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Field Manual on Design and Construction of Seal Coats

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THE STATE OF TEXAS

FIELD MANUAL

on

DESIGN AND CONSTRUCTION OF SEAL COATS

by

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The contents of this report reflect evaluations of seal coats using a Texas Grade 4 Aggregate. Texas grade 4 aggregate meets the following specification requirements:

	% by weight
Retained on 5/8" seive	0
" " 1/2" "	0-2
" " 3/8" "	20-35
" " No.4 "	95-100
" " No.10 "	99-100

Care should be exercised when designing a seal coat by the procedure in this manual if the aggregate varies significantly.

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INTRODUCTION

Seal coats* have been successfully used on Texas highways for many years and with traffic volumes as high as 4000 vehicles per lane per day. The average life of seal coats is about six to seven years in Texas, however; some seal coats have performed successfully for periods of 20 or more years. These economical surfaces will continue to be a popular rehabilitation and maintenance alternative in Texas and their use in other states will increase as available highway funds decrease.

The purpose of this manual is to provide guidelines for the design and construction of seal coats. If followed, these guidelines will improve the chance of successfully placing seal coats. The manual is directed primarily to office and field engineers, laboratory personnel, and field inspectors responsible for the design and construction of seal coats. An extensive discussion of the variables affecting the design and construction of seal coats is not presented in this manual. References 1 to 15 contain a detailed discussion.

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*A seal coat is a bituminous surface that results from one or more successive alternative applications of bituminous binder and cover aggregate to an existing paved surface. A surface treatment is a bituminous surface that results from one or more successive alternative applications of bituminous binder and cover stone to a prepared compacted gravel, crushed stone, stabilized soil or similar base.

PURPOSE AND USES OF SEAL COATS

Seal coats are applied to an existing bituminous surface for one or more of the following purposes:

1. Seal an existing bituminous surface against the entrance of air and water
2. Enrich an existing dry or raveled surface
3. Provide a skid resistant surface
4. Increase pavement visibility at night
5. Reduce tire noise
6. Improve demarcation of traffic lanes or other geometric features
7. Attain a uniform appearing surface

Little increase in load carrying capacity is obtained from the additional pavement thickness supplied by the seal coat; however, an effective seal may improve the load carrying ability of a pavement by altering the water content of the materials composing the pavement structure. If a pavement surface shows evidence of traffic load associated cracking (alligator, longitudinal, transverse), a seal coat is only a temporary solution. A thick asphalt concrete overlay or reconstruction is normally required to correct these types of problems.

Rough riding pavement surfaces cannot be improved significantly by the application of a seal coat. Overlays of various thickness, spot level-up maintenance patches, or reconstruction is normally required to restore pavement ride quality.

Seal coats applied to pavements showing signs of non-traffic load associated longitudinal and transverse cracks have proved somewhat effective. Seal coats usually bridge these cracks in a more satisfactory manner than thin asphalt concrete overlays. Other pavement overlay systems, some of which contain seal coats with special binders are being developed and appear promising.

Pavements demonstrating flushing or bleeding are difficult to repair with seal coats. The bleeding normally migrates through the new seal coat unless the asphalt quantity applied to the roadway can be altered at these spot locations. Asphalt concrete overlays have proven to be more effective in reducing or eliminating flushed surfaces. Seal coats utilizing a large maximum size aggregate are suggested, if seals are utilized on flushed surfaces.

Pavements with ruts or corrugations normally must be repaired with an overlay, heater planer or cold planers. Seal coats are not an effective treatment for these types of distress.

Seal coats have been used successfully on pavements carrying 5,000 vehicles per day per lane in rural areas. The probability of successfully placing a seal coat is,.however, greatly increased on roadways carrying lower traffic volumes. The use of seal coats in urban areas where accelerating and decelerating traffic frequently occurs should be approached with caution.

DESIGN OF SEAL COATS

The design of seal coats involves the selection of the type and amount of bitumen or asphalt and the type and amount of aggregate. Selection of the type of aggregate and asphalt will be discussed followed by the description of a method to determine the amount of asphalt and aggregate.

Type of Aggregate

The mineral aggregate in a seal coat is expected to:

1. Transmit the vehicle wheel load to the underlying surface.
2. Provide a skid resistant surface.
3. Resist abrasion from moving wheel loads.
4. Resist the deteriorating effects of weather exposure.

In addition, cover aggregates sometimes are used to improve light reflection from the roadway and/or to provide a demarkation of shoulders or other limited traffic areas.

Aggregates for seal coats are adequately specified under the following Texas State Department of Highways and Public Transportation specification items (16).

Item 301 - Aggregate for Surface Treatments (Class A)

Item 302 - Aggregate for Surface Treatments (Class B)

Item 303 - Aggregate for Surface Treatments (Lightweight)

Item 304 - Aggregate for Surface Treatments (Precoated) (Class B)

Item 305 - Aggregate for Surface Treatments (Precoated) (Class A)

Precoated aggregates are more expensive than untreated aggregates but have been utilized to reduce the effect of a dusty aggregate, to reduce automobile glass damage due to flying stone and to promote bond with the asphalt. Lightweight aggregates have been utilized since 1961 in Texas to provide pavements with a high coefficient of friction, color contrast and to reduce or eliminate glass damage due to flying stone. Selection of the specification item for designation of cover stone has been based largely on availability and cost of materials, materials performance and skid resistance considerations. A preferred natural aggregate is that specified under Item 301 with a one size gradation. The one size gradations allow additional asphalt to be used effecting a more positive seal and reducing the likelihood of aggregate loss and the associated resulting automobile glass damage and bleeding surfaces. If there is too much difference between the largest and smallest size particles, the asphalt film may completely cover the smaller sizes but will not adequately grip the larger sizes. In addition, a "one size" aggregate will produce superior particle interlocking and will result in an optimum contact area between the tire and road surface. For practical purposes, a cover aggregate having 85 weight percent passing a specified size sieve and retained on a sieve having a opening one-half the specified size can be considered to be "one-size".

The ideal cover aggregate particle shape is cubical or pyramidal, but rounded gravels have provided satisfactory service on low traffic volume roads. Crushed gravels provide improved performance as compared to subrounded or rounded gravels. Lightweight aggregates often are not cubical or pyramidal, but they tend to have the rough surface features desired for a good cover aggregate. Flat and enlongnated particles should be avoided. The presence of such particles can be minimized by specifying a maximum percentage of particles having a ratio of width (smallest dimension) to average particles size less than 0.5 (flakiness index Tex-224-F).

The selection of the maximum size of aggregate is normally based on economic and traffic considerations. Large maximum size cover stones require larger amounts of asphalt than small maximum size cover stones. For example, a Grade 5 cover stone with a maximum size of one-quarter inch requires approximately 0.20 gallons of asphalt per square yard while a Grade 3 cover stone with a maximum size of five-eights inch requires approximately 0.40 gallons of asphalt per square yard. It is evident that Grade 3 cover stone will provide a more effective seal because of the thickness of the applied asphalt film. Field variations in applied asphalt quantities which are of the order of 0.06 gallons per square yard are much more critical for Grade 5 than for Grade 3 cover stone.

It is a common practice in the state to select the larger maximum size aggregates for the high traffic volume facilities. Grade 3 or 4 is normally utilized on these facilities. In addition, the larger maximum size cover stone improves pavement surface drainage and thus reduces the potential for hydroplaning. Tire-pavement noise is usually higher with Grade 3 aggregates.

As mentioned above, skid resistance is an important if not the controlling factor, in the selection of the type of aggregate to be used as a surface treatment or seal coat cover stone. It is important that the aggregate have an adequate initial coefficient of friction, and that a prolonged coefficient is maintained under the traffic imposed on the facility. Polish values, as determined by Test Method Tex-438-A, may be utilized to select acceptable aggregates for individual projects.

Potential benefits and problem areas associated with the selection of lightweight and normal weight aggregates are shown in Table 1. Table 2 recommends types and grades of aggregates for seal coats.

These should be considered as guidelines rather than firm recommendations. Modifications should be made (as necessary) to fit specific local conditions.

Type of Asphalt

The type and grade of asphalt selected for a particular seal coat project should have the following characteristics:

1. Fluid enough at the temperature of spraying to allow uniform application,

2. Fluid enough at the time the cover aggregate is applied to develop rapid wetting and fast initial adhesion between the binder and the aggregates as well as to the underlying road surface.

3. Viscous or hard enough to retain the cover stone when the surface is opened to traffic.

4. Viscous or hard enough to prevent plastic distortion in hot weather.

5. Fluid or soft enough (not brittle) in cold weather that the aggregate will not be whipped off and the road surface will not crack.

6. Resistant to the effects of sunlight and air (prevent excessive hardening due to aging of the asphalt)

7. Resistant to the combined action of water and traffic such that stripping of the aggregate will not occur.

Asphalt cements, emulsified asphalts and cut-back asphalts, as specified by Item 300 of the Texas State Department of Highways and Public Transportation Standard Specification, are utilized for seal coats. Each of the three types of asphalt products has its own virtues and problems which should be recognized when a selection is made.

Table 3 lists advantages and potential problems associated with these asphalt types.

Many grades of the three types of asphalt are available, but only a few are normally used for seal coats. These are shown below.

Asphalt Type	Identification Under Item 300.2 SDHPT Standard Specifications
Asphalt Cement	Viscosity Grades AC-5, AC-10
Asphalt Emulsion (Anionic)	EA-HVRS, EA-HVRS-90 (EA-HFRS)
Asphalt Emulsion (Cationic)	ER-CRS-2, EA-CRS-2h
Cut-Back Asphalt*	RC-2, RC-250, RC-3, RC-4, RC-5, MC-800, MC-3000

Recommendations for selection of asphalt type and grade based on criteria for the construction environment and expected surface exposure conditions in various parts of the state are given in Tables 4 and 5 and supported by Figure 1. These should be considered to be guidelines rather than firm recommendations. Modifications should be made (as necessary), to fit specific local conditions.

Selection of the proper type and grade of asphalt also depends on the type of cover aggregate to be spread on the asphalt layer. Guidance for making a selection on the basis of aggregate type is given in Table 6 and Figure 2. Application of Figure 2 for classification of natural gravels may pose some problems since aggregates often consist of a mixture of a number of rock types. However, aggregates may be classified from a knowledge of the local geology, and petrographic and/or visual examination. For example, most natural gravel taken

*Energy conservation and air quality problems will usually rule out the use of cut-back asphalts except for emergency repair during the winter months.

from the Brazos River terraces have a relatively high silica content and are therefore mostly hydrophilic. When there is doubt, personnel of the Texas State Department of Highways and Public Transportation Materials and Test Division (D-9) should be consulted.

The final selection of the type and grade of asphalt to be used should be made on the basis of recommendations presented on Tables 4, 5, 6, and Figure 2 (17). For example, if a chip seal is to be applied during the summer in a Zone IA climate and trap-rock aggregate is used the following types of asphalts would be expected to give satisfactory performance; AC-5, AC-10, EA-CRS-2, and EA-CRS-2h. If a chip seal is to be applied in the spring in a Zone IIB climate and a lightweight aggregate is used, the best choice is the cationic asphalt emulsion EA-CRS-2. An RC-4 or RC-5 could be used.

Selecting asphalts for late season construction presents special problems as the cover stone is normally not embeded to the desired level prior to the occurrence of cold nights. With shallow embedment depths and a somewhat brittle asphalt; raveling at the centerline, between the wheel paths and perhaps in the wheel path will likely occur. If construction must occur late in the summer or early in the fall, the grade of asphalt cement to be selected should be one grade softer than normally used (i.e., AC-5 rather than AC-10 and AC-3 rather than AC-5).

Design Method

The design method recommended and described below is based on a modification of the original Kearby method which has been utilized by several districts (7, 9, 14). Laboratory tests and calculations required in the design method are given below.

Laboratory Tests

Dry Loose Unit Weight. The dry loose unit weight determination shall be made in accordance with Tex-404-A, except that the aggregate shall be tested in an oven-dry condition.

Bulk Specific Gravity. The bulk specific gravity shall be made in accordance with Tex-403-A for all natural aggregate and by the test method Tex 433-A for synthetic aggregates.

Board Test. Place a sufficient quantity of aggregate on a board of known area such that full coverage one stone in depth is obtained. A one-half square yard area is a convenient laboratory size. The weight of the aggregates applied in this area is obtained and converted to units of pounds per square yard. Good lighting is recommended and care should be taken to place the aggregate only one stone deep.

Calculations

The quantity of aggregate expressed in terms of square yards of road surface that can be covered with a cubic yard of aggregate and the quantity of asphalt in gallons per square yard can be found as described below:

Aggregate Quantity

$$S = \frac{27W}{Q}$$

$$A = 5.61E\ (1 - \frac{W}{62.4G})\ (T) + V$$

where:

S = Quantity of aggregate required, sq. yds. per cu. yd.

W = Dry loose unit weight, lbs. per cu. ft.

Q = Aggregate quantity determined from board test, lbs. per sq. yd.

A = Asphalt quantity, gallons/sq. yd. @ 60°F

E = Embedment depth obtained from Figure 3 as follows:

$$E = ed$$

where:

e = Percent embedment (Figure 3)

d = Average mat depth, inches

$= \frac{1.33Q}{W}$

G = Dry bulk specific gravity of aggregate

T = Traffic correction factor obtained from Table 7

V = Correction of surface condition obtained from Table 8

5.61 = (7.48) (9/12), or conversion factor

Note: Asphalt quantities calculated by these methods are for asphalt cement. Appropriate corrections must be made where a cutback or an emulsion is used as illustrated in the examples given below.

Sample Calculations

Given:

(W) Dry loose unit weight of aggregate = 52.4 lbs/cu.ft.

(G) Dry bulk specific gravity of aggregate = 1.57

(Q) Quantity of aggregate (board test) = 9.7 lbs./sq.yd.

Traffic = 700 vehicles per day per lane

Roadway Surface Condition + slightly pocked, porous, oxidized

Quantity of Aggregate

$$S = \frac{27W}{Q} = \frac{27(52.4)}{97} = 146 \text{ sq. yds. (square yards of roadway surface per 1 cubic yard of aggregate)}$$

Quantity of Asphalt

$$A = 5.61E\ (1 - \frac{W}{62.4G})\ (T) + V$$

$$d = \frac{1.33Q}{W} = \frac{1.33(9.7)}{52.4} = .246 \text{ inches}$$

e = 40 percent from Figure 3 for synthetic aggregates

$E = ed = .40(.246) = 0.0985$ inches

$T = 1.05$ from Table 7

$V = +0.03$ from Table 8

$$A = 5.61\ (0.0985)\ (1 - \frac{52.4}{62.4(1.57)})\ (1.05) + 0.03$$

A = 0.30 gallons of asphalt per square yard of roadway surface

If an emulsion or cutback is to be used, the quantity to be utilized must be corrected for the amount of volatiles present in the asphalt material. The approximate amount of volatiles present in those cutbacks recommended for use in seal coats is shown on Table 9. For example, the seal coat design method suggests that 0.30 gallons per square yard of residual asphalt cement is required. Theoretically the amount of RC-250 to be placed on the pavement is

$$\frac{0.30}{.75} = 0.40 \text{ gallons per square yard}$$

However, field experience indicates that bleeding is likely if the theoretical amount is utilized. Thus, it is recommended that the calculated theoretical value be reduced and the method described below be utilized to calculate the amount of cutback to be utilized.

$$A_{recommended} = A + K\,(A_{theoretical} - A)$$

where:

$A_{recommended}$ = recommended quantity of cutback or emulsified asphalt

A = residual quantity of asphalt obtained from the design method given above

$A_{theoretical}$ = theoretical quantity of cutback or emulsified asphalt obtained by dividing A by the quantity of residual asphalt in the cutback (Table 9) or emulsion and as described above.

K = correction factor based on field experience

It should be noted that correction factors (K) have not been verified for cutbacks by carefully controlled field experiments and therefore should be used as guidelines only: Suggested K factors for cutbacks are as follows:

K = 0.70 for spring construction

K = 0.60 for summer construction

K = 0.80 for fall construction

K = 0.90 for winter construction

If the RC-250 is to be placed in the fall, the quantity to be used is

$$A_{recommended} = 0.30 + 0.80\,\left(\frac{0.30}{0.75} - 0.30\right)$$

$A_{recommended}$ = 0.38 gallons of RC-250 per square yard of roadway surface

Field trial sections placed in Texas and reported in reference 18 suggest that reduced quantities of emulsion (as compared to the theoretical value calculated) can be utilized successfully. Thus, it is recommended that the calculated theoretical value be reduced and the method outlined above be utilized.

It should be noted that corrective factors (K) have not been verified by extensive controlled field experiments and therefore should be used as guidelines only. Suggested K factors for emulsions are as follows:

K = 0.60 for spring construction

K = 0.40 for summer construction

K = 0.70 for fall construction

K = 0.90 for winter construction

Assuming that the design method suggests that 0.30 gallons per square yard is required, the amount of an EA-CRS-2h emulsion that contains 70 percent residual asphalt that should be used in the summer is

$$A_{recommended} = 0.30 + 0.40 \left(\frac{0.30}{0.70} - 0.30\right)$$

$$A_{recommended} = 0.35 \text{ gallons of EA-CRS-2h emulsion}$$

per square yard of roadway surface.

It should be noted that the quantity of asphalt to be sprayed from the asphalt distributor must be corrected for temperature in order that the proper quantity will be retained on the roadway as measured at 60°F. If the design quantity of asphalt cement was 0.30 and the spray temperature was 340°F, the temperature correction factor would be 0.9057 (Table 10). Thus, $\frac{0.30}{0.9057}$ or 0.33 gallons of asphalt cement per square yard would be sprayed at 340°F in order to have 0.30 gallons per square yard on a 60°F surface. Temperature correction factors for asphalt cement are shown in Table 10, for cutbacks in Table 11 and for emulsions in Table 12.

Environmental Considerations

Experience shows that the ideal environment for the construction of seal coats is hot, dry weather with no rain for the next several days. Thus, the two most important environmental factors are temperature and moisture. Wind velocity is also a factor to be considered.

Both road surface and atmospheric temperatures are important because they will influence how well the cover aggregate can be embeded in the binder and then how soon the roadway can be reopened to traffic. Soon after the asphalt is shot, its temperature will approach that of the roadway surface temperature. At this temperature the asphalt will be much more viscous (thicker) than at the spraying temperature. If the road surface is cool, the binder may become so viscous (depending on the type and grade of asphalt) that it will become nearly impossible to obtain adequate adhesion between the aggregate and asphalt and proper aggregate embedment during the rolling operation. The net result will be aggregate loss when the roadway is opened to traffic. Aggregate loss may also cause windshield damage and even result in loss of friction. On the other hand, if the road surface temperature is too high and the asphalt is low in viscosity a longer time will be required to cool the mat to the point where traffic will no longer dislodge the aggregate particles. During hot, sunny weather, the most critical time of day to reopen a new seal coat job to traffic is between midday and late afternoon when the pavement surface temperature is highest. This problem will be most serious when dark colored aggregates are used and the area is one of high solar flux.

Asphalt emulsions have relatively low viscosities at low temperature as compared to asphalt cement. This physical feature of emulsions allows this asphalt material to satisfactorily adhere to the aggregate and to obtain adequate embedment at lower road surface temperatures.

Wet aggregates will not adhere to asphalt cements. However, wet aggregates can be used with asphalt cements provided the water evaporates from the aggregate surface and adequate adhesion is obtained prior to finish rolling and opening to traffic. If wet aggregates and asphalt cements are to be used successfully, they should be used on hot, low humidity days. Wind will speed aggregate drying and thus promote adhesion. Similar reasons dictate that asphalt cement should not be sprayed on top of a wet pavement surface.

The problems with moisture are reduced considerably if cationic asphalt emulsions are used. If properly compounded and used, such emulsions tend to displace surface water and allow the binder to make direct contact with the aggregate surface. However, an excess of moisture may slow the emulsion break and the evaporation of the separated water which may still present problems.

Wind speed is also a consideration. A light breeze may help evaporate moisture (or the solvent from cutbacks). High winds may distort the distributor spray pattern making it impossible to obtain uniform asphalt coverage. Also, in some areas the dust carried by high winds will have detrimental effects.

Specific limits for the environmental conditions prevailing during construction are given in Table 5. If these limits are carefully observed the chance of successfully placing a seal coat is greatly improved.

Aggregate Embedment

The seal coat design method, the construction operations and considerations for climatic conditions should be aimed at providing adhesion between the asphalt binder and the aggregate and proper embedment of the aggregate into the asphalt film. Improper adhesion and/or inadequate embedment depth will result in loss of coverstone aggregate. Suggested percent embedment depths during the life of seal coats are listed below:

immediately after construction	30 ± 10%
start of cool weather (first year)	35 ± 10%
start of cold weather (first year)	45 ± 10%
after two years of service	70 ± 10%

For low traffic facilities aggregate embedment immediately after construction should be in the range of 30 to 40 percent while 20 to 30 percent embedment is the preferred range for high traffic volume facilities.

CONSTRUCTION

The performance of seal coats is largely dependent upon the quality of construction. Design quantities of asphalt and aggregate must be placed uniformly on the roadway using a sequence of operations which results in proper adhesion between the aggregate and the asphalt binder. Quality construction requires a coordinated effort among the construction labor force, the construction equipment, traffic control personnel and field inspection personnel. Key items associated with proper construction of seal coats are discussed below.

Equipment

Successful construction of high quality, long service life seal coats depends to a large degree on the equipment selected for the job, its operating condition and the way it is handled during construction. The following form basic types of equipment that are required.

1. Asphalt distributors,
2. Aggregate spreaders,
3. Rollers and
4. Cleaning Equipment

The asphalt distributor must be able to spray the asphalt binder uniformly across and along the road surface at a rate to give the coverage indicated by the design calculations. The operator should be able to maintain close control of the asphalt application rate regardless of changes in grade. The major features of an asphalt distributor are shown in Figure 4.

The function of an aggregate spreader is to apply the cover aggregate uniformly on top of the asphalt shot at the specified spread rate. A good spreader, properly operated, will conserve aggregate as well as help to obtain a high quality seal coat. A good spreader should be able to:

1. Keep up with the asphalt distributor,
2. Cover the asphalt shot with a minimum of stopping to reload and
3. Synchronize the aggregate discharge rate with the forward speed to minimize the effect of small changes in grade, etc. in the spread rate.

Self-propelled spreaders such as the ones illustrated in Figure 5 will usually meet these requirements.

The purpose of the rolling operation is to press the cover aggregate particles firmly into the asphalt layer so as to improve embedment, and to promote adhesion and particle interlock. A self-propelled pneumatic-tired roller, as illustrated by Figure 6, is preferred. These pneumatic rollers tend to minimize the tendency for weak aggregate particles to degrade during the rolling operation. The use of steel wheel rollers should be avoided.

Suitable equipment is required to clean the existing surface and to remove excess aggregate after the asphalt hardens on the road. Power brooms such as that shown on Figure 7 are typically utilized for these operations.

A large number of manufacturers produce the four types of equipment required to construct seal coats. Many models will do an excellent job, but among the various manufacturers, design details will differ considerably.

Construction Operations

The sequence and timing of construction operations are critical if a properly performing seal coat is to be constructed. The key operations and the sequence of these operations are given below.

1. Preconstruction preparation,
2. Traffic control,
3. Asphalt application,
4. Aggregate spreading,
5. Rolling and
6. Final clean-up

Timing of the construction sequence is critical. For example, patching of the old surface prior to placing the seal coat should be completed several months (if possible) before a seal coat is applied. The time available between patching and placing of the seal coat will allow volatiles to escape from the patching materials and thereby reduce bleed-through. Patch densification by traffic is also beneficial.

The time delay between asphalt application and aggregate spreading very critical when asphalt cements are utilized. The delay should be minimized and is especially critical for early morning construction and/or early and late season construction when the surface temperature of the old pavement is low.

The time delay between emulsion or cutback application and aggregate spreading is not as critical as that associated with the use of asphalt cements. In general, aggregate should be applied to the emulsion or cutback shot as soon as possible (provided the aggregate is not picked up by the wheels of the aggregate spreader). It is not necessary for the emulsion to break or the cutback to cure before the aggregate is applied.

Rolling should be initiated immediately after aggregate spreading, provided aggregate pick up is not a problem. The time delay between aggregate spreading and rolling is critical and should be held to a minimum when asphalt cements are used. The time delay between aggregate application and rolling is not as critical for emulsions and cutback as compared to asphalt cements. However, this time delay should also be minimized provided rolling can be accomplished without aggregate pick up.

Aggregate pick up by the aggregate spreader or rollers is not necessarily due to spreading the rock or rolling too soon after placing the asphalt. In-
the asphalt. Incorrect selection of the asphalt, improper delivery of
excess asphalt application rate, insufficient aggregate spread rate and asphalt on roller tires are some of many reasons why pick up could also occur.

Final clean-up which usually consists of brooming of excess and/or loose aggregate from the pavement and shoulders should be attempted only after the aggregate is firmly set in the asphalt. This time delay is usually 15 to 24 hours after construction but may be longer during hot weather and/or when emulsions or cutbacks are used. Final brooming is normally performed during the cooler morning temperatures.

Several key steps should be taken in each of the identified seal coat construction operations. The exact sequence of steps and the degree of execution of each of those steps will depend, in part, on the local conditions such as highway geometrics, special aggregate considerations, environmental conditions, personnel available, equipment available, etc. Rather than attempt to present specific directions for conducting each of the construction operations a series of summary tables has been prepared to identify key steps of each operation. This information is summarized below and should be supplemented by Chapter 8 of the SDHPT construction Manual (19).

Preconstruction Preparation. Careful planning and preparation for a seal coat job will yield many benefits. After the materials have been selected and produced, the design calculation made, contractural arrangements completed, and the construction schedule determined, the following actions are particularly important and may very well determine the success of the project.

Preparation of Existing Asphalt Pavement. Often the condition of the old pavement upon which the seal coat is to be placed is in need of repair prior to application of the seal coat. Suggested actions are shown on Table 13 for various types of pavement distress. If the pavement has excessive bleeding, rutting, or alligator cracking, a seal coat may not be an acceptable rehabilitation alternative.

Aggregate. Sufficient quantities of aggregate should be stockpiled along the road to complete the project. Stockpiles should be spaced for most efficient operation of the aggregate trucks and spreader. Stockpile areas should be well drained to minimize the flow of water through and under the aggregate, and should be free of grass, rubbish and other contaminants. In areas of high rainfall, the engineer should consider covering stockpiles to insure that they remain dry.

Each aggregate stockpile should be sampled and tested well before construction begins. Stockpiled aggregate should give uniform test results consistent with the values used in design calculations. All specification requirements should be met.

Asphalt. Adequate asphalt storage facilities should be provided in convenient locations. Adequacy is determined by facility type (capable of handling the type and grade of asphalt specified), size, and condition (clean, leak free, operation without excessive maintenance and repair). Each lot of asphalt should be sampled and tested for specification compliance. Uniform test results consistent with values used in design should be required. Special sampling and handling may be required for asphalt emulsions in view of their tendency to separate.

Equipment. The contractor should be required to permanently assign equipment to the project, in adequate numbers of each kind, for the duration of the project. This action will reduce delays and avoid having to proceed on a makeshift basis which is almost certain to result in poor performance. The responsible engineer should insist on compliance with the operational requirements specified for each item of equipment. All adjusting mechanisms should be fully operational. Distributor tank and other calibrations required should be on hand; not merely promised at a future date.

Traffic Control. Traffic must be controlled to protect the driving public and their vehicles, the construction crew and construction equipment and to avoid damage to the seal coat during construction and when the job is first opened to traffic. The preferred method is to detour traffic completely until the binder is hard enough to hold the aggregate tightly. When this is not possible, half width construction should be used and traffic confined to lanes not under construction. If traffic must be maintained during construction, vehicle speed must be limited to 5 to 10 mph using a pilot vehicle. After rolling is complete, traffic speed on the newly placed surface should be limited to 20 mph for the following time periods;

1. Asphalt cement, hot weather - 2 hours
2. Asphalt cement, cool weather - 1 hour
3. Emulsion and cutbacks - 2 hours (extend to 3 or more hours in calm, humid weather)

Longer time delays may be required if the seal coat is placed on a high traffic volume facility and/or if the facility has a high volume of trucks.

Asphalt Application. The asphalt must be applied to the old roadway surface in a uniform manner and at an amount equal to the design quantity. Modern equipment is capable of applying a uniform coverage of asphalt of the correct quantity provided the equipment is maintained in proper operating condition and the asphalt is sprayed at the proper viscosity. The spray bar height and nozzle angles must be properly adjusted if the desired uniformity is to be achieved (Table 14, Figure 8).

Distributor Calibration. All distributors should be calibrated. Two types of calibrations should be performed. The asphalt tank on the distributor should be calibrated such that an accurate relationship between fluid level and asphalt binder quantity is obtained. The second calibration involves the determination of the variation in transverse and longitudinal distribution or spread of the asphalt along the roadway. Transverse spread should not be allowed to vary more than 15 percent for asphalt emulsions and no more than 10 percent for other types of asphalt binders. Longitudinal spread should not vary more than 10 percent regardless of the type of binder. Methods for determining transverse and longitudinal spread have been developed by the Texas State Department of Highways and Public Transportation (22), the Asphalt Institute (2), and the California Division of Highways (20). Appendix A contains a description of the California test method.

Spray Nozzles. Recent research conducted by Distric 23 of the Texas State Department of Highways and Public Transportation has indicated that spray nozzles of identical manufacture identified size deliver liquid quantities at widely different rates and fan widths. If transverse distribution cannot be controlled within desired limits it may be necessary to replace individual nozzles.

Under certain conditions it may be desirable to vary the transverse distribution of asphalt. For example, the wheel paths may be bleeding with little or no surface texture while the areas of the roadway between the wheel path and outside the wheel path may appear dry with considerable surface textures. Since the surface demand for asphalt varies transversely on the pavement, it is desirable to vary the applied rate transversely. District 23 has successfully installed different size nozzles in the spray bar to achieve the desired transverse variation. Additional information may be obtained by contacting the district office in Brownwood.

Spray Temperature. The temperature at which the asphalt binder is to be discharged or sprayed from the distributor is based on the viscosity of the binder. The recommended viscosity range for spraying is 20 to 120 centistokes or centipoises. A temperature-viscosity chart is the best method for selecting the temperature that defines the viscosity for spraying. Figures 9 and 10 are typical graphs for asphalt materials used for seal coats in Texas. The temperature-viscosity relationship for the asphalt to be used on the project should be obtained from the Materials and Tests Division in Austin and plotted as shown in Figure 11. Typical temperatures for spraying seal coat binders are shown on Table 15.

Distributor Speed. Distributor speed for any rate of application can be determined from the following formula.

$$S_f = \frac{9G_t}{WR}$$

where:

S_f = road speed, feet per minute

G_t = spray bar output, gallons per minute

W = sprayed width, feet and

R = rate of binder application, gallons per square yard

The rate of binder application is obtained from the design calculations and corrected for temperature. For example, the design quantity of AC-10 to be used on a project is 0.30 gallons per square yard. Temperature-viscosity data have been obtained for the asphalt cement and plotted on Figure 11. An asphalt temperature of 340^{o}F is selected (viscosity of 33 centipoises, i.e., between 20 and 120 centistokes as suggested by the Asphalt Institute and discussed previously). The rate of binder application at 340^{o}F is equal to

$$\frac{0.30}{0.9057} = 0.33 \text{ gallons per square yard}$$

This rate of application will provide 0.30 gallons per square yard on the pavement surface at 60^{o}F.

The spray bar output can be obtained from the distributor manufacturers manual of operation. The discharge quantity is a function of the pump RPM, pump pressure, binder viscosity, spray bar width, etc. The discharge quantity should be converted to gallons per minute for the spray bar width to be used on the job.

The distributor speed for equipment that will spray 90 gallons per minute on a roadway 12 ft. wide at an application rate of 0.33 gallons per square yard is.

$$\frac{9 \times 90}{12 \times 0.33} = 205 \text{ ft. per minute}$$

Length of Shot. The length of spread or the length of a distributor shot may be calculated by using the following formula:

$$L_A = \frac{9T}{WR}$$

where:

L_A = Length of asphalt shot, feet

T = total quantity of hot binder to be shot from the distributor, gallons

For example, if 1500 gallons of asphalt cement were to be shot at a rate of 0.33 gallons per square yard on a roadway 12 ft. wide, the length of shot would be

$$\frac{9 \times 1500}{12 \times 0.33} = 3409 \text{ lineal ft. of roadway 12 ft. wide}$$

Aggregate Spreading. The aggregate must be applied on top of the asphalt in a uniform manner and at a rate equal to the design quantity. Modern self propelled aggregate spreaders are capable of applying a uniform quantity of aggregate at the correct rate provided the equipment is maintained in proper operating condition. Key steps associated with proper aggregate spreading are shown on Table 16.

If aggregate is spread at the desired spread rate, a one stone thick mat will result. The asphalt will be readily visible immediately after the distribution of the coverstone if the correct quantity has been placed. If asphalt is not visible, excess coverstone has been applied. Construction crews will more often have a tendency to use excess stone as opposed to using too little stone. If insufficient quantities of coverstone are applied, aggregate pick up by the tires of the spreading equipment or rolling equipment may result.

The rate of aggregate spreading is determined by the size of opening set on the spreader box, the speed of the spreader and aggregate characteristics including size, shape and weight. Rock lands should be set at the start of each project in order that spreader box opening and the spreader speed can be adjusted to give the desired quantity. The length of the rock lands can be calculated from the following equation:

$$L_R = \frac{9QS}{W}$$

where:

L_R = Length of rock land or aggregate spread for a truck load of aggregate, feet,

Q = Quantity of aggregate in truck load, cubic yards,

S = Aggregate spread rate, square yards of roadway surface per 1 cubic yard of aggregate and

W = Width of aggregate distribution, feet.

For a project using 5 cubic yard trucks and spreading aggregate 12 feet wide at a rate of 1:120 (1 cubic yard to cover 120 square yards of roadway), the rock lands should be set at

$$\frac{9 \times 5 \times 120}{12} = 450 \text{ feet}$$

Rolling. Rolling seats the aggregate in the asphalt and thus promotes the bond which is necessary to resist traffic stresses. When good quality aggregates are utilized it is nearly impossible to over-roll a roadway. The maximum amount of rolling should be determined by economics while the minimum amount should be set at no less than 2 to 3 coverages. Most projects find that economic rolling can be achieved with 3 to 5 rollers operating in a pattern that provides from 3 to 7 coverages on each area of the roadway.

Pneumatic tired (rubber tired) rollers should be used on all seal coats. Both pneumatic-tired and steel-wheeled rollers have been used successfully. Pneumatic tired rollers, however, give a more uniform pressure over the entire area while the steel-wheeled roller will "hit" only the high spots and frequently crush the coverstone. Contact pressures on pneumatic tired rollers can be adjusted to minimize crushing of soft particles. Key operations associated with rolling are shown in Table 17.

Final Clean-up. It is often necessary to remove loose aggregate and/or excess aggregate from the newly constructed seal coat. This operation should be performed as soon as possible to prevent stone damage to vehicles. Power brooming is most often performed about 15 to 24 hours after construction. It is important that this operation be performed when the binder is hard thus, the early morning hours are preferred (Table 18).

Inspection and Quality Control. Selection of a qualified contractor is necessary to achieve success in any construction project. However, even with the best qualifications and intentions, mistakes can and will be made. One way to reduce the number and impact of such errors is to implement an adequate field inspection and quality control plan.

Staffing of the field inspection force should be arranged well in advance of the start of seal coat construction. Except for small jobs, most projects will require a force of two qualified inspectors.

Large projects will require an even larger staff. Qualified inspectors should have prior experience in construction and/or inspection of similar jobs, and the supervising engineer must insist that these inspectors be thoroughly familiar with applicable specifications and documents covering the project.

There are four major elements of field inspection and quality control for seal coat projects:

1. Materials sampling and testing,
2. Construction equipment inspection,
3. Inspection of construction operations and
4. Inspection of completed road segments (performance).

An outline of the actions recommended for on-site materials inspection and sampling, laboratory testing, and corrective action is given on Table 19.

Before construction begins, the contractor's construction equipment must be inspected to ensure specifications compliance, adequate calibration, and good operating condition. Initial inspection can best be accomplished at a convenient assembly point. Follow-up equipment inspection is required each construction day. Guidelines for equipment inspection are shown on Table 20 with additional detail given in Appendix B as Inspectors Checklist No. 1.

During construction, the important steps of each operation must be carefully checked. This inspection requires not only visual observation but also certain on-site tests and measurements. Guidelines for inspection of construction operations are given in Table 21 with additional detail given in Appendix B which is supported by

Inspectors Checklists No. 2 (Asphalt Distributor Operation), No. 3 (Aggregate Spreader Operation), No. 4 (Roller Operation) and No. 5 (Brooming Operation).

Inspection of the completed job is necessary not only for final acceptance and payment, but also to provide feedback for future seal coat projects. This inspection should be performed in a systematic manner and should be at regularly scheduled intervals following constructions. Table 22 defines the types of distress and possible causes for typical seal coat operations (23). The form shown on Figure 12 has been utilized to evaluate seal coat performance by research teams composed of members from the Texas State Department of Highways and Public Transportation and the Texas Transportation Institute. The form should be considered for use in evaluating seal coats and will act as an invaluable training aid for inspectors.

Preconstruction, construction and performance data can be used to revise existing seal coat design methods (19) as well as act as an invaluable training aid for inspectors. Districts 13 and 15, among others, have established data input forms for collecting seal coat preconstruction, construction and performance information. These districts should be contacted for additional information and or the form shown in Figure 13 should be considered for use in the data gathering effort. References 23 and 24 may be used to assist in defining the condition of the pavement prior to placing of the seal coat.

SUMMARY

This manual has been prepared to provide guidelines for the design and construction of seal coats. If followed these guidelines will improve the chance of successfully placing seal coats under a variety of traffic, pavement and environmental conditions. The manual discusses the purposes and appropriate uses of chip seal coats and presents design, construction and performance evaluation guidelines. It is hoped that this manual will improve the overall performance of seal coats in Texas.

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Table 1. Potential Benefits and Problem Areas Associated With Lightweight and Normal Weight Aggregates.

Aggregate Type	Potential Benefits	Potential Problem Areas
Lightweight	1. High skid resistance. 2. Reduced windshield damage. 3. Good color contrast 4. Reduced paint stripe maintenance.	1. Aggregate degradation during handling. 2. Abrasion resistance. 3. Gradation control. 4. High water absorption. 5. Higher cost.
Normal Weight	1. Availability and cost. 2. Relatively low water absorption. 3. High resistance to degradation and abrasion.	1. Poor skid resistance if polish value is low. 2. Windshield damage. 3. Poor asphalt adhesion with high silica aggregates. 4. Dusting.

Table 2. Recommended Aggregates for Seal Coats.

Specifications		Traffic Volume, Vehicles Per Day Per Lane			
Item	Grade	<200	200-4000	4000-5000	Greater than 5000
301 Class A	3				X
	4			X	X
	5		X	X	X
302 Class B	3			X	X
	4			X	X
	5		X	X	X
303 Lightweight	3			X	X
	4			X	X
	5		X	X	X
304 Precoated Class B	3			X	X
	4			X	X
	5		X	X	X
305 Precoated Class A	3				X
	4			X	X
	5		X	X	X

X - Indicates that this grade of aggregate should not be used for defined applications.

Table 3. Comparison of Asphalt Product Types Used For Surface Treatments and Seal Coats.

Asphalt Type	Advantages	Potential Problem Areas
Asphalt Cement	1. Few cure time problems: road surface will usually accept traffic without raveling when rolling is completed.	1. High spraying temperature required: a. May reduce durability of asphalt if overheated. b. Introduces operator safety and discomfort problems. c. Demands careful control to obtain uniform asphalt distribution. d. Is influenced by atmospheric and road surface temperatures. 2. Sensitivity to aggregate surface moisture. 3. Aggregate must be spread and rolled soon after asphalt is distributed.
Asphalt Emulsion (Anionic)	1. Can be applied with little or no heat on distributor. 2. Water dilution can be used except for rapid setting emulsions.	1. Separation of asphalt and water on long storage or after freezing. 2. Asphalt stripping with high silica aggregates 3. Emulsion may run off if road surface temperature is too high. 4. Cure time problems: traffic control required until cure is completed. 5. Will separate if mixed with cationic emulsions.
Asphalt Emulsion (Cationic)	1. Can be applied with little or no heat on distributor. 2. Good adhesion with all aggregate types. 3. Good adhesion with moist aggregates. 4. Can be used in cool weather. 5. Resistant to wash-off if rain occurs soon after placement.	1. Separation of asphalt and water on long storage or after freezing. 2. Emulsion may run off if road surface temperature is too high. 3. Water dilution may cause premature break 4. Cure time problems: traffic control required until cure is completed. 5. Will break if mixed with anionic emulsions.
Cut-Back Asphalt	1. Convenient to use: Uniform distribution 2. Requires lower spraying temperature than asphalt cement. 3. Can be used in cool weather 4. Residue will not be brittle in cold weather.	1. Cure time problems. 2. Cut-back solvent creates air quality problems 3. Waste of energy in cut-back solvent. 4. Solvents have low flash and fire points thus workman safety problems. 5. Bleeding problems.

Table 4: General Recommendation for Asphalt Selection Based on Climatic Conditions.

Type of Asphalt		Spring I	Spring II	Spring III	Summer I	Summer II	Summer III	Fall I	Fall II	Fall III	Winter I	Winter II	Winter III
Asphalt Cements**	AC-5		X	X							X	X	X
	AC-10	X	X	X			X		X	X	X	X	X
Anionic Emulsions	EA-HVRS	X*	X*	X	X*	X*		X*	X*		X*	X*	X
	EA-HVRS-90	X*	X*	X	X*	X*	X	X	X	X	X	X	X
Cationic Emulsions	EA-CRS-2			X									X
	EA-CRS-2h	X	X	X			X	X	X	X	X	X	X
Cutbacks	RC-2	X	X	X	X	X	X	X			X		
	RC-250	X	X	X	X	X	X	X			X		
	RC-3	X	X	X	X	X	X	X			X		
	RC-4	X			X	X	X	X					
	RC-5	X			X	X	X	X					
	MC-800	X	X	X	X	X	X	X			X		
	MC-3000	X	X	X	X	X	X	X			X		

(Header: Construction Season / Climatic Region (Fig. 1) / Type of Asphalt)

Spring - March, April, May

Summer - June, July, August

Fall - September, October

Winter - November, December, January, February

*Do not use in high humidity areas.
**Use caution when using dusty rock.
X-Indicates that this grade of asphalt <u>should not</u> be used for defined applications.

Table 5. Temperature Limitations for Asphalt Selection at the Time of Construction.

Temperature Limitations ^{o}F	AC	Anionic	Cationic
Min. Surf Temp. for 2 Days Prior	70	60	60
Min. Ambient Temp. for 7 Days After	70	60	60
(With moderate traffic after construction)	No rainfall in 48 hours		

Table 6. General Recommendations for Asphalt Selection Based on Aggregate Type.

	Type of Asphalt	Aggregate Type* Natural Hydrophobic	Natural Hydrophilic	Lightweight
ASPHALT CEMENTS	AC-5			
	AC-10			
ANIONIC EMULSIONS	EA-HVRS		X	X
	EA-HVRS-90		X	X
CATIONIC EMULSIONS	EA-CRS-2			
	EA-CRS-2h			
CUTBACKS	RC-2			
	RC-250			
	RC-3			
	RC-4			
	RC-5			
	MC-800			
	MC-3000			

*Aggregate classification shown on Figure 2
X-Indicates that this grade of asphalt <u>should not</u> be used for defined application.

Table 7. Asphalt Application Rate -- Correction Due To Traffic

	Traffic - Vehicles Per Day Per Lane				
	Over 1,000	500 to 1,000	250 to 500	100 to 250	Under 100
Traffic Factor (T)	1.00	1.05	1.10	1.15	1.20

Table 8. Asphalt Application Rate Correction Due to Existing Pavement Surface Condition

Description of Existing Surface	Asphalt Quantity Correction gal/sq. yd.
Flush asphalt surface	-0.06
Smooth, nonporous surface	-0.03
Slightly porous, slightly oxidized surface	0.00
Slightly pocked, porous, oxidized surface	+0.03
Badly pocked, porous, oxidized surface	+0.06

Table 9. Approximate Quantity of Cutter Stock in Cutbacks Commonly Used for Seal Coat Operations

Type of Grade Of Cutback	Approximate Quantity of Cutter Stock, percent	
	by weight	by volume
RC-2	18	23
RC-250	18	23
RC-3	11	14
RC-4	8	12
RC-5	6	9
MC-800	11	14
MC-3000	6	8

Table 10. Temperature-Volume Corrections for Asphalt Contents.*

t	M	t	M	t	M	t	M	t	M
0	1.0211	50	1.0035	100	0.9861	150	0.9689	200	0.9520
1	1.0208	51	1.0031	101	0.9857	151	0.9686	201	0.9516
2	1.0204	52	1.0028	102	0.9854	152	0.9682	202	0.9513
3	1.0201	53	1.0024	103	0.9851	153	0.9679	203	0.9509
4	1.0197	54	1.0021	104	0.9847	154	0.9675	204	0.9506
5	1.0194	55	1.0017	105	0.9844	155	0.9672	205	0.9503
6	1.0190	56	1.0014	106	0.9840	156	0.9669	206	0.9499
7	1.0186	57	1.0010	107	0.9837	157	0.9665	207	0.9496
8	1.0183	58	1.0007	108	0.9833	158	0.9662	208	0.9493
9	1.0179	59	1.0003	109	0.9830	159	0.9658	209	0.9489
10	1.0176	60	1.0000	110	0.9826	160	0.9655	210	0.9486
11	1.0172	61	0.9997	111	0.9823	161	0.9652	211	0.9483
12	1.0169	62	0.9993	112	0.9819	162	0.9648	212	0.9479
13	1.0165	63	0.9990	113	0.9816	163	0.9645	213	0.9476
14	1.0162	64	0.9986	114	0.9813	164	0.9641	214	0.9472
15	1.0158	65	0.9983	115	0.9809	165	0.9638	215	0.9469
16	1.0155	66	0.9979	116	0.9806	166	0.9635	216	0.9466
17	1.0151	67	0.9976	117	0.9802	167	0.9631	217	0.9462
18	1.0148	68	0.9972	118	0.9799	168	0.9628	218	0.9459
19	1.0144	69	0.9969	119	0.9795	169	0.9624	219	0.9456
20	1.0141	70	0.9965	120	0.9792	170	0.9621	220	0.9452
21	1.0137	71	0.9962	121	0.9788	171	0.9618	221	0.9449
22	1.0133	72	0.9958	122	0.9785	172	0.9614	222	0.9446
23	1.0130	73	0.9955	123	0.9782	173	0.9611	223	0.9442
24	1.0126	74	0.9951	124	0.9778	174	0.9607	224	0.9439
25	1.0123	75	0.9948	125	0.9775	175	0.9604	225	0.9436
26	1.0119	76	0.9944	126	0.9771	176	0.9601	226	0.9432
27	1.0116	77	0.9941	127	0.9768	177	0.9597	227	0.9429
28	1.0112	78	0.9937	128	0.9764	178	0.9594	228	0.9426
29	1.0109	79	0.9934	129	0.9761	179	0.9590	229	0.9422
30	1.0105	80	0.9930	130	0.9758	180	0.9587	230	0.9419
31	1.0102	81	0.9927	131	0.9754	181	0.9584	231	0.9416
32	1.0098	82	0.9923	132	0.9751	182	0.9580	232	0.9412
33	1.0095	83	0.9920	133	0.9747	183	0.9577	233	0.9409
34	1.0091	84	0.9916	134	0.9744	184	0.9574	234	0.9405
35	1.0088	85	0.9913	135	0.9740	185	0.9570	235	0.9402
36	1.0084	86	0.9909	136	0.9737	186	0.9567	236	0.9399
37	1.0081	87	0.9906	137	0.9734	187	0.9563	237	0.9395
38	1.0077	88	0.9902	138	0.9730	188	0.9560	238	0.9392
39	1.0074	89	0.9899	139	0.9727	189	0.9557	239	0.9389
40	1.0070	90	0.9896	140	0.9723	190	0.9553	240	0.9385
41	1.0067	91	0.9892	141	0.9720	191	0.9550	241	0.9382
42	1.0063	92	0.9889	142	0.9716	192	0.9547	242	0.9379
43	1.0060	93	0.9885	143	0.9713	193	0.9543	243	0.9375
44	1.0056	94	0.9882	144	0.9710	194	0.9540	244	0.9372
45	1.0053	95	0.9878	145	0.9706	195	0.9536	245	0.9369
46	1.0049	96	0.9875	146	0.9703	196	0.9533	246	0.9365
47	1.0046	97	0.9871	147	0.9699	197	0.9530	247	0.9362
48	1.0042	98	0.9868	148	0.9696	198	0.9526	248	0.9359
49	1.0038	99	0.9864	149	0.9693	199	0.9523	249	0.9356

t	M	t	M	t	M	t	M	t	M
250	0.9352	300	0.9187	350	0.9024	400	0.8864	450	0.8705
251	0.9349	301	0.9184	351	0.9021	401	0.8861	451	0.8702
252	0.9346	302	0.9181	352	0.9018	402	0.8857	452	0.8699
253	0.9342	303	0.9177	353	0.9015	403	0.8854	453	0.8696
254	0.9339	304	0.9174	354	0.9011	404	0.8851	454	0.8693
255	0.9336	305	0.9171	355	0.9008	405	0.8848	455	0.8690
256	0.9332	306	0.9167	356	0.9005	406	0.8845	456	0.8687
257	0.9329	307	0.9164	357	0.9002	407	0.8841	457	0.8683
258	0.9326	308	0.9161	358	0.8998	408	0.8838	458	0.8680
259	0.9322	309	0.9158	359	0.8995	409	0.8835	459	0.8677
260	0.9319	310	0.9154	360	0.8992	410	0.8832	460	0.8674
261	0.9316	311	0.9151	361	0.8989	411	0.8829	461	0.8671
262	0.9312	312	0.9148	362	0.8986	412	0.8826	462	0.8668
263	0.9309	313	0.9145	363	0.8982	413	0.8822	463	0.8665
264	0.9306	314	0.9141	364	0.8979	414	0.8819	464	0.8661
265	0.9302	315	0.9138	365	0.8976	415	0.8816	465	0.8658
266	0.9299	316	0.9135	366	0.8973	416	0.8813	466	0.8655
267	0.9296	317	0.9132	367	0.8969	417	0.8810	467	0.8652
268	0.9293	318	0.9128	368	0.8966	418	0.8806	468	0.8649
269	0.9289	319	0.9125	369	0.8963	419	0.8803	469	0.8646
270	0.9286	320	0.9122	370	0.8960	420	0.8800	470	0.8643
271	0.9283	321	0.9118	371	0.8957	421	0.8797	471	0.8640
272	0.9279	322	0.9115	372	0.8953	422	0.8794	472	0.8636
273	0.9276	323	0.9112	373	0.8950	423	0.8791	473	0.8633
274	0.9273	324	0.9109	374	0.8947	424	0.8787	474	0.8630
275	0.9269	325	0.9105	375	0.8944	425	0.8784	475	0.8627
276	0.9266	326	0.9102	376	0.8941	426	0.8781	476	0.8624
277	0.9263	327	0.9099	377	0.8937	427	0.8778	477	0.8621
278	0.9259	328	0.9096	378	0.8934	428	0.8775	478	0.8618
279	0.9256	329	0.9092	379	0.8931	429	0.8772	479	0.8615
280	0.9253	330	0.9089	380	0.8928	430	0.8768	480	0.8611
281	0.9250	331	0.9086	381	0.8924	431	0.8765	481	0.8608
282	0.9246	332	0.9083	382	0.8921	432	0.8762	482	0.8605
283	0.9243	333	0.9079	383	0.8918	433	0.8759	483	0.8602
284	0.9240	334	0.9076	384	0.8915	434	0.8756	484	0.8599
285	0.9236	335	0.9073	385	0.8912	435	0.8753	485	0.8596
286	0.9233	336	0.9070	386	0.8908	436	0.8749	486	0.8593
287	0.9230	337	0.9066	387	0.8905	437	0.8746	487	0.8590
288	0.9227	338	0.9063	388	0.8902	438	0.8743	488	0.8587
289	0.9223	339	0.9060	389	0.8899	439	0.8740	489	0.8583
290	0.9220	340	0.9057	390	0.8896	440	0.8737	490	0.8580
291	0.9217	341	0.9053	391	0.8892	441	0.8734	491	0.8577
292	0.9213	342	0.9050	392	0.8889	442	0.8731	492	0.8574
293	0.9210	343	0.9047	393	0.8886	443	0.8727	493	0.8571
294	0.9207	344	0.9044	394	0.8883	444	0.8724	494	0.8568
295	0.9204	345	0.9040	395	0.8880	445	0.8721	495	0.8565
296	0.9200	346	0.9037	396	0.8876	446	0.8718	496	0.8562
297	0.9197	347	0.9034	397	0.8873	447	0.8715	497	0.8559
298	0.9194	348	0.9031	398	0.8870	448	0.8712	498	0.8556
299	0.9190	349	0.9028	399	0.8867	449	0.8709	499	0.8552

*Specific gravity of materials at $60^{O}F$ above 0.966.

t = Observed temperature in degrees Fahrenheit.

M = Multiplier for correcting oil volumes to the basis of $60^{O}F$.

Table 11. Temperature-Volume Correction for Cutback Asphalts.*

t	M	t	M	t	M	t	M	t	M	t	M	t	M	t	M	t	M	t	M
0	1.0241	50	1.0040	100	0.9842	150	0.9647	200	0.9456	250	0.9268	300	0.9083	350	0.8902	400	0.8724	450	0.8550
1	1.0237	51	1.0036	101	0.9838	151	0.9643	201	0.9452	251	0.9264	301	0.9080	351	0.8899	401	0.8721	451	0.8547
2	1.0233	52	1.0032	102	0.9834	152	0.9639	202	0.9448	252	0.9260	302	0.9076	352	0.8895	402	0.8717	452	0.8543
3	1.0229	53	1.0028	103	0.9830	153	0.9635	203	0.9444	253	0.9257	303	0.9072	353	0.8891	403	0.8714	453	0.8540
4	1.0225	54	1.0024	104	0.9826	154	0.9632	204	0.9441	254	0.9253	304	0.9069	354	0.8888	404	0.8710	454	0.8536
5	1.0221	55	1.0020	105	0.9822	155	0.9628	205	0.9437	255	0.9249	305	0.9065	355	0.8884	405	0.8707	455	0.8533
6	1.0217	56	1.0016	106	0.9818	156	0.9624	206	0.9433	256	0.9245	306	0.9061	356	0.8881	406	0.8703	456	0.8529
7	1.0213	57	1.0012	107	0.9814	157	0.9620	207	0.9429	257	0.9242	307	0.9058	357	0.8877	407	0.8700	457	0.8526
8	1.0209	58	1.0008	108	0.9810	158	0.9616	208	0.9425	258	0.9238	308	0.9054	358	0.8873	408	0.8696	458	0.8522
9	1.0205	59	1.0004	109	0.9806	159	0.9612	209	0.9422	259	0.9234	309	0.9050	359	0.8870	409	0.8693	459	0.8519
10	1.0201	60	1.0000	110	0.9803	160	0.9609	210	0.9418	260	0.9231	310	0.9047	360	0.8866	410	0.8689	460	0.8516
11	1.0197	61	0.9996	111	0.9799	161	0.9605	211	0.9414	261	0.9227	311	0.9043	361	0.8863	411	0.8686	461	0.8512
12	1.0193	62	0.9992	112	0.9795	162	0.9601	212	0.9410	262	0.9223	312	0.9039	362	0.8859	412	0.8682	462	0.8509
13	1.0189	63	0.9988	113	0.9791	163	0.9597	213	0.9407	263	0.9219	313	0.9036	363	0.8856	413	0.8679	463	0.8505
14	1.0185	64	0.9984	114	0.9787	164	0.9593	214	0.9403	264	0.9216	314	0.9032	364	0.8852	414	0.8675	464	0.8502
15	1.0181	65	0.9980	115	0.9783	165	0.9589	215	0.9399	265	0.9212	315	0.9029	365	0.8848	415	0.8672	465	0.8498
16	1.0177	66	0.9976	116	0.9779	166	0.9585	216	0.9395	266	0.9208	316	0.9025	366	0.8845	416	0.8668	466	0.8495
17	1.0173	67	0.9972	117	0.9775	167	0.9582	217	0.9391	267	0.9205	317	0.9021	367	0.8841	417	0.8665	467	0.8492
18	1.0168	68	0.9968	118	0.9771	168	0.9578	218	0.9388	268	0.9201	318	0.9018	368	0.8838	418	0.8661	468	0.8488
19	1.0164	69	0.9964	119	0.9767	169	0.9574	219	0.938[illegible]	269	0.9197	319	0.9014	369	0.8834	419	0.8658	469	0.8485
20	1.0160	70	0.9960	120	0.9763	170	0.9570	220	0.9380	270	0.9194	320	0.9010	370	0.8831	420	0.8654	470	0.8481
21	1.0156	71	0.9956	121	0.9760	171	0.9566	221	0.9376	271	0.9190	321	0.9007	371	0.8827	421	0.8651	471	0.8478
22	1.0152	72	0.9952	122	0.9756	172	0.9562	222	0.9373	272	0.9186	322	0.9003	372	0.8823	422	0.8647	472	0.8474
23	1.0148	73	0.9948	123	0.9752	173	0.9559	223	0.9369	273	0.9182	323	0.9000	373	0.8820	423	0.8644	473	0.8471
24	1.0144	74	0.9944	124	0.9748	174	0.9555	224	0.9365	274	0.9179	324	0.8996	374	0.8816	424	0.8640	474	0.8468
25	1.0140	75	0.9940	125	0.9744	175	0.9551	225	0.9361	275	0.9175	325	0.8992	375	0.8813	425	0.8637	475	0.8464
26	1.0136	76	0.9936	126	0.9740	176	0.9547	226	0.9358	276	0.9171	326	0.8989	376	0.8809	426	0.8633	476	0.8461
27	1.0132	77	0.9932	127	0.9736	177	0.9543	227	0.9354	277	0.9168	327	0.8985	377	0.8806	427	0.8630	477	0.8457
28	1.0128	78	0.9929	128	0.9732	178	0.9539	228	0.9350	278	0.9164	328	0.8981	378	0.8802	428	0.8626	478	0.8454
29	1.0124	79	0.9925	129	0.9728	179	0.9536	229	0.9346	279	0.9160	329	0.8978	379	0.8799	429	0.8623	479	0.8451
30	1.0120	80	0.9921	130	0.9725	180	0.9532	230	0.9343	280	0.9157	330	0.8974	380	0.8795	430	0.8619	480	0.8447
31	1.0116	81	0.9917	131	0.9721	181	0.9528	231	0.9339	281	0.9153	331	0.8971	381	0.8792	431	0.8616	481	0.8444
32	1.0112	82	0.9913	132	0.9717	182	0.9524	232	0.9335	282	0.9149	332	0.8967	382	0.8788	432	0.8612	482	0.8440
33	1.0108	83	0.9909	133	0.9713	183	0.9520	233	0.9331	283	0.9146	333	0.8963	383	0.8784	433	0.8609	483	0.8437
34	1.0104	84	0.9905	134	0.9709	184	0.9517	234	0.9328	284	0.9142	334	0.8960	384	0.8781	434	0.8605	484	0.8433
35	1.0100	85	0.9901	135	0.9705	185	0.9513	235	0.9324	285	0.9138	335	0.8956	385	0.8777	435	0.8602	485	0.8430
36	1.0096	86	0.9897	136	0.9701	186	0.9509	236	0.9320	286	0.9135	336	0.8952	386	0.8774	436	0.8599	486	0.8427
37	1.0092	87	0.9893	137	0.9697	187	0.9505	237	0.9316	287	0.9131	337	0.8949	387	0.8770	437	0.8595	487	0.8423
38	1.0088	88	0.9889	138	0.9693	188	0.9501	238	0.9313	288	0.9127	338	0.8945	388	0.8767	438	0.8592	488	0.8420
39	1.0084	89	0.9885	139	0.9690	189	0.9498	239	0.9309	289	0.9124	339	0.8942	389	0.8763	439	0.8588	489	0.8416
40	1.0080	90	0.9881	140	0.9686	190	0.9494	240	0.9305	290	0.9120	340	0.8938	390	0.8760	440	0.8585	490	0.8413
41	1.0076	91	0.9877	141	0.9682	191	0.9490	241	0.9301	291	0.9116	341	0.8934	391	0.8756	441	0.8581	491	0.8410
42	1.0072	92	0.9873	142	0.9678	192	0.9486	242	0.9298	292	0.9113	342	0.8931	392	0.8753	442	0.8578	492	0.8406
43	1.0068	93	0.9869	143	0.9674	193	0.9482	243	0.9294	293	0.9109	343	0.8927	393	0.8749	443	0.8574	493	0.8403
44	1.0064	94	0.9865	144	0.9670	194	0.9478	244	0.9290	294	0.9105	344	0.8924	394	0.8746	444	0.8571	494	0.8399
45	1.0060	95	0.9861	145	0.9666	195	0.9475	245	0.9286	295	0.9102	345	0.8920	395	0.8742	445	0.8567	495	0.8396
46	1.0056	96	0.9857	146	0.9662	196	0.9471	246	0.9283	296	0.9098	346	0.8916	396	0.8738	446	0.8564	496	0.8393
47	1.0052	97	0.9854	147	0.9659	197	0.9467	247	0.9279	297	0.9094	347	0.8913	397	0.8735	447	0.8560	497	0.8389
48	1.0048	98	0.9850	148	0.9655	198	0.9463	248	0.9275	298	0.9091	348	0.8909	398	0.8731	448	0.8557	498	0.8386
49	1.0044	99	0.9846	149	0.9651	199	0.9460	249	0.9272	299	0.9087	349	0.8906	399	0.8728	449	0.8554	499	0.8383

*Specific gravity of materials at 60^{o}F of 0.850 to 0.966.
After Reference 21.

t = Observed temperature in degrees Fahrenheit.

M = Multiplier for correcting oil volumes to the basis of 60^{o}F.

Table 12. Temperature-Volume Corrections for Emulsified Asphalts.

t	M	t	M	t	M
60	1.00000	90	.99250	121	.98475
61	.99975	91	.99225	122	.98450
62	.99950	92	.99200	123	.98425
63	.99925	93	.99175	124	.98400
64	.99900	94	.99150	125	.98375
65	.99875	95	.99125	126	.98350
66	.99850	96	.99100	127	.98325
67	.99825	97	.99075	128	.98300
68	.99800	98	.99050	129	.98275
69	.99775	99	.99025	130	.98250
70	.99750	100	.99000	131	.98225
71	.99725	101	.98975	132	.98200
72	.99700	102	.98950	133	.98175
73	.99675	103	.98925	134	.98150
74	.99650	104	.98900	135	.98125
75	.99625	105	.98875	136	.98100
76	.99600	106	.98850	137	.98075
77	.99575	107	.98825	138	.98050
78	.99550	108	.98800	139	.98025
79	.99525	109	.98775	140	.98000
80	.99500	110	.98750	141	.97975
81	.99475	111	.98725	142	.97950
82	.99450	112	.98700	143	.97925
83	.99425	113	.98675	144	.97900
84	.99400	114	.98650	145	.97875
85	.99375	115	.98625	146	.97850
86	.99350	116	.98600	147	.97825
87	.99325	117	.98575	148	.97800
88	.99300	118	.98550	149	.97775
89	.99275	119	.98525	150	.97750
		120	.98500		

t = Observed temperature in degrees Fahrenheit.

M = Multiplier for correcting volumes to the basis of 60°F.

Table 13. Preparation Of Existing Asphalt Pavement Surface for Seal Coat

Key Steps of Operation	Action To Be Taken
General	Pavement distress due to structural weakness cannot be repaired by seal coating.
Pot Holes: Broken Edges	Chip out broken material, leaving vertical sides. Clean, prime and patch (hot mix preferred). For hot mix patches, complete at least 30 days before asphalt shot is scheduled. For cold patch material, allow 60 days minimum.
Raveling: Streaking	If severe, fill depressions with slurry seal about 30 days prior to sealing or fog seal.
Cracks-Longitudinal and transverse	Fill large cracks with crack sealing material.
Slippage	Remove all slipped material and replace with suitable patching material.
Bleeding Asphalt	If severe remove excess asphalt with heater-planer or cold milling machine or heat surface and roll-in hot aggregate.
Rutting and Corrugations	If greater than 3/4 inch remove with heater planer or cold milling machine.
Alligator Cracking	If severe remove and replace with suitable patching material.
Pavement Edge	Remove grass and debris build up from edge of pavement and patch raveled edge as required. Proper drainage should be maintained.
Cleaning	Clean surface immediately prior to asphalt shot; remove mud and other foreign matter; sweep thoroughly with power broom; flush with clean water if necessary and allow to dry.

Table 14. Asphalt Application

Key Step of Operation	Action To Be Taken
Equipment Check	Before work begins inspect distributor for operating condition (Inspectors Checklist No. 1, Appendix B).
Alignment	Place string-line along road edge or use center line to guide driver of the distributor.
Travel speed	Determine distributor speed (S_f) for spray bar output (G_t) width of shot (W) and rate of binder application (R) $$S_f = \frac{9G_t}{WR}$$
Length of Shot	Determine length of application (shot) (L_A) to balance aggregate availability (number of loaded trucks), size of tank, type of asphalt, allowable time delays (asphalt shot/aggregate speed and aggregate spread/rolling), and traffic control. $$L_A = \frac{9T}{WR}$$
Nozzle Adjustment	Adjust angle between long axis of nozzle orifice and spray bar longitudinal axis to value specified by distributor manufacturer (normally between 15 and 30 deg.) Adjust end nozzles to greater angle (see Figure 8) or use a deflector nozzle. Replace clogged or damaged nozzles.
Spray-Bar Height	Adjust height accurately to produce exact double-lap or triple-lap pattern determined by distributor calibration and test. (Double-check height control (see Figure 8).
Spraying Temperature	Set tank heater to control temperature to give correct viscosity for type and grade of asphalt being shot (Table 15, Figure 9, 10, 11, Appendix C).

Table 14. Asphalt Application - Continued

Key Step of Operation	Action To Be Taken
Transverse Joints	Avoid overlap by starting and ending the shot applied by the distributor on building paper.
Longitudinal Joints	Overlap preceeding shot by 1/2 width of spray from end nozzle. Accurate alignment by distributor driver is essential. If a good driver is available better performance can be obtained by using a deflector nozzle. If possible keep joint at edge of lane (¢ of 2-lane highways).

Table 15. Typical Temperatures for Applying, Mixing and Storing Asphalt Binders

Type of Asphalt		Application and Mixing: Recommended Range °F	Application and Mixing: Maximum Allowable, °F	Heating and Storage Maximum, °F
Asphalt Cement	AC-5	275-325	350	400
	AC-10	275-325	350	400
Anionic Emulsions	EA-HVRS	110-150	160	160
	EA-HVRS-90	110-150	160	160
Cationic Emulsion	EA-CRS-2	110-150	160	160
	EA-CRS-2h	110-150	160	160
Cutbacks	RC-2	125-180	200	200
	RC-250	150-200	210	210
	RC-3	160-210	230	230
	RC-4	180-240	270	270
	RC-5	215-270	285	285
	MC-800	175=260	275	275
	MC-3000	225-275	290	290

after reference 22

Table 16. Aggregate Spreading

Key Steps of Operation	Action To Be Taken
Equipment Check	Before work begins inspect spreader for operating condition (Inspectors Checklist No. 1 (Appendix B)
Aggregate Supply and Delivery	Make sure enough approved aggregate and sufficient number of trucks are available so that one asphalt shot can be covered without delay.
Aggregate Moisture	Dry aggregate surface desired. On sunny, dry days a small amount of surface moisture on stockpiled aggregate will be removed in the handling operations.
Timing	Cover asphalt shot as quickly as possible; within one minute for asphalt cements; somewhat longer delays are often acceptable for asphalt emulsions and cutbacks.
Travel Speed	Depends on type of spreader. Set and hold uniform speed to produce specified spread rate. Avoid lopping, bumping, or other maneuvers resulting in non-uniform aggregate discharge.
Overlap	Operate spreader to limit placing of stones on top of aggregate already spread. If excess overlap occurs remove with hand broom as soon as possible.
Hand Spotting	Hand spotting is normally not required. Place aggregate on bare asphalt as required.

Table 17. Rolling

Key Steps of Operation	Action To Be Taken
Equipment Check (pneumatic rollers)	Before work begins, inspect rollers for operating condition (Inspectors Checklist No. 1 (Appendix B). Particularly important: front wheel wobble, total weight, tire pressure.
Timing	Begin rolling operations immediately following start of aggregate spreading.
Speed	Operate so that tires do not pick up or shove aggregate particles.
Sequence	Begin at outside edge and progress toward center. Overlap preceding pass by about 1/2 rolling width. Make at least 2 to 3 coverages. The first coverage should be completed soon after application of the aggregate. Avoid tight turning movements and sudden stops and starts.

Table 18. Final Clean-Up

Key Steps of Operation	Action To Be Taken
Timing	Begin power brooming only after aggregate is completely set and asphalt has hardened usually at least 24 hours after rolling is complete. Operate broom when pavement surface is cool preferably in the early morning hours.
Sequence	Operate power broom to lightly brush loose stones toward outer edge of lane. Bonded stones should not be dislodged.

Table 19. Guidelines for On-Site Materials Inspection and Sampling

Materials	Action To Be Taken
Cover Aggregate	1. Take representative sample from each stockpile. 2. Quarter each stockpile sample. Test one quartered sample from each stockpile. 3. Label and retain unused samples. 4. Check test results against a) Specifications b) Acceptance tests made prior to delivery c) Test data used for design 5. Take appropriate action if: a) Significant deviations in test data are noted b) There is significant pile-to-pile variation in test results 6. Inspect piles for drainage and cleanliness 7. Make visual check for excess moisture before aggregate is loaded into trucks
Asphalt Binder	1. If asphalt storage and distributor tanks are not clean and empty when placed on the project, take a representative sample of the material in each tank. 2. Have each sample tested to establish the type and grade of asphalt remaining in each tank. 3. If the type and grade of asphalt in a tank does not correspond to the type and grade specified for the project, the tank must be drained and cleaned before refilling. 4. Carefully check delivery document for each load of asphalt delivered to the site to ensure application of the proper type and grade. 5. Make visual check for separation before loading asphalt emulsions into the distributor tank. 6. The inspector should take samples and have them tested if he has reason to believe that contamination of the asphalt has occurred.

Table 19. Guidelines For On-Site Materials Inspection and Sampling - Continued

Materials	Action To Be Taken
	7. Obtain D-9 test number for asphalt shipments and obtain viscosity-temperature data from Division 9 in Austin. Plot on Figure in Appendix C.

Table 20. Guidelines for Construction Equipment Inspection

Inspection Timing	Action To Be Taken
Prior to Starting Construction	1. Make sure numbers of each kind of construction equipment assigned are adequate for project scope and schedule. 2. Check each piece of equipment for: a) Specification compliance, b) Required calibrations and adjustments, c) Operating condition. 3. Check against Inspectors Checklist No. 1, Appendix B.
At Beginning of Each Construction Day	1. Check operating condition, use Inspectors Checklist No. 1, Appendix B

Table 21. Guidelines for Inspection of Construction Operations

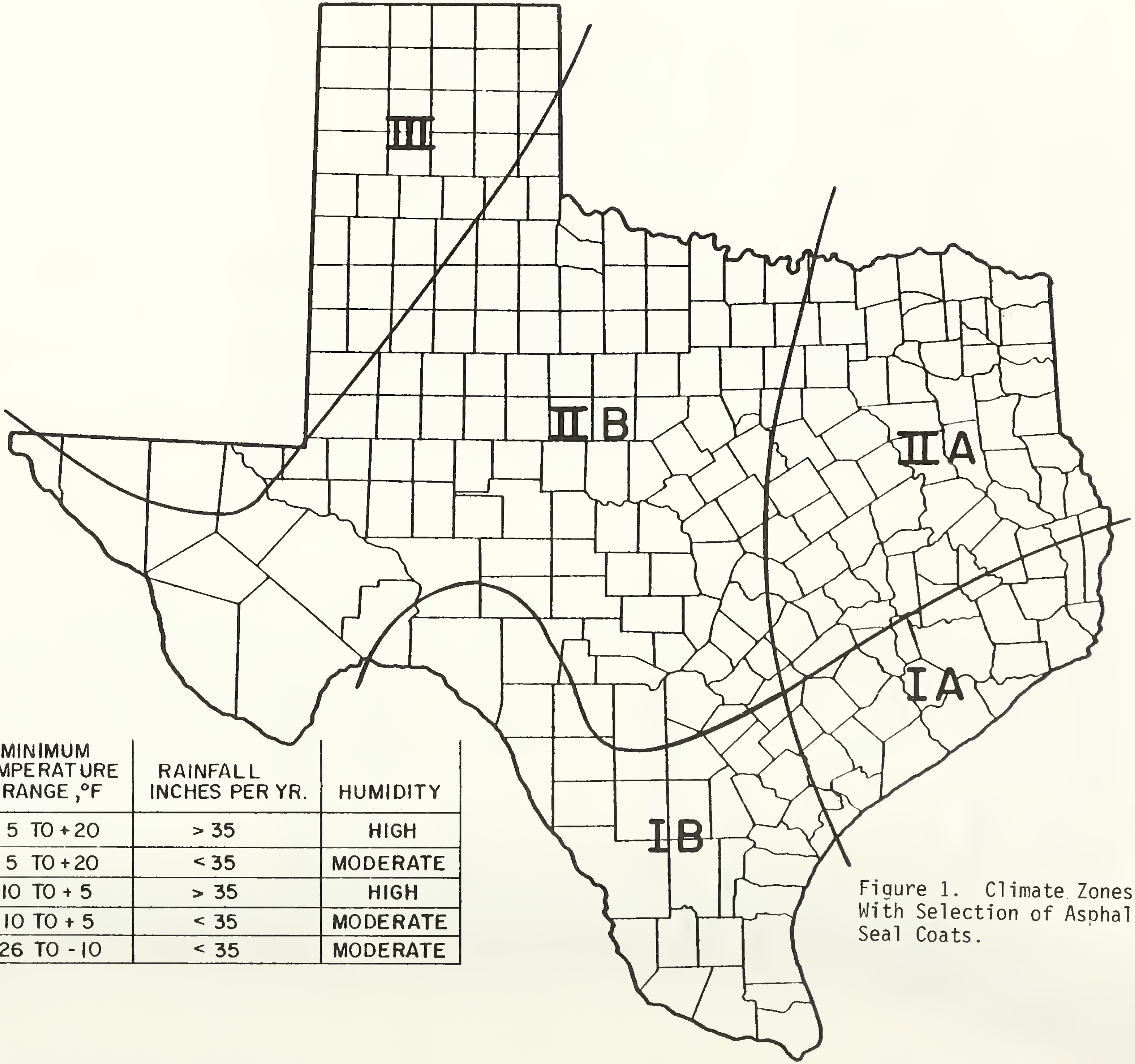
Operation and Step Inspected	Action To Be Taken
Existing Asphalt Pavement Surface	Visual inspection for repair of defects (pot-holes, cracks, etc). All patching should be completed 30 to 60 days before seal coating begins. Inspect for cleanliness.
Asphalt Distribution Rate	1. On first shot, then periodically during job, measure transverse variation in rate by catching spray on cotton pads spaced across pavements, Appendix A. Transverse variation in rate should be less than 15 percent for asphalt emulsions and less than 10 percent for asphalt cements and cutbacks.
	2. On first shot, then periodically during job, measure longitudinal variation in spray rate by catching asphalt in 12 in. x 12 in. shallow paper-lined pans placed at 100 to 150 ft. intervals along the direction of travel. The longitudinal variation in rate should be less than 10 percent.
	3. By gauging tank before and after shot, determine total asphalt applied (T) and calculate distribution on a gallons per square yard basis. $R = \frac{9T}{WL} \quad gal/yd^2$
Asphalt Distributor	Inspect as indicated in Inspectors Checklist No. 2, Appendix B.
Aggregate Spread Rate	1. Check spreader adjustment before first application. Place 1 yd^2 pans (or cloths) at intervals across spread width and operate spreader over these. Average of weights retained in the pans should equal the design spread rate. Transverse variation in spread rate should be less than 10 to 15 percent.

Table 21. Guidelines for Inspection of Construction Operations - Continued

Operation and Step Inspected	Action To Be Taken
	2. Use tachometer to assure spreader box speed control.
	3. Check spread rate by laying off road length for each truck load of aggregate.
Aggregate Spreader Operation	Inspect as indicated in Inspectors Checklist No. 3, Appendix B
Roller Operation	Inspect as indicated in Inspectors Checklist No. 4, Appendix B
Brooming and Other Cleaning Operations	Inspect as indicated in Inspectors Checklist No. 5, Appendix B

Table 22. Types and Causes of Seal Coat Distress

Distress	Possible Causes
Streaking	Longitudinally distributed deficiencies in asphalt application due to: inoperative nozzles, incorrect nozzle angles, incorrect distributor bar height, low asphalt temperature, low pump pressure, incorrect fan widths at a given height, high distributor speed. These problems are particularly troublesome at spread rates below 0.1 gal/yd.^{2}
Corduroying	Uneven and bumpy aggregate spreader operation. Bent or warped roll base.
Incipient Bleeding	Underlying surface condition (too soft, inadequate preparation, excess asphalt not removed, base not compacted, primer incorrectly applied). Asphalt spread rate too high. Asphalt spread rate OK, but aggregate spread rate too low. Aggregate loss due to moisture problems.
Raveling	Asphalt spread rate too low. Aggregate loss due to moisture problems. Fast traffic allowed on surface too soon.
Transverse Joints (Bumps)	Overlap of asphalt at beginning and end of a shot.
Longitudinal Ridges	Too much overlap of asphalt and aggregate spread which results in excesses of one or both materials.



ZONE	MINIMUM TEMPERATURE RANGE, °F	RAINFALL INCHES PER YR.	HUMIDITY
IA	+ 5 TO + 20	> 35	HIGH
IB	+ 5 TO + 20	< 35	MODERATE
IIA	- 10 TO + 5	> 35	HIGH
IIB	- 10 TO + 5	< 35	MODERATE
III	- 26 TO - 10	< 35	MODERATE

Figure 1. Climate Zones Associated With Selection of Asphalt Type for Seal Coats.

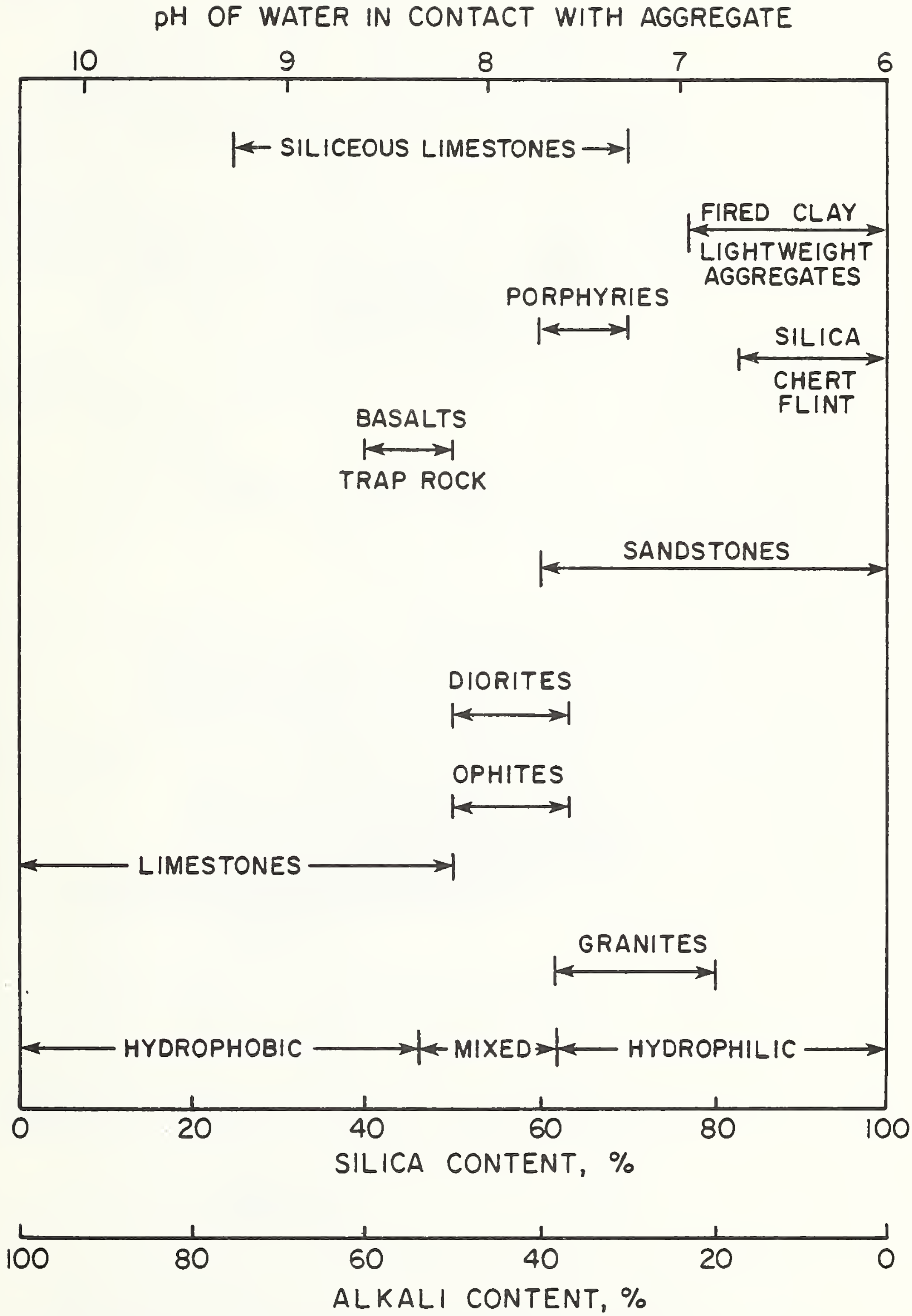


Figure 2. Aggregate Type Classification Chart.
(After Reference 17.)

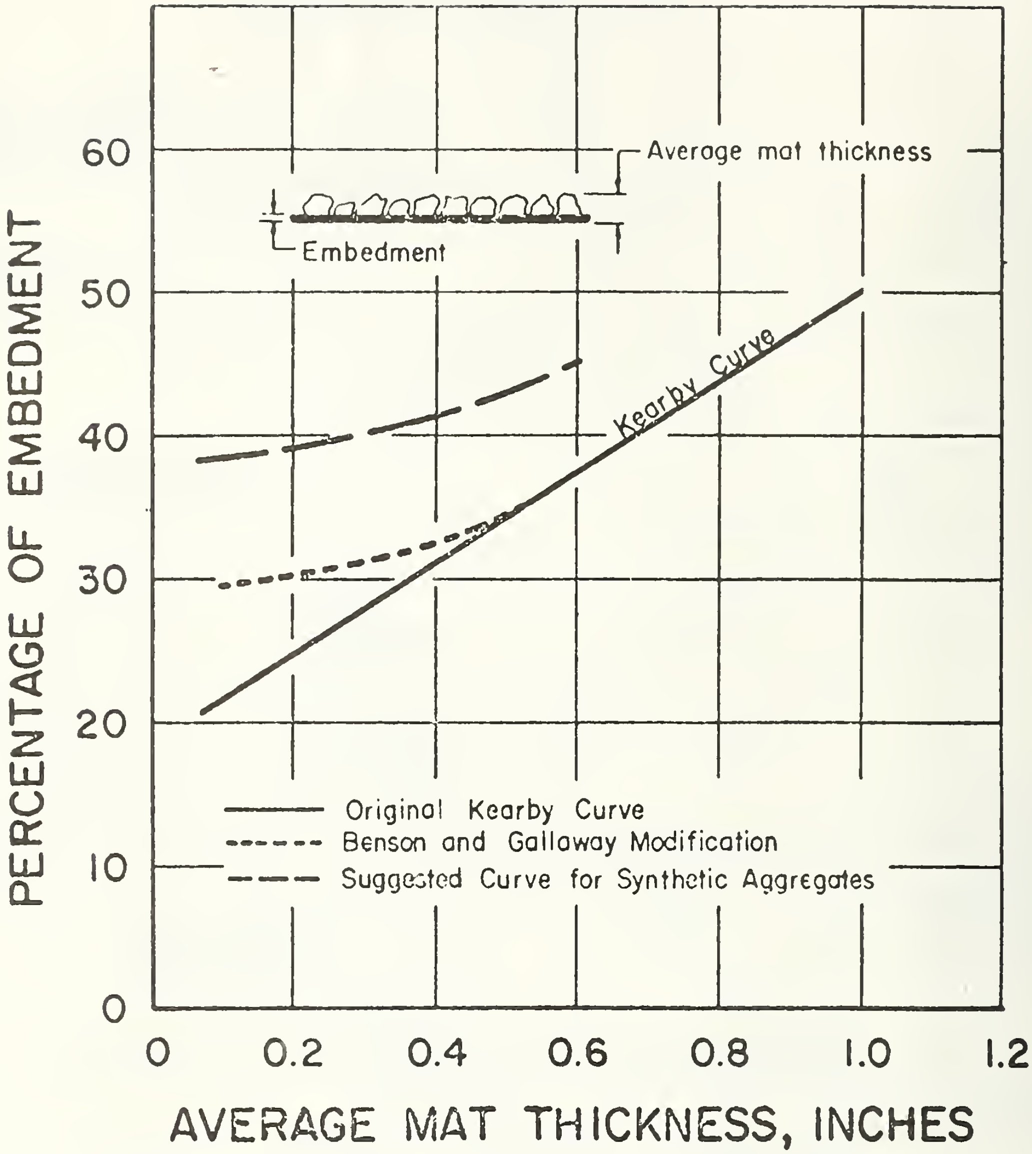


Figure 3. Relation of Percent Embedment to Mat Thickness for Determining Quantity of Asphalt.

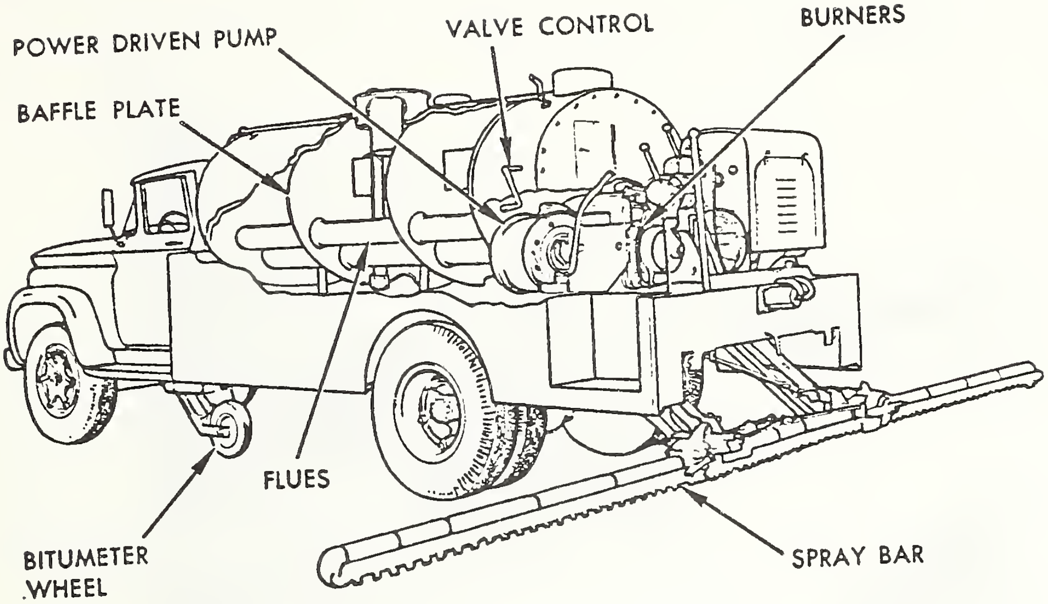
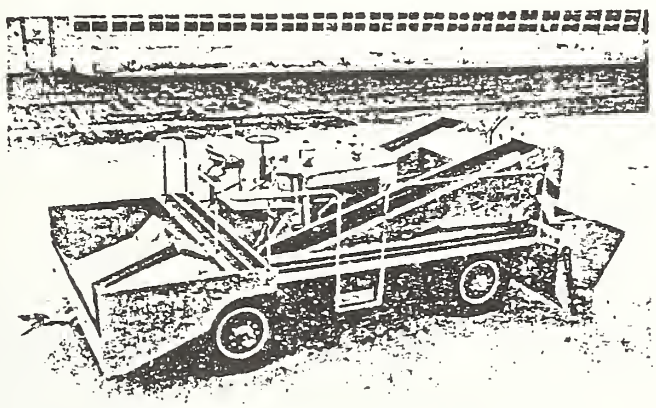
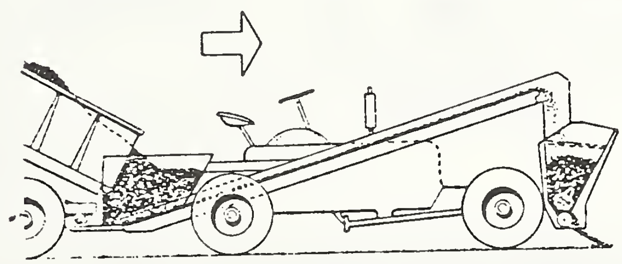


Figure 4. Asphalt Distributor.
(After Reference 2.)



Self-Propelled Aggregate Spreader



Flow of Aggregate Through a Self-Propelled Spreader

Figure 5. Aggregate Spreader.
(After Reference 2.)

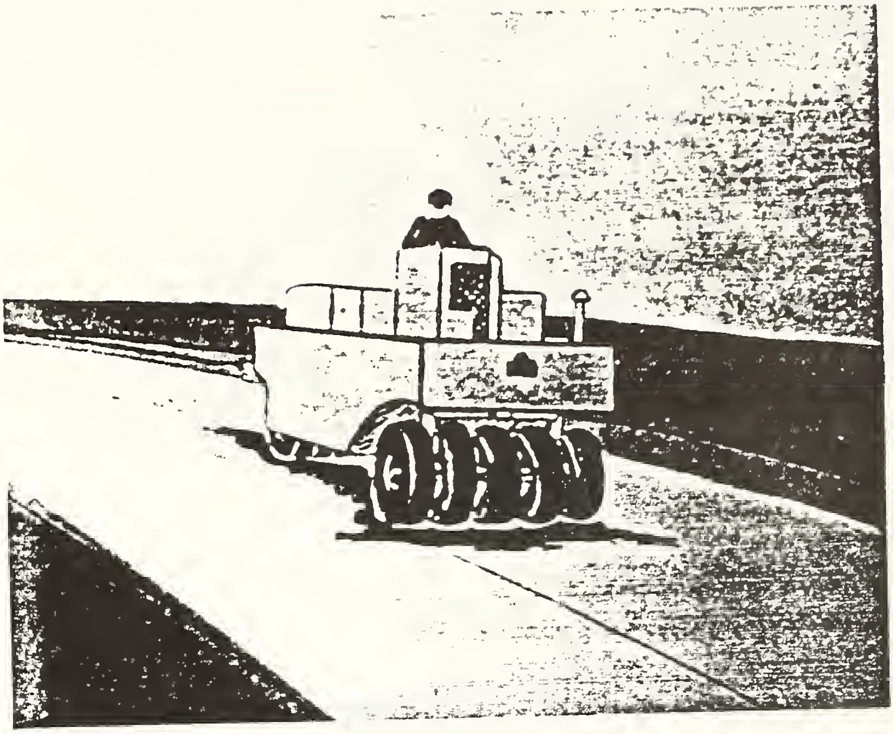


Figure 6. Pneumatic-Tired Roller.

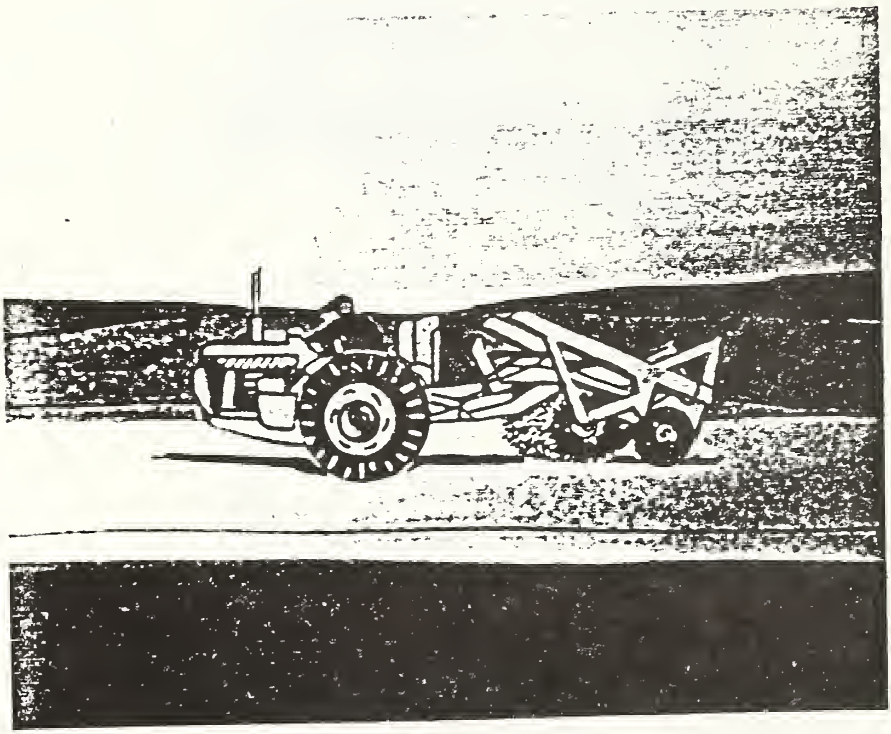


Figure 7. Power Broom

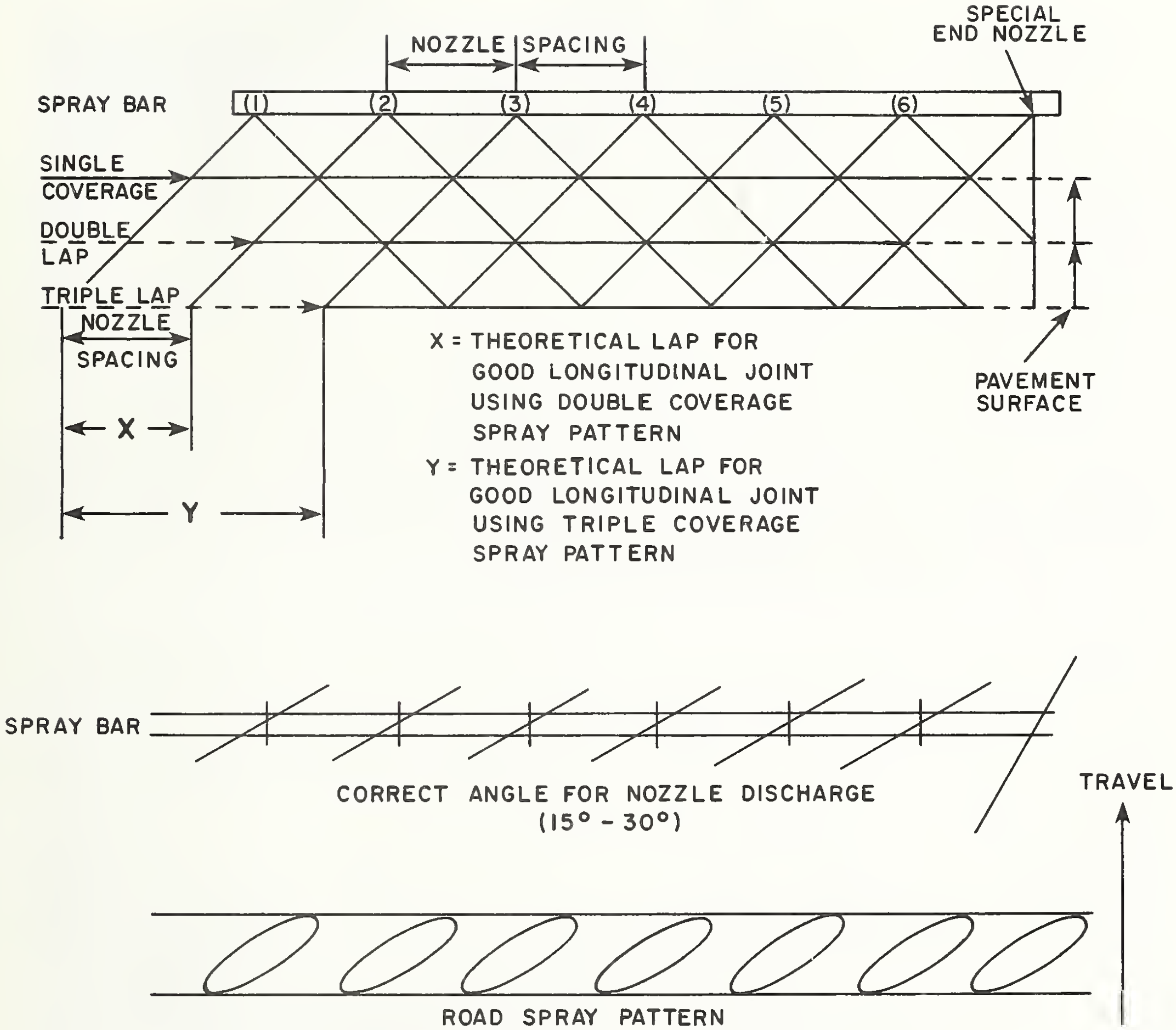


FIGURE 8. DESIRED SPRAY BAR HEIGHT AND NOZZLE ANGLES

(After Reference 2)

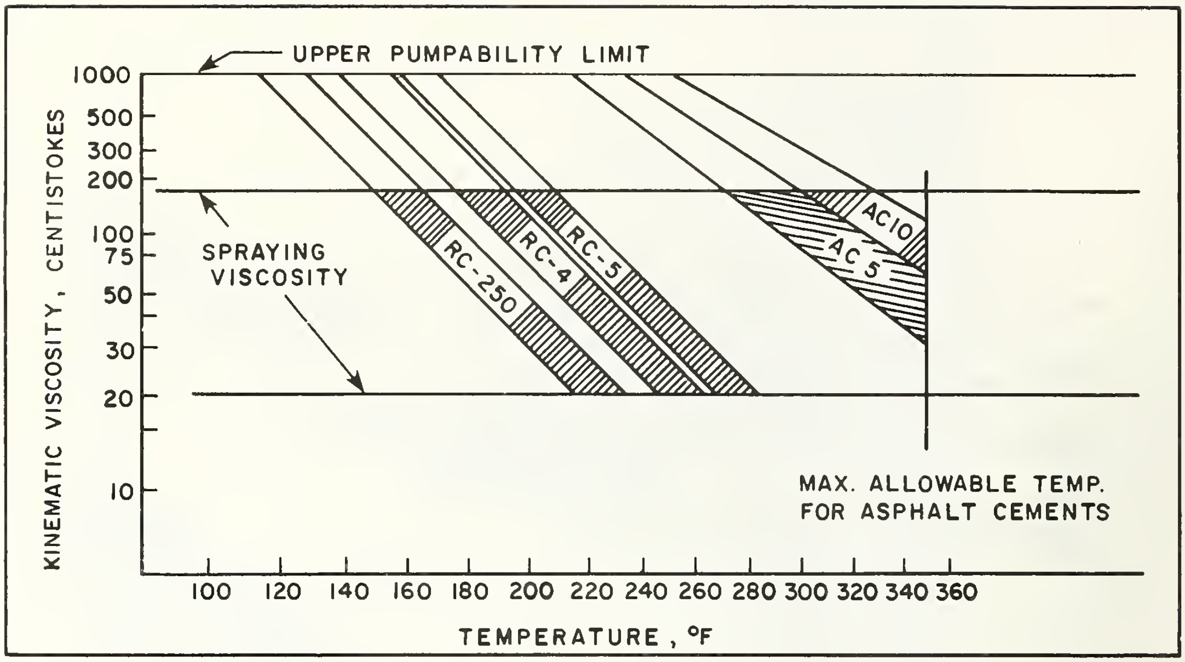
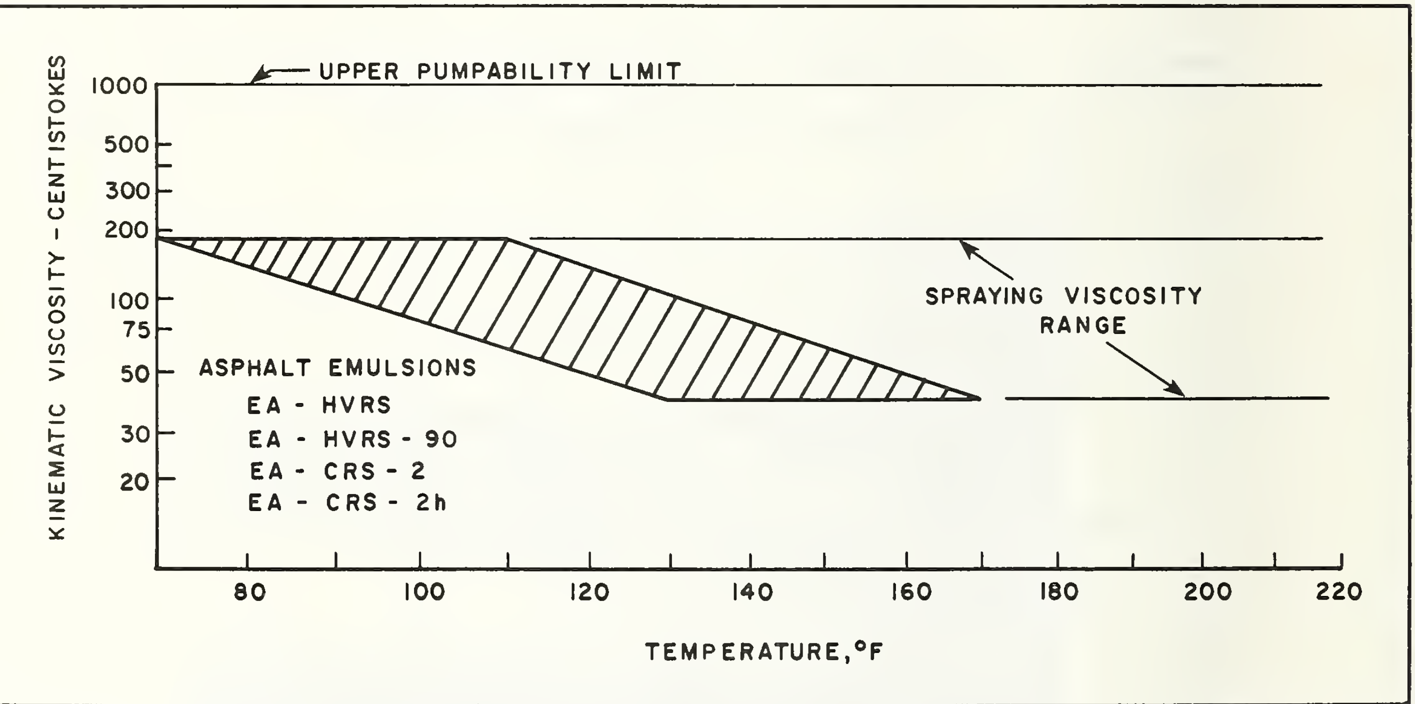


FIGURE 9. DISTRIBUTOR OPERATING TEMPERATURE LIMITS FOR ASPHALT CEMENTS AND CUT-BACKS (AFTER REFERENCES 3 AND 4)



NOTE: ESTIMATES ONLY. THIXOTROPIC BREAKDOWN OF ASPHALT EMULSIONS IN PUMPING OR SPRAYING MAKE VISCOSITY LIMITS DIFFICULT TO ESTABLISH.

FIGURE 10. DISTRIBUTOR OPERATING TEMPERATURE LIMITS FOR ASPHALT EMULSIONS.

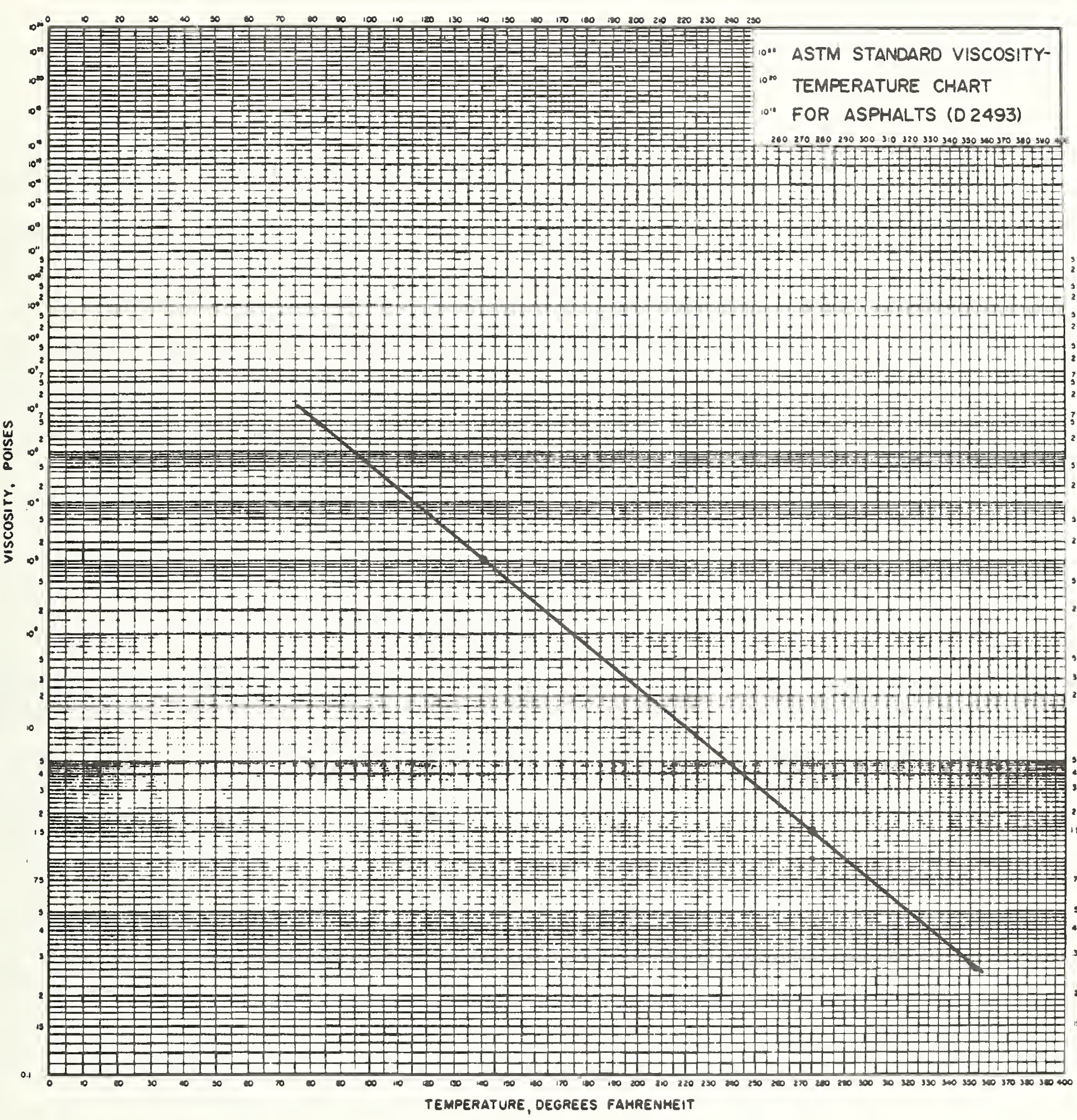


Figure 11. Viscosity-Temperature Chart.

1 poise = 100 centipoise

Figure 12. Chip Seal Evaluation Form.

CHIP SEAL EVALUATION

LOCATION

State ____________ County ____________ Highway ____________

Mile Post or Station Limits: From ____________ To ____________

Section Identification Number ____________

CONDITION

	Poor		Fair		Good
Overall Condition	0	2	4	6	8	10

AGGREGATE RETENTION

Percent Aggregate Loss

Outer Wheel Path (Percent Aggregate Loss)	100	50	25	15	10	5	2	0	
Outer Wheel Path	0	2	4	6	8	10			
Inner Wheel Path	0	2	4	6	8	10			
Between Wheel Path	0	2	4	6	8	10			
Centerline	0	2	4	6	8	10			

BLEEDING

	Severe		Moderate		Slight	
Outer Wheel Path	0	2	4	6	8	10
Inner Wheel Path	0	2	4	6	8	10
Between Wheel Path	0	2	4	6	8	10
Centerline	0	2	4	6	8	10

AGGREGATE EMBEDMENT & SURFACE TEXTURE

	Embedment	Texture
Outer Wheel Path	______ %	______ cu. in./sq. in.
Inner Wheel Path	______ %	______ cu. in./sq. in.
Between Wheel Path	______ %	______ cu. in./sq. in.
Centerline	______ %	______ cu. in./sq. in.

OTHER INFORMATION

Skid Number SN_{40} ______

SN ______

SN ______

Comments ____________

Rater(s) ____________ Date ____________

Figure 13: Data Gathering Form For Seal Coats

Location

District__________ County__________ Highway__________

Mile Post or Station Limits: From__________ To__________

Section Identification Number__________

Lane__________

Preconstruction

Type of Surface on Old Roadway__________

Condition of Old Surface:

Rutting	________	Alligator Cracking	________
Raveling	________	Longitudinal Cracking	________
Flushing	________	Transverse Cracking	________
Corrugations	________	Patching	________

Deflection:	Mean______	Std. Deviation______	Range______	No.______
Road Roughness:	Mean______	Std. Deviation______	Range______	No.______
Skid Number:	Mean______	Std. Deviation______	Range______	No.______

Surface Texture: Outer Wheel path________ Between wheel path________

Inner wheel path________ Centerline________

Traffic: ADT Per Lane______ % Trucks______ Eq. 18 Kips per lane______

Design

Type of Asphalt________ D-9 Test No________

Type of Aggregate________ Source of Aggregate________

Design Asphalt Quantity________ Gallons per sq. yd.________

Aggregate Quantity 1: ________ Square yards

Construction

Asphalt Shot:	Mean______	Std. Deviation______	Range______	No. ______

Temperature of Shot:______ °F

Aggregate Quantity:	Mean______	Std. Deviation______	Range______	No.______

Climatic Conditions: Temperature Low________ High______ ____

Rainfall: Day Before Construction________

Day of Construction ________

Day After Construction ________

2 Days After Construction ________

Figure 13: Data Gathering Form For Seal Coats Continued

Date(s) of Construction: From________________ To_________________

Performance

Date	Overall	Aggregate Retention	Bleeding	Aggregate Embedment

APPENDIX A

TENTATIVE METHOD OF FIELD TESTS FOR THE DETERMINATION OF DISTRIBUTOR SPREAD RATE

TENTATIVE METHOD OF FIELD TEST FOR THE DETERMINATION OF DISTRIBUTOR SPREAD RATE

Scope

This description covers the procedure for determining the transverse and longitudinal spread rate in gallons per square yard of bituminous distributors.

PART I. TRANSVERSE SPREAD RATE DETERMINATION

Procedure

A. Apparatus

1. Balance sensitive to 0.1 g.
2. Suitable weighing box or shield for balance.
3. Metal sheets 7⅞″ x 60″—20 gauge galvanized.
4. Balance table and work table.

B. Materials

1. Absorbent panels. There are seven 4″ x 8″ absorbent cotton pads attached to each panel with perforations between each pad so that they may be easily separated. These may be obtained from Service and Supply.

NOTE: The above panels may be prepared, if not available, by cementing 4″ x 8″ cotton pads (Bauer & Black, No. 540 sponges, 4″ x 4″) to suitable heavy weight paper. Each panel should be 16″ x 28″. The panel should be perforated accurately at 4″ intervals at right angles to the 28″ length, prior to attaching the pads. It should also be creased the long way so as to leave an 8″ x 28″ area in the center. See Fig. I. Panels may be perforated down the center the long way to facilitate folding after the binder has been caught.

C. Materials (Alternate Method)

1. Cotton pads 4″ x 8″. These are sold by Bauer & Black, No. 540 Sponges 4″ x 4″ (they are designated as 4″ x 4″ but open out into 4″ x 8″).

2. 5″ x 10″ strips cut from heavy wrapping paper.

3. 7⅞″ x 60″ sheets cut from 20 gauge galvanized metal scribed at 4″ intervals after the first one at 5″.

4. Masking tape, ½″ width.

5. Suitable adhesive for fastening cotton pads to paper; latex, rubber cement or asphalt emulsion have been used.

D. Preparation of Test Plates

1. Remove several individual pads from a panel and weigh to determine the average tare weight. The remainder of the panel may be used for the longitudinal spread determination.

2. Fold 2 absorbent panels, Fig. I, over each metal sheet with the cotton pad side out. One end of panel must be flush with the end of the metal sheet. Place second panel snug against end of first panel.

3. Secure panels to metal sheet with tape on reverse side of sheet.

E. Preparation of Test Plates (Alternate Method)

1. Attach the 5″ x 10″ paper strips to the metal sheets with masking tape, each strip overlapping the adjacent strip 1 inch.

2. After all the paper strips have been attached to the metal sheets coat the top surface uniformly with the adhesive. Then place the cotton pads on the paper so that each pad covers exactly the exposed 4″ x 8″ paper surface. Fig. II shows the paper strip and part of the cotton pads in place.

3. Weigh several of the pads with the paper backing attached after they are thoroughly dry to determine the tare weight.

F. Sampling

1. As the distributor approaches, place the test plates across the roadway; see Figs. III and IV. In laying the plates across the pavement it is good practice to place the bare ends towards the shoulder side of the lane. This procedure will facilitate removal from the pavement and aid in keeping the pads in proper sequence.

2. As soon as the distributor has passed remove the test plates from the pavement. When the procedure involves the use of absorbent panels, (see B-1) remove the panels, fold along the center line and then remove each pad by tearing along the perforations. In the case of test plates prepared by the alternate method, place the entire assembly on a rack, (see Fig. V) then remove and fold each pad and paper strip. In order to properly identify the pads and expedite weighing operations, number the pads on the back side of the test plate starting with pad Number 1 nearest the center line of the pavement. Remove the pads in order starting with the pad nearest the shoulder line and stacking each pad on the previous one so that the stack will be completed on removal of the pad numbered one that is nearest the center line.

3. As soon as the removal operation is completed place the pads in the weigh box, and then weigh in order to the nearest 0.1 g; see Figs. VI and VII. Record the weight of each pad on Form T-3025, (Rev. 1-60) starting the recording with pad No. 1, the pad nearest the center line of the pavement. If a tare is used during weighing, then record the net weight of the bitumen in column 2 of Form T-3025, otherwise the previously determined average weight of the individual pads must be subtracted from the total weight of pad + bitumen.

G. Calculations

1. Multiply the net weight of binder on each pad by 0.0107, or use the attached table to obtain the spread rate in gal./sq.yd. The conversion table is also found on the back side of Form T-3025.

2. Determine the average spread rate in gal./sq.yd. by dividing the total quantity of binder collected on the pads by the number of pads. Omit end pads that show very low spread rates due to feathering and also end pads showing a heavy rate due to the use of shields. Normally those to be eliminated can be de-

termined by inspection but if a more uniform method is desired the following procedure may be used:

Calculate the average spread rate using all pads having a binder content of over 0.05 gal./sq.yd. Omit all end pads varying more than 15% (plus and minus), then recalculate the average spread rate.

3. For further study plot the test results together with the average spread rates and the specified limits.

H. Precautions

1. Do not allow traffic to drive over the sample pads (the relatively slow moving distributor does not disturb the test plates).

2. In very hot weather, remove and weigh the sample pads in the shade and with as little delay as possible. If substantial delay occurs, prepare a control sample with a known weight of binder and weigh at intervals to determine the evaporation loss rate and a correction.

I. Notes

A light metal camp table has been found very useful in removal and separation of the sample pads; see Fig. V. Since all weighing must be done at the job site and as rapidly as possible it has been found best to use a separate table for the balance. The balance is placed inside a specially constructed box (available from Service and Supply) so that the operator can work with his hands and forearms inside; see Fig. VII. A small torsion balance IL5 graduated to 0.1 gram available through Service and Supply will fit in this box. The quantity on each pad, in gal./sq.yd., should be recorded or plotted directly on graph paper. A convenient graph paper has been found to be one having a scale 12 x 20 to the inch, such as Kueffel and Esser Co. No. 359-21.

PART II. LONGITUDINAL SPREAD RATE DETERMINATION

A. Apparatus

1. Balance sensitive to 0.1 g.

B. Materials

1. Absorbent panels.

2. Cotton pads 4″ x 8″, of the same type used for transverse measurements (see C-1 of Part I).

3. 5″ x 10″ strips cut from heavy wrapping paper.

4. 7⅞″ x 12″ sheets cut from 20 gauge galvanized metal.

5. Masking tape, ½″ width.

6. Suitable adhesive for fastening cotton pads to paper (see C-5 of Part I).

C. Preparation of Test Plates

1. Remove a section of three pads from the transverse pad panel, see Fig. 1, by tearing along a line of perforations.

2. Secure panel containing the three pads to the metal sheet using tape on the reverse side of sheet.

3. Determine tare weight of pads, and if desired, prepare a tare weight.

D. Preparation of Test Plates (Alternate Method)

1. Attach cotton pads to the 5″ x 10″ paper strips with adhesive, leaving a 1″ margin on three sides; see Fig. VIII.

2. Fasten three paper strips with attached pads to the metal sheet by folding the ends over the sheet and attaching with masking tape. Each successive strip overlaps the exposed paper on the previously fastened strip; see Fig. VIII. Trim off the excess 1″ edge of the last paper backing strip that extends over the metal sheet.

3. Weigh several of the pads with the paper backing after they are thoroughly dry and determine the average tare weight.

4. Prepare a tared weight if desired for use in weighing.

E. Sampling

1. Place test panels at not less than 100 foot intervals and equidistant from the centerline and edge of pavement.

2. After the distributor has passed, remove pads from metal sheets and weigh to nearest ± 0.1 g. (See F, Sampling, of Part I.)

F. Calculations

1. Subtract the tare weight of the pads and multiply the total net weight of the binder on the 3 pads by 0.00356 to obtain the spread rate in gals. per sq. yd., or determine the average for one pad and use the attached table.

G. Precautions

1. Care should be taken to place all the sampling units equidistant from the center line or edge of pavement in order that the same jets of the distributor will pass over all the sampling units.

REFERENCE

A California Method

End of Text on Calif. 339-A

CONVERSION TABLE

Net wt. of binder on 4" x 8" pads to gals./sq. yd.

grams	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8	.086	.087	.088	.089	.090	.091	.092	.093	.094	.095
9	.096	.097	.098	.099	.100	.102	.103	.104	.105	.106
10	.107	.108	.109	.110	.111	.112	.113	.114	.116	.117
11	.118	.119	.120	.121	.122	.123	.124	.125	.126	.127
12	.128	.129	.131	.132	.133	.134	.135	.136	.137	.138
13	.139	.140	.141	.142	.143	.144	.146	.147	.148	.149
14	.150	.151	.152	.153	.154	.155	.156	.157	.158	.159
15	.160	.162	.163	.164	.165	.166	.167	.168	.169	.170
16	.171	.172	.173	.174	.175	.177	.178	.179	.180	.181
17	.182	.183	.184	.185	.186	.187	.188	.189	.190	.192
18	.193	.194	.195	.196	.197	.198	.199	.200	.201	.202
19	.203	.204	.205	.206	.208	.209	.210	.211	.212	.213
20	.214	.215	.216	.217	.218	.219	.220	.221	.223	.224
21	.225	.226	.227	.228	.229	.230	.231	.232	.233	.234
22	.235	.236	.237	.239	.240	.241	.242	.243	.244	.245
23	.246	.247	.248	.249	.250	.251	.252	.254	.255	.256
24	.257	.258	.259	.260	.261	.262	.263	.264	.265	.266
25	.267	.269	.270	.271	.272	.273	.274	.275	.276	.277
26	.278	.279	.280	.281	.282	.284	.285	.286	.287	.288
27	.289	.290	.291	.292	.293	.294	.295	.296	.297	.298
28	.300	.301	.302	.303	.304	.305	.306	.307	.308	.309
29	.310	.311	.312	.313	.315	.316	.317	.318	.319	.320
30	.321	.322	.323	.324	.325	.326	.327	.328	.330	.331
31	.332	.333	.334	.335	.336	.337	.338	.339	.340	.341
32	.342	.343	.344	.346	.347	.348	.349	.350	.351	.352
33	.353	.354	.355	.356	.357	.358	.359	.361	.362	.363
34	.364	.365	.366	.367	.368	.369	.370	.371	.372	.373
35	.374	.376	.377	.378	.379	.380	.381	.382	.383	.384

TEST PANEL

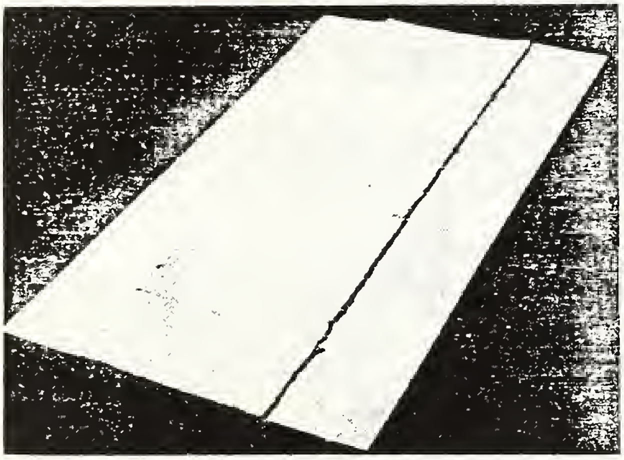


FIGURE I

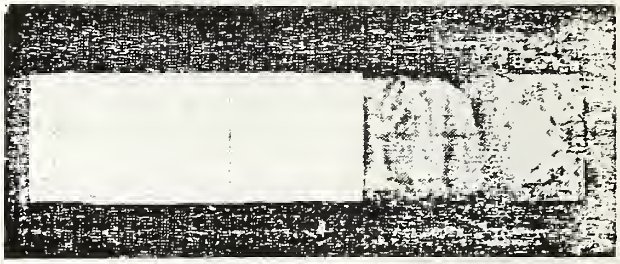


FIGURE II
TEST PANEL—ALTERNATE METHOD

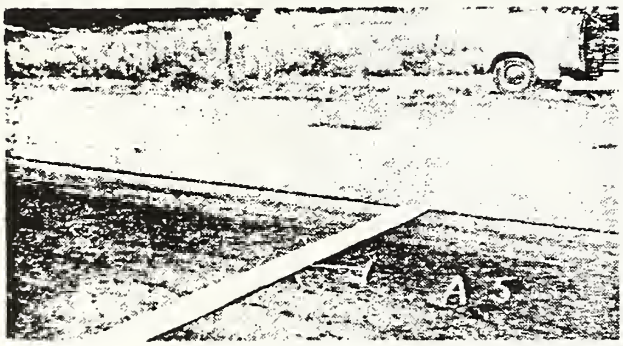


FIGURE III
TEST PLATES IN POSITION FOR TEST

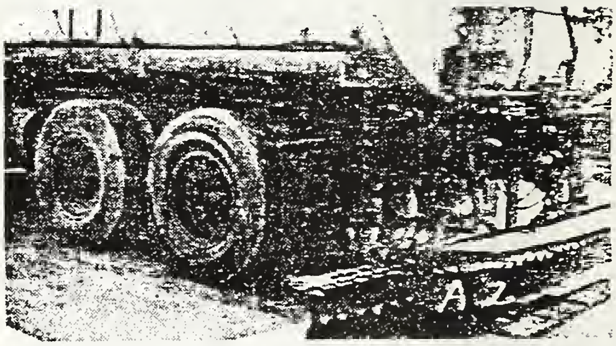


FIGURE IV
DISTRIBUTOR JUST BEFORE PASSING OVER TEST PLATES

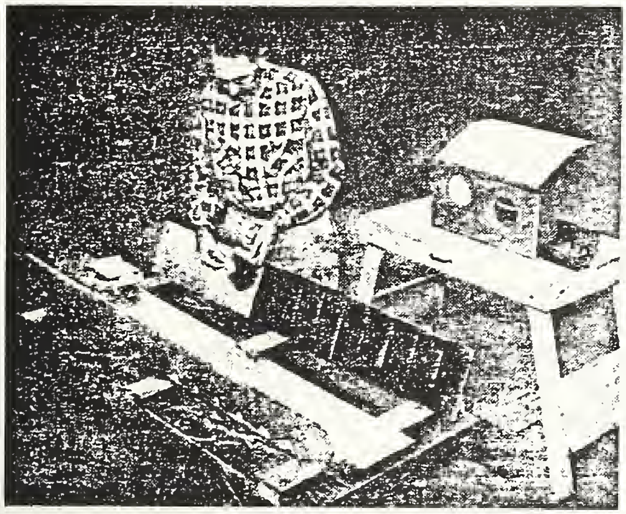


FIGURE V

REMOVING PADS FROM STEEL PLATE, ALTERNATE METHOD

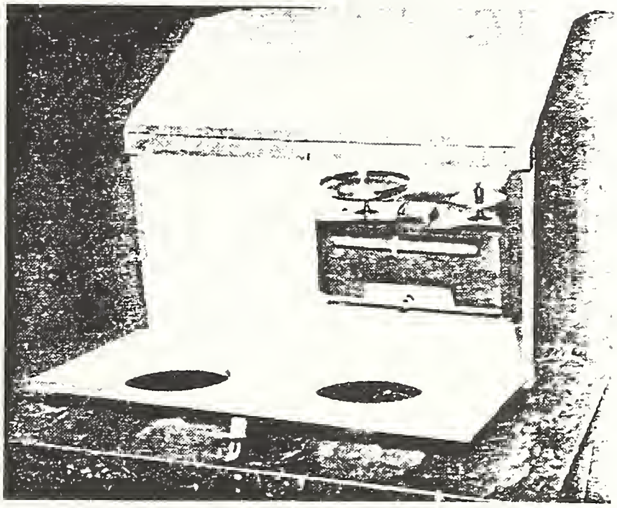


FIGURE VI

WEIGHING BOX

FIGURE VII

WEIGHING PADS—NOTE PAD STACK INSIDE BOX

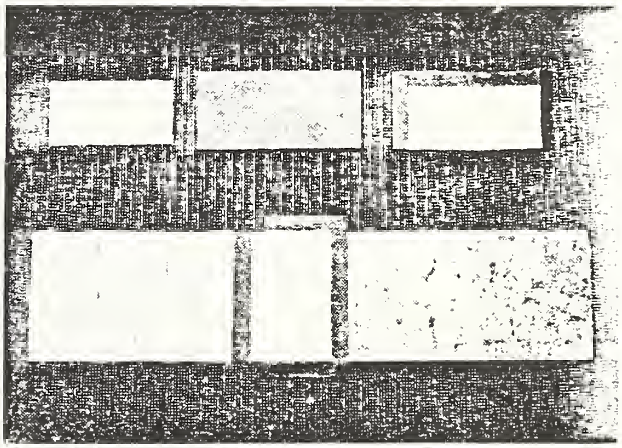


FIGURE VIII

PLACING OF 4" x 8" COTTON PADS ON METAL SHEET

MATERIALS & RESEARCH DEPARTMENT

TRANSVERSE & LONGITUDINAL DISTRIBUTOR SPREAD RATES

TEST BY	SHEET NO.

PAD NO.	PAD WEIGHT		SPREAD RATE GALS./YD.	OUTSIDE LIMITS
	GROSS GRAMS	NET GRAMS		
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
	TOTALS			

Contract__________ Date__________

Co.__________ Rte.______ Sec.______

Contractor__________ R.E.______

Dist. Owner__________ No.______

Sta.__________ Lane__________

Type Binder__________ Temp.__________

Dist. Condition__________

Spec. Spread__________ Gals./Sq. Yd.

Tank Gauging__________ Gals./Sq. Yd.

Direction of Distributor__________

CALCULATIONS TRANSVERSE SPREAD

$$\text{Avg.} = \frac{\text{Total gals/yd (omitting end pads*)}}{\text{No of pads}}$$

Avg. = __________ Gals./Sq. Yd.

Avg. +15% __________ Gals./Sq. Yd.

Avg. −15% __________ Gals./Sq. Yd.

*See Section G, Calculations of Part I

LONGITUDINAL SPREAD DETERMINATION

TARE = ______ GRAMS		SPREAD RATE GALS./YD.	OUTSIDE LIMITS
GROSS GRAMS	NET GRAMS		

Constants, etc.

Start from ℄ pavement at top of page.

Pad Tare = __________ grams.

Binder on pad x 0.0107 = gals./sq. yd.

FORM T-3025 (REV. 1-60)

FIGURE IX

APPENDIX B

INSPECTOR CHECKLISTS

Asphalt Distributors

1. Do distributors assigned to the job meet specifications requirements?
2. Are heaters and pumps in good operating condition?
3. Are certified calibrations for tank, tachometer and other measuring devices available?
4. Are spray bars and nozzles in good condition, clean and correctly adjusted?
5. Have all other adjustments been made in accordance with manufacturers instructions?
6. Has rate of application (including transverse and longitudinal variation) been checked?
7. Will spray bar height adjustment give required double-lap or triple-lap spray pattern with nozzle set as installed?
8. Does distributor have a means of maintaining constant spray bar height? Is it in good operating condition?

Aggregate Spreaders

1. Do spreaders assigned to the job meet specification requirements?
2. Has spreader operation been checked, including spread rate and transverse and longitudinal variation?
3. Can aggregate trucks assigned to the job be connected quickly and positively to the spreader?
4. Have all other adjustments been made in accordance with manufacturers instructions?

Rollers (pneumatic)

1. Do rollers assigned to the job meet specification requirements?
2. Are total weight and tire pressures within limits specified for the job?
3. Can each roller start, stop and reverse smoothly?
4. Are wheelbearings free from excessive wear?
5. Do the wheels track properly? Are they free from excessive wobble?

Cleaning Equipment

1. Are boom bristles in good condition - clean and free from excessive wear?
2. Does the power drive on all brooms operate properly?
3. Are blowers operating properly?
4. Are flusher nozzles free from obstructions and operating properly?

Inspectors Checklist No. 2 - Asphalt Distribution Operation

1. Is stringline or centerline in place for all distance of shot? Is distributor guideline marker correctly in place?
2. Is asphalt temperature in distributor tank at correct value?
3. Is sufficient quantity of asphalt in the distributor tank to make the full shot?
4. Are pump pressures and travel speed set to produce specified asphalt application rate?
5. Are all nozzles open and set at correct angle?
6. Is spray bar set at correct height?
7. Is paper in place at beginning and end of shot? Is it held down so it will not be disturbed by wind or distributor passage?
8. As shot begins and throughout the shot, visually check flow for uniformity over full width. If streaks appear, stop distributor and correct the trouble. Streaking is usually caused by improper spray bar height adjustment, improper asphalt temperature, or worn or clogged nozzles. Use of worn or clogged nozzles should not be tolerated. Nozzles should only be cleaned by soaking in kerosene or other solvent and air blowing. Nozzles should not be cleaned by insertion of a wire into the orifice.
9. Does outside edge of application coincide with stringline or centerline over full length of shot?
10. Make sure that flow of asphalt is cut off as soon as distributor crosses paper at end of the shot and that distributor is backed up so that any nozzle drip will fall on paper.
11. After gaging tank at end of shot, calculate average spread (R) corrected back to 60°F. If this value does not coincide with design (A), within specified limits, make necessary adjustments so correct spread rate is delivered on subsequent shots.

12. Where pavement width on curves is larger than on tangents, make sure that extra material for the widening is applied on the upper side of the roadway instead of the lower side (inside the curve).

Inspectors Checklist No. 3 - Aggregate Spreader Operation

1. Are surfaces of aggregate particles free of moisture?
2. Are trucks loaded with sufficient aggregate to cover the asphalt shot before shot is begun?
3. Has asphalt shot been completely covered with aggregate within required time limit?
4. Does the spreader distribute aggregate uniformly over the entire width and length of the asphalt shot?
5. Is the operator avoiding excess overlap of aggregate spread on the surface?
6. Is the spreader operator holding a constant speed, without bumping, jerking, or loping?
7. Do trucks hitch and unhitch with the spreader quickly, positively, and without bumping or jerking?

Inspectors Checklist No. 4 - Pneumatic Roller Operation

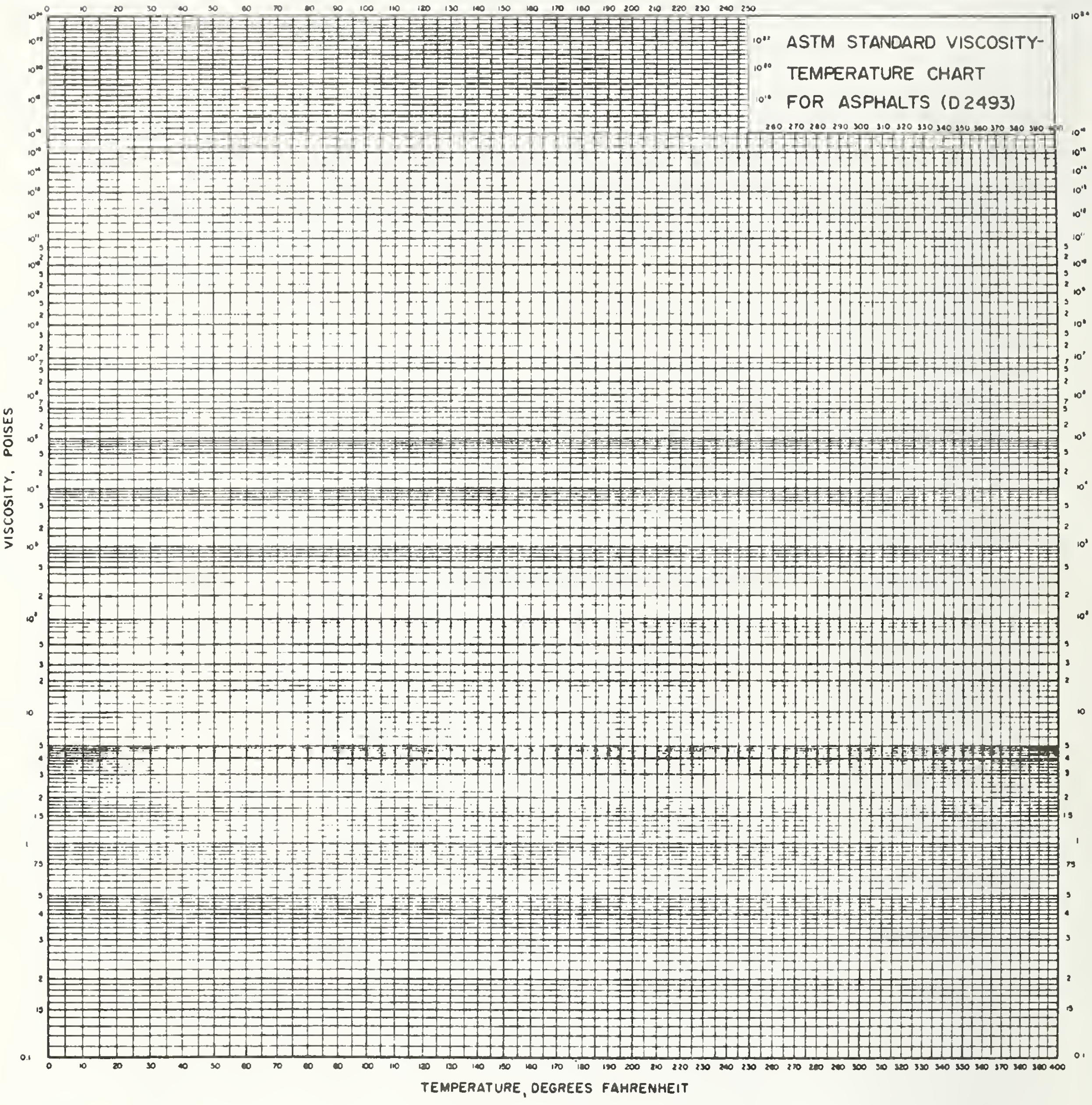
1. Just before rolling operation begins: are all tire pressures adjusted to the specified value?
2. Does rolling begin immediately after the aggregate has been placed on the surface?
3. Is a proper rolling sequence being followed?
4. Are at least 2-3 coverages being made?
5. Is roller operating speed held so that tire pickup does not occur?
6. Does the operator start, stop, and reverse the roller smoothly?
7. Are all tires tracking properly without wobble?

1. Is asphalt mat completely hardened before cleaning operations begin? (A 24 hour delay after rolling may be necessary).
2. Is broom pushing loose particles toward the edge without moving or dislodging aggregate embedded in the asphalt mat?
3. Does the broom (or other cleaning operation) remove nearly all of the loose particles?

APPENDIX C

Viscosity-Temperature Chart

VISCOSITY - TEMPERATURE CHART



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