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MILITARY STANDARD

TEST METHODS FOR BITUMINOUS PAVING MATERIALS

FSC MISC

DEPARTMENT OF DEFENSE

WASHINGTON, D. C.

1. This Military Standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to U. S. Army Engineer Research and Development Laboratories, Mobility Command, Fort Belvoir, Virginia - SMOFB-KT.

FOREWORD

This standard was developed to establish methods of testing bituminous paving materials for pavement in those instances not covered by American Society for Testing and Materials (ASTM) tests or American Association of State Highway Officials (AASHO) procedures, or where tests for which the procedure required by the Military services differs from that prescribed by ASTM or AASHO.

CONTENTS

1. SCOPE

This standard establishes test methods that set forth ways and means to determine the suitability of bituminous paving materials.

2. REFERENCED DOCUMENTS

The issues of the following documents in effect on the date of invitation for bids or request for proposal form a part of this standard to the extent specified herein.

2.1 Governmental.

Federal Specification

SS-R-406 — Road and Paving Materials; Methods of Sampling and Testing.

2.2 Nongovernmental.

ASTM C127 — Method of Test for Specific Gravity and Absorption of Coarse Aggregate.

ASTM C188 — Method of Test for Specific Gravity of Hydraulic Cement.

ASTM D95 — Method of Test for Water in Petroleum Products and Other Bituminous Materials.

ASTM D244 — Methods of Testing Emulsified Asphalts.

ASTM D322 — Methods of Testing for Dilution of Gasoline Engine Crankcase Oils.

ASTM D854 — Method of Test for Specific Gravity of Soils.

ASTM D1075 — Standard Method of Test for Effect of Water on Cohesion of Compacted Bituminous Mixtures.

ASTM E11 — Specification for Sieves for Testing Purposes (Wire Cloth Sieves, Round-Hole and Square - Hole Screens or Sieves).

3. DEFINITIONS

3.1 Not applicable.

4. GENERAL STATEMENT

In the usual operation, samples of bituminous materials for pavements are tested in the laboratory to determine the suitability of the properties of the samples. The specific test methods contained herein are designed to meet the Department of Defense requirements in those instances where the established industry tests and procedures are inadequate for Military application.

5. DETAILED REQUIREMENTS

5.1 Test methods.

Custodians:

Army — MO

Navy — YD

Air Force — 69

Review activities:

Army — MO

Navy — YD

Air Force — 69

User activities:

Army — GL MD MU

Navy — CG MC

Air Force — None

Preparing activity:

Army — MO(ERDL)

Project No. MISC-0181

Method 100
UNIT WEIGHT, MARSHALL STABILITY, AND FLOW OF BITUMINOUS MIXTURES

1. SCOPE

1.1 This test method is applicable for evaluation of all hot-mix bituminous pavement mixes in which not more than 10 percent of the aggregate is greater than 1 inch in size.

2. APPARATUS

2.1 **Specimen mold assembly.** Mold cylinders 4 inches in diameter by 3 inches in height, base plates, and extension collars, as shown in figure 100–1, and conforming to details shown in figure 100–2. Six mold cylinders, two base plates, and two extension collars are recommended.

2.2 **Specimen extractor.** A specimen extractor or plunger (figure 100–2) for pushing the compacted specimen from the mold cylinder by the use of a jack and frame.

2.3 **Compaction hammer.** A compaction hammer (figures 100–1 and 100–3) having a flat, circular tamping face and a 10-lb. sliding weight with a free fall of 18 inches. Two compaction hammers are recommended. NOTE: Mechanical hammers may be used when properly correlated with the standard hand hammer by determining number of blows to use to produce same density as that produced by hand hammer.

2.4 **Compaction pedestal.** A pedestal, on which to rest the mold during compaction of the test specimen, consisting of a timber post having a minimum cross section of 5½ by 5½ inch (nominal 6 by 6 inches), capped by a 1-inch-thick steel plate. The pedestal cap may consist of a 12- by 12- by 1-inch steel plate, supported by a 12- by 12- by 2-inch wood section over the 6- by 6-inch post if arrangements are made for placing the compaction mold directly over the 6- by 6-inch post. The compaction pedestal must be placed on a concrete floor slab or base resting on the ground, or directly over an interior building column or similar location. Wooden floors or unsupported areas of concrete floors are unsuitable supports for the compaction pedestal. The provision of a pedestal in accordance with these requirements is very important; otherwise the compaction obtained will not agree with field conditions.

2.5 **Specimen mold holder.** A steel or cast-iron holder (figure 100–2) consisting of a semicircular base and a circular top to hold the specimen mold in place during compaction of the specimen. The top section should be flanged to fit over the collar of the specimen mold and should be attached to the base by means of a fulcrum on one side and a tension spring on the other. Two holes shall be provided in the base for mounting the holder on the compaction pedestal. The specimen mold holder shall be mounted on the pedestal cap so that the center of the mold is over the center of the post.

2.6 **Breaking head.** A breaking head (figures 100–1 and 100–4) consisting of upper and lower cylindrical segments or test heads which have an accurately machined inside radius of curvature of 2 inches. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be posi-

tioned so as to direct the two segments together without appreciable binding or loose motion on the guide rods.

2.7 **Loading jack.** A loading jack (figures 100–1 and 100–5) consisting of a screw jack, mounted in a testing frame, which will produce a uniform vertical movement of 2 inches per minute. An electric motor may be attached to the jacking mechanism. NOTE: In lieu of the loading jack, a mechanical or hydraulic testing machine (figure 100–6) may be used if the rate of movement can be maintained at 2 inches per minute while the load is applied.

2.8 **Proving ring assembly.** One proving ring (figures 100–1 and 100–5) of 5,000-pound capacity and sensitivity of 10 pounds for loads up to 1,000 pounds and 25 pounds for loads between 1,000 and 5,000 pounds and equipped with a micrometer dial. The micrometer shall be graduated in 0.0001 inch increments. Upper and lower proving ring attachments are required for fastening the proving ring to the testing frame and transmitting the load to the breaking head. NOTE: In lieu of the proving ring assembly, any suitable load-measuring device may be used, if the capacity and sensitivity meet the requirements.

2.9 **Flowmeter.** A flowmeter (figure 100–1) consisting of a guide sleeve and a gage. The activating pin of the gage slides inside the guide sleeve with a slight amount of frictional resistance, and the guide sleeve slides freely over the guide rod of the breaking head. The flowmeter gage shall be adjusted to zero when in position on the breaking head with a 4.000 plus or minus 0.005-inch-diameter metal cylinder inserted between the breaking-head segments. The flowmeter gage shall be graduated in 0.01-inch divisions.

2.10 **Ovens or hotplates.** Ovens or hotplates for heating aggregates, bituminous material, specimen molds, and compaction hammers. Required temperatures for materials range from 200° F. to 300° F. It is recommended that the heating units be thermostatically controlled to maintain the required temperatures. Shields, baffle plates, or sandbaths shall be used on the surfaces of the hotplates to minimize localized overheating.

2.11 **Mixing apparatus.** A metal pan or bowl. Hand mixing may be used; however, mechanical mixing is recommended. Any type of mechanical mixer may be used if the required mixing temperature can be maintained and a well-coated, homogeneous mixture can be produced in the allowable time. Two 10-quart mixing bowls and two wire stirrers are recommended.

2.12 **Water bath.** A water bath at least 6 inches deep provided with mechanical water agitator, heating elements, and thermostatic controls capable of maintaining the bath water at temperatures ranging from 100° F. to 140° F. The bath shall have a perforated false bottom or be equipped with a shelf for supporting specimens 2 inches above the bottom of the bath.

2.13 **Sieve shaker.** Any type of mechanical sieve shaker provided it has a capacity of six full-height, 8-inch-diameter sieves.

2.14 **Sieves.** Eight-inch-diameter sieves of the following sizes are required: 1-, ¾-, ½-, and ⅜-inch and Nos. 4, 10, 20, 40, 80, and 200. The sieves shall conform to the requirements of ASTM E11. Large, rectangular-shaped screens and shaking facilities are recommended for preparation of large samples.

2.15 **Sink.** One sink with cold running water to cool molded specimens prior to extrusion from the mold cylinder.

2.16 **Appurtenant equipment.**

(a) Containers for heating aggregates, such as flat-bottom metal pans, or other suitable containers.

(b) Containers for heating bituminous material, such as metal cups, beakers, or pouring pots.

(c) Mixing tool, either steel trowel (garden type) or spatula, for spading and handmixing.

(d) Thermometers for determining temperatures of aggregates, bitumen, and bituminous mixtures. Armored glass thermometers or dial-type with metal stem are recommended. They must have a range of 50° F. to 400° F., with a sensitivity of 50° F.

(e) Thermometers for water bath with a range of 100° F. to 140° F. and graduated to 0.5° F.

(f) Balance, 2-kg capacity, sensitive to 0.1 g, for weighing molded specimens.

(g) Balance, 20-kg capacity, sensitive to 1.0 g, for preparing bitumen and aggregate mixtures.

(h) Wire basket and water bucket suitable for weighing molded specimens in water.

(i) Gloves for handling hot equipment.

(j) Rubber gloves for removing specimens from water bath.

(k) Marking crayons for identifying specimens.

(l) Scoop, 2-quart size, for handling hot aggregates.

(m) Scoop, flat bottom, for placing mixture in specimen molds.

3. PREPARATION OF SPECIMENS

3.1 **Preparation of aggregates.** Dry aggregates to constant weight at 110° C. plus or minus 5° C. (221° to 239° F.), and separate the aggregates by sieving into the desired sieve fractions. The following separations are recommended for paving mixes having ¾-in. maximum size aggregate: ¾- to ⅜-in., ⅜-in. to No. 10, No. 10 to No. 40, finer than No. 40, and mineral filler. Aggregate separation may be accomplished in a large, processing-type sieve shaker, a standard mechanical sieve shaker, or a rocker-type hand shaker. Sieve analysis of each separated portion is required to calculate the percentage of each size range to use in the required mix.

3.2 **Preparation of mixtures.** Weigh into individual pans the amount of each size fraction required to produce a batch that will result in either one or two compacted specimens, each 2½ inches ± ⅛ in. in height. This will require approximately 1400 g of blended aggregate per specimen. Figure 100-7 illustrates the form recommended for recording these laboratory batch weights. Place the pans on the hotplate or in the oven, and heat to the temperatures indicated in the following tabulation.

Type bitumen	*Mixing temperature, °F.*	
	Aggregate	*Bitumen*
Asphalt cement	300 ± 5	270 ± 5
Tar, RT-10, -11, or -12	225 ± 5	200 ± 5
Rubberized tar	250 ± 5	225 ± 5

Charge the heated aggregate into the mixing bowl, and mix the dry aggregate thoroughly. Form a crater in the dry blended aggregate, and add the required weight of bitumen at the required temperature. Mix the aggregate and bituminous material rapidly until the aggregate is thoroughly coated.

3.3 **Compaction of specimens.** Thoroughly clean the specimen mold assembly and the face of the compaction hammer, and heat them either in hot water or on a hotplate to a temperature between 180° and 250° F. Place a piece of filter paper or paper toweling cut to size in the bottom of the mold before the mixture is introduced. Place the mixture in the mold, and spade with a heated spatula or trowel twice around the perimeter. Remove the collar, and smooth the surface of the mix with a trowel to a slightly rounded shape. Temperatures of the mixtures immediately prior to compaction shall be—

Type bitumen	*Compaction temperature, °F.*
Asphalt cement	250 ± 5
Tar, RT-10, -11, or -12	180 ± 5
Rubberized tar	200 ± 5

Replace the collar, place the mold assembly on the compaction pedestal in the mold holder, and apply 50 or 75 blows, with the compaction hammer with a free fall of 18 in. Remove the base plate and collar, and reverse and reassemble the mold. Apply the same number of compaction blows to the face of the reversed specimen. Fifty blows on each side of the specimen are used for mix design for roads, streets, and facilities for aircraft with tires inflated to 100 psi or less; 75 blows on each side of the specimen are used for mix designs for facilities that will be used by aircraft with tire pressures greater than 100 psi. After compaction, remove the base plate and immerse the mold containing the specimen in cool water for not less than 2 minutes. Remove specimen from mold by means of the sample extractor and a suitable jack and frame arrangement. Since rubberized-tar specimens stick tightly in the mold, place them in 120° F. bath for a few seconds to release them from the wall of the mold. After removal from the mold, carefully transfer the specimen to a smooth, flat surface.

4. **Test procedure.**

4.1 **Density determination.** Weigh the specimen in air and in water that is clean and is at a temperature of approximately 77° F. The difference between the two weights in grams gives the volume in cubic centimeters. The density (or specific gravity) of the specimen is determined by dividing the weight of the specimen in grams by the volume in cubic centimeters, which can be converted into pounds per cubic foot by multiplying by 62.4. Open-textured or porous specimens will absorb water, giving an erroneous result when weighed in water. Therefore, it is recommended that the specimen be reweighed in air directly after weighing in water and correction made for absorbed water (fig. 100–8). For extremely porous specimens, it is recommended that the specimen be coated with paraffin to seal all void openings and then weighed in air and water (fig. 100–9). Correction shall be made for weight and volume of the paraffin. Fig. 100–10 is the form recommended for recording density and other required data.

4.2 **Determination of maximum load and flow.** Bring the specimen to the test temperature indicated in the following tabula-

tion by immersing in the water bath for not less than 20 minutes. Thoroughly clean the guide rods and the inside surfaces of the test heads, and lubricate the guide rods so that the upper test head slides freely over them.

Type bituminous material	*Marshall stability test water temperature, °F.*
Asphalt	140 ± 1
Tar	100 ± 1
Rubberized tar	120 ± 1

Adjust the flowmeter to zero. Remove the specimen from the water bath, and place it in the lower segment of the breaking head. (The testing head temperature shall be maintained between 70 and 100° F., using a water bath when necessary.) Place the upper segment of the breaking head on the specimen, and place the complete assembly in position on the testing machine (figs. 100–1 and 100–6, respectively, show the Marshall test apparatus and the Universal testing machine using the Marshall breaking head). When using the Marshall apparatus, place the adjusted flowmeter in position over one of the guide rods, and hold the sleeve firmly against the upper segment of breaking head while load is applied. When using the Universal machine, an extensometer is normally used.

Apply load to the specimen at constant rate of movement of 2 in. per minute until the maximum load is reached and the load begins to decrease. Record the maximum load. Remove the flowmeter from its position over the guide rod the instant the maximum load begins to decrease. Note and record the indicated flow value. Elapsed time for the test from removal of test specimen from the water bath to the maximum load determination shall not exceed 30 seconds. Correct the load for variations from the standard 2½-in. length by using the proper multiplying factor from table I.

5. Calculations and Report.

5.1 A summary of computations, such as that shown in figure 100–10, shall be prepared.

TABLE I. *Stability-correlation ratio*

Volume[1] of specimen in cubic centimeters	Approximate thickness of specimen in inches	Correlation ratio
200–213	1	5.56
214–225	1-1/16	5.00
226-237	1-1/8	4.55
238–250	1-3/16	4.17
251–264	1-1/4	3.85
265–276	1-5/16	3.57
277–289	1-3/8	3.33
290–301	1-7/16	3.03
302–316	1-1/2	2.78
317–328	1-9/16	2.50
329–340	1-5/8	2.27
341–353	1-11/16	2.08
354–367	1-3/4	1.92
368–379	1-13/16	1.79
380–392	1-7/8	1.67

TABLE I. *Stability-correlation ratio*—(Cont'd)

Volume[1] of specimen in cubic centimeters	Approximate thickness of specimen in inches	Correlation ratio
393–405	1-15/16	1.56
406–420	2	1.47
421–431	2-1/16	1.39
432–443	2-1/8	1.32
444–456	2-3/16	1.25
457–470	2-1/4	1.19
471–482	2-5/16	1.14
483–495	2-3/8	1.09
496–508	2-7/16	1.04
509–522	2-1/2	1.00
523–535	2-9/16	0.96
536–546	2-5/8	0.92
547–559	2-11/16	0.89

TABLE I. *Stability-correlation ratio*—(Cont'd)

Volume[1] of specimen in cubic centimeters	Approximate thickness of specimen in inches	Correlation ratio
560–573	2-3/4	0.86
574–585	2-13/16	0.83
586–598	2-7/8	0.81
599–610	2-15/16	0.78
611–625	3	0.76
626–637	3-1/16	0.74
638–649	3-1/8	0.71
650–662	3-3/16	0.69
663–676	3-1/4	0.68

Note. The measured stability of a specimen multiplied by the ratio for the thickness of the specimen equals the corrected stability for a 2½ in. specimen.

[1] Volume-thickness relation is based on a specimen diameter of 4 in.

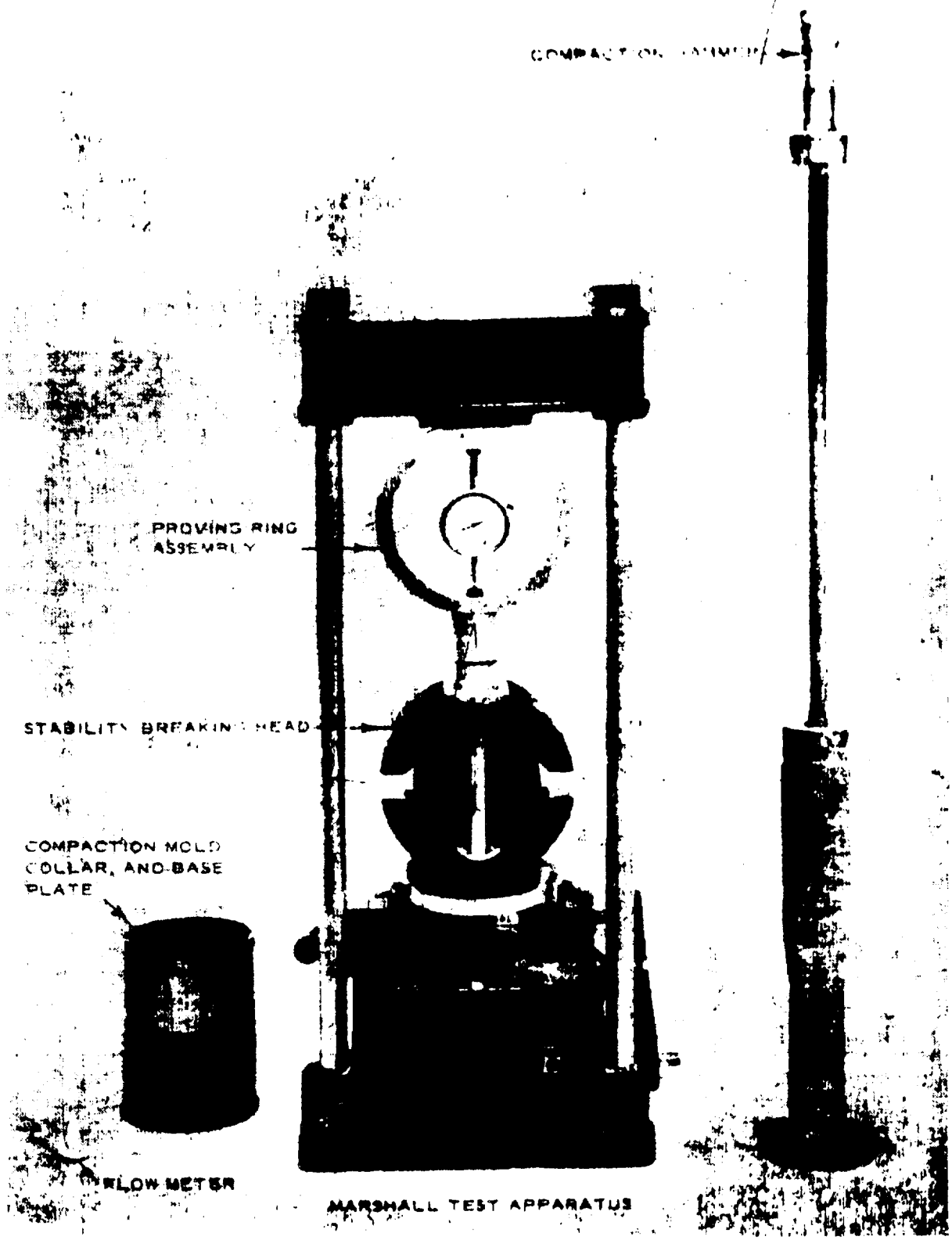

FIGURE 100-1 *Marshall stability test apparatus.*

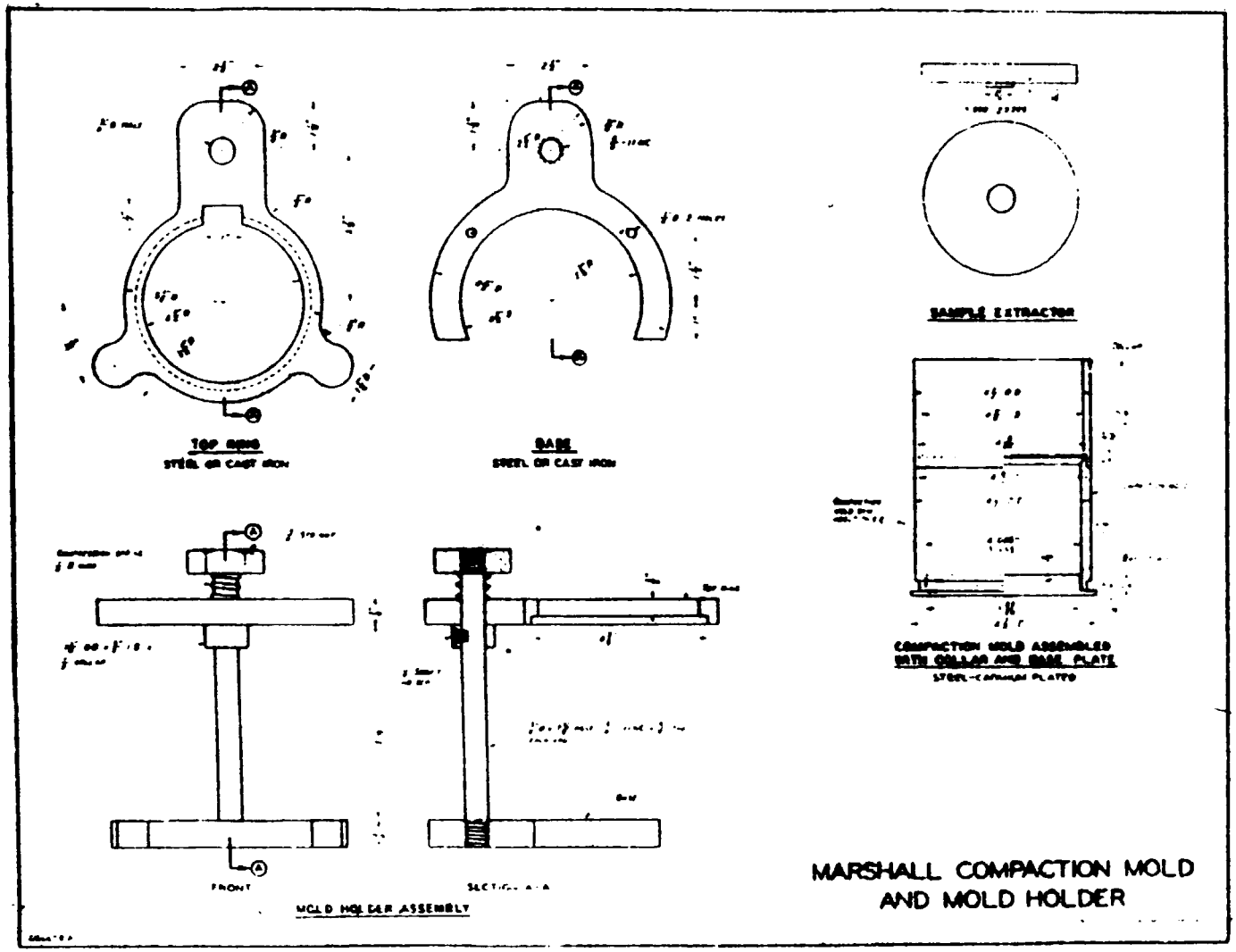

FIGURE 100-2. *Marshall compaction mold and mold holder.*

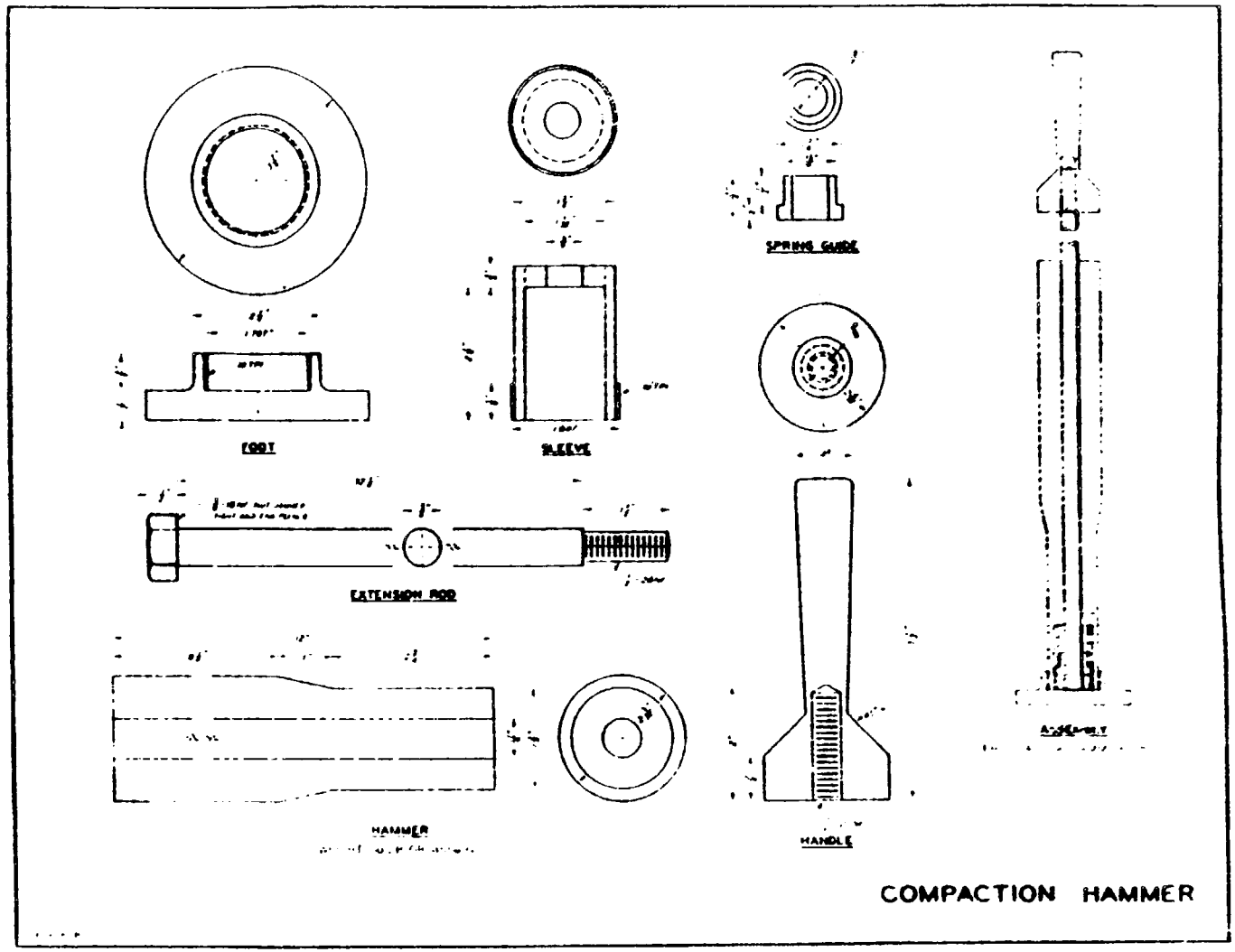

FIGURE 100-8. *Compaction hammer.*

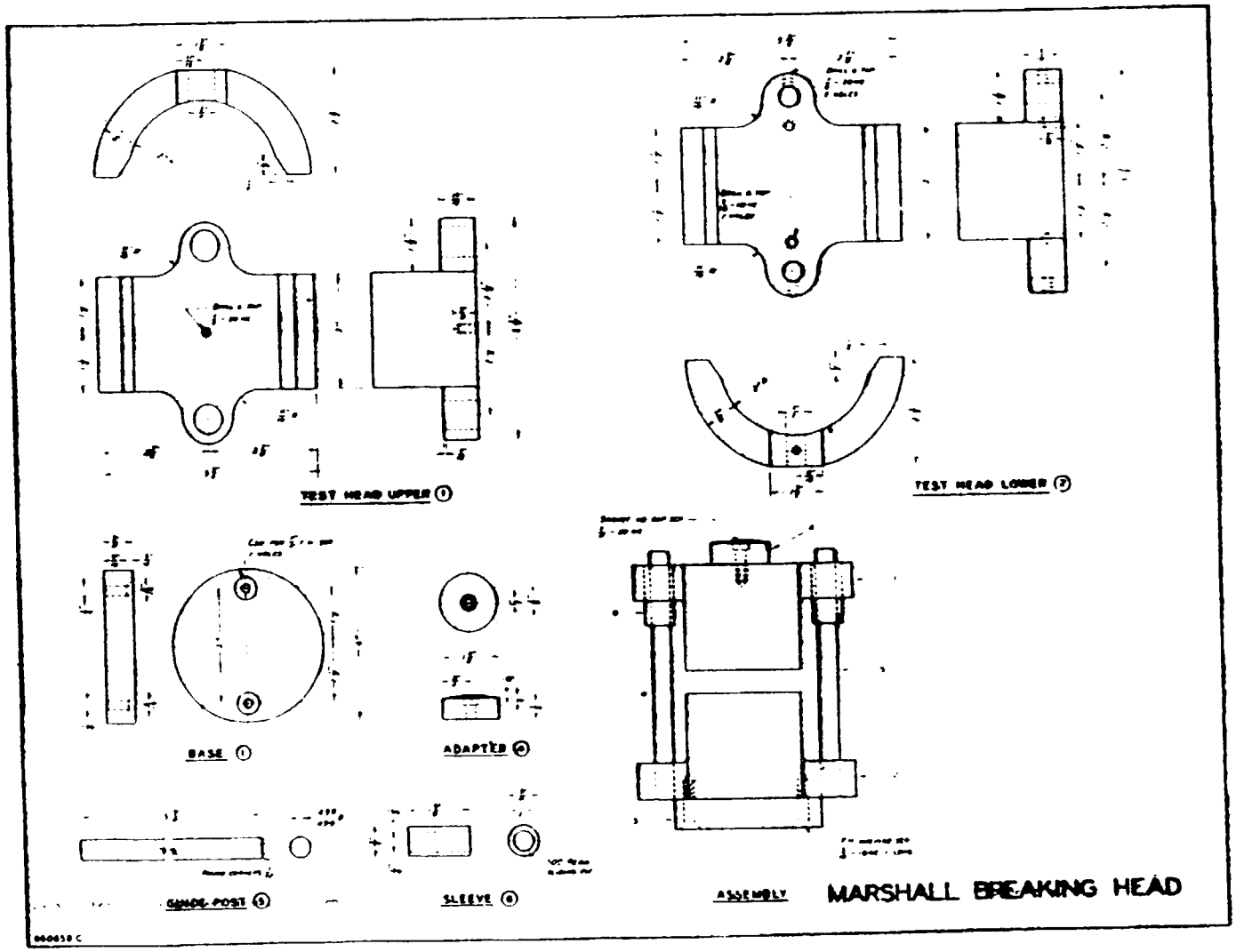

FIGURE 106-4. *Marshall breaking head.*

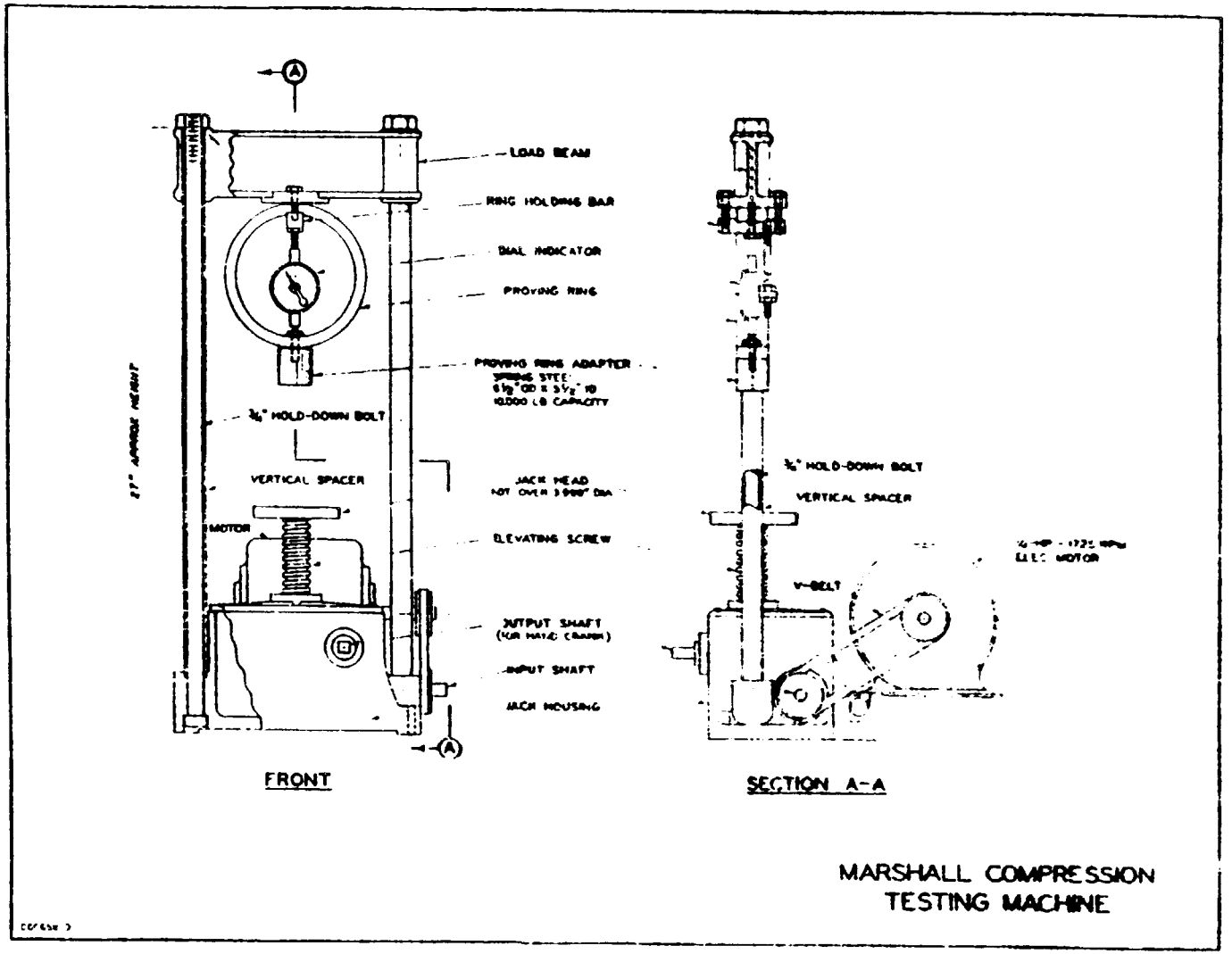

FIGURE 100-5. *Marshall compression testing machine.*

recorder

BITUMINOUS MIXTURE WEIGHTS

JOB NO.:	W/R NO.: —	DATE: 5 June 1959
PROJECT: Typical Mix		
DESCRIPTION OF BLEND USED: Processed Samples		
TYPE OF BITUMEN: 85-100 Pen Asphalt Cement		
AGG TEMP: 300° F	BITUMEN TEMP. 270° F	COMP TEMP: 250° F

BLEND NO. A

AGG SIZE	PER CENT	WEIGHTS		PER CENT	WEIGHTS*
3/4 - 3/8	19	532		No. A-3.5	
3/8 - 10	35	980	Aggregate	96.5	2800
-10	43	1204	Bitumen	3.5	—
LSD	3	84	Agg & Bitumen	100	2902
				No. A-4.0	
			Aggregate	96.0	2800
			Bitumen	4.0	—
			Agg & Bitumen	100	2917
				No. A-4.5	
			Aggregate	95.5	2800
			Bitumen	4.5	—
			Agg & Bitumen	100	2932
				No. A-5.0	
			Aggregate	95.0	2800
			Bitumen	5.0	—
			Agg & Bitumen	100	2947
				No. A-5.5	
			Aggregate	94.5	2800
			Bitumen	5.5	—
			Agg & Bitumen	100	2963
TOTAL	100	2800	* $\frac{\text{AGGREGATE WT}}{\text{PER CENT AGG}} 100$ = AGG + BITUMEN WT		

COMPUTED BY: DPB	CHECKED BY: MES	AGG BLEND PREPARED BY: ES	MIX PREPARED BY: PSM COMPACTED BY: SJ-AC

FIGURE 100-7. *Batch weight record form.*

WEIGHT AND VOLUME DETERMINATION FOR SLIGHTLY POROUS BITUMINOUS PAVEMENT SAMPLES

JOB NO.: PROJECT: *Typical Mix* DATE: *4 June 1959*

SPECIMEN NUMBER	BITUMEN CONTENT %	INITIAL WEIGHT IN AIR	WEIGHT IN WATER	SECOND WEIGHT IN AIR	ABSORPTION	CORRECTED WEIGHT IN WATER	VOLUME
		A	B	C	D (C - A)	E (B - D)	F (A - E)
L-10-7	4.5	1248.6	741.6	1257.8	9.2	732.4	516.2

TECHNICIAN: *JMP* COMPUTER: *DPB* CHECKED: *MLS*

FIGURE 100-8. *Slightly porous sample data sheet*

VOLUME DETERMINATION OF PARAFFIN-COATED SAMPLES

JOB NO.: PROJECT: Typical Mix DATE: 16 July 1946

SAMPLE NO.	WEIGHT IN AIR, g			VOLUME OF PARAFFIN cc	WT IN WATER OF SAMPLE + PARAFFIN g	VOLUME OF SAMPLE + PARAFFIN cc	VOLUME OF SAMPLE cc
	SAMPLE	SAMPLE + PARAFFIN	PARAFFIN				
A	B	C	D = C − B	E = $\frac{D}{0.9}$	F	G = C − F	H = G − E
856-A	1200.3	1250.6	50.3	55.9	600.0	650.6	594.7
862-C	1275.9	1351.1	75.2	83.6	675.7	675.4	591.8
858-B	1175.9	1220.5	44.6	49.6	585.6	634.9	585.3
863-A	1400.0	1460.1	60.1	66.8	720.0	740.1	673.3

TESTED BY: BHS COMPUTED BY: VAW CHECKED BY: DAB

FIGURE 100-9. *Open textured sample data sheet.*

DATA AND COMPUTATION SHEET FOR BITUMINOUS PAVEMENT TEST SAMPLES

JOB NO: | PROJECT: Typical Mix | DESCRIPTION OF BLEND: Processed samples of AS-100 pen. AC

DEGREES KNEADING: — | NO. GYRATIONS: — | PRESSURE: — | DATE: 5 June 59

SPECIMEN NO	BITUMEN CONTENT %	WEIGHT - GRAMS IN AIR	WEIGHT - GRAMS IN WATER	VOLUME CC	SPECIFIC GRAVITY	UNIT WEIGHT LB/CU FT TOTAL MIX	UNIT WEIGHT LB/CU FT AGG ONLY	MARSHALL STABILITY LB - TOTAL MEASURED	MARSHALL STABILITY LB - TOTAL CONVERTED	FLOW UNITS OF 1/100 IN.	REMARKS
A	B	C	D	E	F	G	H	I	J	K	
				C - D	$\frac{C}{E}$	F × 62.4	G (100 - B)		*		
A3.5 1	3.5	1228.3	716.3	512.0	2.399			2080	2020	11	
2		1819.5	717.2	507.3	2.404			1862	1930	10	
3		1205.5	703.3	500.2	2.410			1881	1894	8	
4		1206.2	708.4	497.8	2.425			1892	1968	8	
Avg					2.409	150.3	145.0		1955	9	
A4.0 1	4.0	1276.9	747.3	529.6	2.411			2110	2026	10	
2		1852.6	733.3	519.3	2.412			2025	2025	9	
3		1243.5	730.7	512.8	2.425			1995	1995	9	
4		1250.4	722.8	507.6	2.424			2080	2101	9	
Avg					2.418	150.9	144.9		2037	9	
A4.5 1	4.5	1254.4	736.2	518.2	2.430			2050	2050	12	
2		1736.3	726.8	511.5	2.421			2095	2095	9	
3		1259.0	724.9	514.1	2.410			2110	2110	10	
4		1273.5	752.0	521.5	2.442			2048	2065	10	
Avg					2.426	151.4	144.0		2075	10	
A5.0 1	5.0	1257.9	727.0	510.9	2.423			1875	1875	14	
2		1300.0	763.7	536.3	2.424			2150	1981	10	
3		1273.6	746.9	526.7	2.418			1900	1824	12	
4		1287.9	731.8	516.1	2.418			1855	1855	12	
Avg					2.421	151.1	143.5		1884	12	

COMPACTED BY: SJ/AC | TESTED BY: JLP | COMPUTED BY: DPB | * FROM CONVERSION CHART

Figure 100-10. *Example of recorder data.*

DATA AND COMPUTATION SHEET FOR BITUMINOUS PAVEMENT TEST SAMPLES

JOB NO: | PROJECT: Typical 11.x (Cont'd) | DESCRIPTION OF BLEND: Processed samples ¢ 85-100 pen. AC

DEGREES KNEADING: — | NO. GYRATIONS: — | PRESSURE: — | DATE: 5 June 59

SPECIMEN NO.	BITUMEN CONTENT %	WEIGHT - GRAMS IN AIR	WEIGHT - GRAMS IN WATER	VOLUME CC	SPECIFIC GRAVITY	UNIT WEIGHT LB/CU FT TOTAL MIX	UNIT WEIGHT LB/CU FT AGG ONLY	MARSHALL STABILITY LB - TOTAL MEASURED	MARSHALL STABILITY LB - TOTAL CONVERTED	FLOW UNITS OF 1/100 IN.	REMARKS
A	B	C	D	E	F	G	H	I	J	K	
				C - D	$\frac{C}{E}$	F x 62.4	G (100 - B)		*		
A5.5 1	5.5	1837.3	724.1	513.2	2.411			1430	1450	12	
2		1864.0	740.6	523.4	2.415			1530	1469	14	
3		1886.4	752.4	534.0	2.409			1615	1550	13	
4		1853.5	733.8	519.7	2.412			1505	1505	16	
Avg					2.412	150.5	142.2		1494	14	

COMPACTED BY: SJ/AC | TESTED BY: J L P | COMPUTED BY: D P B | * FROM CONVERSION CHART

Figure 100.10 Continued.

Method 101
DENSITY AND PER CENT VOIDS OF COMPACTED BITUMINOUS PAVING MIXTURES

1. SCOPE

1.1 This method of testing is used on either laboratory-compacted samples or samples taken from actual pavements.

2. APPARATUS

2.1 Balance, 2-kg capacity, sensitive to 0.1 g.

2.2 Wire basket for weighing samples suspended in water.

2.3 Tank or bucket of sufficient capacity to completely immerse the sample in water.

3. PREPARATION OF SPECIMENS

3.1 All specimens shall be marked for identification. Each specimen shall be air-dried prior to testing.

4. TESTING PROCEDURES

4.1 Nonporous samples. Weigh these samples in air and in water and record the weights in the appropriate spaces on a form such as that shown in figure 101–1.

4.2 Slightly porous samples. Samples having a fine-textured but slightly porous surface (particularly the cut surface of some pavement cores and sawed samples) shall be weighed in air, then in water, and then in air again (after blotting excess water with cloth or paper towel) make a correction for error in bulk volume caused by the penetration of the water. Record these weights in the appropriate columns on a form such as figure 100–8. The volume of the sample determined as shown in figure 100–8 is then entered on a form similar to figure 101–2 for use in the remaining calculations.

4.3 Open-textured samples. Open-textured samples shall be weighed in air and then coated with paraffin for volume determination as illustrated in figure 100–9. The volume thus determined is entered on a form similar to figure 101–2 for use in the remaining calculations.

5. CALCULATIONS

5.1 Before the voids can be calculated, the specific gravity of both the aggregate and asphalt and the percentage of each must be known. Figure 101–2 shows typical data and calculations needed in order to complete the calculations shown in figure 101–1. Procedures for the specific-gravity tests on the individual components are presumed to be available and are therefore not described herein. Formulas for the complete calculations are indicated at the top of the respective columns in figure 101–1.

6. REPORT

6.1 A summary of computations, such as that shown in figure 101–1, shall be prepared for all samples tested.

COMPUTATION OF PROPERTIES OF BITUMINOUS MIXTURES

JOB NO.: PROJECT: Typical Mix DESCRIPTION: Processed Samples DATE 4 June 1959

SPECIMEN NO.	BITUMEN CONTENT, %	WEIGHT, G		VOLUME cc	SPECIFIC GRAVITY		BITUMEN BY VOLUME, %	VOIDS, %		UNIT WT LB CU FT	
		IN AIR	IN WATER		ACTUAL	THEOR.		TOTAL MIX	FILLED	TOTAL MIX	AGG. ONLY
A	B	C	D	E	F	G	H	I	J	K	L
				(C - D)	$\left(\frac{C}{E}\right)$		$\left(\frac{B \times F}{\text{SP GR OF BIT.}}\right)$	$\left(100 - 100\ \frac{F}{G}\right)$	$\left(\frac{H}{H+I}\right)$	F · 62.4	K(100 - B)
A-4.5 1	4.5	1254.4	738.2	516.2	2.430	2.539	10.7	4.3	71.3	151.6	144.8
2		1238.3	726.8	511.5	2.421		10.7	4.6	69.9	151.1	144.3
3		1239.0	724.9	514.1	2.410		10.6	5.1	67.5	150.4	143.6
4		1273.5	752.0	521.5	2.442		10.8	3.8	74.0	152.4	145.5
Avg					2.426		10.7	4.5	70.4	151.4	144.6

TECHNICIAN: JLP COMPUTER: DPB CHECKED BY: MES

FIGURE 101-1. *Nonporous sample data sheet.*

THEORETICAL SPECIFIC GRAVITY			DATE: 4 June 1959
JOB NO.:		PROJECT: Typical Mix	
DRY AGGREGATE FRACTIONS A	PER CENT OF FRACTIONS B	SPECIFIC GRAVITY OF FRACTION C	FACTOR $D = \frac{B}{C}$
3/4 to 3/8	19	2.761	6.882
3/8 to No. 10	35	2.752	12.718
Minus No. 10	43	2.698	15.938
Limestone Dust Filler	3	2.762	1.086
		SUM OF FACTORS = K FACTOR =	36.624
SPECIFIC GRAVITY OF DRY AGGREGATE = $\frac{100}{K}$ = $\frac{100}{36.624}$ =			2.730

PER CENT AC E	SPEC. GRAV. OF AC F	$\frac{E}{F}$	K (100 − E)	$\frac{E}{F}$ + K (100 − E)	THEO. S/G OF TOTAL MIX $\frac{100}{\frac{E}{F} + K(100 - E)}$
4.5	1.020	4.412	34.976	39.388	2.539

REMARKS: ASTM apparent sp gr determinations for processed samples.
Sp. Gr. of Asphalt = 1.020

COMPUTED BY: DPB CHECKED BY: MES

FIGURE 101-2. *Typical data and calculations.*

Method 103
PROPERTIES OF BITUMINOUS MIXTURES IN WHICH MORE THAN 10 PERCENT OF AGGREGATE EXCEEDS 1-IN. MAXIMUM SIZE

1. SCOPE

1.1 This test method is intended for use on bituminous mixtures in which more than 10 percent of the aggregate exceeds 1-in. maximum size.

2. **Apparatus.** Apparatus shall be as specified in method 100.

3. **Specimens.** Specimens shall be prepared as specified in method 100 except as otherwise specified herein.

4. PROCEDURE

4.1 Mix bitumen with entire aggregate gradation (including plus 1-in. portion) at bitumen content selected for testing.

4.2 Pass mixed batch through a standard 1-in. sieve (while still hot). Discard the plus 1-in. portion, and test the minus 1-in. portion as described in method 100 or 101 whichever is applicable.

5. CALCULATIONS

5.1 Use the stability and flow values obtained on the processed samples without further correction. Correct the values for unit weight and percent voids.

5.2 Calculate the adjusted specific gravity using the bulk specific gravity[1] of the plus 1-in. aggregate and the specific gravity of compacted cores of the minus 1-in. portion as follows:

$$\text{Adjusted specific gravity} = \frac{100}{\frac{A}{C} + \frac{B}{D}} 0.995$$

where

A=dry, plus 1-in. (previously determined) material expressed as percent of total batch weight. Total batch weight includes asphalt plus aggregate. See column A, fig. 103–1.

B=portion of total batch remaining after removal of dry, plus 1-in. material (100 percent — A percent). See column B, fig. 103–1.

C=bulk specific gravity of plus 1-in. aggregate. See column C, fig. 103–1.

D=actual specific gravity of compacted specimens of material with plus 1-in. portion removed. See column D, fig. 103–1.

0.995=empirical factor.

[1] Bulk specific gravity of each fraction of the plus 1-in. portion of the aggregate is determined at the same time as the apparent specific gravities, shown in column C of figure 103–2 using the formulas shown in ASTM C 127–59.

6. EXAMPLE

6.1 Figures 103-1 through 103-1 show an example of the data, computations, and presentation of data involved in this method of test.

COMPUTATION OF PROPERTIES OF BITUMINOUS MIXTURES

Specimen No.	Bitumen Content %	A	B	C	D	A/C	B/D	Adjusted Specific Gravity*	Theoretical Specific Gravity**	Voids, %† Total Mix	Voids, %† Filled/AC	Unit Weight lb/cu ft††
GR-2.5 1	2.5	798/3897 = 20.5%	79.5	2.558	2.3[illegible]	[illegible]	[illegible]	2.393				
2					2.379		[illegible].417	2.402				
3					2.369		33.558	2.393				
4					2.363		33.644	2.388				
								Avg 2.394	2.533	5.5	52.2	149.4
GR-3.0 1	3.0	798/3918 = 20.4%	79.6		2.396	7.975	33.222	2.415				
2					2.384		33.389	2.406				
3					2.379		33.459	2.401				
4					2.386		33.361	2.407				
								Avg 2.407	2.513	4.2	63.2	150.[illegible]
GR-3.5 1	3.5	798/3938 = 20.3%	79.7		2.392	7.936	33.319	2.412				
2					2.402		33.181	2.420				
3					2.394		33.292	2.414				
4					2.383		33.445	2.405				
								Avg 2.413	2.494	3.2	72.4	150.6
GR-4.0 1	4.0	798/3958 = 20.2%	79.8		2.385	7.897	33.459	2.406				
2					2.376		33.586	2.399				
3					2.384		33.473	2.405				
4					2.375		33.600	2.398				
								Avg 2.404				150.0
								Curve 2.407	2.475	2.7	78.0	150.2
GR-4.5 1	4.5	798/3979 = 20.1%	79.9		2.369	7.858	33.727	2.393				
2					2.369		33.727	2.393				
3					2.355		33.928	2.381				
4					2.365		33.784	2.389				
								Avg 2.389				1[illegible]
								Curve 2.388	2.456	2.8	79.3	14[illegible]

Sp Gr AC = 1.005

* The actual specific gravity (C) shown in fig. B4-4 is the specific gravity of the minus 1-in. portion of the compacted mix. It is desired to calculate an adjusted or theoretical weighted actual specific gravity of the total mix as if the plus 1-in. aggregates were in[illegible] into this matrix portion. This can be done with reasonable accuracy as follows:

Let A = dry, plus 1-in. material expressed as per cent of total batch weight (see fig. B4-3 for laboratory batch weights).
B = portion of batch remaining after removal of dry plus 1-in. material (100 per cent - A per cent).
C = bulk specific gravity of plus 1-in. aggregate.
D = actual specific gravity of compacted specimens of material with plus 1-in. portion removed (from fig. B4-4, sheets 1 and 2).

Then the adjusted specific gravity of the compacted mix = $\left(\frac{100}{\frac{A}{C} + \frac{B}{D}}\right) 0.995$.

** From fig. B4-2.
† Formulas in fig. B4-4.
†† (Adj Sp Gr) 62.4.

Figure 108-1. *Computation sheet.*

THEORETICAL SPECIFIC GRAVITY			DATE 12 August 1956
JOB NO.:	PROJECT: Bit Stab - Lg Agg		
DRY AGGREGATE FRACTIONS A	PER CENT OF FRACTIONS B	SPECIFIC GRAVITY OF FRACTION C	FACTOR $D = \frac{B}{C}$
2 to 1½	7	2.584	2.709
1½ to 1	14	2.603	5.378
1 to ¾	7	2.606	2.686
¾ to ½	10	2.610	3.831
½ to ⅜	7	2.615	2.677
⅜ to 4	13	2.624	4.954
4 to 10	12	2.638	4.549
-10	18	2.674	6.731
Fine River Bar Sand	7	2.677	2.615
Limestone Dust	5	2.755	1.815
		SUM OF FACTORS = K FACTOR =	37.945

SPECIFIC GRAVITY OF DRY AGGREGATE = $\frac{100}{A} = \frac{100}{37.945} =$

PER CENT AC E	SPEC. GRAV. OF AC F	$\frac{E}{F}$	K (100 - E)	$\frac{E}{F} + K(100 - E)$	THEO. S/G OF TOTAL MIX $\frac{100}{\frac{E}{F} + K(100 - E)}$
2.5	1.005	2.488	36.996	39.484	2.533
3.0		2.985	36.807	39.792	2.513
3.5		3.483	36.617	40.100	2.494
4.0		3.980	36.427	40.407	2.475
4.5		4.478	36.237	40.715	2.456

REMARKS

COMPUTED BY: DPA CHECKED BY: TBG

FIGURE 108-2. *Typical data and calculations.*

BITUMINOUS MIXTURE WEIGHTS

JOB NO | W R NO 6 | DATE 5 August 1956

PROJECT: Bituminous Stability - Large Aggregate Study

DESCRIPTION OF BLEND USED: Gravel, fine river sand, limestone dust

TYPE OF BITUMEN: 85 - 100 pen asphalt cement

AGG TEMP 300 F | BITUMEN TEMP 270 F | COMPACTION 250 F

BLEND NO GR

AGG SIZE	PER CENT	WEIGHTS		PER CENT	WEIGHTS*
2 to 1-1/2	7	266		No. GR-2.5	
1-1/2 to 1	14	532	Aggregate	97.5	3800
1 to 3/4	7	266	Bitumen	2.5	—
3/4 to 1/2	10	380	Agg & Bitumen	100	3897
1/2 to 3/8	7	266			
3/8 to 4	13	494		No. GR-3.0	
4 to 10	12	456	Aggregate	97.0	3800
Minus 10	18	684	Bitumen	3.0	—
FRB sand	7	266	Agg & Bitumen	100	3918
LS dust	5	190			
				No. GR-3.5	
			Aggregate	96.5	3800
			Bitumen	3.5	—
			Agg & Bitumen	100	3938
				No. GR-4.0	
			Aggregate	96.0	3800
			Bitumen	4.0	—
			Agg & Bitumen	100	3958
				No. GR-4.5	
			Aggregate	95.5	3800
			Bitumen	4.5	—
			Agg & Bitumen	100	3979
TOTAL	100	3800			

* $\frac{\text{AGGREGATE WT}}{\text{PER CENT AGG}} 100 = \text{AGG + BITUMEN WT}$

COMPUTED BY: DPB | CHECKED BY: MES | AGG BLEND PREPARED BY: | MIX PREPARED BY: | COMPACTED BY: SJ-AC

FIGURE 103-8. *Batch weight record form.*

COMPUTATION OF PROPERTIES OF BITUMINOUS MIXTURES

JOB NO.: PROJECT: Bit Stab - Large Agg DESCRIPTION: Gravel, sand & Limestone dust DATE: 2 Oct 1956

SPECIMEN NO	BITUMEN CONTENT, %	WEIGHT, G		VOLUME cc	SPECIFIC GRAVITY		BITUMEN BY VOLUME, %	VOIDS, %		UNIT WEIGHT LB/CU FT
		IN AIR	IN WATER		ACTUAL	THEOR.		TOTAL MIX	FILLED	
A	B	C	D	E	F	G	H	I	J	K
				(C - D)	$\left(\frac{C}{E}\right)$		$\left(\frac{B \times F}{\text{SP GR OF BIT.}}\right)$	$\left(100 - 100\,\frac{F}{G}\right)$	$\left(\frac{H}{H+I}\right)$	(F × 62.4)
Gr 2.5 1	2.5	1266.7	731.7	535.0	2.368					
2		1255.0	727.4	527.6	2.379					
3		1235.1	713.8	521.3	2.369					
4		1243.2	717.1	526.1	2.363					
Gr 3.0 1	3.0	1247.4	726.8	520.6	2.396					
2		1252.2	727.0	525.2	2.384					
3		1289.8	747.2	542.0	2.379					
4		1216.0	706.4	509.6	2.386					
Gr 3.5 1	3.5	1261.0	733.8	527.2	2.392					
2		1272.1	742.6	529.5	2.402					
3		1270.0	739.5	530.5	2.394					
4		1282.2	744.2	538.0	2.383					
Gr 4.0 1	4.0	1289.7	748.9	540.8	2.385					
2		1224.1	709.0	515.1	2.376					
3		1264.7	734.3	530.4	2.384					
4		1250.2	723.8	526.4	2.375					

TECHNICIAN: PSM COMPUTER: DPB CHECKED BY: TBG

FIGURE 103-4. *Sample, recorded data.*

COMPUTATION OF PROPERTIES OF BITUMINOUS MIXTURES

JOB NO.: PROJECT: Bit Stab-Large Agg DESCRIPTION: Gravel, sand & Limestone DATE: 2 Oct 1956

SPECIMEN NO.	BITUMEN CONTENT, %	WEIGHT, G		VOLUME	SPECIFIC GRAVITY		BITUMEN BY VOLUME, %	VOIDS, %		UNIT WEIGHT
		IN AIR	IN WATER	CC	ACTUAL	THEOR.		TOTAL MIX	FILLED	LB/CU FT
A	B	C	D	E	F	G	H	I	J	K
				(C - D)	$\left(\frac{C}{E}\right)$		$\left(\frac{B \times F}{\text{SP GR OF BIT.}}\right)$	$\left(100 - 100\,\frac{F}{G}\right)$	$\left(\frac{H}{H+I}\right)$	(F × 62.4)
Gr 4.5 1	4.5	1275.5	737.2	538.3	2.369					
2		1269.2	733.4	535.8	2.369					
3		1216.6	700.0	516.6	2.355					
4		1227.5	708.5	519.0	2.365					

TECHNICIAN: PJM COMPUTER: DPB CHECKED BY: TEC

Figure 103-5.—Continued.

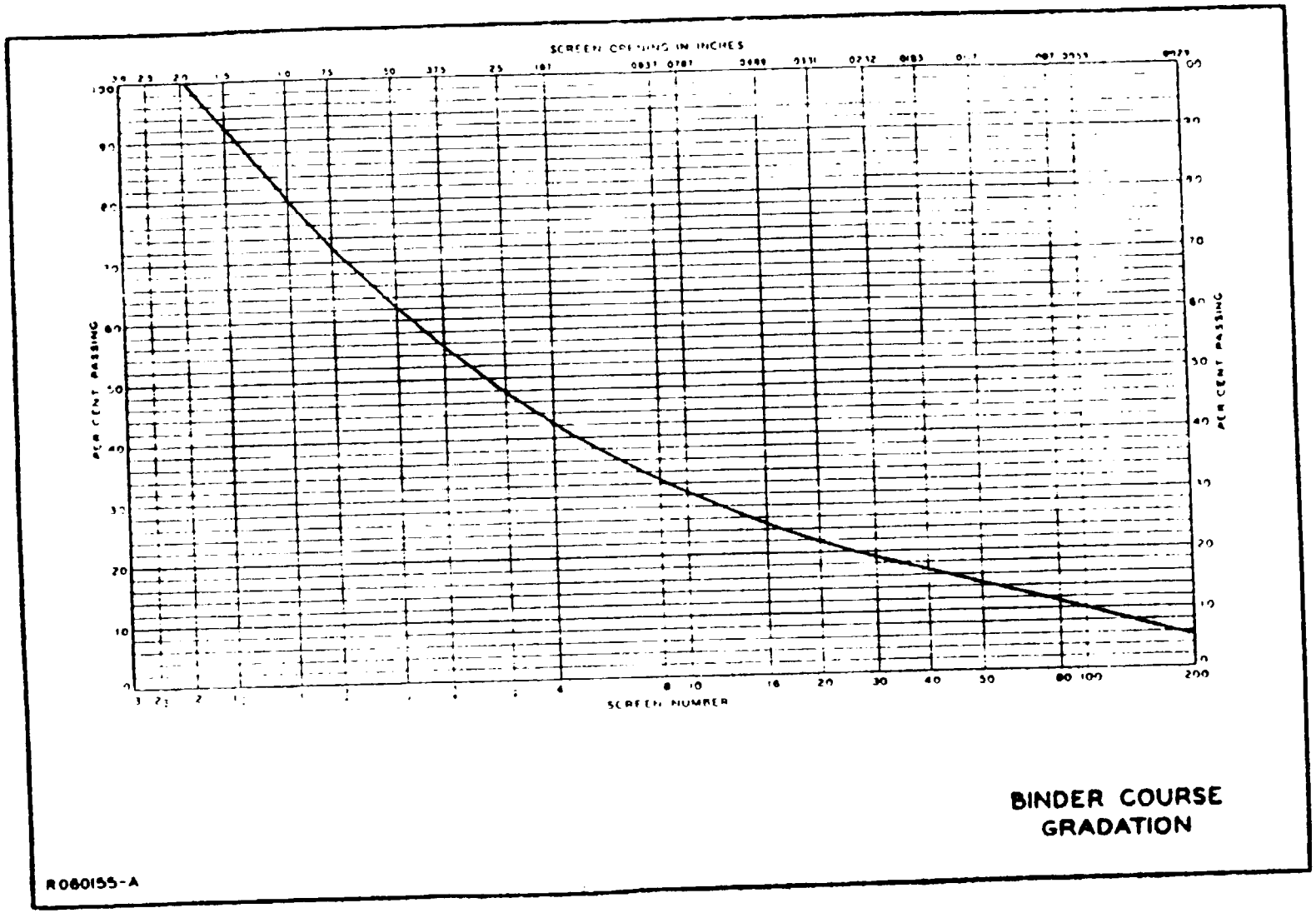

FIGURE 103-6. *Binder course gradation.*

Method 104
MEASUREMENT OF REDUCTION IN MARSHALL STABILITY OF BITUMINOUS PAVEMENTS CAUSED BY IMMERSION IN WATER [1]

1. SCOPE

1.1 This test method is intended to measure the reduction in Marshall stability resulting from the action of water on compacted bituminous mixtures containing penetration grade asphalt, tar, or rubberized tar. A numerical index of reduced stability is obtained by comparing the stability of specimens determined in accordance with usual Marshall procedures with the stability of specimens that have been immersed in water for a prescribed period.

2. APPARATUS

2.1 **Water bath.** A water bath at least 6 inches deep provided with mechanical water agitator, heating elements, and thermostatic controls capable of maintaining the bath water at temperatures ranging from 100° to 140° F. The bath shall have a perforated false bottom or be equipped with a shelf for supporting specimens 2 inches above the bottom of the bath.

2.2 Balance and water container with accessory equipment for weighing the test specimens in air and in water.

2.3 Transfer plates, flat, of glass or metal. One of these plates shall be kept under each test specimen during immersion and subsequent handling, except when weighing and testing, in order to prevent breakage or distortion of the specimens.

3. SPECIMENS

3.1 A minimum of eight standard Marshall test specimens, 4 in. in diameter and 2½ inches ± ⅛ in. in height, shall be prepared for each test in accordance with the procedures described in method 100. The compaction effort used shall be 50 blows on each end of the specimen.

4. PROCEDURE

4.1 Weigh each test specimen in air and in water.

4.2 Calculate the specific gravity of each test specimen as follows:

$$\text{Specific gravity} = \frac{A}{A - B}$$

where

A = weight of specimen in air, g

B = weight of specimen in water, g

4.3 Sort the test specimens into two groups so that the average specific gravity of the specimens in group 1 is essentially the same as that of group 2.

4.4 Test the specimens in group 1 for Marshall stability and flow as described in method 10.

[1] This method is based in part on ASTM D 1075, Standard Method of Test for Effect of Water on Cohesion of Compacted Bituminous Mixtures.

4.5 Immerse the group 2 specimens in water for 24 hours at the temperatures specified in the following tabulation.

4.6 Test immediately upon removal from the water for stability and flow as described in method 100.

Type bituminous material	*Marshall stability test water temperature, °F.*
Asphalt	140 ± 1
Tar	100 ± 1
Rubberized tar	120 ± 1

5. CALCULATION

5.1 The numerical index of resistance of bituminous mixtures to the detrimental effect of water shall be expressed as a percentage of the original stability as follows:

$$\text{Index of retained stability} = \frac{S_2}{S_1} \times 100$$

Where

S_1 = Marshall stability of group 1 (average)

S_2 = Marshall stability of group 2 (average)

Method 105
DETERMINATION OF BULK-IMPREGNATED SPECIFIC GRAVITY OF AGGREGATE PROPOSED FOR USE IN BITUMINOUS PAVING MIXES

1. SCOPE

1.1 This test method is for determination of the specific gravity of the coarse, fine, and blended aggregates (including filler) proposed for use in hot-mix bituminous paving mixes. It is to be used only when the water absorption for the entire blend of aggregates selected for the job-mix formula exceeds 2½ percent. The method is not applicable for determination of specific gravity of mineral filler except when mineral filler is included in the blended aggregate. Specific gravity of mineral filler alone shall be determined in accordance with ASTM D 854 or C 188, whichever is applicable for the type material to be examined.

2. APPARATUS

2.1 **Oven.** A large, thermostatically controlled oven, sensitive to ± 5° F., capable of maintaining temperatures in the approximate range of 275° to 325° F.

2.2 **Balance.** A balance of approximately 5000-g capacity, sensitive to 0.1 g, arranged for weighing sample in air and suspended in water.

2.3 **Pails.** Pails of 1-gal capacity (syrup can with top rim removed to eliminate entrapped air is satisfactory) equipped with wire handle for suspending in water.

2.4 **Pans.** Metal pans of a size suitable for retaining approximately 1000 g of aggregate.

2.5 **Stirrer.** One heavy sheet-metal strip about 1 in. wide for stirring content of each pail.

2.6 **Appurtenant equipment.** A container for immersing the 1-gal pail, and an assembly for suspending the pail from the balance.

3. SAMPLE

3.1 Sufficient quantities of materials shall be obtained at time of sampling to meet the specification requirements of SS–R–406, and to provide for the tests described herein. Samples shall consist of the following.

3.1.1 *Aggregate.* Aggregate samples shall consist of 1000 g of fine aggregate, 1500 g of coarse aggregate, or 1500 g of blended aggregate, taken with care to insure that the aggregate to be tested represents prototype grading.

3.1.2 Asphalt cement. Asphalt cement of 85 to 100 penetration grade.

4. TEST PROCEDURE

4.1 Dry the aggregate sample to a constant weight at a temperature not less than 230° F. nor greater than 290° F., and weigh to nearest 0.1 g.

4.2 Heat the previously specified asphalt to 280° ± 5° F., taking care that the temperature never exceeds 285° F., and pour into the 1-gal pail about one-third full. In-

sert the sheet-metal stirrer, and allow pail and contents to cool to 72° ± 2° F.

Note. A minimum of 8 hours is usually required to accomplish this, and preferably pail and contents are allowed to cool overnight.

4.3 Weigh pail plus asphalt and stirrer in air at room temperature and in water at 72° ± 2° F.

4.4 Place the pail of asphalt with stirrer and also the sample of aggregate in an oven maintained at a temperature of 280° ± 5° F., and leave both until temperatures are equalized (a minimum of 4 hours is usually required).

4.5 Remove aggregate and asphalt from oven, and add aggregate gradually to the hot asphalt while stirring thoroughly. Continue to stir uniformly after all aggregate is added until the total elapsed time from start of mixing to end of stirring is 2 minutes. Cool to 72° ± 2° F. Flame surface during the cooling period to remove air bubbles if such are present.

Note. It is preferable to cool overnight.

5. CALCULATIONS AND REPORT

5.1 Calculate the bulk-impregnated specific gravity as follows:

$$\text{Bulk-impregnated specific gravity} = \frac{A}{(D - E) - (B - C)}$$

where

A = weight of oven-dried aggregate, g

B = weight of pail plus stirrer plus asphalt in air, g

C = weight of pail plus stirrer plus asphalt in water, g

D = weight of pail plus stirrer plus asphalt aggregate in air, g

E = weight of pail plus stirrer plus asphalt plus aggregate in water, g

5.2 The results are tabulated and reported on a form such as that shown in figure 105–1.

6. REPRODUCIBILITY OF RESULTS

6.1 Duplicate determinations of the bulk-impregnated specific gravity must check within 0.04. If the values are within the 0.04 tolerance, use the average value. If the duplicate tests do not produce values within the 0.04 tolerance, perform two additional duplicate tests. If the average value of the second two tests is not within the tolerance, then average the values determined in all four tests and use this value.

BULK-IMPREGNATED SPECIFIC GRAVITY

JOB NO.:	PROJECT:	DATE

SAMPLE NO. ________ TYPE OF AGGREGATE ________

(1) WEIGHT OF OVEN-DRIED AGGREGATE, A ________ G
(2) WEIGHT PAIL + STIRRER + ASPHALT IN AIR, B ________ G
(3) WEIGHT PAIL + STIRRER + ASPHALT IN WATER, C ________ G
(4) B − C = LINE (2) − LINE (3) ________ G
(5) WEIGHT PAIL + STIRRER + ASPHALT + AGGREGATE IN AIR, D ________ G
(6) WEIGHT PAIL + STIRRER + ASPHALT + AGGREGATE IN WATER, E ________ G
(7) (D − E) − (B − C) = LINE (5) − LINE (6) − LINE (4) ________ G

BULK-IMPREGNATED SPECIFIC GRAVITY = $\frac{A}{(D - E) - (B - C)} = \frac{(1)}{(7)}$ ________

SAMPLE NO. ________ TYPE OF AGGREGATE ________

(1) WEIGHT OF OVEN-DRIED AGGREGATE, A ________ G
(2) WEIGHT PAIL + STIRRER + ASPHALT IN AIR, B ________ G
(3) WEIGHT PAIL + STIRRER + ASPHALT IN WATER, C ________ G
(4) B − C = LINE (2) − LINE (3) ________ G
(5) WEIGHT PAIL + STIRRER + ASPHALT + AGGREGATE IN AIR, D ________ G
(6) WEIGHT PAIL + STIRRER + ASPHALT + AGGREGATE IN WATER, E ________ G
(7) (D − E) − (B − C) = LINE (5) − LINE (6) − LINE (4) ________ G

BULK-IMPREGNATED SPECIFIC GRAVITY = $\frac{A}{(D - E) - (B - C)} = \frac{(1)}{(7)}$ ________

SAMPLE NO. ________ TYPE OF AGGREGATE ________

(1) WEIGHT OF OVEN-DRIED AGGREGATE, A ________ G
(2) WEIGHT PAIL + STIRRER + ASPHALT IN AIR, B ________ G
(3) WEIGHT PAIL + STIRRER + ASPHALT IN WATER, C ________ G
(4) B − C = LINE (2) − LINE (3) ________ G
(5) WEIGHT PAIL + STIRRER + ASPHALT + AGGREGATE IN AIR, D ________ G
(6) WEIGHT PAIL + STIRRER + ASPHALT + AGGREGATE IN WATER, E ________ G
(7) (D − E) − (B − C) = LINE (5) − LINE (6) − LINE (4) ________ G

BULK-IMPREGNATED SPECIFIC GRAVITY = $\frac{A}{(D - E) - (B - C)} = \frac{(1)}{(7)}$ ________

SAMPLE NO. ________ TYPE OF AGGREGATE ________

(1) WEIGHT OF OVEN-DRIED AGGREGATE, A ________ G
(2) WEIGHT PAIL + STIRRER + ASPHALT IN AIR, B ________ G
(3) WEIGHT PAIL + STIRRER + ASPHALT IN WATER, C ________ G
(4) B − C = LINE (2) − LINE (3) ________ G
(5) WEIGHT PAIL + STIRRER + ASPHALT + AGGREGATE IN AIR, D ________ G
(6) WEIGHT PAIL + STIRRER + ASPHALT + AGGREGATE IN WATER, E ________ G
(7) (D − E) − (B − C) = LINE (5) − LINE (6) − LINE (4) ________ G

BULK-IMPREGNATED SPECIFIC GRAVITY = $\frac{A}{(D - E) - (B - C)} = \frac{(1)}{(7)}$ ________

TESTED BY:	COMPUTED BY:	CHECKED BY:

FIGURE 105–1. *Record form of specific gravity.*

Method 106
DETERMINATION OF WATER CONTENT OF BITUMINOUS MIXTURES USING A NONFLAMMABLE SOLVENT

1. SCOPE

1.1 The proposed procedure is intended for the determination, by direct measurement, of the water content of hot-mix bituminous mixtures.[1]

2. APPARATUS

2.1 Metal still of the vertical, cylindrical type, similar to that used in ASTM D 244, having a faced flanged at the top, to which the head is tightly attached by means of a clamp. The head shall be of metal, preferably copper or brass, and shall be provided with a tabulation 1 in. in inside diameter.

2.2 Condenser of the water-cooled, reflux, glass-tube type, having a condenser jacket not less than 400 mm (15¾ in.) long, with an inner tube 9.5 to 12.7 mm (⅜ to ½ in.) in outside diameter. The end of the condenser that is inserted in the trap shall be ground off at an angle of 30 degrees from the vertical axis of the condenser.

2.3 Trap, of well-annealed glass, conforming to the dimensions shown in figure 1 of ASTM D 322.

2.4 **Heating device.** Any satisfactory source of heat capable of maintaining a rate of distillation of 2 to 3 drops per sec.

3. SAMPLE

3.1 The sample of bituminous mix shall be representative of the material to be tested and of such size as practically to fill the container in which it is transported to the laboratory. For duplicate tests, a sample filling a ½-gallon, friction-top, tin pail is satisfactory.

3.2 Break up the sample and mix throughly. Weigh out an amount estimated to contain a percentage of moisture that is within the capacity of the trap calibration. Keep the remainder of the sample in a tightly covered container. (Preferably the sample should weigh not less than 500 g for normal mixtures.) Place the sample in the still and add the solvent as prescribed in 4.1.

3.3 Use only one of the following solvents.

3.3.1 1,1,2 trichlorethane (active ingredient 100 percent), known also as vinyl trichloride ($ClCH_2CHCl_2$).

3.3.2 1,1,1 trichloroethane (methyl chloroform) (CH_3CCl_3).

4. TEST PROCEDURE

4.1 Place the prepared sample in the still, add 250 ml of the solvent, and quickly stir into the sample. Attach the still cover firmly, and assemble the trap and condenser in the manner prescribed in ASTM D 95. (Fill the trap with solvent prior to assembly of apparatus.)

[1] A control test is to be conducted as a part of this procedure in order to determine a correction factor, application of which is given in paragraph 5.2.

4.2 Apply heat at such a rate that refluxing will start within 3 to 6 minutes after application of heat. Exercise caution that heat is not applied too rapidly. The condensed solvent should drip into the trap at a rate of 2 to 3 drops per second. Continue the distillation for 1 to 1¼ hours, then allow the trap and contents to cool to room temperature.

4.3 Dislodge any drops of water adhering to the sides of the trap with a glass or polytetrafluorethylene rod or other suitable means, and add these drops to the water layer. Gently agitate the two menisci with a small wire to separate the water and solvent.

5. RESULTS

5.1 **Water content.** Record the volume of water in the trap, and add or subtract the correction quantity; calculate and report the water content as a percentage of the total weight of the sample.

5.2 **Method of determining correction quantity.** The correction is determined by making a control test with 247.5 ml of the solvent and 2.5 ml of water. The difference in milliliters between the water added and recovered is the correction. If more water is recovered than was added (indicating that the solvent contains water), the correction will be negative. If less water is recovered than was added, the correction will be positive. (Experiments have indicated that the correction is a fixed quantity in milliliters and not a fixed percentage.)

Method 107
EVALUATION OF RUBBERIZED-TAR CEMENT PROPOSED FOR USE AS BINDING AGENT IN HOT-MIX RUBBERIZED-TAR PAVEMENT

1. SCOPE

1.1 This method of testing is used for evaluation of rubberized-tar cement proposed for use in the manufacture of hot-mix rubberized-tar pavements.

2. APPARATUS

2.1 **Melting unit.** A unit, for melting laboratory samples, of the double-boiler type employing a high flash-point oil as the heat-transfer medium and equipped with:

(a) A bottom discharge of opening controlled by a knife or blade valve to permit drawing off melted material.

(b) A mechanical agitator installed in each material chamber.

(c) Two metal thermometers, dial-type, capable of measuring temperatures as high as 245° F., and graduated in 5° subdivisions.

(d) One thermometer, metal or glass, 275° F., capacity, 5° subdivisions.

2.2 **Oven.** Thermostatically controlled oven capable of maintaining a temperature of 100° ± 2.0° F.

2.3 **Water bath.** A water bath with mechanical agitator, thermometer, heating element, and thermostatic controls capable of maintaining a water temperature of 77° ± 0.2° F.

2.4 **Viscometer.** A Brookfield viscometer, Model LVF.

2.5 **Metal panels.** Bright tin-coated panels at least 4 in. wide and 6 in. long. The panels shall be free of any foreign material (dust, oil, etc.), shall not be warped or bent, and shall be discared after each flow test.

2.6 **Molds.** Amalgamated brass molds 6 cm long, 4 cm wide, and 0.32 cm deep.

2.7 **Containers.** Containers approximately $2\frac{1}{8}$ in. in diameter and $1\frac{1}{4}$ in. deep (3-oz seamless ointment boxes).

2.8 **Balance.** Laboratory balance, 2-kg capacity, sensitive to 0.1 g.

2.9 **Appurtenant equipment.**

(a) 1 wire basket and water bucket suitable for weighing test specimens in water.

(b) 2 spatulas or knives, 1- by 6-in. blade.

(c) 1 pair of gloves, leather palm or welders, for handling hot equipment.

(d) 1 pair of gloves, rubber, gauntlet-type, for lifting test specimens from water bath.

(e) 1 clip board.

(f) Data sheets similar to those shown in figures 107-1, 107-2, 107-3, and 107-4.

3. SAMPLE

3.1 Melt approximately 800 g of the rubberized-tar blend in a melting unit.

3.2 Stir the rubberized-tar blend continuously by mechanical means during the melting operation.

3.3 Make frequent temperature measurements to assure that the material is held within the following limits:

(a) The temperature of the blend during melting shall not exceed 245° F.

(b) The temperature of the heat-transfer oil shall not exceed 275° F.

(c) The pouring temperature of the blend shall be 235° ± 10° F.

(d) The melting time shall not exceed 60 minutes.

4. TEST PROCEDURES

4.1 Penetration.

4.1.1 Prepare two pentration test specimens in accordance with SS-R-406, method No. 214.01. Allow specimens to cool in air at a temperature not higher than 85° F. nor lower than 70° F. for not less than 1½ nor more than 2 hours. Set one test specimen aside temporarily.

4.1.2 Immerse one test specimen in synthetic fuel, composed of 70 percent by volume of ASTM iso-octane and 30 percent by volume of ASTM industrial-grade toluene, for a period of 18 hours during which time the fuel shall be maintained at a temperature of 100° ± 2° F.

4.1.3 Upon completion of the immersion period, remove the specimen from the synthetic fuel and dry under forced draft at room temperature for 1 hour.

4.1.4 After completion of the drying period, conduct pentration test in accordance with SS-R-406, method No. 214.01.

4.1.5 At approximately the same time that the penetration is determined on the specimen that had been immersed, make a penetration test on the test specimen temporarily set aside.

4.1.6 Record penetration test data before and after immersion on data sheets similar to that shown in figure 107-1.

4.2 Volume and weight changes during immersion in fuel.

4.2.1 Pour a portion of the sample prepared as described in 3.1 through 3.3 into the metal containers described in 2.7. The depth of the material in the container shall be approximately 1 in.

4.2.2 Cool the specimen in air at a temperature not higher than 85° F. nor lower than 70° F. for not less than 1½ nor more than 2 hours; then weigh the sample in air.

4.2.3 Place the specimen in a water bath maintained at a temperature of 77° ± 0.2° F. for not less than 1½ nor more than 2 hours.

4.2.4 After the specimen has been in the water bath for the specified time, weight it in water at the same temperature as the water bath.

4.2.5 Determine the difference between

the weight in air and the weight in water, and record it as the volume of the specimen plus container in cubic centimeters before immersion in fuel.

4.2.6 After the weight in water is obtained, dry the specimen with a clean, dry cloth and immerse it in synthetic fuel along with the penetration specimen.

4.2.7 Remove the sample from the fuel and dry under forced draft at room temperature for 1 hour along with the penetration sample.

4.2.8 At the completion of the drying period, weigh the sample in air and in water.

4.2.9 Determine the difference between the weight in air and the weight in water, and record it as the volume of the sample plus container in cubic centimeters after immersion in fuel.

4.2.10 Record the test data on a data sheet similar to that shown in figure 107-2.

4.3 Flow.

4.3.1 Pour a portion of the sample prepared as described in 3.1 through 3.3 into an amalgamated mold 4 cm wide by 6 cm long by 0.32 cm deep, placed on a bright tin panel. Fill the mold with an excess of material, allow it to cool at room temperature for at least ½ hour, and then trim the material flush with the face of the mold with a heated knife or spatula.

4.3.2 Remove the mold, and place the panel containing the specimen in an oven maintained at 100° ± 2° F. for 60 minutes. The panel shall be mounted so that the longitudinal axis of the specimen is at an angle of 75 degrees ± 1 degree with the horizontal, and the transverse axis is horizontal.

4.3.3 Record the changes in length of the test specimen, in centimeters, on a data sheet similar to that shown in figure 107-3.

4.4 Softening point.

4.4.1 Determine the softening point of the blend in accordance with SS-R-406, method No. 216.0.

4.4.2 Record the softening point in degrees Fahrenheit on a data sheet similar to that shown in figure 107-3.

4.5 Viscosity.

4.5.1 Fill a 400-ml, Griffin, low-form beaker to within about ½ in. of the top with material prepared as specified in 3.1 through 3.3. Place the beaker in an oil bath, and condition the material to the temperatures shown in the tabulation in 4.5.2.

4.5.2 Determine the viscosity of the material by use of a Brookfield viscometer, Model LVF, at approximately the temperatures indicated below for the spindle and revolutions per minute specified. Take readings 60 seconds after the spindle is actuated.

Temperature °F	*Spindle No.*	*Revolutions per min*
200	4	6
225	4	6
250	2	6

4.5.3 Plot the viscosity in centipoises (Brookfield) at each actual test temperature

on a semilog similar to figure 107-4 and draw the best possible straight line through these three points. Read the viscosity in Brookfield centipoises at the points where the line intercepts the test temperatures indicated above, and record on a data sheet similar to that shown in figure 107-3.

4.6 Moisture content.

4.6.1 Determine the moisture content of the rubberized-tar blend in accordance with ASTM D 95-56T.

4.6.2 Record the moisture content on a data sheet similar to that shown in figure 107-3.

5. REPORT

5.1 A summary report similar to that shown in figure 107-3 shall be prepared.

RUBBERIZED-TAR SPECIFICATION TESTS FOR PENETRATION

JOB NO. _____ SAMPLE NO. FPL No. 4240 DATE 2-16-65

AMOUNT OF MATERIAL USED 1000 g

TIME START BLEND 8:00 AM
TIME FINISH POUR 9:00 AM
TOTAL TIME 1 hr.

TEMPERATURE OF BLEND, °F 235
TEMPERATURE OF OIL BATH, °F 265

NONIMMERSED

CAN NO. 3

TIME IN BATH 11:00 AM
TIME OUT BATH 12:30 PM

RESULTS OF PENETRATION:
NO. 1 126
NO. 2 125
NO. 3 126
AVERAGE PENETRATION, MM/10 126

IMMERSED

CAN NO. 2

TIME PLACED IN FUEL 4:00 PM
TIME OUT OF FUEL 10:00 AM
TIME START AIR DRY 10:00 AM
TIME FINISH AIR DRY 11:00 AM
TIME IN BATH 11:00 AM
TIME OUT BATH 1:00 PM

RESULTS OF PENETRATION:
NO. 1 153
NO. 2 150
NO. 3 150
AVERAGE PENETRATION, MM/10 151

DIFFERENCE BETWEEN IMMERSED AND NONIMMERSED PENETRATION 25

TECHNICIAN FH

FIGURE 107-1. *Penetration record form.*

RUBBERIZED-TAR SPECIFICATION TESTS FOR WEIGHT AND VOLUME CHANGE

JOB NO. _____ SAMPLE NO. FPL No. 4240 DATE 6-16-56

BEFORE IMMERSION IN FUEL

TIME START AIR COOLING	10:00 AM		
TIME FINISH AIR COOLING	12:00 Noon		
TOTAL TIME	2 hr	(A) WT IN AIR, g	112.295
TIME IN WATER BATH	12:00 Noon		
TIME OUT WATER BATH	1:30 PM		
TOTAL TIME	1½ hr	(B) WT IN WATER, g	35.710
		(C) VOLUME SAMPLE + CAN (A − B)	76.585

AFTER IMMERSION IN FUEL

TIME IMMERSED IN FUEL	4:00 PM		
TIME OUT OF FUEL	10:00 AM		
TIME START AIR DRY	10:00 AM		
FINISH AIR DRY	11:00 AM	(D) WT IN AIR, g	113.300
TIME IN WATER BATH	11:30 AM		
TIME OUT WATER BATH	1:30 PM	(E) WT IN WATER, g	35.250
		(F) VOLUME SAMPLE + CAN (D − E)	78.050
		(G) WT CHANGE, g (D − A)	+1.005
		(H) WT CHANGE, PER CENT $\left(\frac{G}{A} 100\right)$	+0.89
NOTE: (H) AND (K) SHOULD BE NOTED AS EITHER + OR −		(J) VOL CHANGE, cc (F − C)	+1.465
		(K) VOL CHANGE, PER CENT $\left(\frac{J}{C} 100\right)$	+1.91

TECHNICIAN _____

FIGURE 107-2. *Volume and weight change record form.*

SUMMARY OF RESULTS OF TESTS ON RUBBERIZED-TAR COMPOUNDS

MATERIAL Rubberized tar JOB NO.

TEST	TEST RESULTS FPL NO. 4212	FPL NO.
PENETRATION, mm/10	151	
IMMERSED	126	
NONIMMERSED	25	
DIFFERENCE		
FLOW, cm	3.6	
CHANGE, PER CENT		
VOLUME	+1.91	
WEIGHT	+0.89	
SOFTENING POINT, °F	105	
VISCOSITY, CENTIPOISES (BROOKFIELD)*		
200 F	6900	
225 F	3950	
250 F	2100	
MOISTURE CONTENT, PER CENT	0	

* THESE DATA ARE READ FROM THE BEST STRAIGHT LINE THROUGH THE ACTUAL TEST POINTS (SEE FIG. 60-31).

FIGURE 107-3. *Summary report record form.*

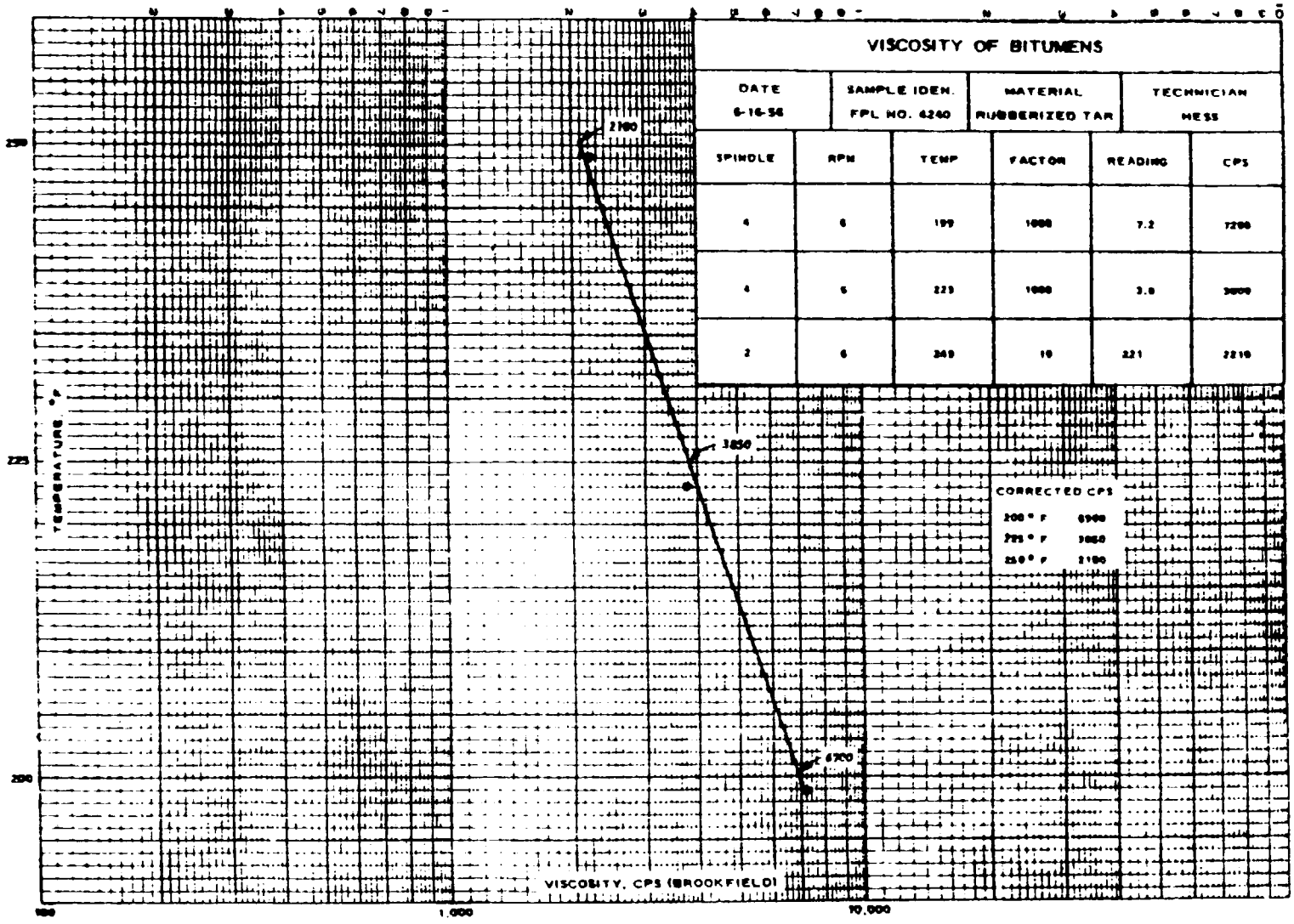

FIGURE 107-1. *Viscosity plot sample.*

Method 108
DETERMINING DEGREE OF STRIPPING OF AGGREGATES

1. SCOPE

1.1 This method of testing is intended for determining the degree of stripping of asphalt-coated aggregates.

1.2 Striping is defined as loss of asphalt coating from the aggregate particles because of displacement by the action of water, leaving exposed aggregate surfaces.

2. APPARATUS

2.1 Mixing apparatus. A metal pan or bowl and a trowel for hand mixing. (Mechanical mixing is permissible.)

2.2 Ovens or hotplates. Ovens or hotplates for heating aggregates and bituminous material to the applicable mixing temperature for the grade of asphalt used.

2.3 Glass jars. One glass jar of 1-qt capacity, fitted with a watertight screwcap, for each specimen.

3. PREPARATION OF SAMPLE

3.1 Mix a test sample consisting of the aggregate and asphalt to be used in the paving mixture at the applicable temperature for the grade of asphalt being used. Then spread the sample in a loose, thin layer and air-cure for 24 hours before testing.

4. TEST PROCEDURE

4.1 Place a representative portion of the sample, not larger than one-half the capacity of the jar, in the glass jar and completely cover with distilled water. Close the jar with a tight screwcap and allow to stand for 24 hours. At the end of 24 hours, shake the jar containing the sample vigorously for 15 minutes. Then examine the sample of the mixture for stripping.

5. REPORT

5.1 The report consists of an estimated percentage of exposed aggregate surface, which is reported as "percent stripping."

*U.S. GOVERNMENT PRINTING OFFICE:1974 603-121/332

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