settling pond is used with most wet collectors in order to decrease the volume of water needed to operate the wet scrubber. The water and dust, in the form of a sludge, is sent from the bottom of the collector, through a pipe, to the pond. Typically the settling pond is divided into several sections, with the dirty water entering the first section continually. Primary separation of the dust from the water occurs in this part of the pond. The heaviest dust particles settle to the bottom of the pond. The cleaner water is drawn off the top of this section through an outlet on the opposite side of the area from the wet collector inlet pipe. This water continues to lose its dust content, through settlement, as the water passes through one or more additional sections of the pond. In each section the dirty water enters one side and the cleaner water is drawn off from the far side. The efficiency of the settlement process is directly related to the size of the settling pond--the bigger and deeper the pond, the more water contained in the pond, and the more time available for the dust to settle out of the sludge before the water is circulated back to the scrubber unit.

Settling ponds fill up with dust. As the pond gets more shallow, the volume of water that can be contained in the pond decreases. This, in turn, reduces the time the water can remain in the pond prior to being recirculated. When a pond becomes too shallow, dirty water will be sent back to the wet collector. Thus it is necessary to periodically clean the sediment from the pond bottom in order to maintain the cleanliness of the scrubber water and the efficiency of the collector. In addition, ponds lose water over time, both through evaporation to the air and through leaks in the piping system. This reduction in the amount of water being used in the system should be corrected periodically in order to maintain the efficiency of the scrubber.

It is obvious that the dust particles carried into the wet collector are lost to the asphalt concrete mix. The material which ends up on the settling pond floor must be wasted. Thus the gradation of the mix produced in the plant is not the same as the gradation of the incoming new and/or reclaimed aggregates. In some cases, where the amount of dust carryout is not great, the change in gradation will be minimal. If there is a large volume of dust captured in the exhaust gas airstream, a significant change can occur in the mix gradation, primarily in the very fine aggregate sizes.

FABRIC FILTERS

The fabric filter, or bag collector, operates on a simple method. Dust laden air from the drum mixer is pulled through a fabric (Fig 9.6). The small openings in the fabric allow the exhaust gases to pass through but capture the dust particles. The dust is removed from the fabric in one of several ways and falls to the bottom of the baghouse. There it is collected, ready to be wasted or returned to the drum mixer.

The dirty exhaust gases coming from the drum mixer are pulled into the ductwork and into the baghouse by the fan (Fig 9.7). In many cases, a primary dry collector (expansion chamber) may be used in front of the first sets of filter bags. In this expansion chamber, the heaviest and largest

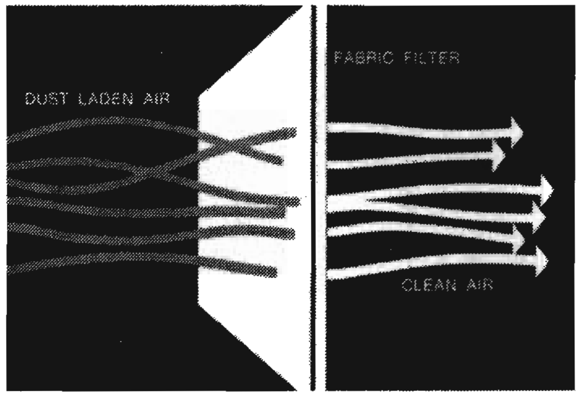

Figure 9.6. Fabric filter (Ref 36)

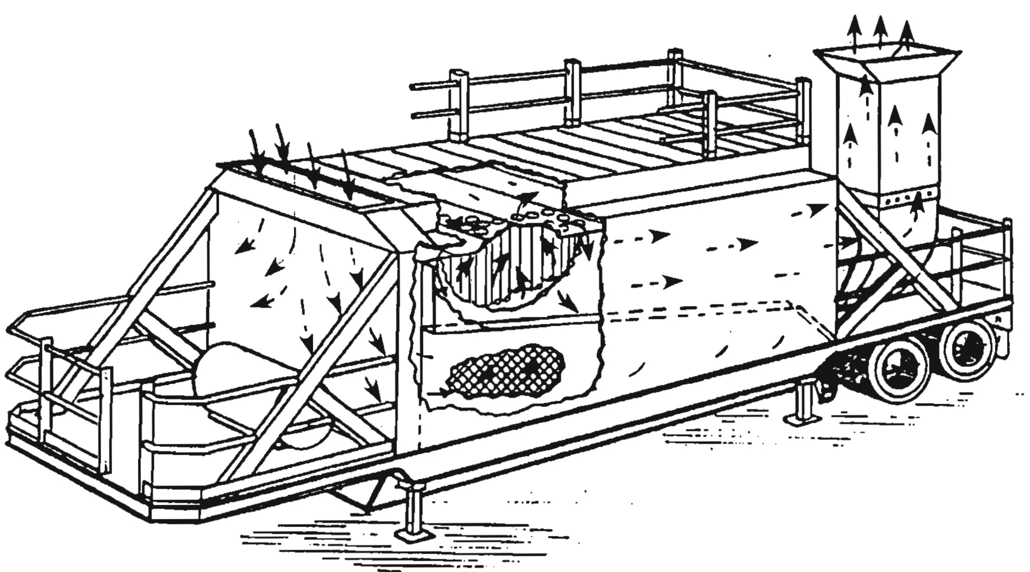

Figure 9.7. Baghouse (Ref 25)

dust particles drop out of the airstream as the gas velocity is decreased. In addition, the knockout box area, if used, acts as a cooler, reducing the temperature of the gases to some degree.

The material used in the filter cloth is usually a high temperature resistant nylon. This material is able to withstand not only gas temperatures up to 450°F, but also is resistant to high dust loadings, high humidity, and multiple bending and flexing. The fabric is dense enough to catch the dust particles while still permitting the air to pass through. The nylon material will disintegrate, or even burn, however, if subjected to exhaust gas temperatures above 450°F.

The filter fabric is formed around a circular metal framework or cage. This tube, or bag, is closed on the bottom but open on the top (Fig 9.8). In order to remove the dust from the plant, multiple bags are employed. These are arranged in multiple rows inside the baghouse. Depending on the volume of air being cleaned, a fabric filter unit can contain from 200 to 800 separate bags (Fig 9.9). The number of bags used also depends on the diameter and length of each individual bag. The filter area of each bag is calculated from the amount of fabric around each bag. In general, one square foot of filter cloth area is needed to clean from 5 to 7 cubic feet per minute (CFM) of exhaust gas. This air to cloth ratio, 5 to 7 CFM per square foot of filter area, can vary with a number of operating conditions. A typical air to filter cloth ratio, however, is 6:1. The number of bags needed in the baghouse (for a given diameter and length of bag) is determined by taking the air to cloth ratio value (CFM per square foot of filter area) divided into the total CFM of the burner exhaust gases.

There are two sections to any baghouse--the dirty air side and the clean air side (Fig 9.10). The exhaust fan pulls the dirty air from outside of the circular fabric filter through the material. The dust particles are caught on the outside surface of the bag. The exhaust gases, relieved of their dust, are carried out the top of the bag and to the stack. The dust particles, stopped on the outside of the bag, build up with time and form a dust cake or coating on each bag. This coating is important to the efficiency of the baghouse. If the bags are clean, only the coarser dust particles will be captured and the finer specks will pass through the fabric.

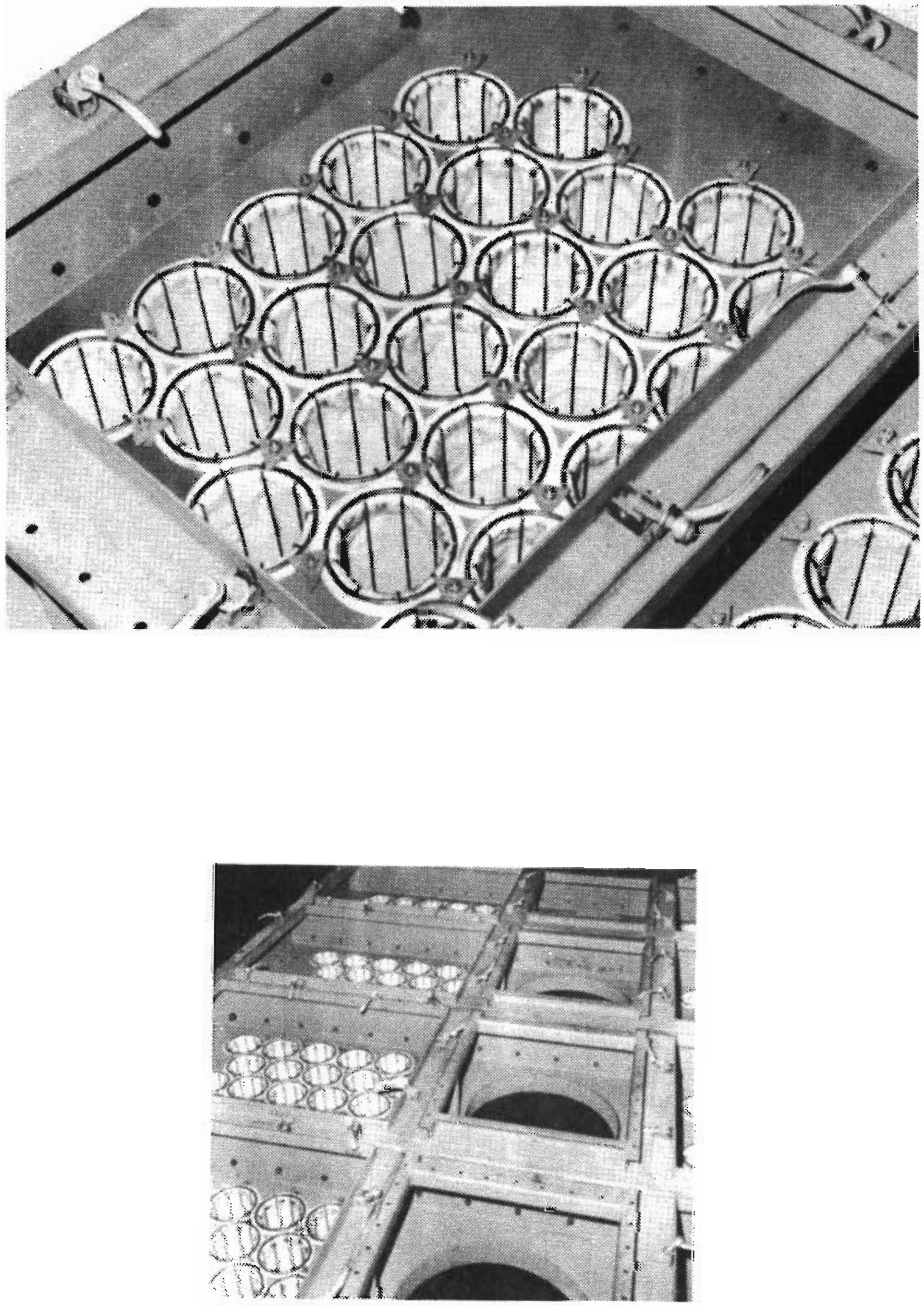

Figure 9.8. Bags and wire cages (Ref 37)

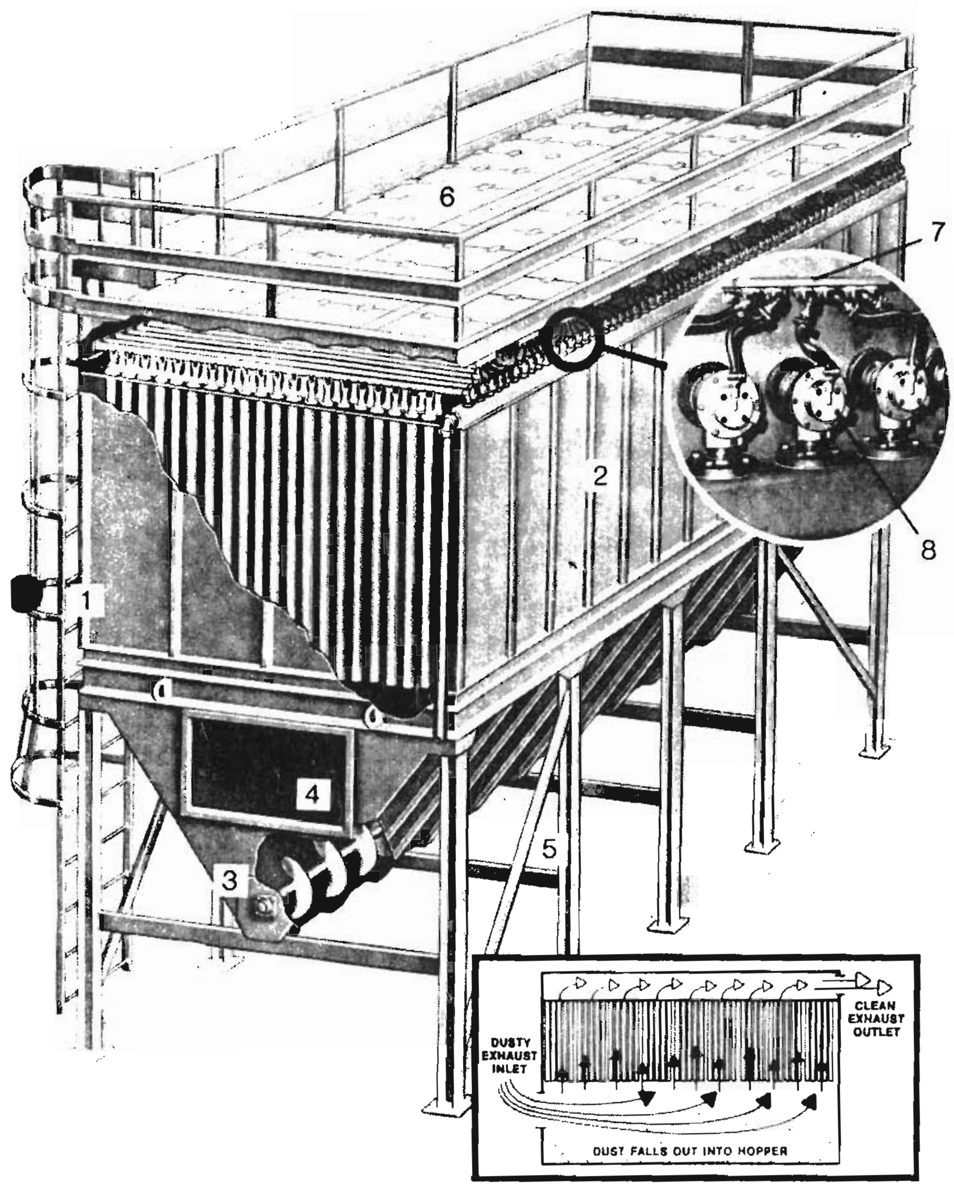

Figure 9.9. Typical baghouse (Ref 37)

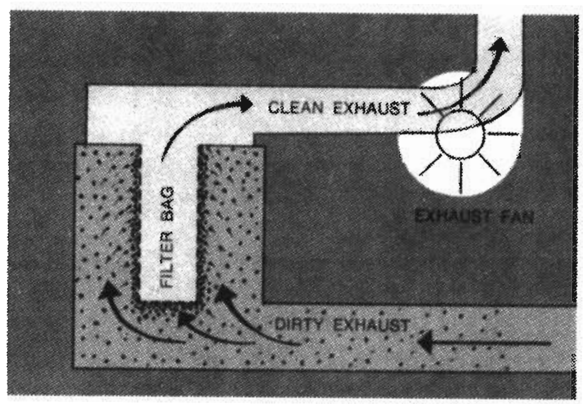

Figure 9.10. Dirty and clean side of baghouse (Ref 36)

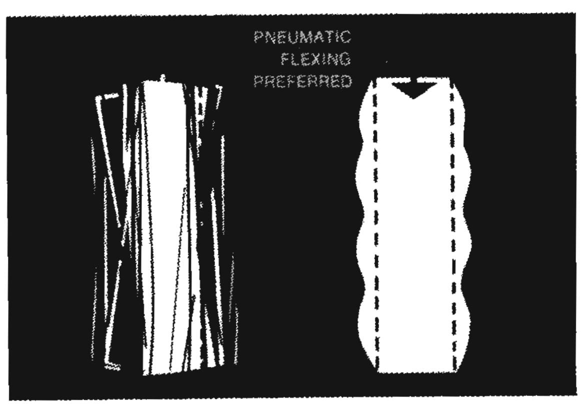

Figure 9.11. Method of cleaning bags (Ref 36)

If the bags are completely blinded, however, the air will be unable to go through the cake and the baghouse will stop functioning. Thus, for maximum efficiency, the dust cake must be periodically removed from the filter fabric surface. This is accomplished by cleaning the bags.

The cleaning cycle depends on the amount of dust loading in the exhaust gases and on the size of the dust particles. Bags are usually cleaned in groups so that some bags are heavily coated with dust while some are only partially covered and some are being cleaned. The cleaning occurs by flexing or shaking the bags, backflushing them with a pulse of clean air, or a combination of both procedures (Fig 9.11). In most cases, the reverse air pulse is used. The dust cake on the bag is blown free as the jet of air flexes the bag from the inside. The dust particles then fall to the bottom of the baghouse. In general, the cleaning cycle occurs for a few seconds every minute or so of air flow time.

A baghouse can remove up to 99.9 percent of the dust particles in the exhaust gas airstream. This efficiency, however, is dependent on several factors. The flow of the air into and through the bags is restricted by the filter fabric itself and by the dust coating on the bags. This degree of resistance is measured as a pressure drop between the dirty side and the clean side of the bags. The pressure drop, given in inches of water, is typically between 2 and 6 inches (Fig 9.12). A low pressure drop, 1 to 2 inches, indicates that the bags are quite clean. This means that some very fine dust particles are probably traveling through the filter cloth. A high pressure drop (over 6 inches), on the other hand, shows that the dust buildup on the bags is excessive and that the air cannot be effectively pulled through the drum and the baghouse. This can result in a substantial reduction in the capacity of the drum mixer.

The efficiency of the baghouse can also be decreased if the dust coating becomes a mud coating, thereby blinding the bags. This problem occurs when the temperature of exhaust gases entering the baghouse is below the dew point--the temperature to which air must be cooled for dew (condensed moisture) to form. The moisture, combined with the dust in the air, forms a mud on the surface of the bag. This heavy, wet coating cannot be easily removed during the bag cleaning cycle. If this happens, the pressure drop

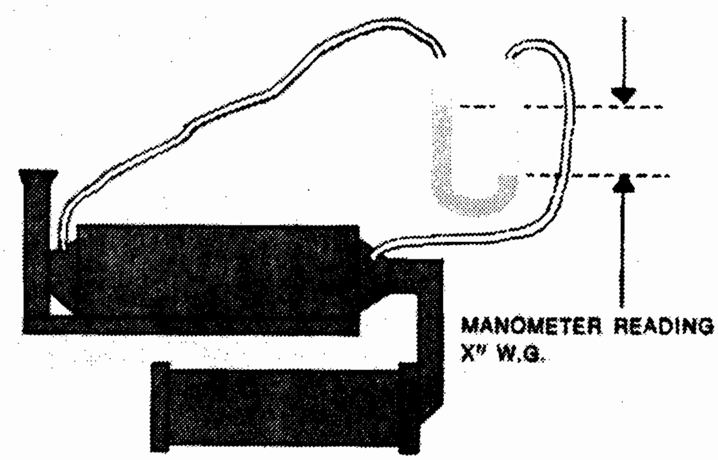

Figure 9.12. Pressure drop across bags (Ref 36)

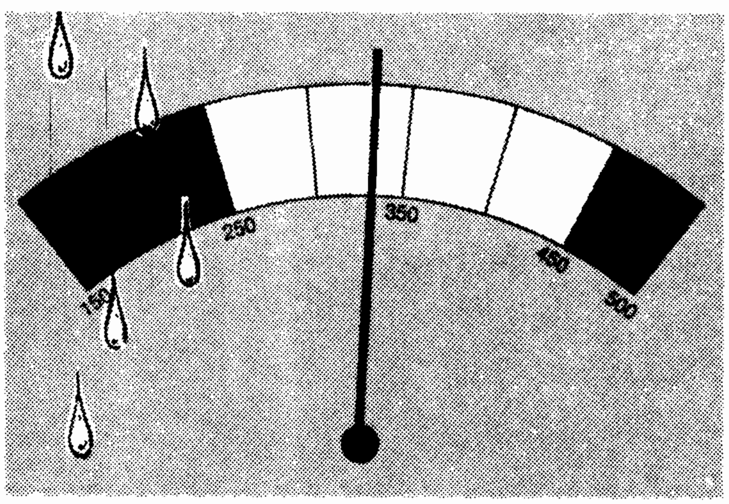

Figure 9.13. Temperature range for baghouse operations (Ref 36)

across the bags increases significantly, reducing the efficiency of the baghouse and even choking off the burner flame in extreme cases.

To prevent mud from collecting on the bags, the fabric filter system must be preheated before mix production is commenced each day. This is accomplished by operating the plant burner in the low fire position for a period of time, with no aggregate in the drum. The heated air, pulled into the dust collector by the exhaust fan, will in turn raise the temperature inside the baghouse above 200°F. This preheating operation will reduce the possibility of water from the aggregates (turned into water vapor inside the drum during the drying process) condensing on the fabric filter surface.

The nylon bags, when subjected to temperatures above 450°F, can char, disintegrate, and burn. The baghouse thus should be protected from high temperatures by automatic shutdown devices (Fig 9.13). In this regard, one or more temperature sensors are usually located upstream of the baghouse, in the ductwork at the end of the drum mixer. The sensor is typically set at a temperature of 400°F. If the temperature of the exhaust gases entering the ductwork exceeds this value, the sensor immediately shuts off the burner by stopping the fuel flow. This prevents damage to the bags and the housing.

The dust collected in a fabric filter is deposited at the bottom of the baghouse. The sloping sides of the housing near the bottom funnel the dust particles to collection troughs. Screw conveyors, located in the troughs, remove the collected dust from the baghouse. The material is carried through an air lock system to a transfer point. From here the material is either wasted or fed back into the drum mix plant.

The gradation of the asphalt concrete mixture produced in the drum mix plant will be different depending on whether or not the baghouse fines are returned to the plant. If the collected dust is wasted, the mix will be somewhat coarser than if the material is fed back into the drum. If the dust is returned to the plant, the mix gradation will more nearly equal the gradation of the incoming new and/or reclaimed aggregates. It is very important, however, for the baghouse fines to be delivered to the drum mixer continuously and uniformly rather than in slugs. This is usually accomplished in one of two ways--either by pneumatically conveying the dust particles directly from the baghouse to the rear of the drum or by first placing the baghouse material in a fines storage silo and then metering the material back into the drum through the fines feed system.

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