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THE COST OF PRODUCING
BITUMINOUS PLANT MIXES

Thesis for the Degree of B. S.
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Arthur H. Leach
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The Cost of Producing
Bituminous Plant Mixes

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by

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The Iowa Manufacturing Company, Cedar Rapids, Iowa.

The Barrett Company, New York, New York.

The Toledo Vitrified Brick Company, Toledo, Ohio.

The W. H. Anderson Company, Detroit, Michigan.

The Construction Machinery Company, Waterloo, Iowa.

The Blaw Knox Company, Pittsburgh, Pennsylvania.

The Anderson Sand and Gravel Company, Saginaw, Michigan.

Hetherington and Berner Company, Indianapolis, Indiana.

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Bituminous mixed aggregate roads have been built successfully in the United States and Europe for many years. Due to the great increase in automobile traffic during the last decade, the secondary roads are needing better and more lasting surfaces. The black-top road is being used more and more to improve these secondary, farm to market, roads.

Because of the increased popularity of this material with highway departments, and, since it is the author's hope to be building some of these roads in the future, the writer has set out to determine, to the best of his present knowledge, "the cost of producing bituminous plant mixes," and their suitability for stockpiling without becoming unworkable.

The prices used in computing costs were collected from companies manufacturing, producing, or refining the materials. These unit prices may not be exact, but are representative for this problem.

At the very beginning of the problem, sieve analyses were run on the available aggregate and filler so as to know what per cent of each size was present. Later these materials will be proportioned together so the final mixture will lie within the limits of size as required by specifications as set up by the American Bitumals Company for the emulsion, and the Nebraska State Highway Department for the asphaltic oils.

The Nebraska specifications were used, as they were used in the highway material and testing course. The

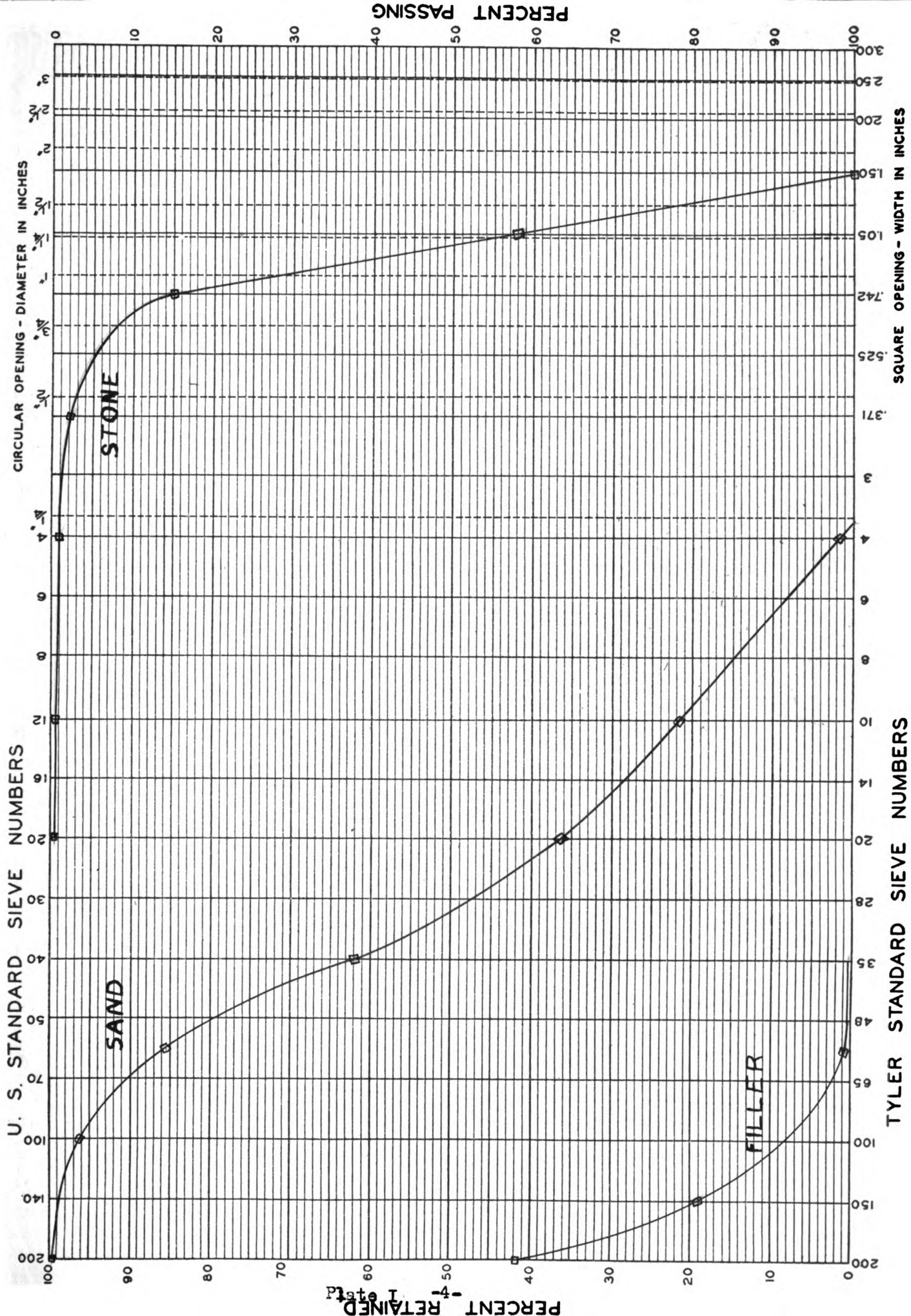
final proportions of these materials fit the above specifications better than they do the Michigan Specifications.

The average of the several analyses of each material available showed the following proportions retained on the sieves. A plot of these values is shown on plate I.

% Retained on	Sand	Stone	Filler
1½ inch square opening	-	0	-
1 inch square opening	-	41.9%	-
¾ inch square opening	-	86.0%	-
⅜ inch square opening	0	97.9%	-
4 Sieve	1.9%	99.0%	-
10 Sieve	21.7%	99.5%	-
20 Sieve	36.4%	99.5%	-
40 Sieve	61.7%	100 %	0.24%
60 Sieve	85.6%	100 %	0.64%
140 Sieve	98.8%	100 %	19.16%
200 Sieve	99.65%	100 %	41.20%
Passing 200 sieve	0.35%	0 %	58.80%

The materials cost \$6.00 for filler, 65 cents for stone, and 30 cents for sand.

With the preliminary work completed, and with the average results of sieve analyses tabulated, the task of proportioning the materials together to meet the requirements as stated in specification H-13 for Bitumals Cold Mixed Asphaltic Concrete Pavements as published by the



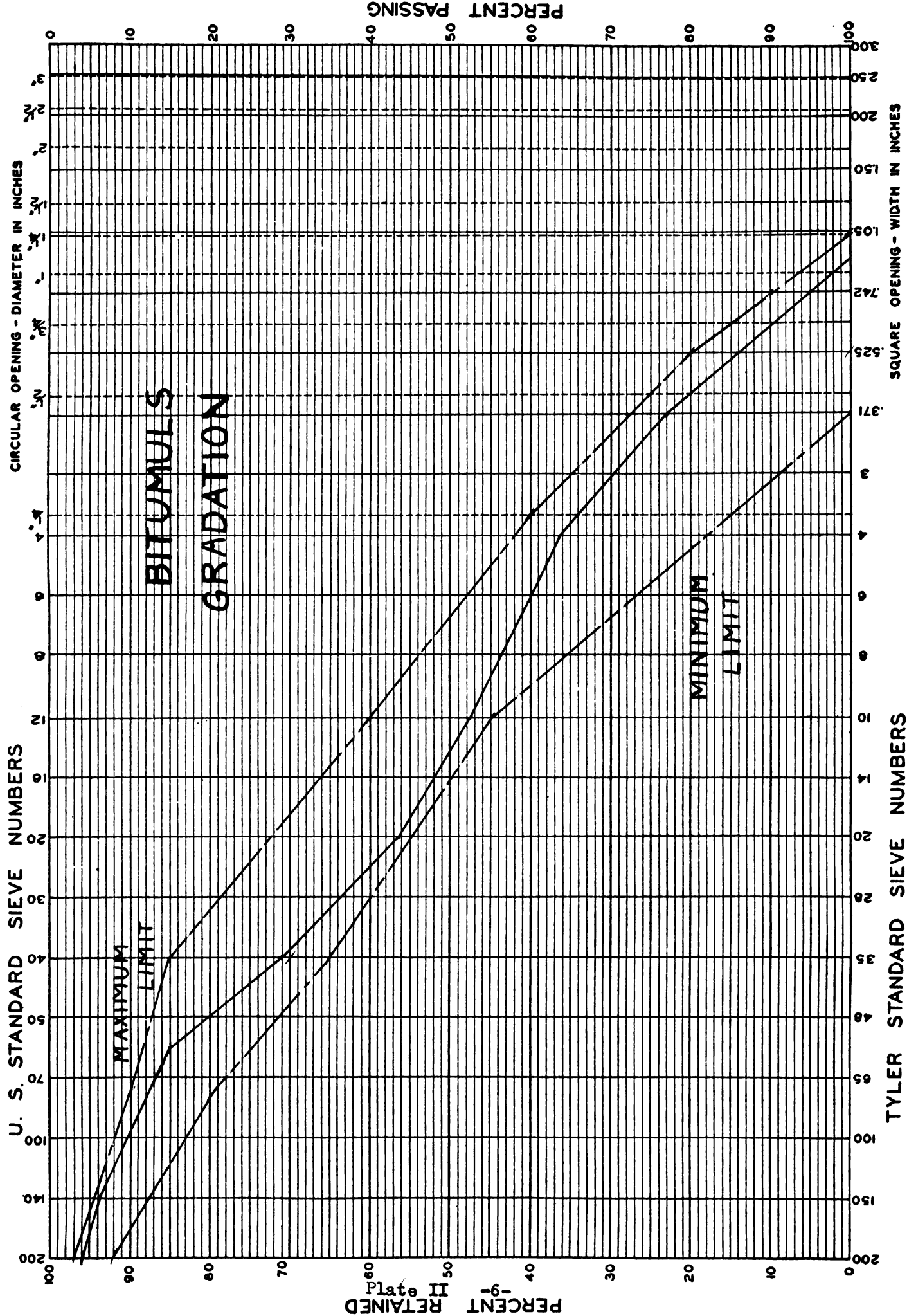
American Bitumals Company. The grading of mineral aggregate for Type C regular surface has the following requirements:

% retained, $1\frac{1}{4}$ inch square screen	0%
% retained, $\frac{3}{4}$ inch square screen	0 - 10
% retained, $\frac{1}{2}$ inch square screen	0 - 20
% retained, $\frac{1}{4}$ inch square screen	15 - 40
% retained, No. 10 sieve	45 - 60
% retained, No. 40 sieve	65 - 85
% retained, No. 80 sieve	80 - 90
% retained, No. 200 sieve	92 - 97

After several trials, the final gradation which fell within the limits as stated above was arrived at, in which 58% sand, 35% stone, and 7% filler were used. This gradation is plotted in Plate II.

The cost of this mixture is \$0.8315 per ton.

		Retained										
Mater-	%											
ial	Used	$\frac{3}{4}$	$\frac{3}{8}$	4	10	20	40	60	140	200	Pass	
											200	
Sand	58			1.1	12.6	21.2	36.0	50.0	57.5	58		
Stone	5	5	5	5	5	5	5	5	5	5		
Stone	18		18	18	18	18	18	18	18	18		
Stone	12			12	12	12	12	12	12	12		
Filler	7								1.3	3	4	
		5	23	36.1	47.6	56.2	71.0	85.0	93.8	96.0	4.0	



The material for the asphaltic oil was proportioned to meet the gradation B of Nebraska specifications:

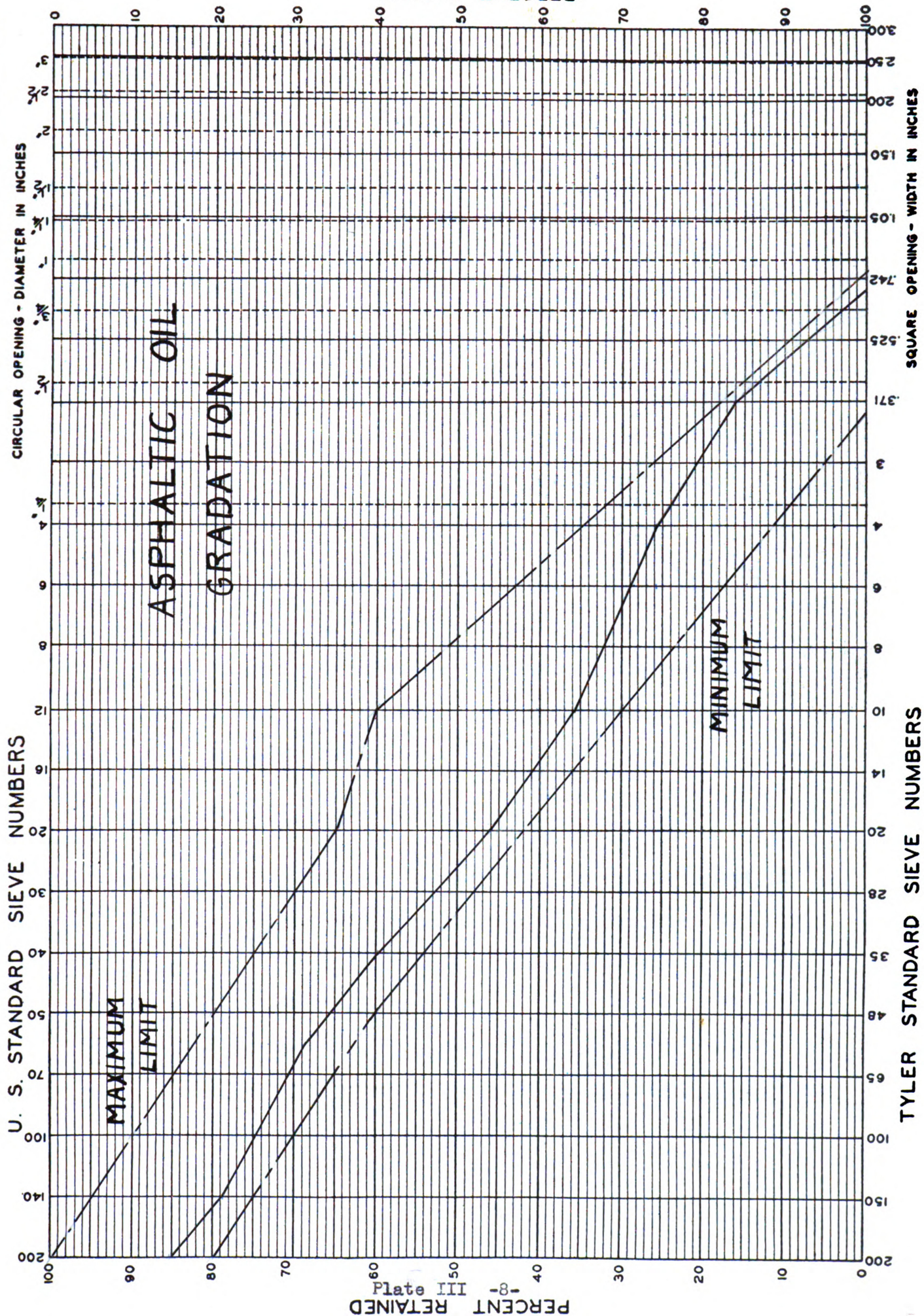
	<u>Minimum</u>		<u>Maximum</u>
% retained on 3/4 inch screen	0	-	5
% retained on No. 10 Sieve	30	-	60
% retained on No. 20 Sieve	45	-	65
% retained on No. 50 Sieve	60	-	80
% retained on No. 100 Sieve	70	-	90
% passing No. 200 Sieve	5	-	20

After several more trials, a gradation was arrived at with 50% sand, 25% stone, and 25% filler which fell within the limits as above stated. The cost of this mixture is \$1.8125 per ton. These results as tabled below are plotted on Plate III:

		<u>% Retained</u>										:Pass- ing
Mater- ial	: % Used	: 3/4	: 3/8	: 4	: 10	: 20	: 40	: 60	: 140	: 200	: 200	
Stone	: 16	: 0	: 16	: 16	: 16	: 16	: 16	: 16	: 16	: 16	:	:
Stone	: 9	:	:	: 9	: 9	: 9	: 9	: 9	: 9	: 9	:	:
Sand	: 50	:	:	: .9	: 10.8	: 21.0	: 30.8	: 42.9	: 49	: 50	:	:
Filler:	: 25	:	:	:	:	:	: 0.6	: 1.6	: 4.7	: 10.3	: 14.7	:
		: 0	: 16	: 25.9	: 35.8	: 46.0	: 59.4	: 69.5	: 78.7	: 85.3	: 14.7	:

The bituminous materials which are standard were furnished by the American Bitumals Company. The bitumals HRM sample is an emulsion of 58% hard asphaltic material and water containing a small amount of emulsifying agent. The RC-2 sample is an

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asphalt cement which has been rendered fluid by fluxing with a naptha type distillate. The MC-3 sample is an asphalt cement fluxed with a kerosene type of distillate. The SC-6A is an asphaltic residual oil which will not volatilize readily. The list price for these oils as quoted f.o.b. at Saginaw, Michigan in tank car quantities was:

Bitumals HRM	9.57 cents per gallon
R. C. - 2	7.90 cents per gallon
M. C. - 3	7.90 cents per gallon
S. C. - 6A	7.40 cents per gallon

These oils are added to the aggregate mixture to bind the fines and the coarse materials together.

The per cent of bitumals to be used is calculated from an empirical equation made up by the experience of the American Bitumals Company.

$$P = 0.05 A + 0.1 B + 0.5 C$$

P is Total per cent by weight of Bitumals based on the weight of the graded mixed aggregate.

A is The per cent of the mineral aggregate retained on a number 10 sieve.

B is The per cent of mineral aggregate passing a number 10 sieve and retained on a number 200 sieve.

C is The per cent of the mineral aggregate passing a number 200 sieve

$$\begin{aligned}
 P &= (0.05) (47.6) (0.1) (85 - 47.6) \div (0.5) (4) \\
 &= 2.38 \div 3.74 \div 2.00 \\
 &= 8.12\%
 \end{aligned}$$

The per cent of asphaltic oil is also calculated from an empirical formula made up by experience of the Nebraska State Highway Department.

$$P = AG (0.02a) \div .06b \div 0.1c \div Sd$$

in which:

P is the percent by weight of Bitumen required in the Bituminous Mixture prior to laying.

a is the percent of aggregate retained on the number 50 sieve.

b is the percent of aggregate passing the Number 50 sieve and retained on the number 100 sieve.

c is the percent of aggregate passing the number 100 sieve and retained on the number 200 sieve.

d is the percent of aggregate passing the number 200 sieve.

S is a factor depending upon the fineness and absorptive capacity of the material passing the number 200 sieve. Generally, a value of 0.2 may be used for "S".

"A" is an absorption factor for the aggregate. This factor will be determined on the basis of the asphaltic material and aggregate selected for each project. The factor should be applied to the portion of the combined aggregate which is absorptive.

The bulk specific gravity was determined by taking a 1/10 cubic foot container and tamping the aggregate into the cylinder. The weight of this material in the cylinder was 6010 grams from which the weight per cubic foot is 60,100 grams.

$$\text{Bulk Specific Gravity} = g_2 = \frac{\text{Wt. per cu. ft.}}{\text{Wt. cu. ft. water}} =$$

$$\frac{(60100)(2.205)}{62.4} = 2.13$$

$$\text{Bulk Specific Gravity of Plate River Gravel} = g_1 = 2.62$$

$$\text{Gravity Correction Factor} = G = \frac{g_1}{g_2} = \frac{2.62}{2.13} = 1.23$$

$$P = AG (0.02a) \neq (0.06)b \neq (0.1) c \neq Sd$$

$$= (1) (1.23) (0.02) (65) \neq (0.06) (11) \neq (0.1) (9.3)$$

$$\neq (0.2) (14.7)$$

$$= 1.60 \neq 0.66 \neq 0.93 \neq 3.54$$

$$= 6.73\%$$

Since the factor P is % bitumen by weight, it is necessary to change this due to the fluxing material in the bituminous material as it is applied to aggregate. This formula corrects for the bituminous material used

$$N = \frac{100 PK}{100-P}$$

in which:

N = Percent of Bituminous material to apply to the combined aggregate.

K is a factor which depends upon the **type** of Bituminous used, and

using RC oil, K = 1.2

$$N = \frac{(100) (6.73) (1.2)}{100 - 6.73} = 8.66\%$$

using MC oil, K = 1.1

$$N = \frac{(100) (6.73) (1.1)}{100 - 6.73} = 7.93\%$$

using SC oil, K = 1.0

$$N = \frac{(100) (6.73) (1.0)}{100 - 6.73} = 7.22\%$$

The percent by weight of sand, stone, and filler needed to give the desired gradation for laboratory use are weighed out proportionately so to make a sample whose final weight is 30 pounds.

16% stone, 3/4 to 3/8 or	4.8 lbs.
9% stone, 3/8 to No. 4 sieve,	2.7 lbs.
50% sand,	15.0 lbs.
25% filler,	<u>7.5 lbs.</u>
	30.0 lbs.

These materials were added together and mixed dry for a few minutes to get a uniform mixture, then the aggregate was heated to a temperature of 50° Centigrade. The oil was added slowly while the material was mixed with trowel and hands. The trowel just turned over the material and did not do very much mixing, while the fingers acted more like

pug mill teeth and completely coated the particles with a thin film of oil. The mixture was allowed to cure for a few days, and then a trowel was used to pile the material up. When this was done, the particles would slowly roll down one stone to another as though the mass was crawling. There is no rapid sliding, but a slow, steady, worm-like movement. The particles finally settle into a position where they will remain until the mixture is stirred again.

To ascertain which material is more stable when compacted, a stability test similar to the Hubbard-Field Stability Test as described in 1925 Proceedings of American Standard Testing Materials was used.

A four inch cylinder and a three and one-half inch orifice were used in this test. The size of the orifice is constructed of such size that the maximum load developed would be the same as though a 2 or 6 inch mold were used. The test cylinders were made by compressing the asphaltic mixtures at room temperature under a load of 3000 pounds per square inch. The density of the compacted material was determined by weighing the compacted cylinder and dividing by the volume. Two cylinders of each material were used.

Cylinder Number 1.

	<u>Weight</u>	<u>Volume</u>	<u>Density</u>
Bitumals	4.05 lbs.	49.4 cu.in.	142 lbs./cu.ft.
R. C. - 2	4.12 "	51.7 "	138 "
M. C. - 3	3.90 "	45.1 "	149 "
S. C. - 6A	3.42 "	43.5 "	136 "

Cylinder Number 2.

	<u>Weight</u>	<u>Volume</u>	<u>Density</u>
Bitumals	4.06 lbs.	51.2 cu.in	137 lbs./cu.ft.
R. C. - 2	3.74 "	48.2 "	134 "
M. C. - 3	4.34 "	56.8 "	132 "
S. C. - 6A	3.72 "	46.2 "	139 "

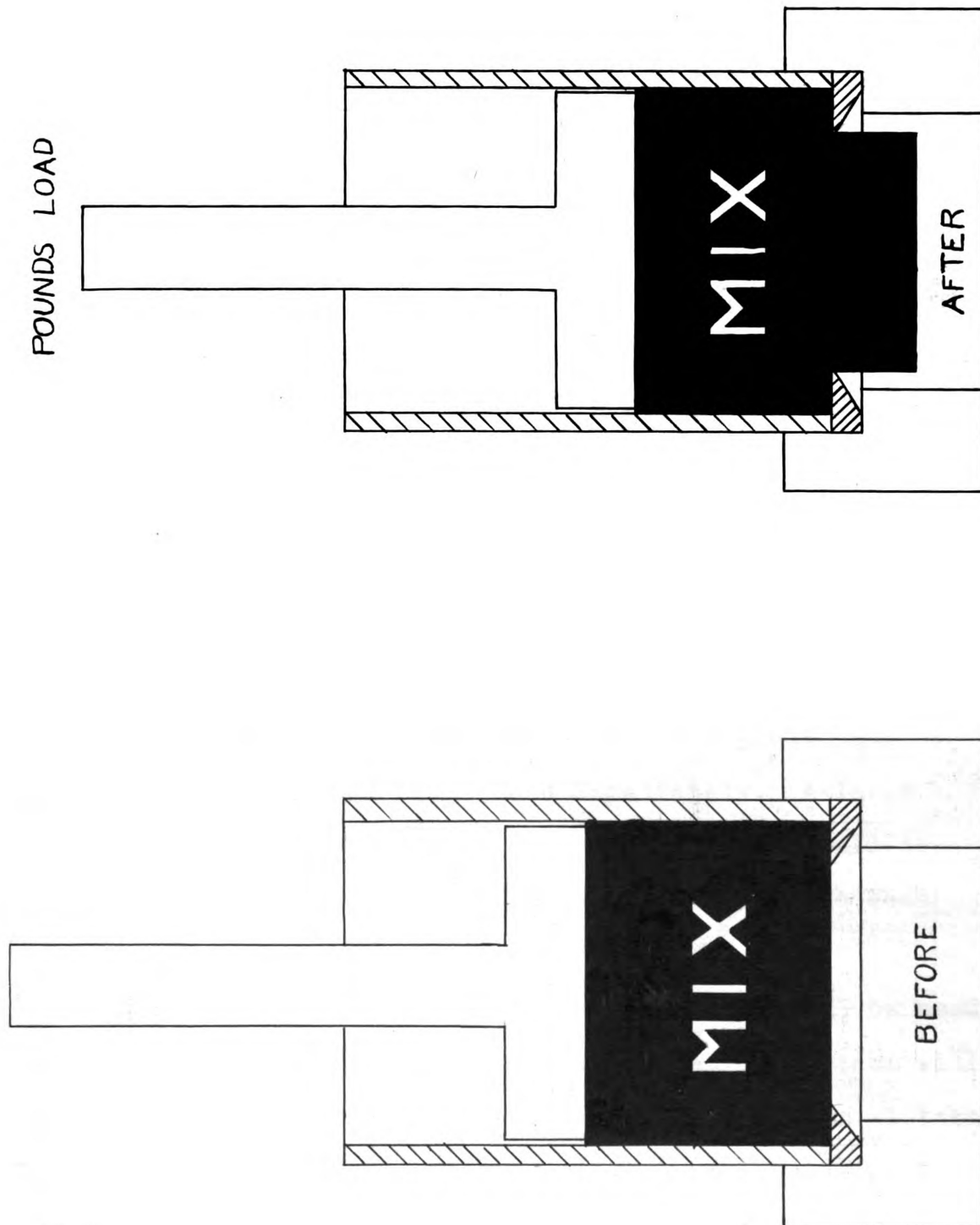
$$\text{Density} = \frac{(\text{Weight})}{(\text{Volume})} 1728 = \frac{(4.05)}{(49.4)} (1728) = 142 \text{ lbs/cu.ft.}$$

The molded cylinder was placed in an oven and heated to 140° F., which represents the maximum temperature the mixture is like to attain during service conditions. The molded cylinder was taken from the oven, placed in a mold which had also been heated. A load was applied to force the mixture thru the orifice.

The load was then applied on an Olsen Universal Beam balance sheer test machine. Diagrams of the mix in mold before and after loading are shown in plate IV. The results for the four materials were:

	(1)	(2)	Average
Bitumals	3020	3060	3040 pounds.
R.C.-2	3072	3065	3068.5 pounds.
M.C.-3	3325	3375	3350 pounds.
S.C-6A	2500	2300	2400 pounds.

The increase of stability for M.C.-3 was due to the fact that this was the last sample run. In repeated for the R.C.-2 it is found that with another week's curing, the stability had increased to 3475 pounds. This test was run



two days after the M.C.-3 test was completed.

Now that the laboratory procedure and results are finished, the method of handling the material in the field will be explained. The asphalt mixing plant is a factory for turning out bituminous mixtures which will meet the required specifications. These plants vary in size and operation as the job may require.

Since there are four kinds of material used in the preliminary part of this paper, it will be hard to get one plant to use all of these materials without making a few alterations each time the type of material is used. The person who has only a small amount of bituminous aggregate to place would be better off to use an emulsion. Here an ordinary concrete mixer is needed to mix the material and a few wheel barrows and buckets to proportion the materials on a volume basis. This method would not be economical where a great deal of material must be mixed and placed immediately. A large plant for mixing, or a traveling road mix plant would be better where a large quantity of material is needed each day.

With the assumption that a large quantity will be needed each day, a 2000 pound batch portable asphalt plant will be illustrated here showing the path that the material takes through the plant. The plant is made up of several parts which all are worked together such that the ~~maximum~~ capacity of each unit can be utilized at all times. The

aggregate is usually charged into a feeding hopper by a clam shell power shovel. The feeder regulates the flow on the cold elevator to the 60 inch by 24 feet drier so that this will not become overloaded and fail to dry the material sufficiently. The drying is done because, except the emulsion, the oil will not get a good bond between itself and aggregate. From the drier the aggregate is elevated on a 33 feet by 6 inch hot elevator with 14 inch by 7 inch buckets to a 3 feet by 10 feet double deck R. C. Symons screen, either before or after cooling, on top of the mixing tower. These screens again separate it in suitable separates for recombination. These separates are stored in a hopper from which they are emptied directly into a 2000 pound batcher by the quick opening, positive acting cut off gates on the bottom of the storage bins. The total capacity of the storage bin is 10,000 pounds, with three compartments which have steep sides so the aggregate will not stick in the hopper. The proportioning devices consist of the batcher, connected to Kron aggregate scales, for the aggregate, and 150 pound steam jacketed asphalt cement bucket. The material from the aggregate batcher drops directly into the 2000 pound steam jacketed anti-friction pugmill where the asphalt is added evenly across the length of the mixer. The pugmill mixes the aggregate and asphalt so each particle is

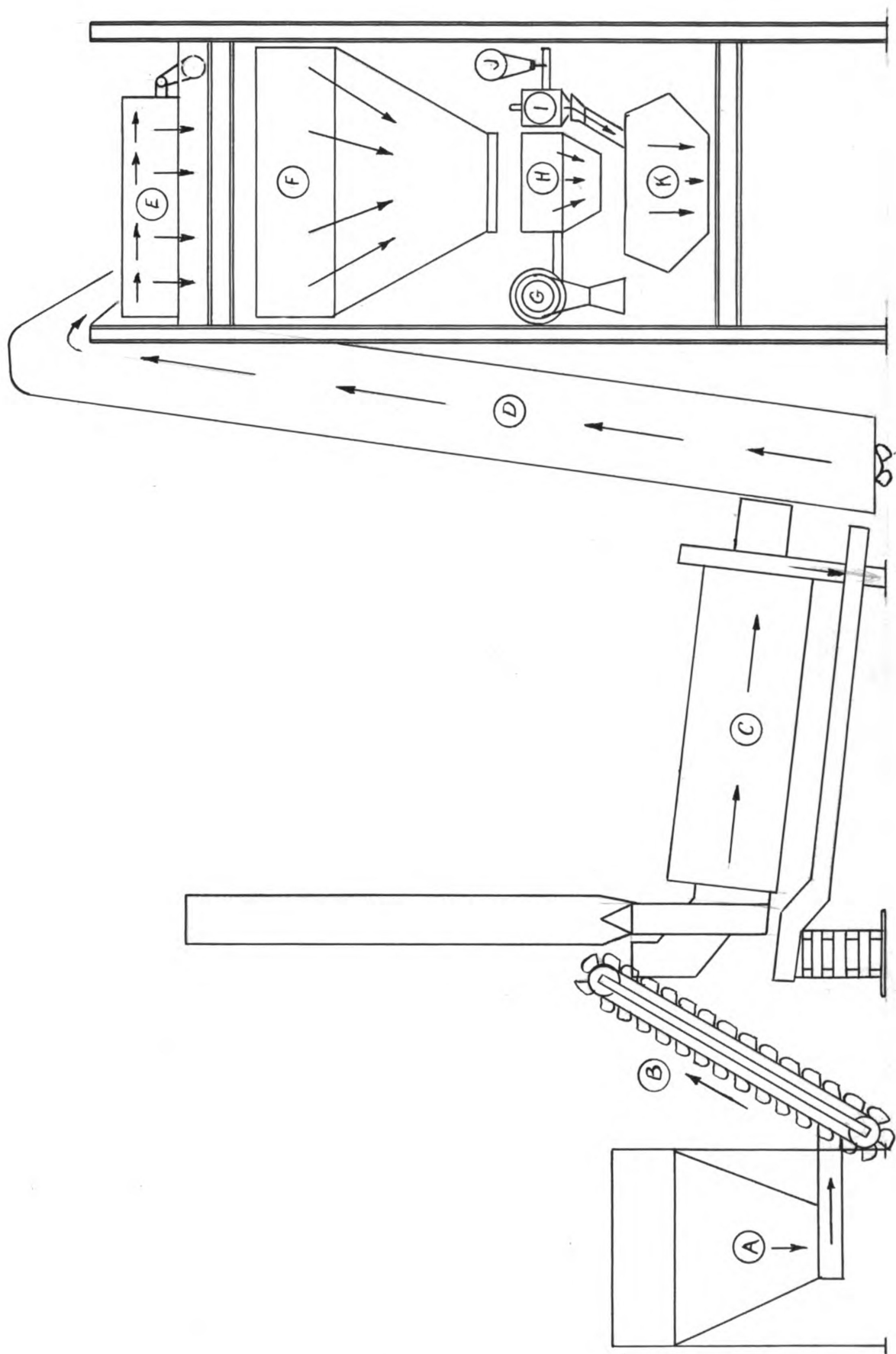
completely covered and the mixture shall be of the same consistency throughout. This mixture is then dumped out the bottom of the pug mill through discharge gate into the vehicle that will carry it to the place of use, or to the stockpile.

Plates V and VI show schematic diagrams of the flow of the material through the plant.

A is Feeder	K is Pug Mill
B is Cold Elevator	L is Oil Storage
C is Drier	M is Motor for Dryer
D is Hot Elevator	N is Tool Shed
E is Screen	O is Office
F is Storage Hopper	P is Platform Scales
G is Batcher Scales	Q is Gasoline Clam Bucket
H is Aggregate Scales	Shovel
I is Asphalt Bucket	R is Roadway
J is Asphalt Scales	S is Stockpile

Photographs of the plant are on Plate VII, VIII, and IX. The plant as set up above and illustrated by diagrams and photographs will produce between 25 and 28 tons of mixed material per hour. For an eight hour day, the plant would produce between 200 and 225 tons when operating on a two minute cycle. This plant, complete with power, costs \$22,500.

There are two more important parts of equipment that must be used. They are a crane for loading the aggregate



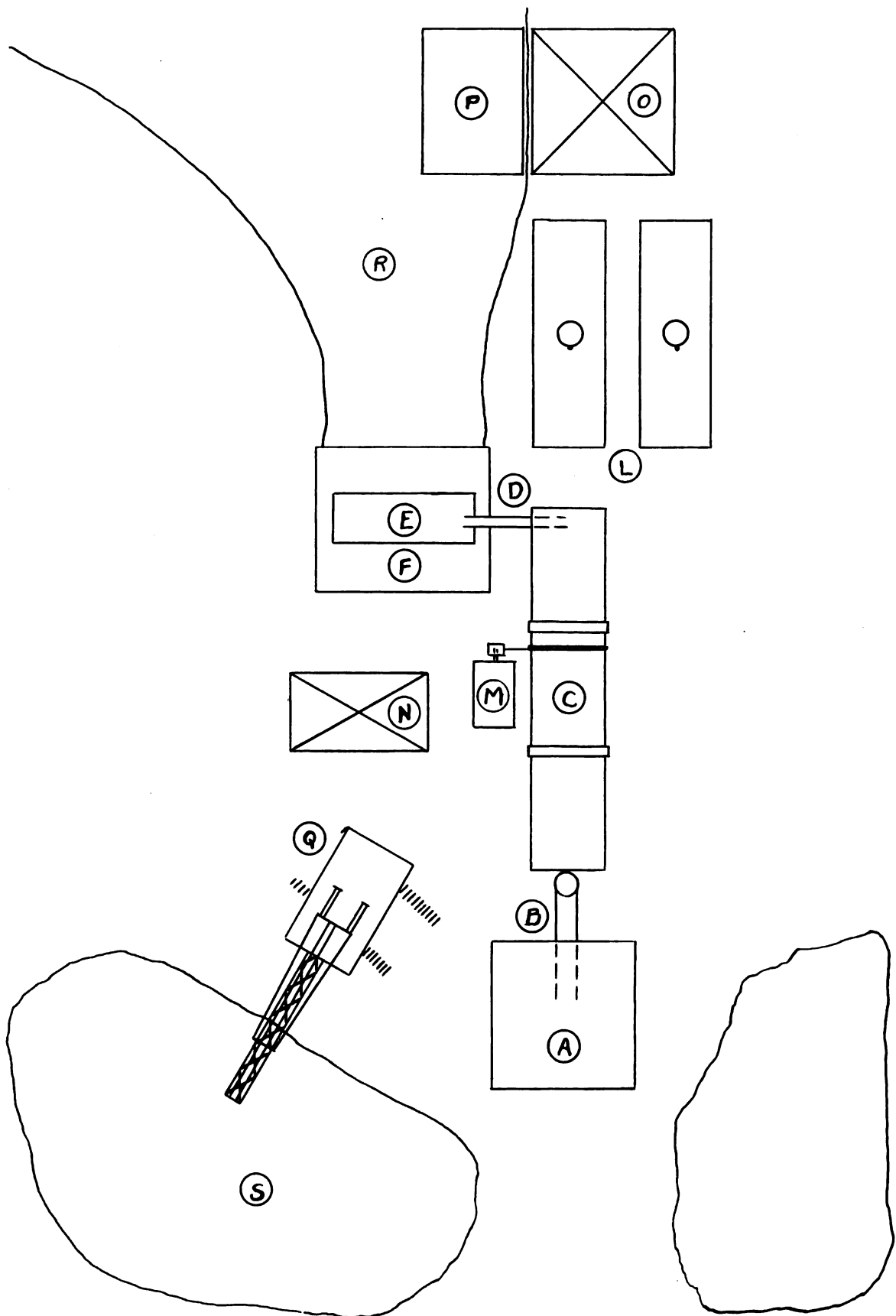




Plate VII
-21-

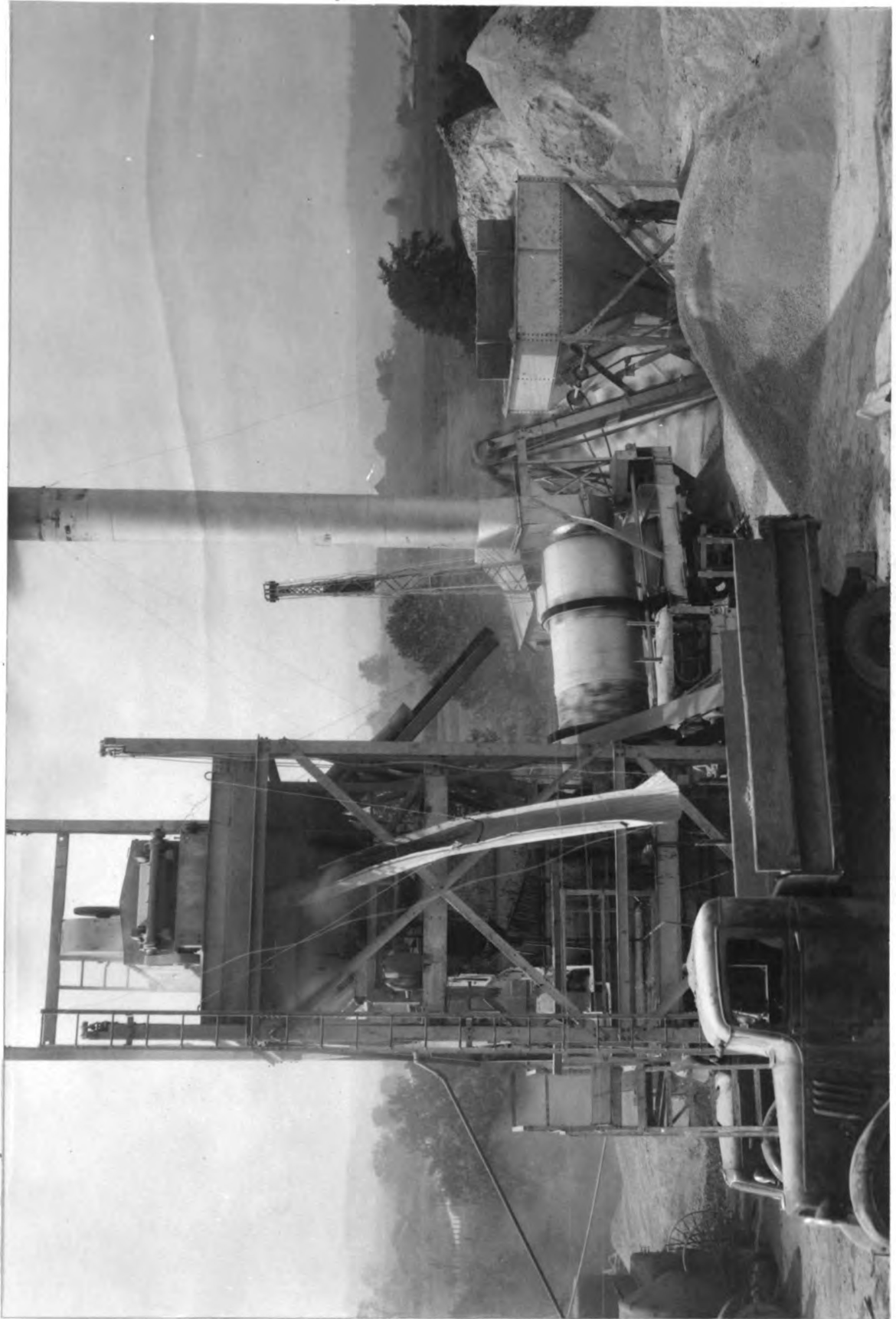


Plate VIII
-22-

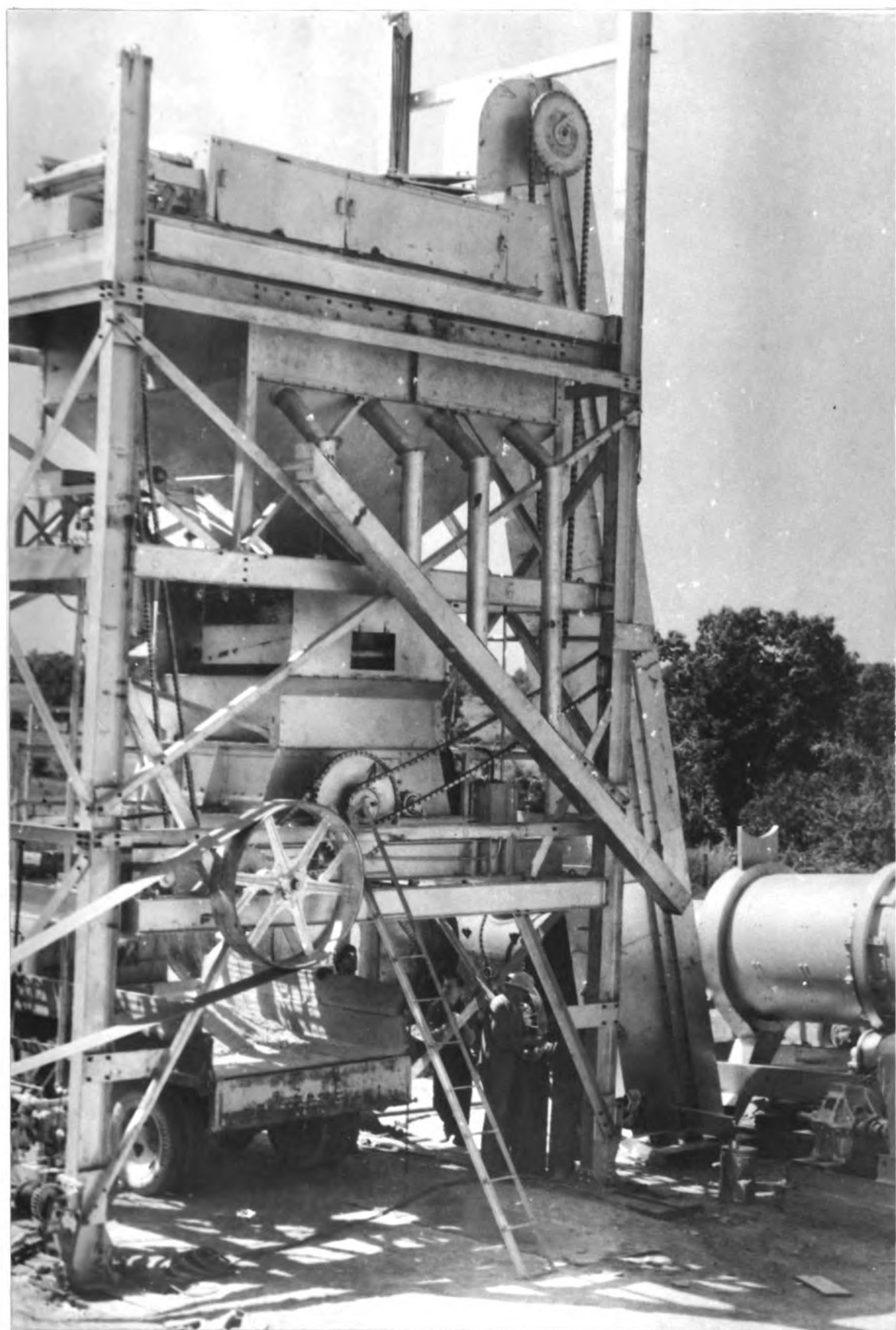


Plate IX
-23-

into the feed hopper, and the platform scales to weigh the loaded trucks as they leave the plant. The crane and the scales installed costs approximately \$9,500, and \$1,200 respectively. The crane would be a 3/4 yard Bay City machine, and the scales a Motor Truck Scales, capacity 15 tons, with a 22 feet by 9 feet platform.

As a general condition in this part of the country the plant would be able to operate only 5 months of the year, or only 126 working days in which material can be produced. Assuming the plant would produce an equal amount of each type of mix, we find that the 27,000 tons of aggregate that would be used during the year, will be divided up so that 6,750 tons will be used with each oil.

	: % by	:Tons	:Tons oil:	Gallons:	Cost	: Cost
	: weight,	: aggregate	: required:	: of	: of	: of
	: oil	: used per	: per year:	: Oil	: Oil	: Aggregate
	: year.	: year.				
R. C.	: 8.66	: 6750	: 585	: 140,300	: \$11,100	: \$13,234
M. C.	: 7.93	: 6750	: 535	: 128,500	: \$10,180	: \$13,234
S. C.	: 7.22	: 6750	: 488	: 117,200	: \$ 8,700	: \$13,234
Bitumals:	: 8.12	: 6750	: 548	: 131,800	: \$12,600	: \$ 5,613
	:	:	:	TOTAL	: \$52,580	: \$45,315

The mixing operation of the plant will add three more cost factors: labor, heat, and power. The labor will be constant for all of the materials. The personnel the plant requires is four laborers taking care of machinery, a super-

intendent; and a crane operator. The labor cost would be, on an average, \$50 per day.

For the emulsion, the heating would be nothing, but would run into a sizeable sum when drying the aggregate for the other materials. The dryer would cost \$10 per day to operate under average conditions. The power for operation of the plant would cost approximately \$27 per day. The depreciation of the equipment is usually considered to be 20% of the outlay for equipment, and a 5% value for overhead. This would be 25% of \$34,200 or \$8,550.

Summing up all of the outlay of money we have:

Depreciation and Overhead	\$8,550
Labor	\$6,350
Operation fuel and power	\$4,720
Bituminous materials	\$52,580
Aggregates	<u>\$45,315</u>
TOTAL COST PER YEAR	\$117,515.

The cost of producing proportional to the cost of materials put into them would be:

Bitumals	\$4.30 per ton	\$29,025 per year
R. C. - 2	\$4.40 per ton	\$29,700 per year
M. C. - 3	\$4.37 per ton	\$29,497.50 per year
S. C. - 6A	\$4.34 per ton	<u>\$29,295. per year</u>
TOTAL		\$117,517.50 per year.

Thus, it is shown that the cost of producing the four mixes will vary from \$4.30 to \$4.40 per ton.

From the stability tests it seems reasonable to conclude that the M.C.-3 and S.C.-6A would be suitable to stockpile for a short period of time where they could lose part of their volatile matter, but not become unworkable so that it cannot be easily laid and compacted.

The emulsion is the cheapest and most easily produced, but has the disadvantage that unless placed and compacted, the emulsion will break, leaving the hard asphalt mixture.

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