CENTRIFUGE KEROSENE EQUIVALENT OF AGGREGATE INCLUDING K-FACTOR

(A Modification of Test No. Calif. 303)

Scope

1. This method of test furnishes a measure of the surface capacity, including absorption, of both coarse and fine aggregates used in bituminous mixtures. The K-factor is an index that indicates the relative particle roughness or degree of porosity.

Apparatus

2. The apparatus shall consist of the following:

(a) Centrifuge. - A hand or power-driven centrifuge with cover, capable of exerting a force of 400 times gravity (400 G) on a 100-g. sample (See Figs. 1 and 2). The required rpm necessary to achieve this force is determined from the following formula:

$$\text{Required rpm of centrifuge head} = \sqrt{\frac{14{,}000{,}000}{r}}$$

Where: R = Radius in inches to center of gravity of sample

(b) Centrifuge Cups. - Aluminum cups 2-13/16 in. in height and 2-1/16 in. in diameter (Fig. 3) with a perforated brass plate containing a minimum

FIGURE 1

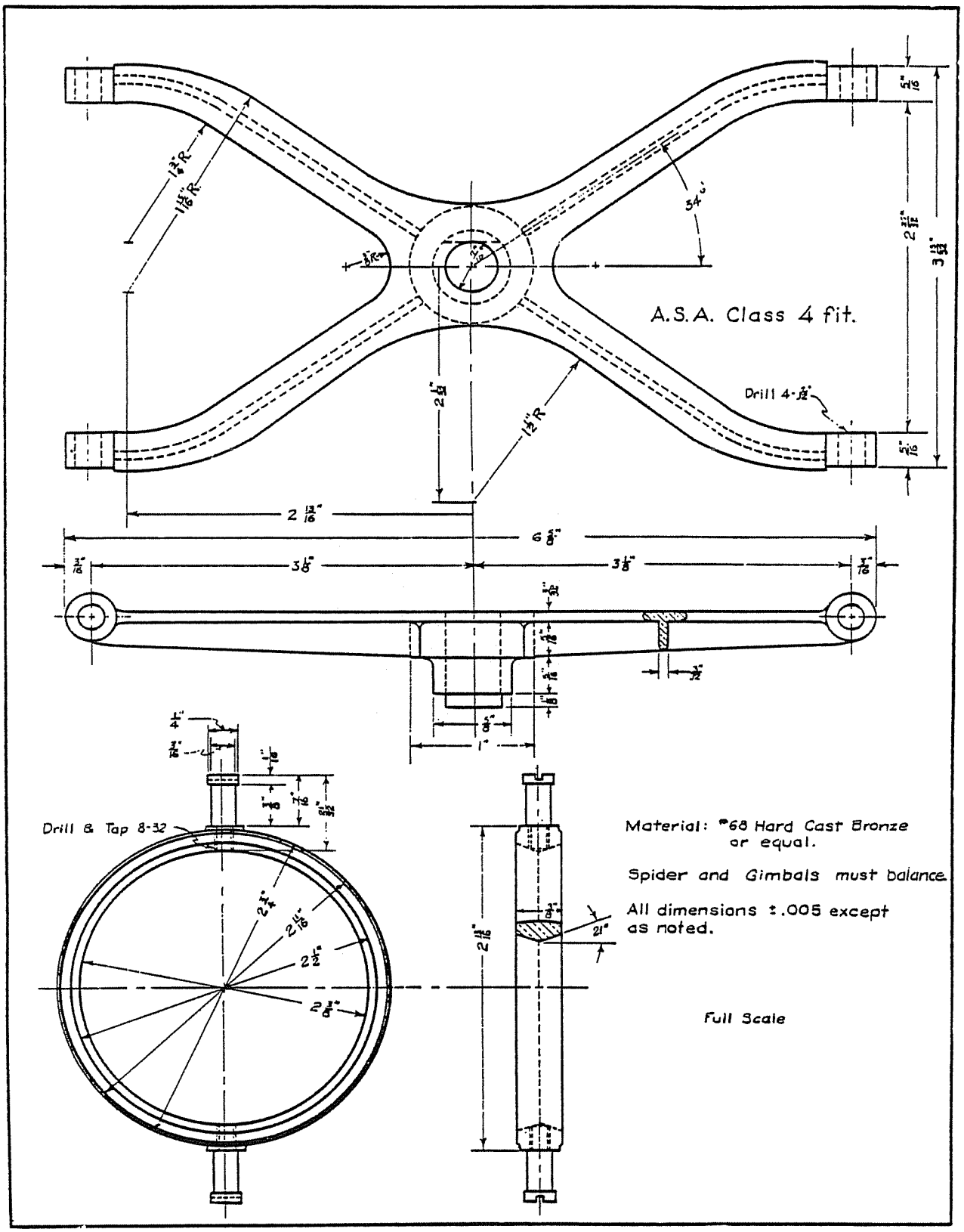


FIGURE 2

DETAILED PLAN OF CENTRIFUGE PARTS

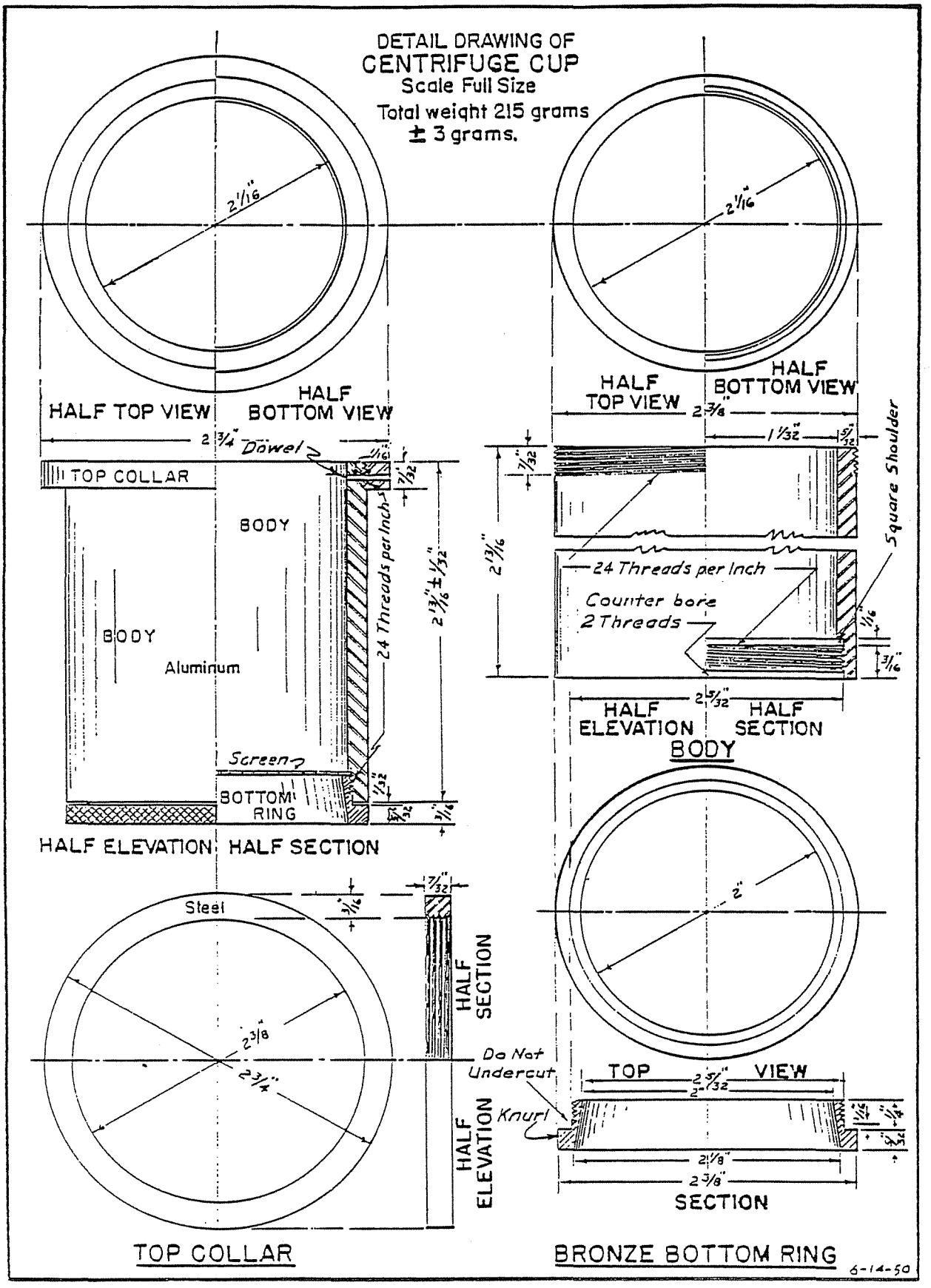

DETAIL DRAWING OF
CENTRIFUGE CUP
Scale Full Size
Total weight 215 grams
± 3 grams.
HALF TOP VIEW
HALF BOTTOM VIEW
2 1/16"
2 3/4"
Dowel
TOP COLLAR
BODY
BODY
Aluminum
24 Threads per Inch
2 13/16" ± 1/32"
Screen
BOTTOM RING
HALF ELEVATION
HALF SECTION
Steel
HALF SECTION
2 3/8"
2 3/4"
HALF ELEVATION
TOP COLLAR
HALF TOP VIEW
HALF BOTTOM VIEW
2 3/8"
1 1/32"
Square Shoulder
2 13/16"
24 Threads per Inch
Counter bore
2 Threads
HALF ELEVATION
HALF SECTION
BODY
2"
Do Not Undercut
Knurl
TOP VIEW
2 1/8"
2 3/8"
SECTION
BRONZE BOTTOM RING
6-14-50

FIGURE 3

of 100 holes, .062 inches in diameter, per square inch.

(c) Balance. - A torsion balance, 500 g. capacity, accurate to 0.1 g.

(d) Metal funnels. - Top diameter 3.5 in., height 4.15 in., orifice 0.5 in., with a piece of No. 10 sieve soldered to the top of the orifice.

(e) Glass Beakers, 1500 ml. capacity.

(f) Timer with sweep second hand.

(g) Pans, 4.5 in. in diameter, 1 in. deep.

(h) Ovens. - One oven capable of maintaining a temperature of 230° F ± 5° F; and an oven capable of maintaining a temperature of 140° F.

Materials

3. (a) Kerosene, 1 gallon.

(b) S.A.E. No. 10 lubricating oil.

NOTE: *Kerosene and S.A.E. No. 10 lubricating oil shall be supplied as "standard" materials by Central Lab.*

(c) Filter paper, 5.5 cm. diameter, Eaton Dikeman No. 613.

Preparation of Sample

4. (a) Separate the aggregate into two size groups; "C" material, used for K_c determination, passing the 3/8" sieve and retained on the No. 4 sieve; "F" material for K_f determination, all passing the No. 4 sieve.

(b) Determine bulk O.D. specific gravity for fine aggregate ("F" material) by ARIZ 211 - Specific Gravity and Absorption of Fine Mineral Aggregate, and for coarse aggregate ("C" material) by AASHTO T 85 - Specific Gravity and Absorption of Coarse Aggregates.

NOTE: *Bulk O.D. specific gravity which has been determined for plus No. 4 material using additional sizes may be used in lieu of running specific gravity for "C" material as described below.*

(c) The gradation of the aggregate employed is used to calculate the surface area of the aggregates. This calculation consists of multiplying the total percent passing each sieve by a "surface area factor" as set forth in Table 1, and dividing by 100. The sum of all the results represents the equivalent surface area of the sample in terms of square feet per pound.

NOTE: *All surface area factors must be used in the calculation. If a different series of sieves is used, different surface-area factors are necessary. An example of calculations is given in Table II, section 13.*

Procedure

5. Fine aggregate shall be tested as follows:

(a) Obtain a representative minimum 210 g. sample of Pass No. 4 material, place in an oven at 230° ± 5° F, and dry to constant weight.

(b) Allow the sample to cool to room temperature and place exactly 100 g. in weighed centrifuge cup fitted with the perforated metal disk underlying a disk of filter paper.

(c) Prepare the other centrifuge cup in the same manner, with another 100 g. of the same material.

(d) Place the centrifuge cups in a pan containing sufficient kerosene (1/2 in. deep) to saturate the samples by capillary action.

(e) When the samples are saturated, place the cups in the centrifuge, and spin for 2 minutes at a force of 400 G (for hand operated centrifuges this force can be developed by turning the handle about 45 revolutions per minute).

(f) Reweigh the cups with the samples to the nearest 0.1 g. and subtract the original weight. The difference is the percent of kerosene retained (based on 100 g. of dry aggregate). Record the average of the two values for duplicate samples.

NOTE: *If the difference between the two samples exceeds 0.20 grams the test should be run again, taking greater care in obtaining duplicate aggregate samples.*

6. Coarse aggregate shall be tested as follows:

(a) Split out two 105 gram minimum representative samples of the passing 3/8 and retained No. 4 sieve material. (If a 1/4 in. sieve was employed in the coarse sieve analysis, the material retained

TABLE I

SURFACE AREA FACTORS

Total Percent Passing Sieve No.	3/4"	3/8"	4	8	16	30	50	100	200
Surface Area Factor	*	*	2	4	8	14	30	60	160

*Assume surface area for all of plus No. 4 material = 2 sq. ft./lb.

on the 1/4 in. and No. 4 sieve shall be graded in proportion with the weight % retained on the respective sieves.) Place in an oven at 230° F ± 5° F. and dry to constant weight.

(b) Allow to cool at room temperature, then weigh out exactly 100 grams from one of the 105 gram samples and transfer to the funnel. Immerse material in S.A.E. No. 10 lubricating oil for 5 minutes by placing funnel in holder (a 500 ml. glass beaker works very well) and pouring adequate amount of oil over aggregate until sample is entirely covered.

(c) Remove funnel and place in a metal quart can. Drain for 2 minutes, then place can with funnel in an oven set at 140° F. for 15 minutes of additional draining.

(d) Obtain the tare weight of a pan, remove the sample from the oven and pour into the pan, allow to cool and then weigh to the nearest 0.1 gram. The difference between the original sample weight (100 grams) and the final sample weight (weight minus the tare weight of pan) is the percent oil retained.

(e) Subject the other 105 gram sample to the same procedure as shown in paragraphs (b), (c) and (d).

(f) Record the average of the two values for duplicate samples.

NOTE: *If the difference between the two samples exceeds 0.30 grams the test should be run again, taking greater care in obtaining duplicate aggregate samples.*

Calculations

7. K_f

(a) K_f is determined from the following factors:

1) Percent of kerosene retained, which represents the total effect of superficial area, the aggregate's absorptive properties, and surface roughness.

2) Computed surface area, based on particle size.

3) Percent passing No. 4 sieve.

(b) If the specific gravity for "F" is greater than 2.70 or less than 2.60, make corrections for percent of kerosene retained with the following formula:

$$\text{Corrected CKE} = (\%\ \text{kerosene ret.}) \times \frac{\text{Sp. Gr. "F"}}{2.65}$$

(c) Start in the lower left hand corner of the chart in Fig. 4 with the value for CKE corrected for specific gravity; follow the straightedge horizontally to the right to the intersection with calculated surface area; hold the point, move vertically upward to the intersection with the percent passing the No. 4 sieve, hold the point, and follow the straightedge horizontally to the right. The value obtained will be the surface constant for the passing No. 4 fraction "F", or "K_f".

8. K_c

(a) K_c is determined from the percent of S.A.E. No. 10 oil retained, which represents the total effect of superficial area, the aggregate's absorptive properties, and surface roughness.

(b) If the specific gravity for "C" is greater than 2.70 or less than 2.60 apply the correction to oil retained by the following formula:

$$\%\ \text{oil ret. corrected} = (\%\ \text{oil ret.}) \times \frac{\text{Sp. Gr. "C"}}{2.65}$$

(c) Start at the bottom of the chart in Fig. 5 with the corrected percent oil retained, follow the straightedge vertically upward to the intersection with the diagonal line, hold the point, and follow the straightedge horizontally to the left. This value is the surface constant for the retained coarse fraction "C", or "K_c".

9. K_m

(a) K_m represents the mean value of K for a given combination of coarse and fine materials on which K_c and K_f have already been determined.

(b) Use the chart in Fig. 6 to combine K_f and K_c for determination of "K_m".

(c) Start in the lower left hand corner of the chart in Fig. 6 with the value of the total Surface Area, follow straightedge horizontally to the right to the percentage of coarse aggregate (+ No. 4), hold point, and follow straightedge vertically upward to the intersection with the difference between K_c and K_f, hold point, and move horizontally to the right to the "correction to K_f". If ($K_c - K_f$) is positive K_m is calculated by $K_m = K_f$ + corr. to K_f; if ($K_c - K_f$) is negative K_m is calculated by $K_m = K_f$ - corr. to K_f. If $K_c = K_f$, the correction is zero, and the chart does not have to be used, K_m simply equals K_f.

10. Bitumen Ratio

(a) The chart in Fig. 7 is used, provided the following factors are known:

1) K_m

2) S.A. (Surface Area of Aggregate)

3) Combined Specific Gravity

$$\text{Combined Sp. Gr.} = \frac{100}{\frac{\%\ \text{coarse}}{\text{sp. gr. coarse}} + \frac{\%\ \text{fine}}{\text{sp. gr. fine}}}$$

(b) Start in the upper left-hand corner with S.A., follow a straightedge horizontally to the right to the intersection with the combined sp. gr., hold point, and move vertically downward to the intersection with known K_m; hold point, and move horizontally to the right. This value is for liquid asphalt SC-250, MC-250, and RC-250 only.

(c) If a heavier asphalt is used, refer to the chart in Fig 8. By means of a straightedge, connect the point on Scale "A" which represents the grade of bitumen to be used with the point on Scale "B" representing the S.A. of the aggregate. Through the point of intersection on line "C" place the straightedge to connect with the previously determined bitumen ratio value on Scale "D". The intersection with Scale "E" represents the bitumen ratio corrected for viscosity of the bitumen.

11. Percentage of Recommended Bitumen

To convert bitumen ratio to percentage of bitumen on the basis of total mix, use the following formula:

$$\% \text{ recommended bitumen} = \frac{\text{Bitumen Ratio}}{100 + \text{Bitumen Ratio}} \times 100$$

Report

12. Report the % bitumen recommended. Also record K_c, K_f, K_m, the grade of bitumen used, specific gravity of coarse and fine aggregate, CKE values, and bitumen ratio.

Example

13. Using the information given in Table II, and that supplied in (a), the data in paragraph (b), (c), (d) and (e) was calculated by the procedure outlined above.

(a) Percent coarse = 38

Percent fine (pass #4) = 62

Bulk O.D. Sp. Gr. coarse = 2.589

Bulk O.D. Sp. Gr. fine = 2.613

Combined Bulk O.D. Sp. Gr. = $\dfrac{100}{\frac{38}{2.589} + \frac{62}{2.613}} = 2.604$

CKE Results

Fines - uncorrected ret. = 4.3
corrected ret. = 4.3 (No correction: 2.7<sp.gr.>2.6)

Coarse - uncorrected ret. = 3.7
corrected ret. = 3.6

(b) $K_f = 1.25$
$K_c = 1.54$
$(K_c - K_f) = 1.54 - 1.24 = 0.30$
"Correction to K_f" = 0 1
$K_m = K_f$ + correction to K_f ($K_c - K_f$ is positive)
$K_m = 1.24 + 0.1 = 1.34$

(c) Bitumen Ratio = 5.4

(d) Corrected Bitumen Ratio = 6.3
(Corrected using AC-20 grade asphalt)

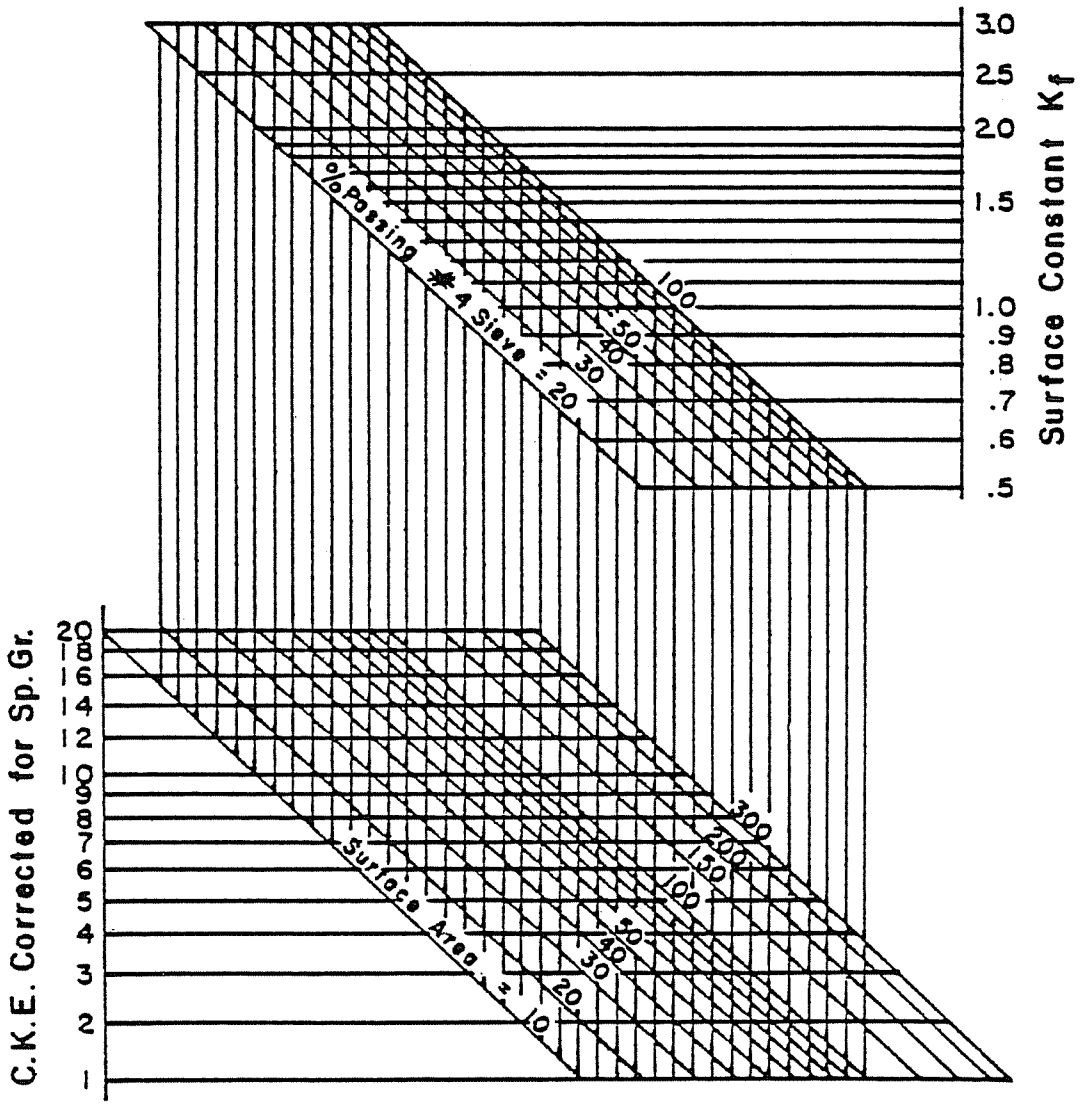
(e) Percent Bitumen recommended = 5.9%

TABLE II

TOTAL SURFACE AREA CALCULATION

Sieve Size	Percent Passing	x	S.A. Factor	÷	100	=	Surface Area (S.A.)
3/4"	100		-				2.0
3/8"	96		-				
No. 4	62		2				1.24
No. 8	31		4				1.24
No. 16	22		8				1.76
No. 30	16		14				2.24
No. 50	14		30				4.20
No. 100	12		60				7.20
No. 200	9.6		160				15.36
						Total Surface Area =	35.24 sq. ft./lb.

CHART FOR DETERMINING K_f FROM C.K.E.



$$\text{C.K.E. Corrected} = \text{C.K.E.} \times \frac{\text{sp. gr. fine}}{2.65}$$

FIGURE 4

CHART FOR DETERMINING K_c FROM COARSE AGGREGATE ABSORPTION

Material Used { Aggregate passing $\frac{3}{8}$", ret.*4 sieve
Oil SAE 10

$$\% \text{ oil ret. corrected} = \% \text{ oil ret.} \times \frac{\text{sp. gr. of aggregate}}{2.65}$$

K_c may also be determined by the following:

$$K_c = [(0.4)(C)] + [(C - 2)(0.01)] + (0.1)$$

Where: C = Percent Oil Retained (Corrected for Sp. Gr.)

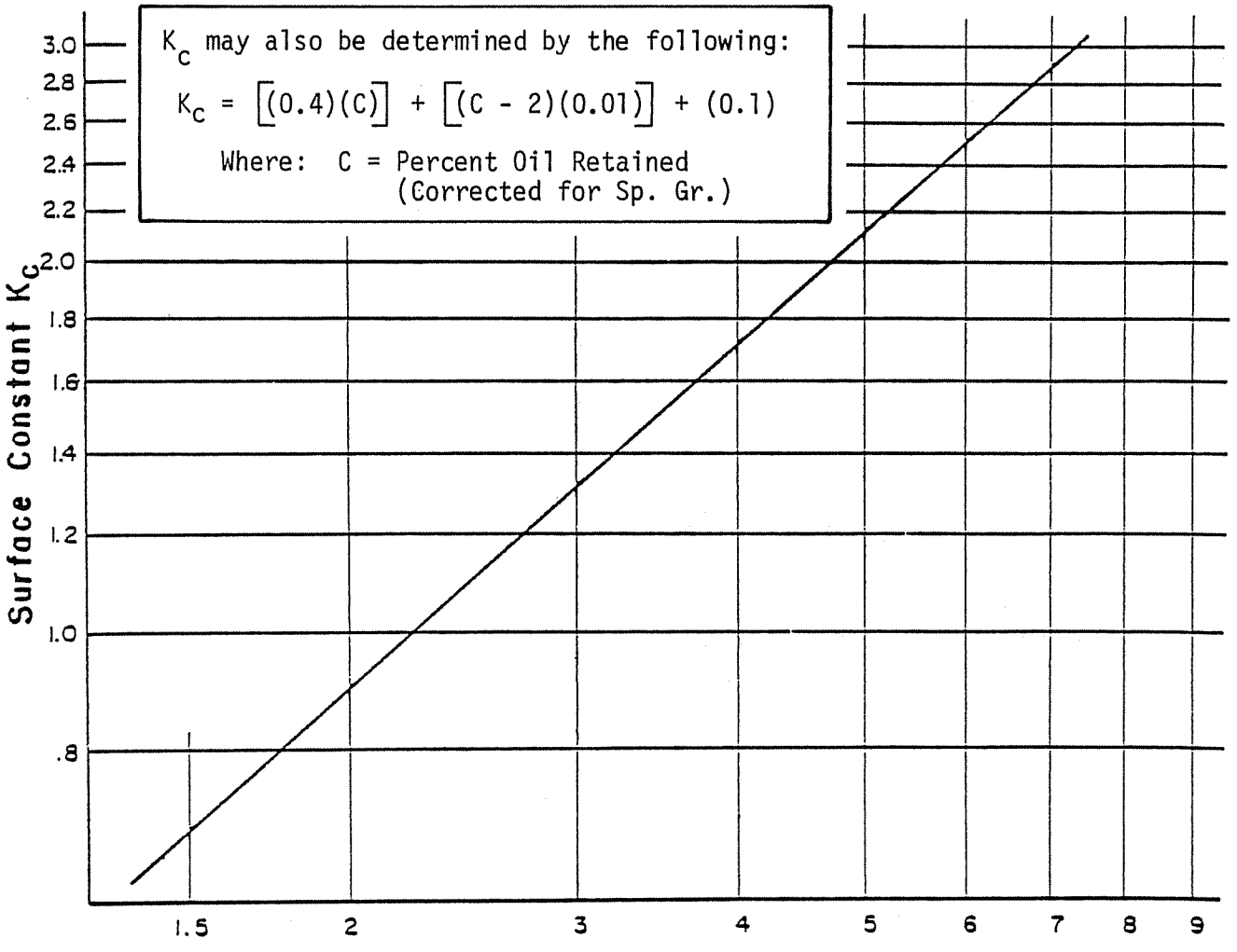


FIGURE 5

CHART FOR COMBINING K_f AND K_c TO DETERMINE K_m

If $(K_c - K_f)$ is negative,
$K_m = K_f$ - correction to K_f
If $(K_c - K_f)$ is positive,
$K_m = K_f$ + correction to K_f
If $K_c = K_f$, $K_m = K_f$

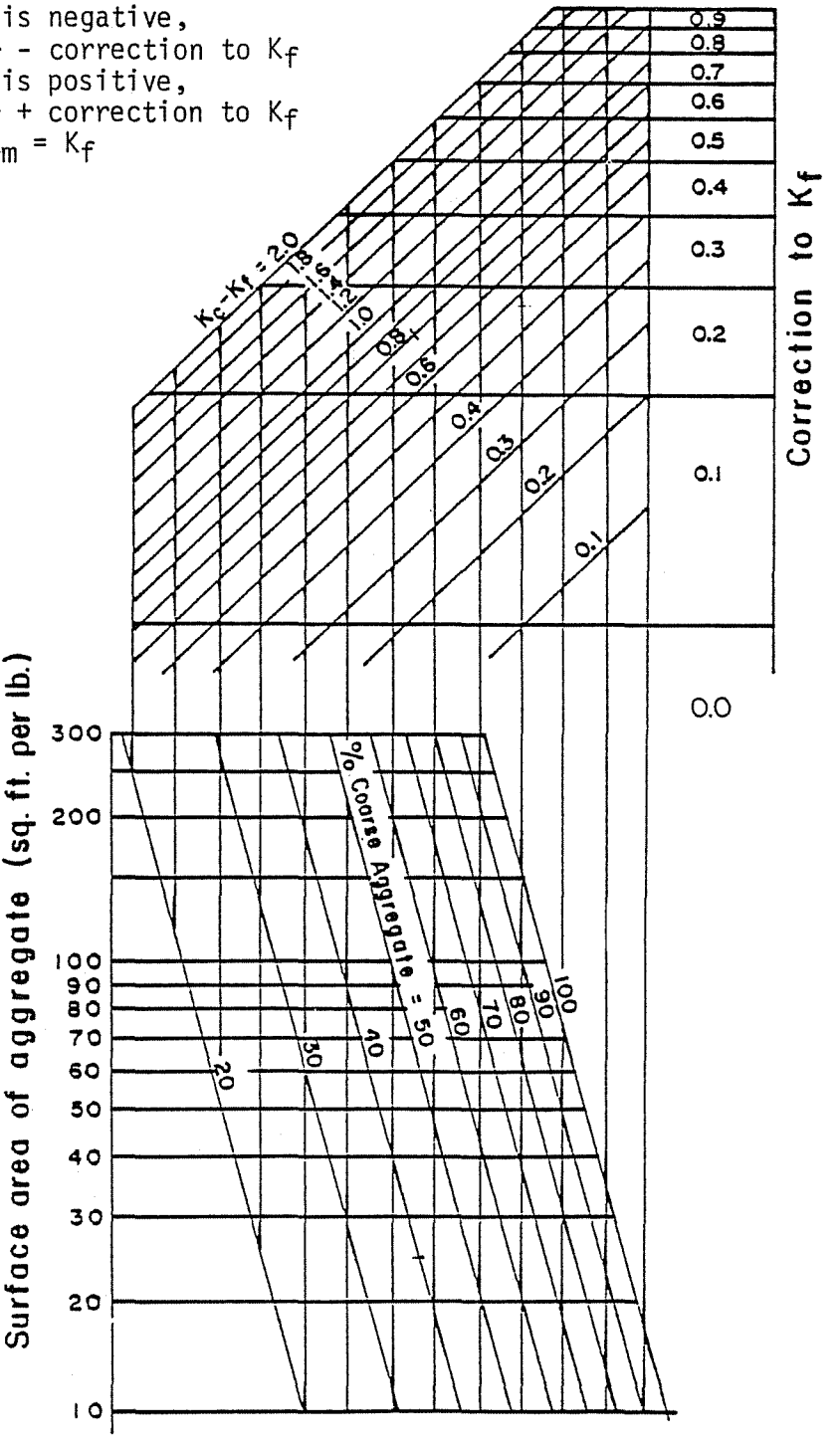


FIGURE 6

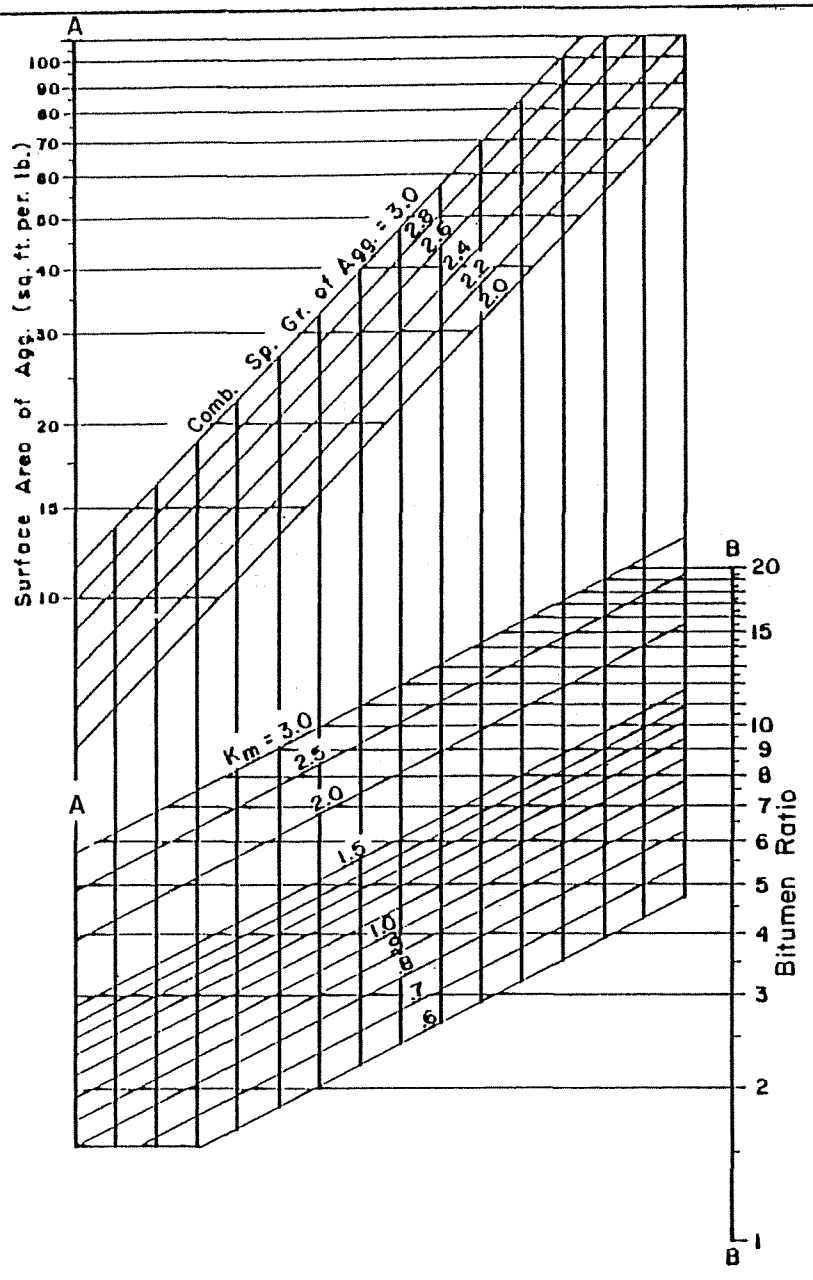


CHART FOR DETERMINING BITUMEN RATIO

PROCEDURE

Given surface area, combined sp. gr., and K_m of aggregate.

Find surface area on scale A. Proceed horizontally to line corresponding to combined sp. gr. of aggregate. Then down to line corresponding to K_m. Then horizontally to scale B for Bitumen Ratio.

Bitumen Ratio = lbs. of bitumen per 100 lbs. of aggregate and applies directly to asphalt of SC 250, MC 250, and RC 250 grades. The bitumen ratio is converted to percent bitumen (based on total mix) by the following:

$$\% \text{ Bitumen} = \frac{\text{Bitumen Ratio}}{100 + \frac{\text{Bitumen}}{\text{Ratio}}} \times 100$$

When heavier liquid or paving asphalts are used a correction must be made to the bitumen ratio. See Figure 8.

FIGURE 7

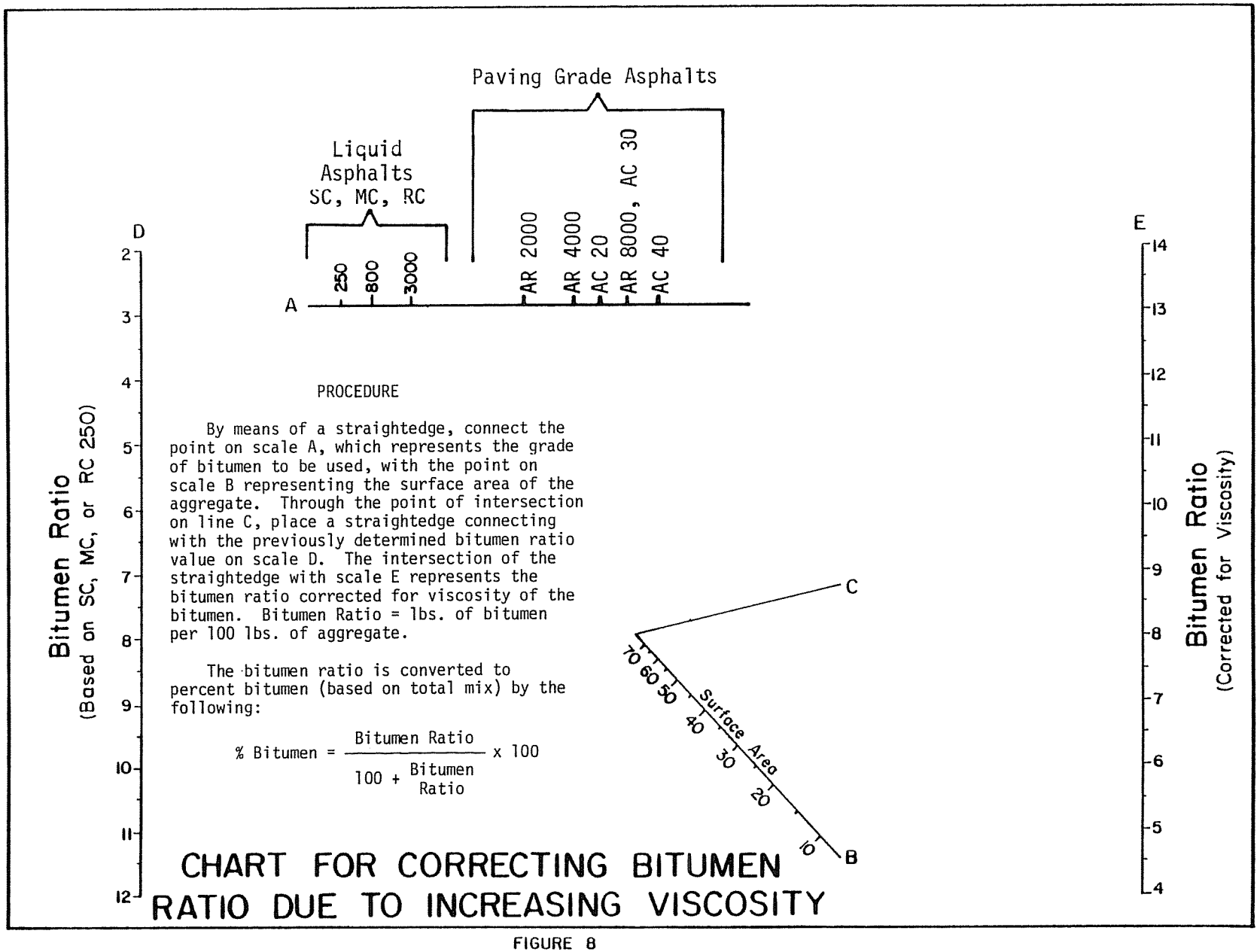

Paving Grade Asphalts
Liquid Asphalts SC, MC, RC
250
800
3000
AR 2000
AR 4000
AC 20
AR 8000, AC 30
AC 40
A
D
E
Bitumen Ratio
(Based on SC, MC, or RC 250)
Bitumen Ratio
(Corrected for Viscosity)
C
B
Surface Area
10
20
30
40
50
60
70
PROCEDURE
By means of a straightedge, connect the point on scale A, which represents the grade of bitumen to be used, with the point on scale B representing the surface area of the aggregate. Through the point of intersection on line C, place a straightedge connecting with the previously determined bitumen ratio value on scale D. The intersection of the straightedge with scale E represents the bitumen ratio corrected for viscosity of the bitumen. Bitumen Ratio = lbs. of bitumen per 100 lbs. of aggregate.
The bitumen ratio is converted to percent bitumen (based on total mix) by the following:
% Bitumen = Bitumen Ratio / (100 + Bitumen Ratio) x 100
CHART FOR CORRECTING BITUMEN RATIO DUE TO INCREASING VISCOSITY

FIGURE 8