ASTECC encourages its engineers and executives to author articles that will be of value to members of the hot mix asphalt (HMA) industry. The company also sponsors independent research when appropriate and has coordinated joint authorship between industry competitors. Information is disbursed to any interested party in the form of technical papers. The purpose of the technical papers is to make information available within the HMA industry in order to contribute to the continued improvement process that will benefit the industry.
INTRODUCTION

The hot mix asphalt industry first faced particulate emissions codes in the early seventies. The initial requirements of 0.04 grain/dscf and maximum opacity of 20 percent, although routine now, were very difficult to meet at the time. Baghouses became the industry’s most effective answer. Today, after more than 25 years of refinement, baghouses are capable of much better performance than the 0.04 grain/dscf standard. With the Clean Air Act Amendment of 1990 came a shift of emphasis, on the part of the Environmental Protection Agency, from regulation of emissions to regulation of ambient air quality. States are now responsible for meeting the federally established ambient air quality standards and must often set emission limits lower than 0.04 grain/dscf in order to comply. An area which is out of compliance with ambient air quality standards is known as a non-attainment area. Within a non-attainment area, emission limits may be set at 0.02 grain/dscf or less. Baghouses now routinely meet these requirements without any special provisions. PM-10 emission control is another challenge baghouses are handling effectively. PM-10 refers to those particles of less than 10 microns diameter. They are of particular concern because the human respiratory system cannot filter them out. When large amounts of PM-10 are present in the exhaust gases a baghouse has to clean, special attention must be given to ensure adequate performance.

In most cases, baghouses are the equipment of choice for particulate emissions control of hot mix asphalt plants (Figure 1). Baghouses are certainly not the only solution to the particulate emissions problem but are usually more cost effective and operationally friendly than the other options. However, to utilize baghouses as effectively as possible, operators need to be familiar with their specific attributes and how to use those attributes to maximum advantage.

One reason baghouses have become the air cleaning system of choice in the HMA industry is that, while providing compliance with pollution codes, they provide economic advantages over scrubbers. By returning dust to the mix instead of wasting it, as scrubbers do, baghouses better utilize the aggregate. Baghouses also require less horsepower than venturi scrubbers. The flexibility of not being tied to a source of water and a settling pond is a further significant advantage because of the resulting savings in trucking costs and increased portability of the facility.

The limitations of baghouses are seen primarily in terms of operating constraints. For instance, aramid fiber bags such as Nomex are limited to a maximum service temperature of 400° F. While scrubbers have no such limitations, high exhaust temperatures are not consistent with efficient plant operation anyway. Baghouses generally should be operated above 220° F to avoid condensation, another potential problem. Moisture condensation can cause accumulation of mud on bags and baghouse walls. This results in blinded bags and clogged dust removal equip-
ment. (The term “blinded” refers to a condition of reduced bag permeability. Bags with permeability of 2 cfm or less are considered blinded.) Contamination of bags by condensed hydrocarbon vapors can also cause blinding of the bags. Fuel vapors or, in parallel flow systems, asphalt vapors can be the source of such problems. Hydrocarbon contamination can also cause a fire in the baghouse with the subsequent loss of bags and baghouse. Baghouses are not useful for removing gaseous pollutants from the plant exhaust.

TECHNOLOGY

A typical baghouse for an HMA operation consists of a fabric filter system enclosed by a steel structure (Figure 1). The basic technology of a baghouse is very simple. The exhaust stream passes through the fabric filter before entering the atmosphere. Series of bags make up the fabric filter (Figure 2). The exhaust stream enters the bags through their felt walls. Dust does not pass through the felt walls and accumulates on the outside of the bags. As the dust accumulation increases, periodic cleaning of the bags becomes necessary. (Although there are several types of cleaning systems, the pulse jet system is most common in the HMA industry.) The dust accumulation on the bags is referred to as the “dust cake” and is of critical importance in the performance of the baghouse (Figure 3). The dust cake is actually the working filter, since the textile felt of the bags, without a dust cake, can only collect relatively large particles. A baghouse with a good dust cake can collect particles as small as 1.0 micron with 99.99% overall efficiency and can even collect some submicron particles.

Relatively large particles, usually about 200 mesh max., collect at the surface of the felt and stack up there. Smaller particles pass through the felt until this happens. As particles stack up at the outer surface of the felt, the
effective opening size decreases and smaller and smaller particles are captured. Even though the dust cake is normally less that 1/16 in. in thickness, this represents a lot of stacking up of particles. It takes 14.5 particles of the 200 mesh size to stack up to 1/16 in. But, it takes an average of 1,587.5 particles of the 1 micron size to accumulate to a 1/16 in. cake thickness. Since the dust cake is always composed of a mixture of particle sizes, it is obvious that there are many layers of particles in the cake (smaller particles being stacked upon larger ones). Baghouse bags without a proper dust cake will pass the smaller particles and, therefore, fail to meet the requirements of emission regulations (Figure 4).

The bags are supported by wire cages, inserted into each bag from the top, that prevent the bags from collapsing under pressure (Figure 5). The open wire construction of the cages allows air to pass through easily while providing internal support to the bags. The bag and cage assembly is supported by a tube sheet (Figure 6). The tube sheet separates the dirty and clean air plenums so that the only way for air to enter the clean air plenum is through the bags.

Particles much less than one micron in diameter are usually not effectively collected by the filter media used in HMA operations. Therefore, smoke, which is composed of particles on the order of 0.3 microns in diameter, will normally not be collected in a baghouse (Figure 7).

**DESIGN**

HMA plant operating and maintenance personnel do not have to be baghouse designers. However, it can be very helpful to understand some of the principles used in baghouse design. Many factors must be considered by design engineers, and an understanding of two of these may be particularly helpful to the contractor's personnel. These two factors are air...
To cloth ratio and can velocity. Air to cloth ratio is gas velocity through the bag fabric. Can velocity is the upward gas velocity between bags measured at the bottom of the bags.

Although air to cloth ratio and can velocity are certainly related, addressing them separately in the design process is simple and effective. Depending primarily upon dust particle size, a good choice of air to cloth ratio is usually in the range of 4 : 1 to 6 : 1 (Figure 8). A good standard air to cloth ratio for HMA plants is 5.5 : 1. With typical aggregate dusts, 5.5 : 1 (5.5 fpm through one square foot of felt) rarely results in stack particulate emissions greater than 0.02 grains/dscf and often results in emission levels below 0.01 grains/dscf. The national standard for particulate emissions is 0.04 grains/dscf.

A very fine dust, for example a dust with more than 80% of its particles by count being smaller than one micron, would require a lower air to cloth ratio than 5.5 : 1. As a gentle breeze will barely move light dust but a tornado can move boulders, high baghouse gas velocity can blow particles through the felt that would not pass through at lower gas velocities. This is why the standard air to cloth ratio for soil remediation plants, which usually have very fine baghouse dust, should be a nominal 4 : 1.

Can velocity must also be chosen with the characteristics of the dust in mind (Figure 9). Most materials used in the HMA industry can be handled adequately in baghouses with can velocities in the 375 fpm range. However, it is not unusual to encounter a material that has too many sub-micron or low density particles to work well in this velocity range. When can velocity is too high for the particular dust, the plant’s capacity will be limited by baghouse pressure drop due to the inability of the baghouse cleaning system to clean properly. Dust discharged from the bags is impeded in its fall into the hopper by the force of the upward flow of exhaust gases.
The energy required to support the suspended dust must be provided by the exhaust fan. This causes the plant to appear to “run out of air.” When dust is suspended in this manner, naturally, the lighter and smaller particles are most readily suspended. These are also the particles most likely to penetrate the felt. That, combined with the resulting high suction, can cause serious baghouse problems. High can velocity will ultimately cause dust to penetrate all the way through the felt (a condition known as migration) and results in visible stack emissions (Figures 10 and 11). HMA baghouses should be designed for can velocities between 265 fpm and 285 fpm. Can velocities in that range will result in good performance even when difficult situations are encountered (Figure 12).

The baghouse must always be designed with the system in mind. It should never be the limiting piece of equipment in the system. Since something obviously must reach its capacity first, it is best that this limiting piece of equipment be the exhaust fan. If this is not the case, it will be possible to pull more exhaust volume through the baghouse than it is able to handle. When this happens, dust will migrate through the bags, eventually damaging them. This is an expensive way to determine the limit of the plant’s capacity. Even though it is often possible to get more production capacity by increasing exhaust fan speed, baghouse problems may crop up soon after such a speed change. Baghouse capacity must be considered before increasing fan speed.

MATERIALS

Bag material is the primary consideration in baghouse material selection. The “standard” filtration media in the industry is aramid fiber felt (Figure 13). Nomex, a trade name of DuPont which has become synonymous with aramid, is one of the fibers used in this application but certainly not the only one. Many materials are avail-
able for the manufacture of bags for baghouses. A few of these materials are: polyester, fiberglass, Ryton, and P-84. These and others are excellent materials; but, all things considered, aramid has been found to be the most suitable material for HMA plants. Several factors have gone into making this determination. Among them are:

- Filtration performance
- Chemical resistance
- Tensile strength
- Durability
- Cost
- Temperature resistance
- Combustibility

The commonly used felt in the industry is 14 oz. aramid felt made of fibers of 2 denier size. The 14 oz. specification denotes the weight of one square yard of the fabric. The term “denier” relates to fiber diameter but more correctly describes how many grams of material it takes to make a certain length of the fiber. Even so, there are major differences in bags. The most critical difference is density. Felt density is achieved by having enough fiber material to start with and then by sufficient needling. Calendering or heat setting is sometimes used to achieve density. These methods involve pressing the felt between hot surfaces to make it dense. However, because nothing holds the fibers together, they will eventually fluff out again. Nominal 14 oz. aramid may vary down to as little as 10 oz. in some areas. It is impossible to achieve sufficient density with so little fiber. To assure sufficient density, felt specifications should assure that weights will be a minimum of 14 oz. at any given location on the bag.

The term “scrim” refers to a woven fabric layer sandwiched between layers of felt in the cloth used to make bags (Figure 14). For 14 oz. bags, the scrim should weigh 2 oz. per square yard (+/- 0.2 oz.). The scrim is included in the bags purely for support. It contributes nothing to filtration. Therefore, extra scrim means less felt for filtration in a bag of a given total weight. Scrimless bags may soon be common in the HMA industry. They rely upon interlocking directional layers of fiber in the felt to make it self-supporting. Theoretically, scrimless bags weighing only 12 oz. per square yard would provide filtration performance equivalent to the 14 oz. scrim supported bags.
P-84 is usually “overkill” for HMA applications. However, it is often standard for soil remediation plants and is sometimes used in hot mix plants to solve emission problems or to address particularly challenging applications. P-84 is superior to aramid with respect to filtration performance and is suitable for service temperature up to 500°F as compared to 400°F for aramid, but its cost is about 1-1/2 times that of aramid. Without this cost differential, P-84 would be the fiber of choice for HMA plants. This is why there are such products as P-84 “capped” bags, which take advantage of the filtration capability of P-84 and the cost advantage of aramid by making a composite of the two. The superior filtration performance of P-84 comes from the shape of the fibers (Figure 15). Unlike aramid, which has a more or less round cross section, P-84 is very irregular in shape. This characteristic provides places for fine particles to become caught.

More and better materials are becoming available regularly. They are not being used much in hot mix plants at this time because of cost and the fact that present regulations can be easily met with 2 denier aramid felt. Much work is being done now with very fine fibers called “micro-deniers” (Figure 16). This is an area to watch as work progresses.

Bag shapes, other than the traditional cylindrical shape, are often tried, some with a fair amount of success (Figure 17). Alternate shapes are generally experimented with in an effort to get more cloth into service in a given volume. This is the purpose of pleated bags. Special bag shapes reduce air to cloth ratio for a given number of bags. However, this will be of no benefit if the baghouse performance is limited by can velocity, as is often the case. One should always keep in mind that there is no bag shape that permits the violation of the fundamental principles of baghouse design. Control of air to cloth ratio and can velocity are necessary with all bag shapes.
Little consideration is usually given to cage material. Cages are commonly made of galvanized carbon steel wire (Figure 5). Basically, all a cage has to do is keep the bag from collapsing under pressure. Any wire cage that fulfills that function is usually acceptable. Sometimes, where special materials dictate, a 20-wire cage may be necessary to limit flexing and associated fatigue failure of the felt. Stainless steel wire is used where chemical attack is anticipated.

The plate and structural members used in HMA plant baghouses are almost always made of structural type carbon steel. An internal coating of epoxy paint is used to provide corrosion resistance. This can be important since fuel oils, even no. 2, often contain sulfur. The sulfur in the fuel can cause sulfuric acid formation in the baghouse.

The basic geometry or shape of the baghouse is straightforward: it is a box. Beyond that, specific dimensions are determined based on performance factors such as gas velocities, dust removal requirements, bag lengths and quantities, and allowable shipping dimensions and weights (Figure 18).

**PRE-CLEANERS**

Pre-cleaners come in several different designs and are important to the performance of the baghouse and entire plant. The total dust load exiting the dryer of the typical HMA plant is a lot for a baghouse to handle alone. Not only is the quantity of dust a problem, but also the size distribution. There are usually a lot of relatively large particles in the exhaust stream before it enters a pre-cleaner. These particles tend to abrade the bags and cause premature failure. Also, large particles tend to form a porous dust cake (Figure 19). Since the dust cake is the filter for very small particles, it is clear that the absence of a pre-cleaner can cripple the filtration performance of the baghouse.
A cyclone is the most commonly used pre-cleaning device, with a knock-out box being the second most common (Figure 20). A few plants are equipped with multi-clones.

A cyclone, as the name suggests, is configured to produce a cyclonic air flow pattern inside. As the air spirals through the cyclone, the centrifugal force causes the dust, which is heavier than the exhaust gases, to move to the outside of the flow toward the plate walls. The gas flow is then turned inward away from the walls leaving the dust to slide down into the cone or hopper. At a particular flow rate and temperature, a cyclone can collect everything larger than a certain size particle and practically no particles smaller than that particular size. This sharp division is called the “cut,” and enables a design engineer to accurately predict the efficiency of a cyclone under specific conditions. Cyclones perform equally well in vertical and horizontal orientations. Horizontal cyclones are usually preferable in HMA applications because they work well, are compact, require minimal support and elevation, and can be easily accessed for inspection or maintenance (Figures 21 and 22).

A knock-out box is simply an enlarged section of ductwork with a hopper underneath (Figure 23). A knock-out box slows the exhaust gas stream and allows some of the dust to settle. However, it is difficult to get even a sufficiently large knock-out box to be really functional. The knock-out box is a pretty turbulent place. One way to improve its effectiveness is to make it a two pass device with gases entering and exiting at the top, making a U-turn at the bottom. The inertial effect of the U-turn aids the settling. In any case, the velocity in the knock-out box has to be reduced to the range of 300 to 500 fpm. This means that it will be a relatively large device.
A certain amount of pre-cleaning occurs in the mixing zone of parallel flow drum mixers (Figure 24). However, the pre-cleaning that occurs there, by capture of dust in the exposed asphalt, is often less than adequate. Even parallel flow drum mixers, in general, need a separate pre-cleaning device.

Pre-cleaning can also be done too well (Figure 25). A high-efficiency cyclone or multicone can collect the larger particles needed in the baghouse to serve as the foundation of the dust cake. The result is the same as with a porous cake caused by no pre-cleaning. The very small particles are not collected. The best pre-cleaning device for a baghouse is a cyclone of moderate efficiency. Its collection efficiency should be in the range of 85% to 90%, at the rated capacity of the exhaust system. The collection efficiency of a cyclone is variable depending upon the conditions under which it operates. Cyclones can be designed for a particular efficiency only under one specific set of operating conditions. Cyclone efficiency changes on any cyclone in service as the exhaust volume changes. For all practical purposes, the harder a cyclone is pushed, in terms of exhaust volume, the more efficient it gets. Exactly the opposite is true of a knock-out box. When you need a knock-out box most is precisely the time when it does the least for you.

It is important to remember that any pre-cleaning device will add a pressure drop to the exhaust system. Because it does more work and is therefore more effective, a cyclone will cause a larger pressure drop than other pre-cleaners. The drop across the cyclone is usually about 3 to 4 inches water column. For this reason, you may not be able to just add a cyclone to an existing system without doing anything else and get the results you are after. In a new plant, this pressure drop is known and ex-
haust fan capability is provided for it. With an existing plant, a system approach to the application must be taken to ensure success (Figure 26).

CLEANING SYSTEMS

By far the most commonly used cleaning system in HMA plant baghouses is the pulse jet system (Figure 27). There are also quite a few older reverse air cleaning systems still in service (Figure 28). The advantage of the pulse jet system over the reverse air system is that no bags have to be removed from service for cleaning. Another system, which is seldom or ever used in the asphalt industry is the shaker system. Regardless of which system is employed, it is important that the dust cake on all bags be kept as nearly uniform as possible. More will be said about this in the section on operation.

The basic action of the pulse jet cleaning system is to direct a burst of compressed air into each bag at its open top. This air burst, or pulse, is admitted by the timed opening and closing of a solenoid valve. The solenoid admits air into the blowpipes, one of which is positioned above each row of bags. The blowpipes have in them small holes positioned over and directed towards each bag top. A venturi is built into the top of each cage. The venturi is used to encourage the entrainment of air by the pulsed air so that a larger volume of air is used in cleaning than can be supplied by the compressed air system alone. (A polished spot inside the top of a venturi indicates that the blowhole for that bag is not properly positioned. If the pulse is not directed straight down the throat of the venturi, the bag will not be cleaned properly.) At each pulse, air is discharged from each of the blowpipes. (Usually two rows are cleaned simultaneously.) The shock and momentary back-flow produced by the compressed air pulse releases...
some of the dust from the bags allowing it to drop into the hopper (Figure 29). Because the bags are not taken out of service for cleaning, discharged dust must fall counter to the rising gas stream. For this reason, the tendency of fine dust to cling together is a characteristic without which the pulse jet system will not work well. It is important for a plant operator to know this because severe cleaning efforts tend to break the agglomerated dust particles into individual particles which then become easily re-entrained in the rising exhaust gas and deposited back on the bag (Figure 30). In general, it is best to clean frequently with the least possible effort. If a baghouse is not overloaded or otherwise distressed, compressed air pressure of 60 to 70 psig will be adequate. Pressures in the 90 to 100 psig range will cause more problems than they solve. While such high pressure may enable an operator to keep the plant running at high rates, it will very likely cause dust migration and damage to the bags by abrading them near their tops. It is also possible to rip seams out at the bottom of the bags (Figure 31).

Control systems for pulse jet cleaning systems should be designed to allow the operator to keep the cleaning system in operation at all times when the plant is running. Turning the cleaning system on and off to control baghouse differential pressure is to be avoided. When the system is turned off, it resets to row one in the cleaning sequence. Therefore, if the system is turned on and off routinely as a means of control, it is very likely that those rows that happen to be early in the sequence will be over-cleaned while those which are late in the sequence may never get cleaned. This has the effect of reducing the effective size of the baghouse. Cleaning systems should have adjustable cleaning speeds. With three adjustable speeds, the system can shift from one speed to another based upon
baghouse differential pressure (Figure 32). When differential pressure rises above the operator’s chosen set point for the upper end of the pressure range, the system reduces the pulse off-time thereby increasing system cleaning speed. Similarly, when the differential pressure falls below the lower set point of the range, off-time is increased, which causes the system to clean more slowly. If these three rates are set and used properly, the operator has to do little to keep the system working. Some good initial settings for the system are as follow:

- Differential Pressure Range - 3 inwg to 5 inwg
- Pulse “on-time” - 0.15 sec.
- Low Pulse Rate - 20 sec. Interval
- Normal Pulse Rate - 15 sec. Interval
- High Pulse Rate - 10 sec. Interval

Both over-cleaning and under-cleaning can cause problems. The operator must be aware that a dust cake has to be developed and maintained on the bags to provide good filtering performance. Keeping the differential pressure in the 3 to 5 inwg range is a reliable indicator of a proper dust cake. However, it is possible, by cleaning slowly with high compressed air pressure, to have the 3 to 5 inwg differential pressure and still have a problem. This is true because under these conditions some bags will be over-cleaned while others will be under-cleaned. If the pulse interval is too large, dirty gas takes the path of least resistance and rushes to the most recently cleaned row of bags (Figure 33). This inrush may pull particles through the bag. As long as the pulse intervals are not extended excessively, the 3 to 5 inwg differential pressure is a reliable indicator of a proper dust cake. As a general rule, it is good practice to clean with the lowest effective pressure. Some pulse jet baghouses clean well with as little as 35 psig compressed air pressure. The operator should find the lowest effective pressure by adjusting pressure downward until the cleaning effort begins to be ineffective and then increase the pressure by about 5 psig. This procedure should be performed when the facility is running at a high production rate; otherwise, the adjustment procedure will have to be repeated when high demand is encountered.
DUST REMOVAL SYSTEMS

Dust that has been discharged from the bags by the cleaning system falls into the hopper. It is then removed from the hopper by one or more screw conveyors. The screw conveyors may be arranged so that they either collect the cyclone dust together with the baghouse dust or separately. It is not unusual to collect cyclone and baghouse dust separately so that baghouse dust can be easily wasted (Figure 34). This is often necessary with aggregates that have a high percentage of fines. Superpave designs are resulting in the need to waste some dust that was previously used in the mix. For these reasons dust removal systems are normally combined with dust return or dust disposal systems. These systems can be set up to control the amount of dust wasted or to control the amount of dust returned to the process. The most common approach, at the time of this writing, is to return all dust to the process by direct screw conveyor return without measurement. It is apparent that this practice is about to change with the implementation of the Superpave mix design system. Since Superpave mixes tend to be relatively low in dust content, effective means of wasting dust and controlling the return of dust to the process will be essential.

Another frequently used method of removing dust is to pneumatically convey it to a storage silo. Once in the silo, the dust can be returned to the process by volumetric or mass flow control, or it can be wasted (Figure 35). This approach satisfies requirements for baghouse operation and of Superpave.

For the successful utilization of the baghouse it makes little difference which of the many available means of dust removal may be employed. It is important to baghouse operation, however, that an effective means of controlling air leakage at dust dis-
charge points is provided. Rotary air locks or double tipping valves are good choices for this service (Figures 36 and 37). Highly abrasive materials may cause a rotary air lock to become a maintenance problem. When a rotary airlock is used with very abrasive materials (i.e. very coarse materials), special care should be taken to keep the air lock in good condition to avoid excessive air leakage into the system. Air leakage reduces plant production capacity and baghouse temperature.

For more information about managing baghouse dust refer to Astec’s Technical Paper T-121 titled Baghouse Fines.

**OPERATION**

Operating the baghouse should not be the main focus of running an HMA facility. The baghouse should require as little attention as possible so that plant personnel can concentrate on making mix. Sometimes, not clearly understanding the factors that affect facility performance ends up causing an undue investment of effort into the baghouse. This section is intended to help plant personnel minimize time and money spent on the baghouse. It could be argued that this is a “pay me now or pay me later” situation. However, “pay me a little now or pay me a lot later” is a more accurate perspective (Figure 38).

At start-up, the baghouse should always be preheated before beginning to feed aggregate into the dryer. This is true even when starting up from a midstream stop, in which case drum rotation will not be restarted until the baghouse has been preheated. If an adequate preheat is not performed, moisture will condense on the metal surfaces of the baghouse and probably even on the bags. Besides forming mud, which will quickly plug the bags, moisture will promote chemical attack of the bags, cages, and baghouse structure (Figure 39).
Chemical compounds typically found in HMA plant exhaust gases, even though they may be low in concentration, can form acids when they contact water. Sulfur dioxide is a prime example. It will form sulfuric acid, which attacks both steel and bags. Sulfur is often present in plant exhaust because most fuel oils have at least a small percentage of sulfur in them, making preheating essential. Adequate preheating may vary according to the situation. The basic principle to observe is that the colder the baghouse prior to start-up the longer it should be preheated. Remember that the purpose of the preheat is to avoid condensation on baghouse surfaces. That means that it is not sufficient just to allow the exhaust gas temperature to get up to normal operating temperature. The bags and plate structures need to get hot. A fairly typical preheat condition is 350°F baghouse inlet temperature for 20 minutes, when starting up for the first time for the day. Cold and/or wet ambient conditions may require longer preheats. Restarting while the baghouse is still warm will require less preheating. Shorter preheats will also be acceptable in hot dry conditions, even on first starts.

Operating temperature may vary quite a bit as conditions vary. The preferred baghouse gas inlet temperature range is 240-250°F. This range provides good efficiency and usually keeps the bags dry. However, cold ambient temperature, production rate, RAP percentage included in the mix, aggregate moisture content, mix gradation, etc. will cause exhaust temperature to change. The operator has to know how various conditions affect operating temperature and what to do about it. He also should know how plant problems may affect exhaust temperature. With aramid felts, such as Nomex, the baghouse inlet temperature should never exceed 400°F.
Operating above this temperature for any significant period of time will destroy the bags (Figure 40). Brief periods over 400°F may cause little damage, but accumulated damage due to repeated brief periods at elevated temperatures can be costly.

Dryer burner suction should always be controlled at the value specified by the burner manufacturer (usually 0.2 inwg) (Figure 41). If burner suction is elevated from 0.2 inwg to 0.4 inwg, which is easily done, the inflow of air at an open-fired burner is increased by 41%. The baghouse must handle the extra air, which can create a number of problems (i.e. blinding, migration, dust carry-out from the drum, excessive fuel consumption, diminished drying capacity, abrasion of bags and structures).

**MAINTENANCE**

When applied and operated properly, baghouses are relatively low maintenance items. Routine maintenance consists of keeping the hanger bearings for the hopper screw conveyors lubricated (Figures 42 and 43). With hard iron bushings, which are typical, lubrication with grease should be done four times daily.

Fan belts should be checked for wear and tightness equalized (for two motor drive arrangements) periodically (Figure 44). Motor amps will be equalized by proper tightening of belts. Belts should not squeal when the exhaust fan is starting.

Solenoid valves for the pulse jet cleaning system require no attention except for replacement of failed valves (Figure 45).

Water should be drained from the compressed air accumulator at least daily. More frequent draining may be necessary during high humidity and/or cold periods. The typical HMA plant compressed air system does not have a dryer. A dryer would be a good
addition to most plants because it would eliminate several problems.

Flexible couplings between the solenoid valves and the blow pipes should be checked for deterioration at least twice annually.

The clean air plenum should be checked twice annually for corrosion and dust accumulation (Figure 46).

The hopper should be checked daily for dust accumulation, which may be caused by dampness (Figure 47).

Keep a daily visual check on the stack plume (Figure 48). Any visible emissions, other than moisture, should be investigated.

The following data should be recorded in an operations log:

- **Differential pressure**
- **Inlet temperature**
- **Outlet temperature**

With a data log, deviations from normal can be quickly noticed and should be promptly investigated.

**PROBLEM CAUSES AND SOLUTIONS**

There are many different potential problem and solution combinations concerning baghouses. A few of the more common ones follow:

**PROBLEM:**

High pressure drop across the bags combined with reduced capacity

**POSSIBLE CAUSE NO. 1:**

Hydrocarbon contamination of bags (Figure 49).

**SOLUTION:**

The first step is to determine the source of the hydrocarbons contaminating the bags. There are only three possible sources. The most likely is the fuel, if the fuel is oil, particularly a heavy or waste oil. In this case, high oil viscosity due to low fuel temperature may prevent the fuel from burning completely. If this is the cause, the problem can be solved by preheating the oil until its viscosity is 90 SSU or less. It is also possible that the asphalt cement is the source of the contaminating hydrocarbons. This may be due to the particular AC having been cut with some volatile component to adjust viscosity. If so, a change of AC sources may be in order. Another possibility is that virgin AC is being introduced into the system onto very hot aggregate. This is most likely to occur when the mix being made includes a significant amount of RAP. In this case, the solution would be to
change the AC injection point so that more time is allowed for mixing of RAP and virgin aggregate before AC is applied. The hydrocarbon source may also be the RAP. This is likely with very high RAP percentages or when RAP is used in a parallel flow drum mixer where it is directly exposed to hot gases. There is no good solution to this problem. In any of these situations, elevating the baghouse temperature will tend to help reduce hydrocarbon condensation in the baghouse. The operator should be aware that hydrocarbon contamination is not only restricts capacity but also represents a dangerous fire hazard.

POSSIBLE CAUSE NO. 2: Ineffective cleaning.

SOLUTION:
Adjust pulse pressure and/or times. Typical initial settings are 0.25 sec. pulse duration, 15 sec. pulse interval, and 80 psig. air pressure. Some newer systems have the capability of being set up with three different pulse intervals. Typical settings are 10 sec., 15 sec., and 20 sec. It may be necessary to decrease the pulse intervals and/or increase air pressure. Decrease the pulse interval as the first step of cleaning system adjustment. If it is necessary to increase air pressure, do not set it above 100 psig. Doing so only causes abrasion of the bags. Make sure blow pipes are properly positioned (Figure 50).

POSSIBLE CAUSE NO. 3: Re-entrainment of collected dust

SOLUTION:
Re-entrainment is caused by vertical velocity (can velocity) being too high to allow the dust to drop into the baghouse following a pulse of cleaning air (Figure 51). This can be due to excessively high can velocity or very light dust particles. Enlarging the baghouse is not a practical option, so the solution for both cases is to decrease the volume of exhaust gases. This can be accomplished by eliminating air leaks, reducing aggregate
moisture content, correcting improper burner adjustment, or reducing production. A condition of locally high can velocity can occur when the pulse interval is set too high. It may be possible to partially compensate by using a high air pressure setting, but this practice is likely to result in dust emissions.

POSSIBLE CAUSE NO. 4: High air to cloth ratio (Figure 52).

SOLUTION: This usually occurs along with re-entrainment (above), and the solution is the same.

PROBLEM: Dust emission with each cleaning pulse (Figure 53).

POSSIBLE CAUSE NO. 1: Over-cleaning.

SOLUTION: Effective filtration with felt media requires a dust cake on the bags. Over-cleaning will prevent the accumulation of an adequate dust cake. Reduce cleaning effort to obtain pressure drop in the range of 3 to 5 inwg.

POSSIBLE CAUSE NO. 2: Bag deterioration.

SOLUTION: Bags can become deteriorated for any of several reasons. Over-heating, chemical attack, and abrasion and fiber fatigue at the bag tops due to high air pressure are all possible causes. Whatever the cause, once a bag has deteriorated, it must be replaced. Bags suspected of deterioration should be sent to a reputable lab for testing. ASTM has established standardized tests for bag materials. The lab should be certified to perform tests to the ASTM methods. Testing is especially important if a large number of bags are suspect. Testing can identify a loss of strength, loss of bag weight, and penetration of dust into or through the felt and prevent unnecessary replacements. Another important reason for testing is to iden-
tify the cause of the deterioration. It will probably happen again unless the cause is found and corrected.

**PROBLEM:**
Continuous dust emission (may be more severe at certain pulses).

**POSSIBLE CAUSE NO. 1:**
A particular bag may have a hole in it due to wear or an unsewn or ripped seam.

**SOLUTION:**
Replace the damaged bag. The hard part is finding it. Taking a look at the tube sheet may reveal a pattern of dust around a particular bag. A black light test is usually a pretty sure way of locating a damaged bag.

**POSSIBLE CAUSE NO. 2:**
One or more bags may not be sealed properly in the tube sheet.

**SOLUTION:**
Finding the poorly seated bag(s) is the problem. The same methods as those used for a damaged bag (above) will work. Once found, the solution is usually just to make sure that the bag seal snaps firmly into place in the tube sheet (Figure 54).

**POSSIBLE CAUSE NO. 3:**
An incomplete or cracked weld in the tube sheet or between the tube sheet and a wall can be the source of a continuous dust leak.

**SOLUTION:**
It will probably be necessary to run a black light test to locate this problem. The solution is usually to weld repair the leaking area (Figure 55).

**PROBLEM:**
Corrosion (Figure 56).

**POSSIBLE CAUSE NO. 1:**
Sulfur in the fuel.

**SOLUTION:**
Any fuel oil is likely to contain some sulfur. Small amounts are usually not a problem. The best solution is to find a low sulfur fuel supply. Elevating the baghouse temperature to avoid moist-
ture condensation will help, since the sulfur dioxide formed by the burner will combine with condensed moisture to form sulfuric acid. Proper preheating and purging with fresh air at shutdown will also help.

POSSIBLE CAUSE NO. 2: Low baghouse temperature.

SOLUTION: Low baghouse temperature will very likely cause condensation in the baghouse, which will contribute to rusting even if no corrosive chemicals are present. Any corrosives will probably be more active when condensed moisture is present.

PROBLEM: Inconsistent differential pressure readings (Figure 57).

POSSIBLE CAUSE NO. 1: Water in the sensing lines.

SOLUTION: A tiny leak in an underground sensing line will cause water to be sucked into the line. The best solution is to use solid lengths of tubing for each of the two sensing lines, since leaks are most likely to occur at connections.

POSSIBLE CAUSE NO. 2: Malfunctioning gauge (Figure 58).

SOLUTION: Replace the gauge.

TESTING

Compliance testing for the purpose of obtaining the pollution permit can only be conducted by a certified testing firm. Application of specific test methods proving attainment of applicable performance standards are required by the responsible agency before a permit will be issued. The Clean Air Act Amendment of 1990 makes the states responsible for meeting federally established ambient air quality standards. Where those standards are being met, even though the state can require performance to a more demanding standard, they will normally only require that the federally mandated emission standard of 0.04 grains/dscf be met. In Non-attainment Areas a lower emission standard of 0.02 grains/dscf is usually imposed. The performance is usually verified by means of an EPA method 5 test, which is an isokinetic particulate test. Limits may also be set for PM-10. PM-10 are those particles smaller than 10 microns in diameter. Many states require periodic particulate testing for the life of the equipment to keep the permit in effect.

It can be very beneficial for plant personnel to run an annual black light test, even though no dust emission is visible. Such a practice can catch a small problem before it becomes a crisis that ends up with the state agency forcing the shutdown of the plant until the problem is corrected.