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16. ABSTRACT

Conclusion and Recommendation

The modified test procedure developed during this investigation appears to provide a simple method for determining the optimum percentages of water and emulsion for slurry mixtures. In most cases the design recommendation for water and emulsion contents will provide a workable mixture for spreading and a durable seal coat. However, changes in weather or changes in equipment may require some field adjustment in water content during construction.

It is recommended that the attached modified test method be substituted for existing Method No. Calif. 355-A.

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Final Report

Slurry Seal Test Study

Introduction

The present the design of slurry seal involve rosene Equivalent apparatus, a quid content and the use of e of the method it was noted tha al liquid content portion of the rform, and failed to produce re e determination of surface area uge kerosene equivalent meth ther elaborate equipment. The stigate possibilities of simplify e of this report is to present leading to a new test pro

71-25

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The modified tes ure developed during this investigation appears to provide a simple method for determining the optimum percentages of water and emulsion for slurry mixtures. In most cases the design recommendation for water and emulsion contents will provide a workable mixture for spreading and a durable seal coat. However, changes in weather or changes in equipment may require some field adjustment in water content during construction.

It is recommended that the attached modified test method be substituted for existing Method No. Calif. 355-A.

Materials

The aggregates used in this study were sampled from five different sources in the State of California.

Source	Test No.
Santa Clara River	68-2066
PCA Rockfield	68-2536
Fenton Murray	68-2612
Pinedale	68-2538
Kings River	68-2558

The emulsion was a slow curing type and was furnished by the Chevron Asphalt Company. Tests indicated the emulsion contained 60% asphalt.

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Slurry Seal Design

An emulsified asphalt slurry is composed of fine aggregate, emulsified asphalt of the slow curing type, and water combined to produce a mixture of fluid consistency.

Unfortunately, a design method must provide a test or tests for determining the optimum water content, sometimes called "premix moisture," as well as the required emulsion content. This is necessary since a certain moisture content must be available in the aggregate or separation of asphalt may occur during the introduction of the emulsion to the aggregate system.

The present test method, California 355-A, determines the total liquid content which is the maximum amount of liquid (emulsion plus water) that the aggregate can accommodate. In this test a known weight of aggregate is placed in a soil tube 1-3/4 inch in diameter, and water is admitted through the bottom of the tube. The water is allowed to rise up through the aggregate column until free water becomes evident at the surface. The amount of water required to reach this point is then determined by weighing the tube and subtracting the initial dry weight. The test was inconsistent in that the pressure of water influenced the results because the aggregate column tended to separate and in some cases floated upwards. Attempts to cure this problem by tapping or jarring the aggregate tube during the test were not successful. Controlled pressure heads of 6" and 12" were also maintained in trials. The results were still erratic as shown in Table A. Therefore, the test was abandoned.

It was discovered by testing slurry specimens in the abrasion procedure, described in Calif. 355-A, that specimens with a specified emulsion content would, after curing, indicate surface flushing or "bleeding" if excessive "premix moisture" was present.

Exploring further with variations of "premix moisture" content and constant emulsion content, it was found that the surface abrasion loss was high on specimens with insufficient "premix moisture." The abrasion loss then decreased as the "premix moisture" increased until a point was reached where an excess of moisture was used. At that point the abrasion loss immediately began to rise, Figure 1.

An examination of the test specimens indicated that insufficient premix moisture affected workability and created a rough textured surface of sufficient magnitude to contribute toward increased surface abrasion. Excess amounts of premix moisture caused a dilution of the emulsion with subsequent migration of the asphalt to the surface. This was not visually

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in evidence until the specimen had cured. The cured specimens had free asphalt on the surface forming a skin. Very little or no asphalt was apparent in the underlying material. Once the abrasion wheels broke through the surface skin, a high amount of abrasion occurred due to the lack of asphalt in the lower portion. It became obvious that there was an optimum amount of premix moisture to be used with each emulsion content. It was also evident that the increase in emulsion content when used with the optimum premix moisture caused a decrease in surface abrasion. This is a desirable feature, unless the emulsion content is increased to the point where it is excessive and surface bleeding will occur.

With this background data from test specimens, a new test method was prepared. A complete description of the method is shown in Appendix A. The following is a summary. Small trial batches are made to determine the premix moisture content, (Figure 2), and then larger test specimens are made with 10%, 15% and 20% emulsion plus the determined premix moisture and subjected to a surface abrasion test. The 10%, 15% and 20% emulsion contents were selected in order to be certain of a difference in abrasion loss. The abrasion loss is plotted in terms of grams loss/sq. ft., on a two cycle semi-log scale (Figure 3) for each emulsion content. The plotted points are connected with a line and the point of intersection of this line with a horizontal line indicating 75 grams/sq.ft. loss is the minimum amount of emulsion that should be recommended.

A visual inspection of several slurries prepared by starting with the minimum emulsion content as determined by the abrasion test and increasing the amounts until surface bleeding occurred, indicated that additional amounts ranging from 2 to 6% could be tolerated. The average was 4%, (Table B). The final recommendation for any specific design, based on the slurry abrasion loss, should then be the minimum amount required plus 2%. This provides additional asphalt without danger of flushing.

Certain aggregate sources do not provide an homogeneous slurry mixture, and tend to separate from the emulsion immediately after mixing. Test specimens made with this type of aggregate can be detected during the determination of premix moisture content. Cured specimens will show surface flushing with very low moisture contents. Inspection of the bottom of the specimens will reveal uncoated aggregate. The addition of 1% cement or hydrated lime to the dry aggregates appeared to cure the problem for the two sources showing this characteristic during this study.

The abrasion method specified in Calif. 355-A uses different equipment than that used by W. J. Kari and L. D. Coyne of Chevron Asphalt Co.* These authors, on the basis of their

*Kari, W. J. and Coyne, L.D., "Emulsified Asphalt Slurry Seal Coats," Proceedings of the Association of Asphalt Paving Technologists, Vol. 33, pp. 502, 1964.

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extensive field studies, recommend that the abrasion loss be limited to 75 grams/sq. ft., and this value has been selected for our requirements. Therefore, in order to determine whether the California unit produced the same values as the Chevron unit, a correlation program was performed. To make the correlation, specimens were prepared from two different aggregate sources and tested by the Chevron Asphalt Co. in Emeryville and the Materials and Research Laboratory in Sacramento using two different types of abrasion wheels. The previously used caster wheels on the M&R unit were difficult to standardize, and it was decided to use steel wheels with a standard knurled surface. These may be constructed in any machine shop.

The results of the correlation study are shown in Table C and Figures 4 and 5. The best correlation is attained with a ten minute test period using steel knurled wheels. Therefore, this type of wheel and test period have been adopted in our test method.

The studies to standardize the abrasion test indicated that wheel wear would influence the final recommendation for emulsion content. Therefore, a standard slurry was developed which may be used for determining wheel wear and the need for application of a correction factor or replacement. On the basis of our studies we estimate that 75 to 100 samples may be tested with a set of wheels before they will be worn sufficiently to require a correction factor.

After a number of trials a slurry containing #20-50 graded Ottawa sand, 2% Type II Portland Cement, 5% water and 10% emulsion was selected as a standard. The curing period has been standardized at 16± 1 hours. Details of the method are shown in Appendix B. One problem in the use of this material is wheel pickup. It is necessary to stop the abrasion process once or twice during the test and clean the wheels with a wire brush. However, this mixture is only used occasionally for calibration.

Calculations indicate that a 15% reduction in abrasion loss by wheel wear would change the design asphalt content determined with new wheels by approximately 0.9%. Therefore, no correction is required up to 15% reduction in abrasion loss. On the basis of observations on knurled wheel wear, it was decided to require replacement of wheels when a reduction of more than 40% in abrasion loss is measured. In the 15-40% range a correction is applied to the measured abrasion loss as shown in Appendix B.

Slurry seal design data for a number of California aggregate sources is shown in Table D. In the case of the Pinedale and Kings River locations low abrasion losses using

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10% emulsion indicated separation of the system. The result is caused by the emulsion moving to the surface. The excess asphalt at the surface following curing, causes a marked reduction in abrasion loss. The laying of such a slurry would cause a serious failure and must be prevented at the design stage. This is indicated in the present method by the appearance of the design pats, and by the abrasion loss result. When this condition is encountered it may be corrected by the addition of small amounts of lime or cement.

This report has presented a modified method of design for slurry seal material including an abrasion test method that may be standardized.

Implementation

The results of this study can be implemented by the modification of Test Method No. Calif. 355-A.

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Table A

Repeatability Study on Total Liquid Limit Test (Calif. 355-A)

Test No. 68-2066

Series I

Water tap used for source of water. Water intake valve on soil tube barely open.

Total Liquid Limit	Remarks
20.3	
22.6	
19.3	Soil tube tapped on side
20.6	"
20.9	
30.0	Soil column separated

Series II

A five gallon container with outlet 6" above inlet of soil tube used.

Total Liquid Limit	Remarks
30.2	Soil column separated
22.0	
22.0	
21.0	
21.8	Soil tube tapped on side
25.8	"

Series III

A five gallon container with outlet 12" above inlet of soil tube used.

Total Liquid Limit	Remarks
30.0	Soil column separated
32.6	"
19.1	Water channeled
20.6	
20.8	Soil tube tapped on side
20.1	"

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Table B

"Flushing" Study - Slurry Seal

Additional emulsion added in two percent increments to the percent of emulsion recommended (at 75 grams loss per square foot).

The premix water content used was the amount recommended, and was kept constant for all additions of emulsion, for a given source.

Test No.	% Emulsion (Min.) (75 gms loss/sq ft)	% Emulsion (Max.) (Flushing)	Recommended Range (%)
68-2065	22.5	26.5	4.0
68-2066	17.1	21.1	4.0
68-2612	18.0	24.0	6.0
68-2613	16.5	18.5	2.0
68-2614	11.0	13.0	2.0
68-2536	13.0	15.0	2.0
68-2558 Lime	16.0	None at 22%	-
68-2558 Cement	12.5	16.5	4.0
68-2538 Lime	11.0	None at 17%	-

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Correlation of Slurry Abrasion Test

Aggregate Test No.	Source	% Premix Moisture	% Emuls	Sample No.	Abrasion Loss-Gms/Sq.Ft. Sacramento Results: Rubber Wheels 15 Min.Abra.	Steel Wheels 10 Min. Abrasion	Steel Wheels 15 Min. Abrasion	Chevron Results
68-2066	Santa Clara River	11	10	A	143	275	520	309
		11	10	B	167	250	682	231
		11	10	C	118	233	675	231
				Avg.	143	252	626	257
		9	15	A	62	85	320	78
		9	15	B	56	105	371	75
		9	15	B	50	72	292	75
				Avg.	56	87	328	76
		7	20	A	31	55	210	11
		7	20	B	31	55	190	15
		7	20	C	28	42	172	15
				Avg.	30	51	191	14
68-2612	Fenton-Murray Canyon	15	10	A	118	312	677	285
		15	10	B	93	275	722	(690)
		15	10	C	105	257	736	441
				Avg.	105	281	711	363
		13	15	A	50	130	318	143
		13	15	B	74	122	396	126
		13	15	C	79	127	372	117
				Avg.	74	126	362	129
		11	20	A	50	60	184	60
		11	20	B	43	57	162	57
		11	20	C	56	55	177	60
				Avg.	50	57	174	59

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Slurry Seal Design Data

ırce	Test No.	%H_2O Added at % Emulsion			Surface Abras. at % Emulsion			Recommended Max. % H_2O	Recommended Min. % Emul	S.E. Spec. 45Min.	FS	Sp Gr of Aggr.	Grading (% Passing) Sieve 4	8	16	30	50	100	200
		10	15	20	10	15	20						Spec. 100	95-100	60-90	40-65			8-15
ıta Clara ver Rio	68-2066	11	9	7	210	98	50	8.2	17.1	66	NS	2.64	100	100	76	51	30	17	12
ı kfield	68-2536	9	7	5	110	60	30	7.8	13.0	75	NS	2.69	100	100	71	48	29	18	12
ıton tray ıyon	68-2612	15	13	11	238	107	60	11.8	18.0	48	NS	2.65	100	100	74	48	34	23	15
ı Harris ınt	68-2613	15	12	9	170	115	35	11.2	16.5	70	NS	2.65	100	100	57	36	21	13	9
.son Sloan ıy	68-2614	13	10	7	120	30	15	12.4	12.0	65	NS	2.70	100	100	67	36	20	14	9
ıedale *	68-2538*	11	8	5	35	17	18			75	NS	2.68	100	100	75	50	35	18	11
	68-2538 +1%Lime	17	15	13	110	25	25	16.5	11.0	75	NS	2.68	100	100	75	50	35	18	12
	68-2538 +1%Cement	13	9	5	100	50	30	10.8	12.5	75	NS	2.68	100	100	75	50	35	18	12
ıgs River ıger *	68-2558*	13	9	5	45	57	42			77	NS	2.68	100	100	84	52	35	20	12
	68-2558 +1%Lime	17	13	11	205	80	50	12.5	16.0	77	NS	2.68	100	100	84	52	35	20	13
	68-2558 +1%Cement	17	13	11	115	50	50	15.0	12.5	77	NS	2.68	100	100	84	52	35	20	13

Table D

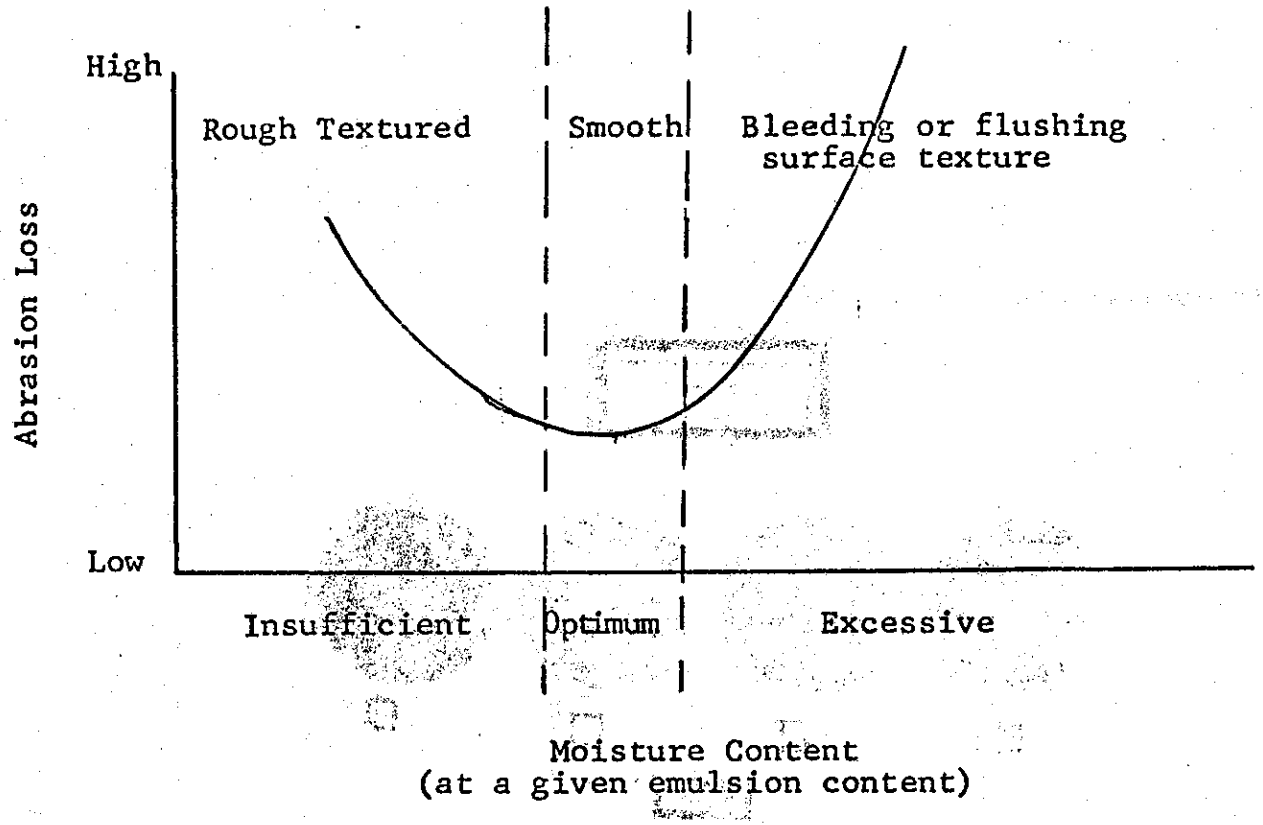
ıources that indicated separation of the emulsion and aggregate. Note low abrasion loss with 10% emulsion. Condition was corrected with the addition of cement or lime.

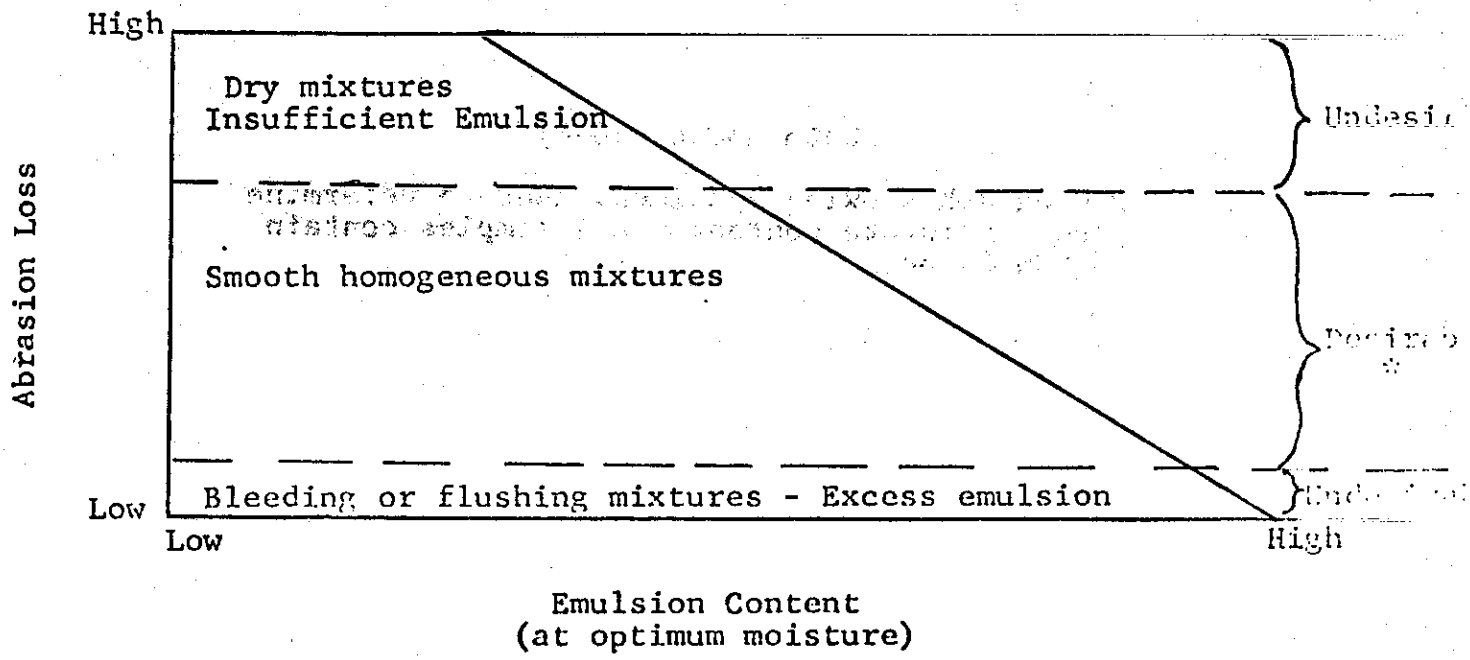
Figure 1

TYPICAL CONSISTENCY CURVES

FOR

SLURRY SEAL COATS





*Ranges approximately 4%

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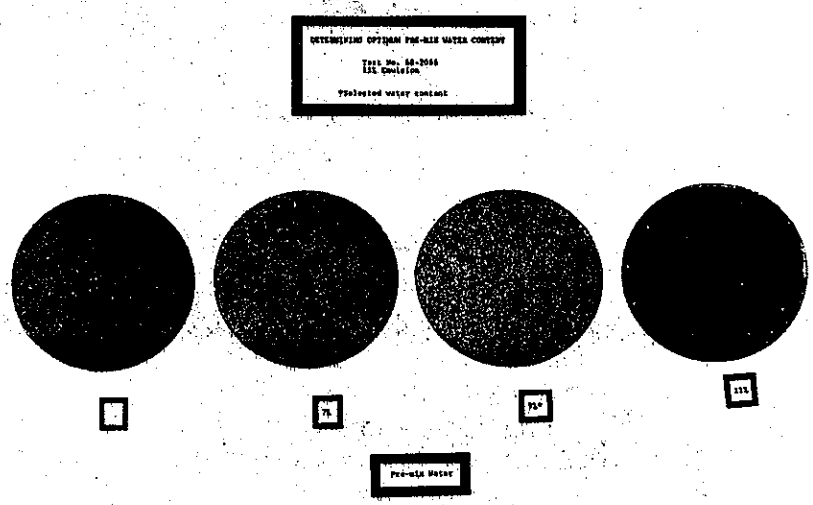
Figure 2



(Photo No. 69-50-1)

Photograph showing specimens used to determine premix moisture content. All samples contain 15% Emulsion.

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FIGURE 3

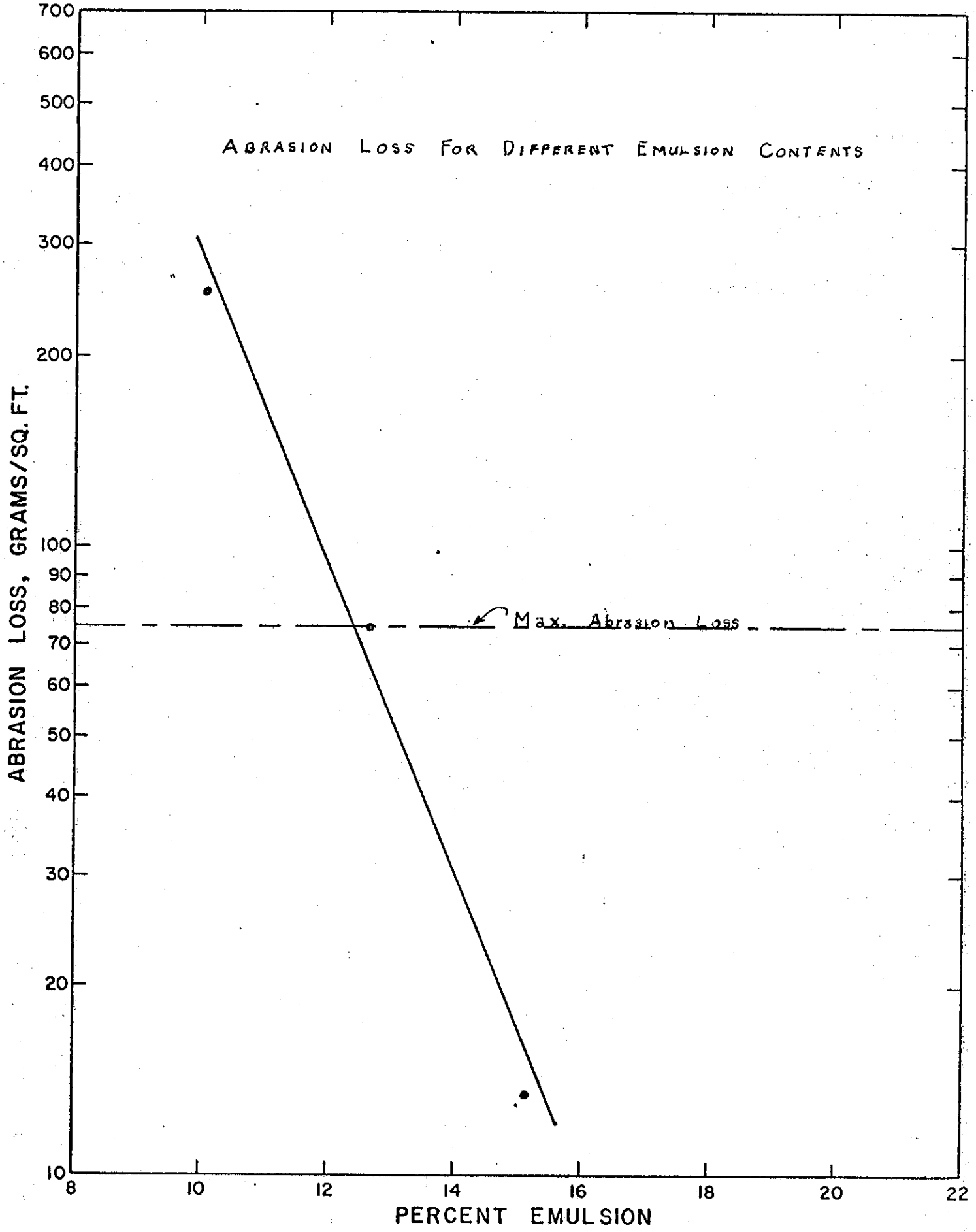

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FIGURE 4

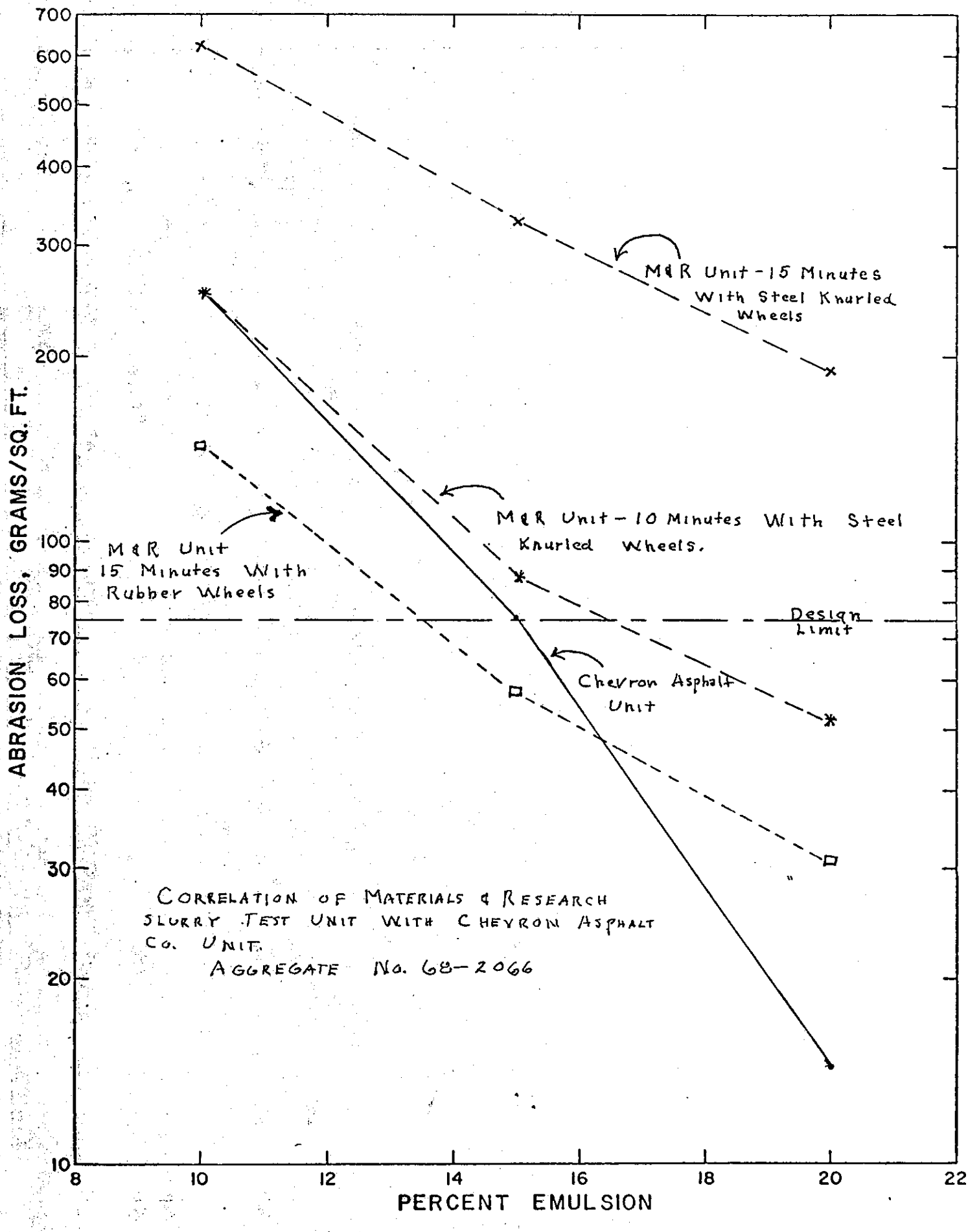

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FIGURE 5

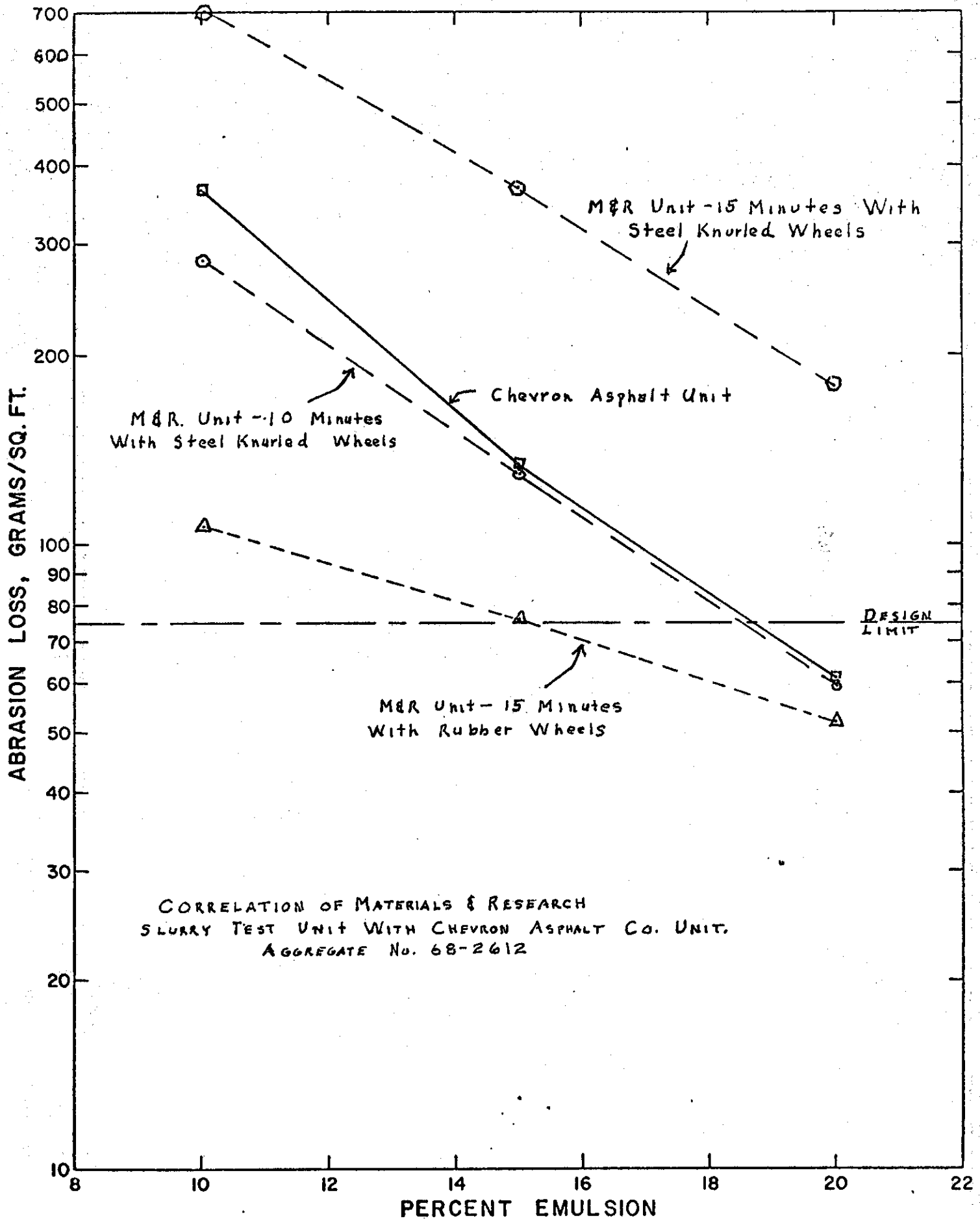

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Figure 6

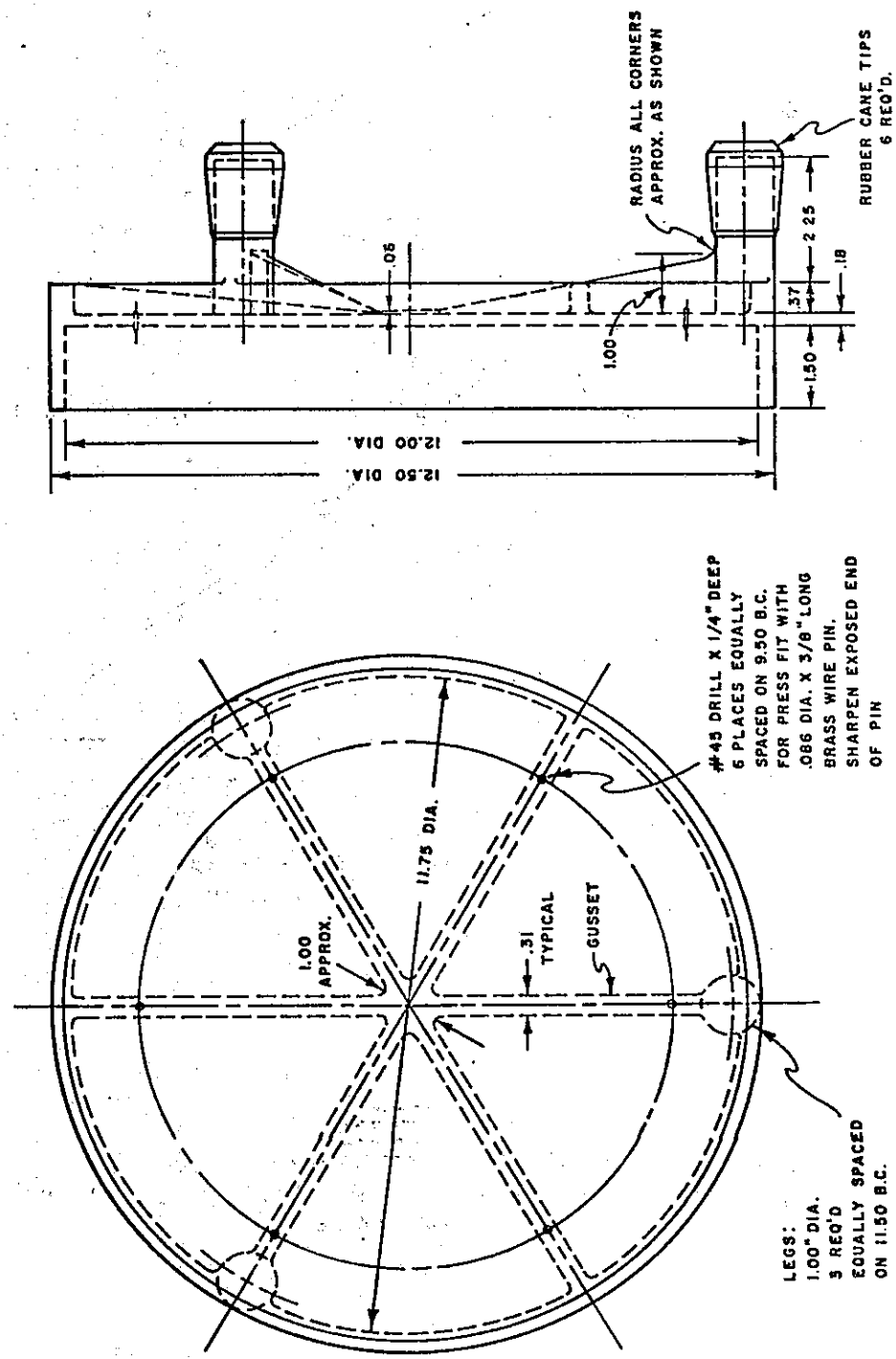

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Figure 7

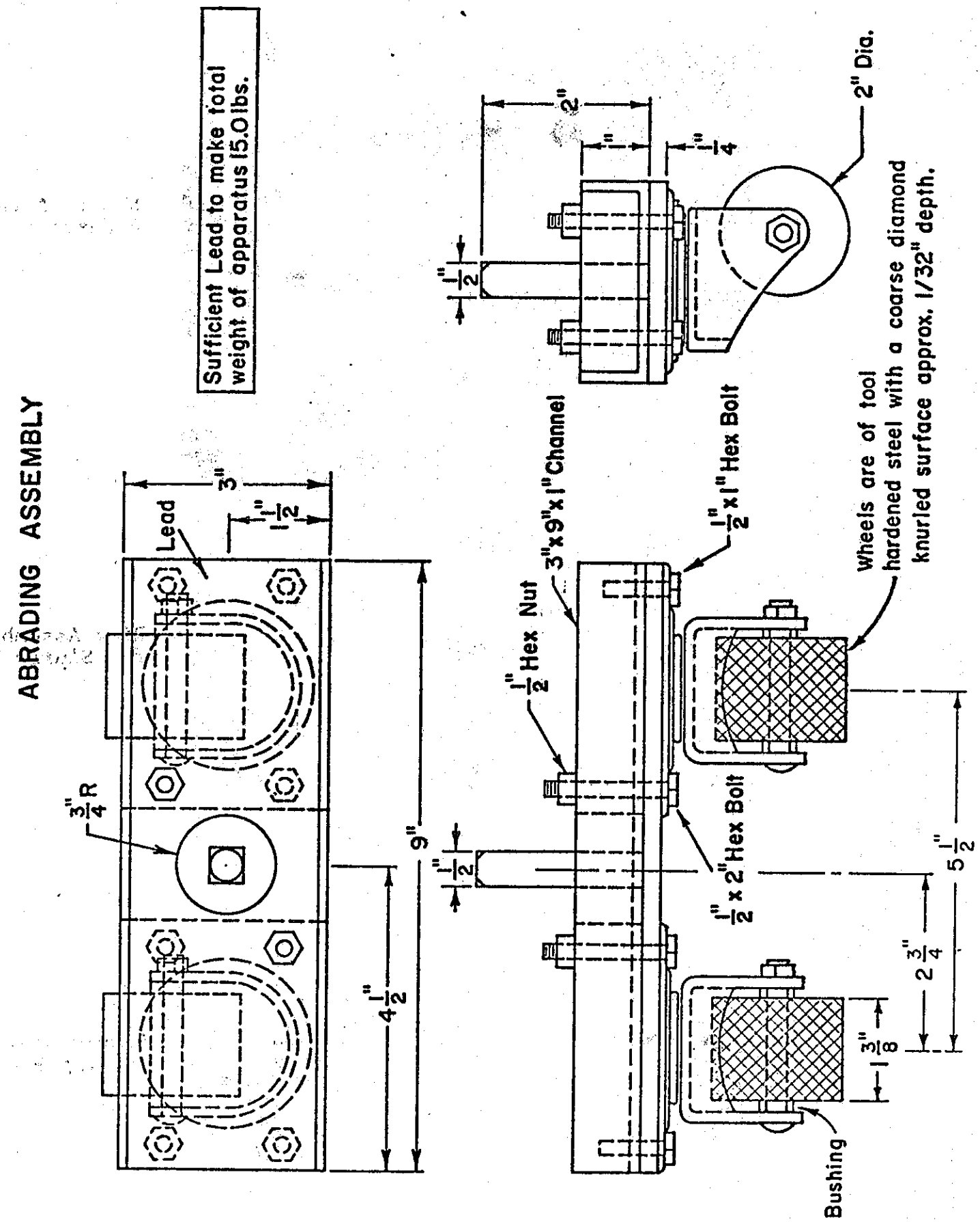

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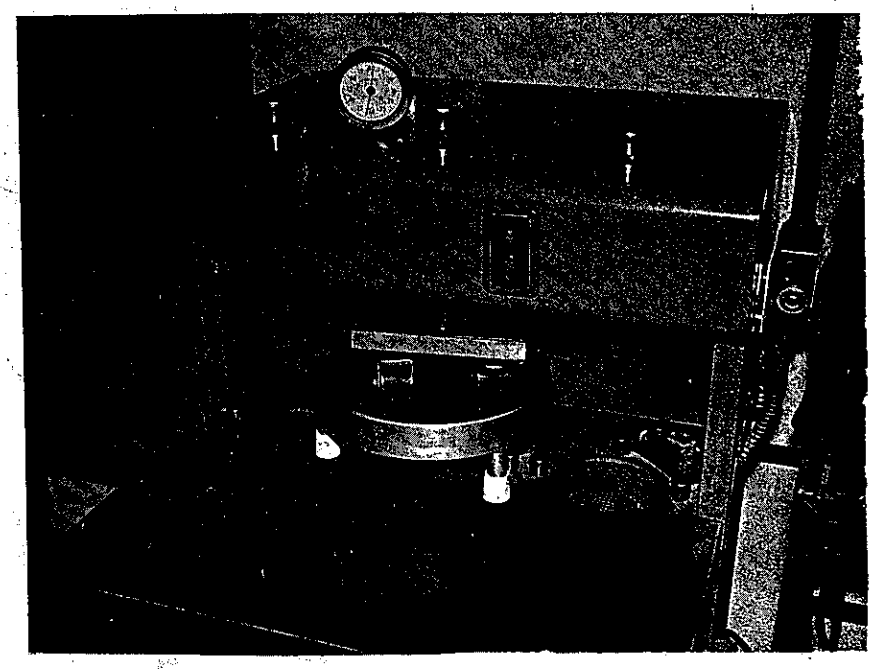
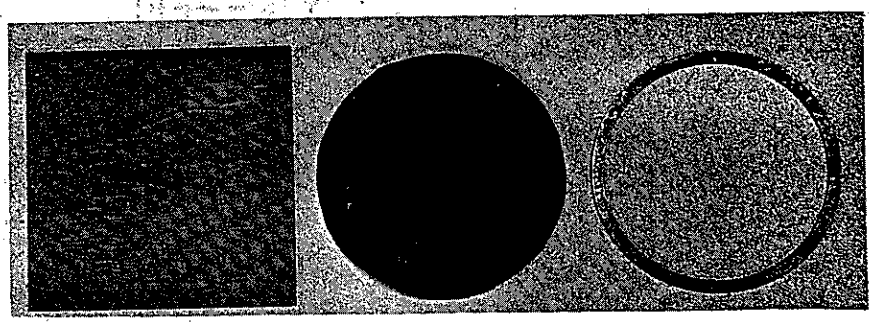
FIGURE 8



Slurry Abrasion Apparatus



Ring Assembly for Slurry Pads

Slurry Seal Testing Pads

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METHOD FOR DESIGN OF SLURRY SEAL

SCOPE

This test method is used to determine a maximum water content for proper consistency and optimum asphalt content for a slurry seal. This test method also furnishes an index of the slurry seal mixture's resistance to abrasion in the presence of water. The results of this test method will generally provide a satisfactory slurry. However, due to evaporation, adjustments in the water content may be required as the daily temperature varies. Only the water content should be changed if necessary for workability, never the emulsion or asphalt content.

PROCEDURE

A. Apparatus

1. Drying oven or hot plate.
2. Round tin pan lids 1/2" deep x 3-7/8" diameter (8-oz. can lids).
3. Round flat bottom pans approximately 10 inches in diameter at the bottom and approximately 3 inches deep.
4. Scale of sufficient capacity to weigh a 1000 gm test sample to an accuracy of ± 1 gm.
5. Circular metal rings 10 inches i.d. (inside diameter) with vertical sides 1/4 inch deep.
6. Abrasion apparatus - See Figure I.
7. Abrasion pan - See Figure II.
8. Mechanical mixer (Bituminous Mix) or other power device to drive abrasion apparatus at 30 RPM ± 1 (See Figure III).

B. Materials

1. Roofing felt 50-60 lb. weight.

C. Test Record Form

Use work card Form T-302 for recording test data.

D. Preparation of Sample

Quarter out 20 samples of 150 grams each and 9 samples of 600 grams each of the passing No. 8 Fraction. This number of samples will generally be sufficient to establish the

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optimum asphalt or emulsion content, however, occasionally additional samples may be required.

Dry to a constant weight.

E. Consistency and Pre-Mix Moisture

1. Select 12-150 gram, dry, quartered samples.

2. Prepared 3 series with 4 samples each as follows:

   Series I - Add 9% water by weight of the dry material to the first test sample and mix thoroughly. Then add 10% emulsion and mix thoroughly. Pour slurry into tin lids (3-7/8" diameter x 1/2" deep). Using a straight edge resting on the rim, strike off with a sawing motion, the excess material so that the surface will be flush with the ring. Use one saw pass only with the straight edge.

   To complete Series I, add 11, 13 and 15% water respectively to the remaining 3 aggregate samples, with 10% emulsion*, and prepare exactly as outlined for the first sample with 9% water and 10% emulsion.

   Series II - Repeat Series I except that the emulsion content shall be 15%.

   Series III - Repeat Series I except that the emulsion content shall be 20%.

3. Cure all specimens in a 140°F oven for 3 hours ± 5 minutes.

4. Remove specimens from 140°F oven. After cooling remove specimens from their molding pans. Visually inspect for evidence of free asphalt on the surface, and evidence of separation indicated by uncoated aggregate on bottom.

5. Select the specimen in each series that contains the maximum amount of pre-mix water with no free asphalt visible on the surface, and no evidence of separation. If free asphalt is not visible on any sample, prepare additional specimens, with higher pre-mix moisture contents, in 2% increments and cure in 140°F oven. Record the selected moisture content for each quantity of emulsion as the optimum pre-mix moisture content.

6. Plot the selected moisture contents on Chart I.

*Based on dry aggregate weight.

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F. Determination of Resistance to Abrasion

1. Place metal ring on disc cut from roofing felt to O.D. of ring.

2. Select nine 600 gram, dry, quartered samples.

3. Prepare in triplicate specimens with the optimum amount of pre-mix moisture as previously determined for 10% emulsion, and mix well.

4. Add 10% emulsion to each sample, mix well, and pour into metal ring. Using a straight edge resting on the ring strike off with a sawing motion the excess material so that the surface will be flush with the ring. Use one saw pass only with the straight edge.

5. Repeat steps 3 and 4 using 15 and 20% emulsion respectively.

6. Allow each specimen to set at room temperature for 15 minutes, remove metal ring and place in 140°F oven, dry to a constant weight.

7. Record the weight, cool to room temperature, place each specimen in a pan, and cover the surface of the specimen with water. Allow to stand in this water bath, at room temperature for one hour.

8. Remove specimen from water bath, place in abrasion pan, cover surface with water, apply abrasion wheels.

9. *Abrade specimen at the rate of 30 ± 1 RPM for 10 minutes.

10. Remove specimen and place in 140°F oven until constant weight is reached. Subtract this weight from the oven dry weight obtained before abrasion test. Record the difference in weight and multiply by 5.00 (abraded area = 1/5 sq. ft.) for gram loss per square foot.

11. Average the results of the three specimens. Plot the average values on Chart No. II. Draw a line connecting the points. (Note emulsion content indicated at intersection of horizontal line representing a loss of 75 gms. per sq. ft.)

12. Record the emulsion content obtained in step 11 as the minimum emulsion content to use.

*Periodically calibrate steel wheels by method described in Appendix B.

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13. Using the minimum emulsion content obtained in step 11, refer to Chart I for the maximum amount of water permissible to start with in the field.

G. Reporting Test Results

Report under remarks of Form T-302 the following recommendations:

A. The max. water content

B. The minimum emulsion content

C. Source of emulsion used

D. Percent asphalt in the emulsion used (actual or assumed)

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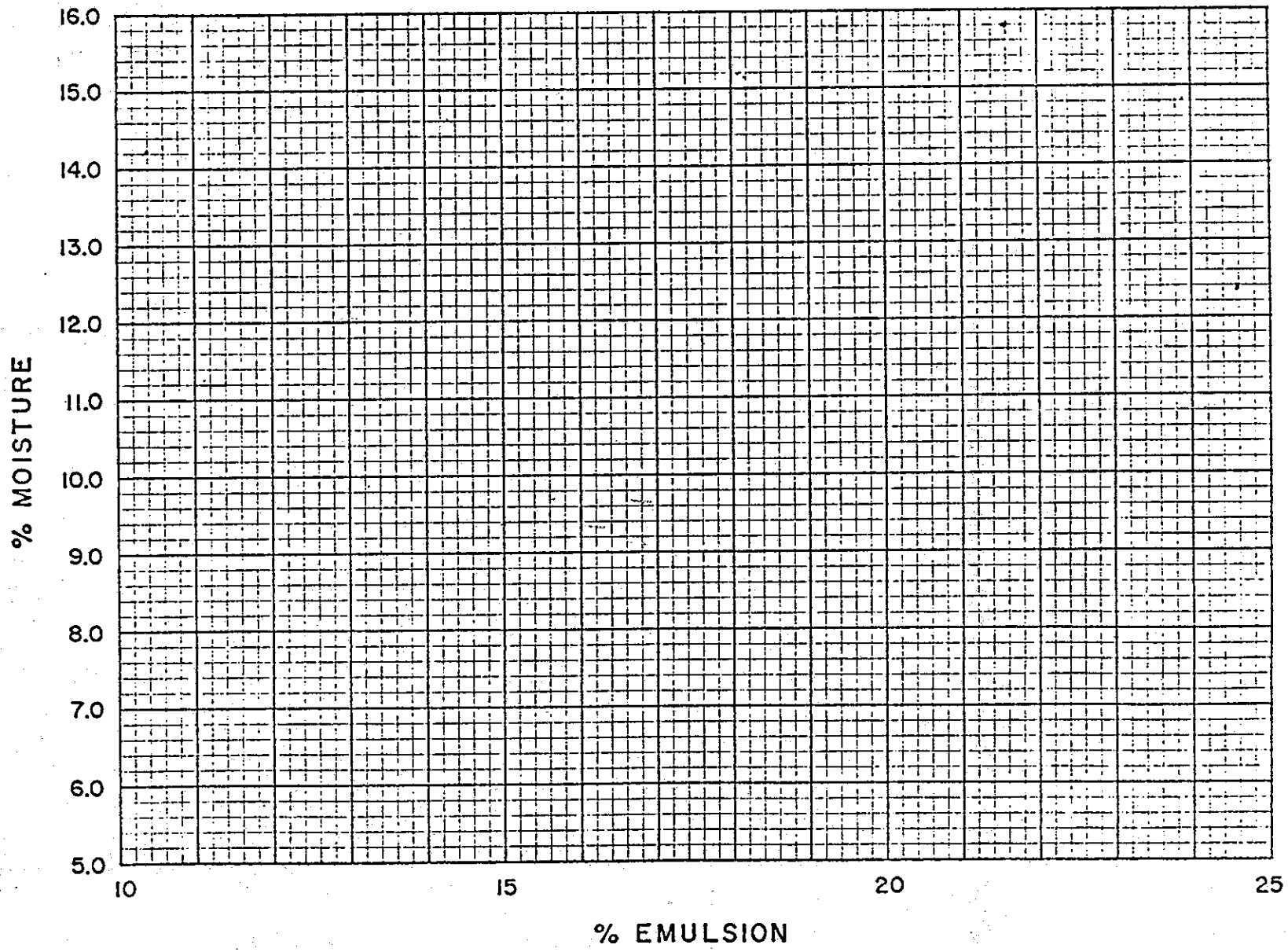
CONSISTENCY CHART
CHART I



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ABRASION CHART
CHART II

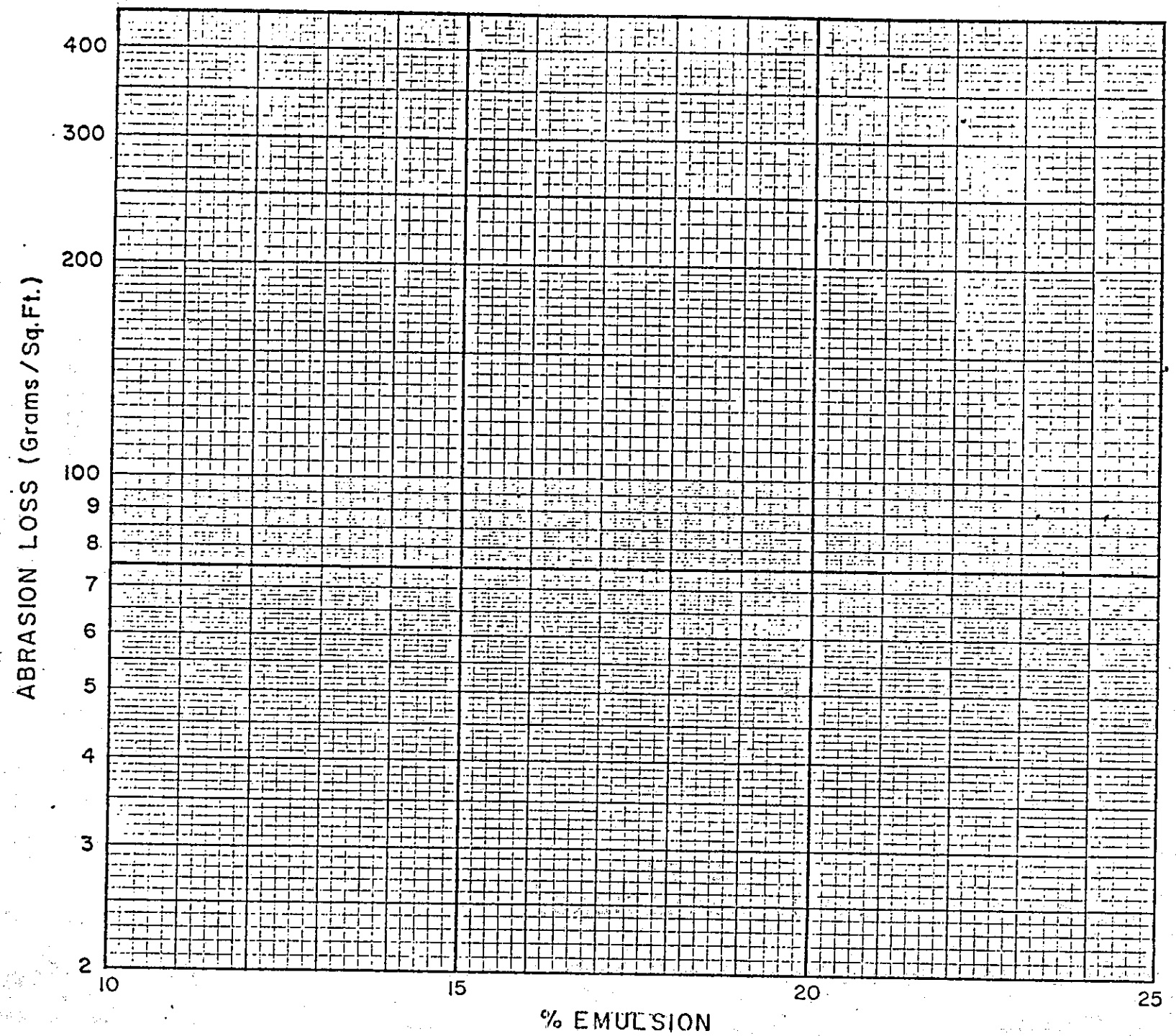

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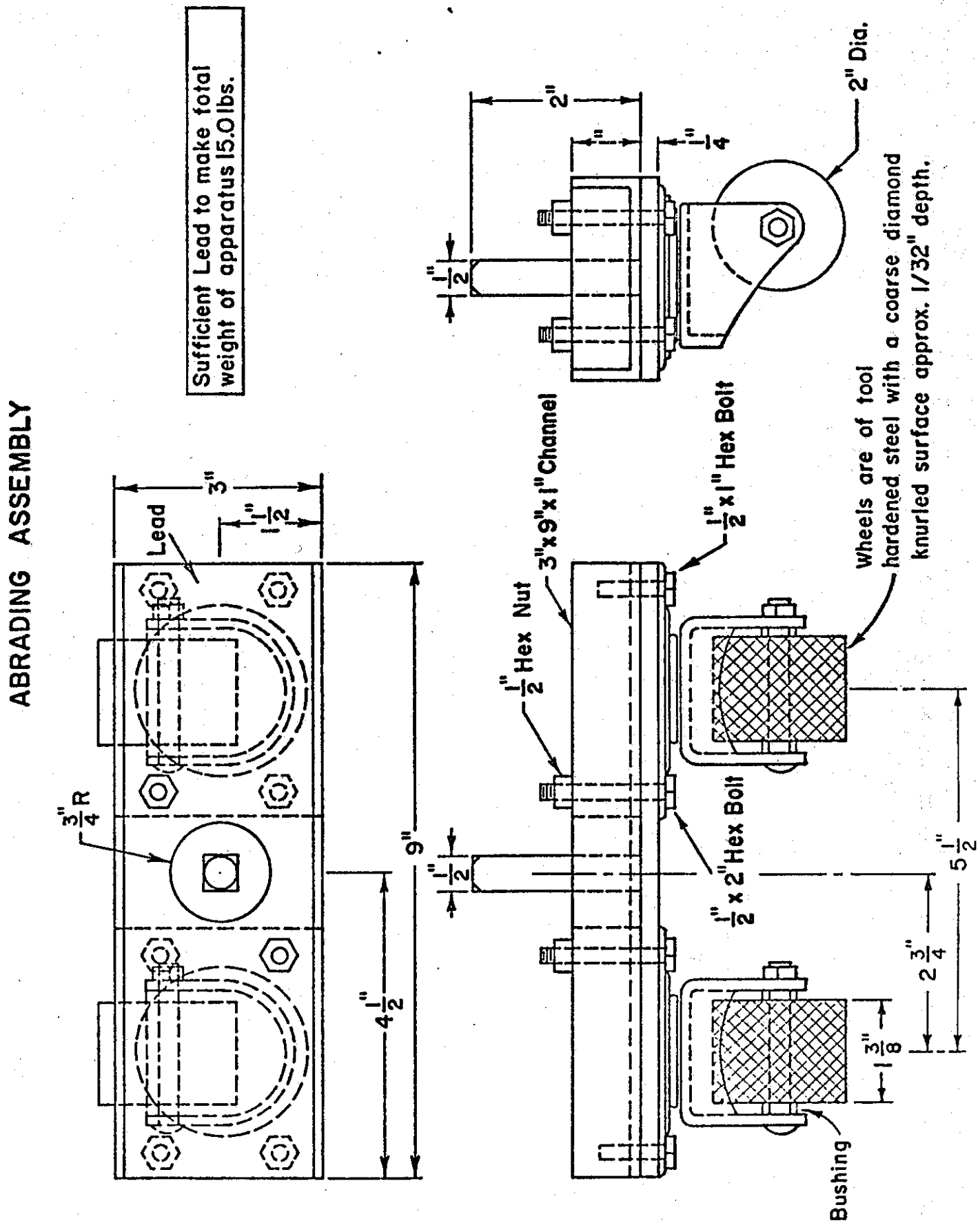
Figure I



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APPENDIX B

METHOD FOR CALIBRATION OF SLURRY SEAL WHEELS

SCOPE

This is an appendix to Test Method. No. Calif. 355-B (Method for Design of Slurry Seal). This method is used to calibrate the steel wheels used for slurry seal design. It provides a measure of wear on the wheels by means of a standard slurry mixture.

PROCEDURE

A. Apparatus

1. Drying oven or hot plate.
2. Slurry abrasion pan.
3. Scale of sufficient capacity to weigh a 1,000 gram test sample to an accuracy of ± 1 gram.
4. Circular metal rings, 10 inches inside diameter, with vertical sides 1/4 inch deep.
5. Abrasion apparatus - See Figure I of Test Method 355.
6. Abrasion pan - See Figure II of Test Method 355.
7. Mechanical mixer (Bituminous Mix) or other power device to drive abrasion apparatus at 30 RPM ± 1 - See Figure III of Test Method 355.

B. Materials

1. Roofing felt 50-60 pound weight.
2. Ottawa Sand 20-50 gradation.
3. Type II Portland Cement.
4. SS-1 emulsion (conforming to AASHO specifications).

C. Preparation of Samples

1. Place metal ring on disc cut from roofing felt to outside diameter of ring.

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2. Prepare in triplicate, the following slurry mixture, in the order indicated and mix thoroughly after each addition.

   a. 600 grams dry Ottawa Sand.

   b. 2% Type II cement (12 grams)

   c. 5% water (30 grams)

   d. 10% emulsion (60 grams)

3. Pour slurry into metal rings. Using a straight edge resting on the ring, strike off the excess material with a sawing motion, so that the surface will be flush with the ring. Use one saw pass only with the straight edge.

4. Allow each specimen to set at room temperature for 15 minutes, remove metal ring and place in 140°F oven, cure for 16 hours ± 1 hour.

5. Record the weight, cool to room temperature, place each specimen in a pan, and cover the surface of the specimen with water. Allow to stand in this water bath, at room temperature, for one hour.

6. Remove specimen from water bath, place in abrasion pan, cover surface with water, apply abrasion wheels.

7. Abrade specimen at the rate of 30 ± 1 RPM for 10 minutes. (Wheels may have to be stopped and cleaned due to pick up at least once.)

8. Remove specimen and place in 140°F oven until constant weight is reached. Subtract this weight from the oven dry weight obtained before abrasion test. Record the difference in weight and multiply by 5.00 (abraded area = 1/5 sq. ft.)

9. Average the results of the three specimens. (New wheels should provide a loss close to 300 gms/sq. ft.)

10. Use the loss obtained with new wheels as the standard to compare used wheel losses.

11. Use the following criteria to calibrate used wheels:

$$\% \text{ wear} = \frac{\text{Grams Loss New Wheels} - \text{Grams Loss Used Wheels}}{\text{New Wheel Loss (Grams)}} \times 100$$

0 - 15% no correction required
16% - 40% correction required
40% + replace wheels

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12. Calculate correction factor and record for applying to grams loss obtained with the used wheels. (Factor x gms loss = corrected grams loss).

$$\text{Correction factor} = \frac{\text{New Wheel Loss}}{\text{Old Wheel Loss}}$$

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Figure II

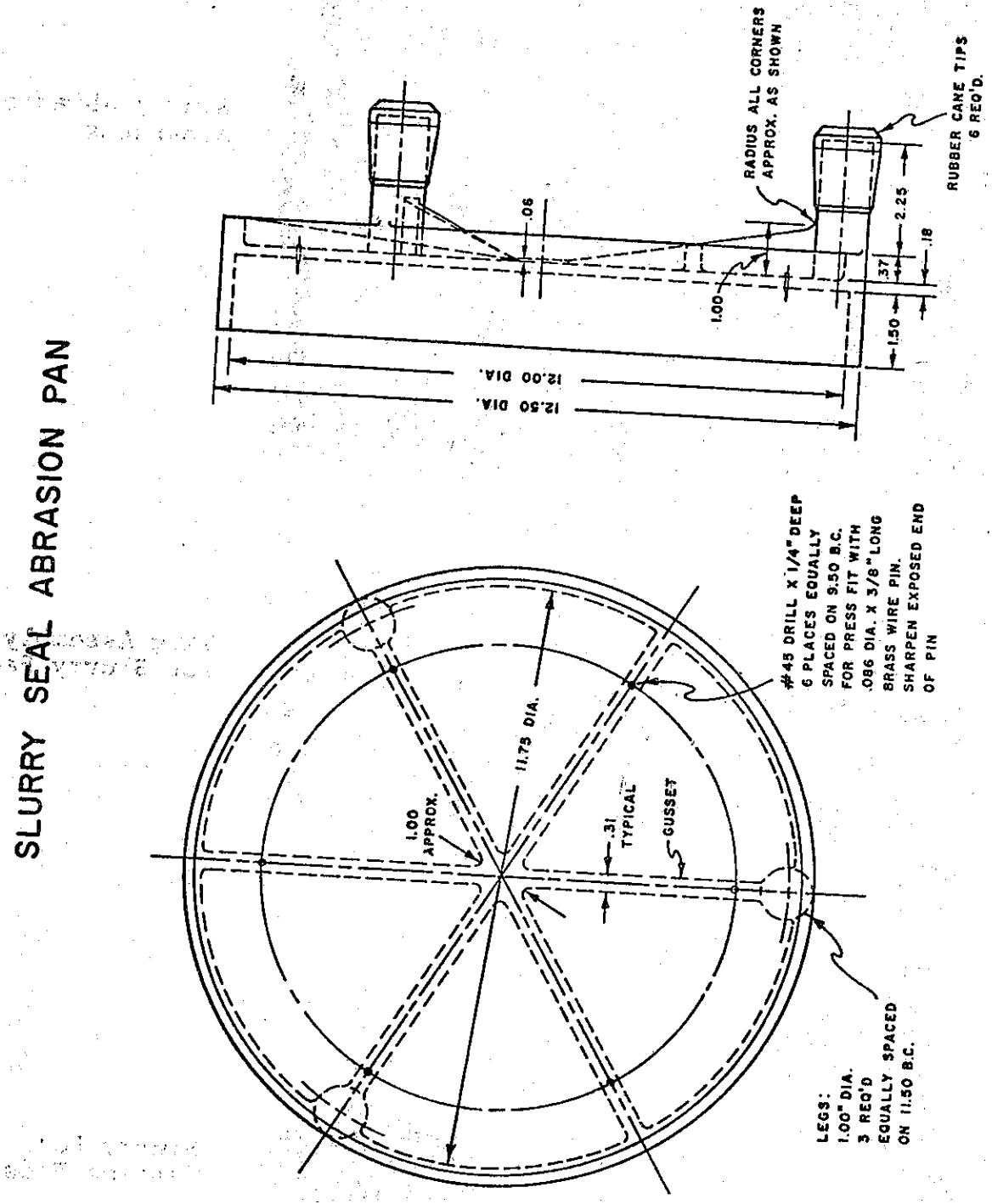

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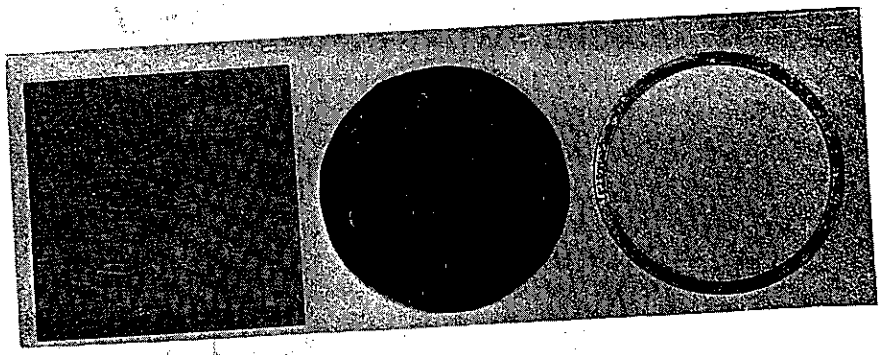
FIGURE III

Slurry Abrasion Apparatus



Ring Assembly for Slurry Pads

Slurry Seal Testing Pads

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