

FINAL REPORT

BITUMINOUS MIX DENSITY BY COATED SPECIMEN

Jack E. Stephens, Professor

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## BITUMINOUS MIX DENSITY BY COATED SPECIMEN

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This study is an outgrowth of an earlier study using a nuclear density probe carried out by the Connecticut Highway Bureau - University of Connecticut Joint Highway Research Advisory Council. In that study the inclusion of a surface texture factor greatly improved the correlation between densities found by nuclear meter and by core weight in water. Further refinements in measurements did not improve this correlation.

A partial explanation of the remaining variation was thought to be in the type of density measured by the different methods. The nuclear meter measures "apparent" density. That is, the volume of material includes all internal voids whether permeable or impermeable.

Core weight combined with the saturated weight in water results in a value approaching true solid density. Core weight, saturated surface dry weight and saturated weight in water are used to determine apparent specific gravity. Two of these weights (core weight and saturated weight in water) can be adequately determined in the laboratory to properly represent these values. However the saturated surface dry weight has a degree of variability inherent to the measurement. There is no positive way of securing and maintaining the same degree of saturation for all samples. Samples with large voids saturate easily but also drain quickly prior to weighing thus giving high densities. Those with small voids saturate slowly but retain water well and may indicate a low density. Of course, many combinations of pore volume and permeability exist to confuse this simple statement.

An evaluation of the effectiveness of the current methods of density determination must be prefaced by careful consideration of the reasons for performing such tests. One of the major uses is for the determination of voids as an indication of potential mix hardening or bleeding. For this purpose, density should include all voids so that comparison to the theoretical solid density will determine the percent voids present.

In an attempt to assess the importance of this discrepancy, a new method of test has been devised which is an improvement on the old test method using a parafine seal on the cores. Modern blister packaging methods are used to fit a plastic jacket to each core and prevent water penetration during weight in water determinations. Use of the plastic weight and density permits adjustment of the computation to compensate for the displacement of the jacket.

As a verification of the method, a number of mixes were prepared and compacted in a marshal mold fitted with machined top and bottom plates. A depth micrometer was used to determine the compacted sample height at 70° F immediately after a static load of 20,000 pounds held for 10 seconds. This load was used to insure that the sample filled the mold at the temperature and time of measurements. The gradation and asphalt content of the samples was varied in order to secure a range of specific gravity and voids content. Mix data and measurements are presented as Appendix B.

Each form of density has been plotted against that found from the measured mold volume. Figure 1 is for density by simple weight in water. Only 6 samples had a density by weight in water,  $D_w$ , less than the density by mold volume,  $D_m$ , and five of those were within measurement error. The one point at 135 lbs/cu. ft. for  $D_w$  probably contains an experimental error.

Line A appears to approximate a limit for  $D_w$  regardless of the density found by mold volume.

Line B, which is a one to one ratio line, should be the lower limit for the data points as the weight in water should not give a volume greater than the mold. Line A appears to be an upper limit for apparent density at values of  $D_m$  less than 145. More explicitly, a  $D_m$  near 145 seems to be at the transition between mixes in which only some voids are permeable and mixes where all voids are permeable. The former group gives a wide range of  $D_w$  due to the uncertainty of water penetration. The latter group with nearly complete water penetration results in high densities similar to those of Rice's method. The near absolute limiting value of Line A of 149 lbs/cu. ft. is not explained at this time.

Reference to Figure 2 supports the long expressed principle that use of saturated weight to determine density is an improvement over the simple weight in water method. At a mold density of 140 lbs/cu. ft. there is still a 3 1/2-pound variation probably due to the problem of determining or maintaining saturation once the sample is removed from the water. The curve of the band and the increased width of the band at the lower end is due to the ease of drainage of the relatively large voids of these materials.

The density by plastic coated specimen,  $D_p$ , as compared to density by mold reduces the scatter even further, Figure 3. The range of  $D_p$  for any value of  $D_m$  is only 2 lbs/cu. ft. At 145 lbs/cu. ft. for  $D_m$  the mean of  $D_p$  is also 145 lbs/cu. ft. At lower values of  $D_m$  the mean  $D_p$  increases to average 1/2 lb/cu. ft. above  $D_m$  at 140 lbs/cu. ft.  $D_m$ . This increase is due to the better fit of the plastic around the perimeter of the mold. Figure 4 shows a sketch of the surface of the sample. The mix against the smooth mold will have some honeycomb which the plastic partially follows.

Recognizing that  $D_m$  is an arbitrary standard, in Figure 5  $D_p$  has been plotted with  $D_{ss}$ . This form of plot indicates a degree of correlation between these two methods. The 3-lb/cu.ft. band width indicates a varying degree of saturation at the time of weighing. The sealed sample weight is probably more consistent.

Although exact cost of plastic coating specimen must remain a function of the quantity processed, a realistic figure can be constructed. The vacuum former used in this study cost \$250 and plastic material 6.6¢ per core. One technician can package 30 cores an hour.

#### CONCLUSIONS

Density found by simple weight in water is erratic due to uncertainty of the depth of penetration of water into the pores. This factor greatly affects the void content found by computation.

Saturated surface dry procedures give a better (less erratic) value for density but retain some variability due to the difficulties in maintaining saturation.

The plastic coated procedure gives the most predictable density. The time required is not significantly greater than the saturated method.

#### RECOMMENDATIONS

As void content is of major concern as a factor in hardening, every reasonable effort must be made to secure the best measure possible. For this purpose, the density found by plastic coating the sample is more nearly correct and thus preferable. The expense is low compared to the improved uniformity to be expected and the improved predictability of pavement performance.

## APPENDIX #1

### TEST PROCEDURE

The steps of this new test procedure are as follows:

1. Determine dry weight of core of molded sample.
2. Place the sample in the vacuum packing machine, Fig. 6, and mold acetate sheet to one end of core and sides, Fig. 7.
3. Trim off surplus plastic leaving one end and sides covered, Fig. 7.
4. Turn sample over and place in vacuum packaging machine, molding acetate sheet to second end and sides.
5. Trim off excess acetate. Sample is now enclosed in acetate with a double layer over the sides, Fig. 7.
6. Weigh packaged core.
7. Weigh packaged core in water.
8. Compute density.

$$D_p = \frac{W_1}{(W_2 - W_3) - \left( \frac{W_2 - W_1}{1.284} \right)} \times 62.4 \text{ (lb/cu.ft)}$$

Where:  $D_p$  = Density by plastic coated sample

$W_1$  = Weight of dry sample, g.

$W_2$  = Weight of packaged sample, g.

$W_3$  = Weight in water of packaged sample, g.

1.284 = Specific gravity of plastic.

For the purposes of this comparative study additional weights and measurements were taken consisting of plain sample weight in water, saturated sample weight, and mold measurements to permit computation of other forms of density.

Water density was found using the core weight and weight in water.

$$D_w = \left( \frac{W_4}{W_4 - W_5} \right) \times 62.4 \quad (\text{lb/cu.ft.})$$

Where  $D_w$  = Density by plain weight in water

$W_1$  = Weight of dry sample, g

$W_5$  = Weight of sample in water, g

Computing density of material based on saturated surface dry weight is intended to adjust the density to include only impermeable voids as part of the volume.

$$D_{ss} = \frac{W_1}{W_6 - W_5} \times 62.4 \quad (\text{lb/cu.ft.})$$

Where  $D_{ss}$  = Density based on saturated surface dry weight

$W_1$  = Weight of dry sample, g

$W_5$  = Weight of sample in water, g

$W_6$  = Weight of saturated surface dry sample, g

Density can also be found by measuring the sample accurately and computing the ratio of sample weight to sample volume. Although the samples were compacted in the molds some space existed between the mold surface and the mix surface. Inclusion of this space as part of the mix volume lowers the resulting density. Molded height was assumed as the difference between readings of a depth micrometer on the mold with bottom and top plates and a similar reading with molded sample between the plates.

$$D_m = \frac{W_1}{\pi r^2 h} \text{ (lb/cu. ft.)}$$

Where  $D_m$  = Density based on mold volume

$r$  = Radius of mold, ft.

$h$  = Height of molded sample, ft.

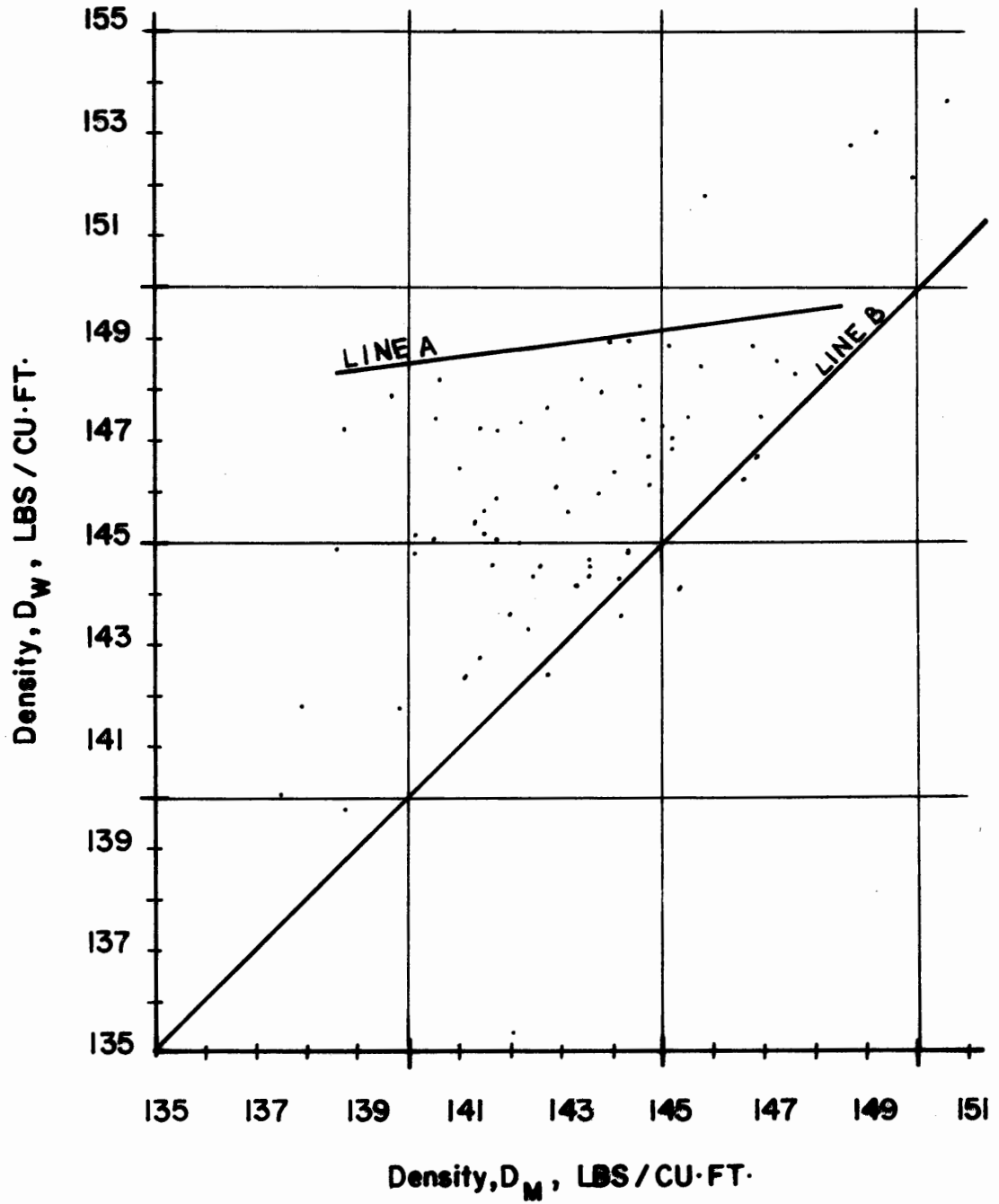
$W_1$  = Weight of dry sample, g



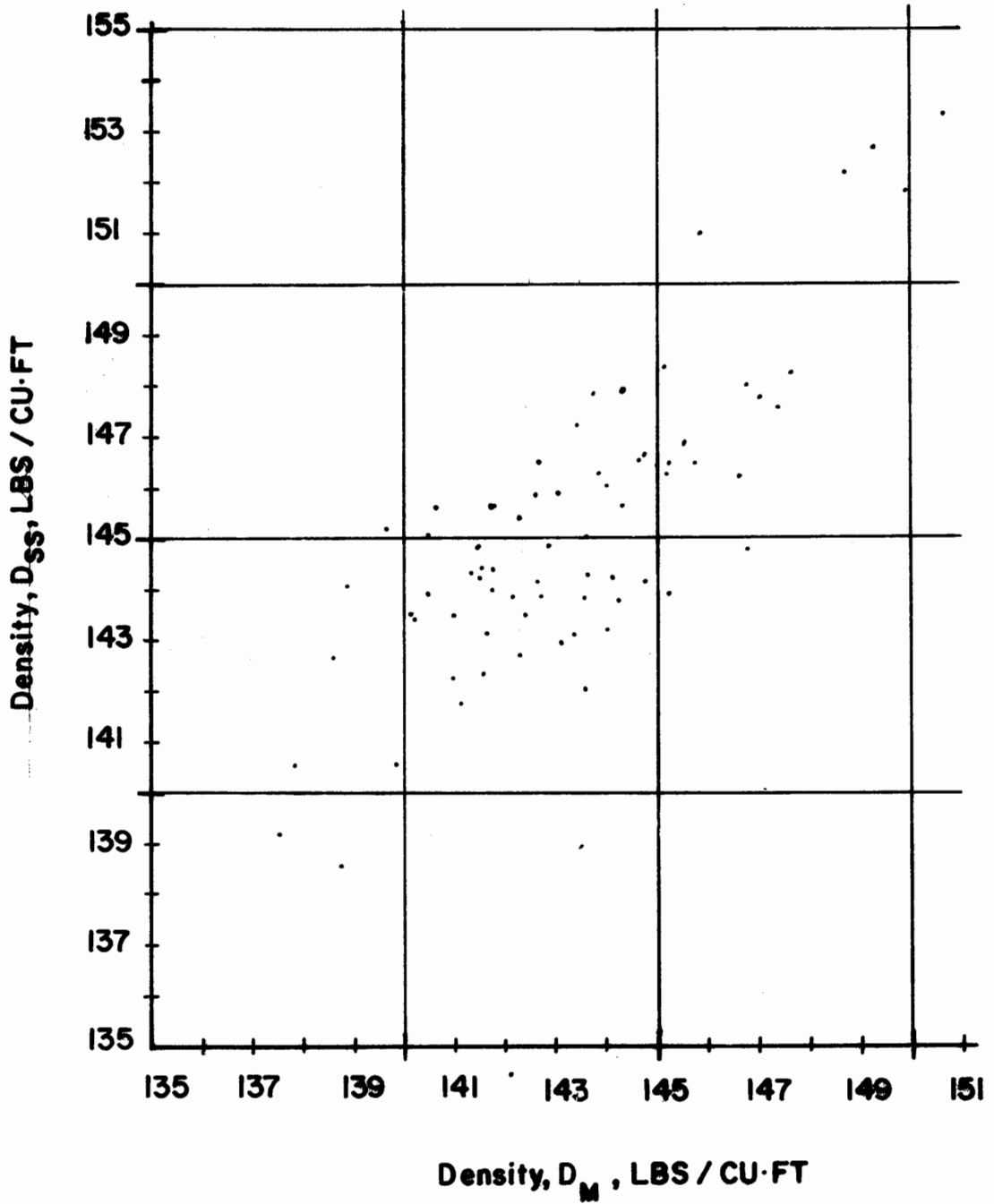
TRIAL MIX DATA

Sieve	Weight, Grams														Asphalt Content %
	3/8 #4	#4 #8	#8 #20	#10 #20	#20 #40	#40 #80	#50 #100	#80 200	#100 200	#200	Asphalt				
Sieve Passing	1110	740	925	370	259	296	222	6.0							
Sieve Retaining	1110	740	925	555	370	185	5.0								
Trial Mix #1	185	740	925	740	370	555	296	8.0							
Trial Mix #2	740	740	740	370	370	185	5.0								
Trial Mix #3	1110	740	740	370	370	185	5.0								
Trial Mix #4	600	1000	400	400	400	222	6.0								
Trial Mix #5	600	1200	500	500	300	185	5.0								
Trial Mix #6	700	900	800	700	200	200	5.5								
Trial Mix #7	400	740	740	600	240	200	5.5								
Trial Mix #8	600	1200	500	500	300	200	5.5								
Trial Mix #9	1000	1000	800	600	300	190	5.13								
Trial Mix #10	1110	740	925	370	260	295	6.0								
Trial Mix #11	1110	740	825	655	370	185	5.0								
Trial Mix #12	1200	1000	700	500	300	200	5.5								

(FIG-1)  
DENSITY BY SIMPLE WEIGHT IN WATER ( $D_w$ )  
V-S.  
DENSITY BASED ON MOLD SIZE ( $D_M$ )

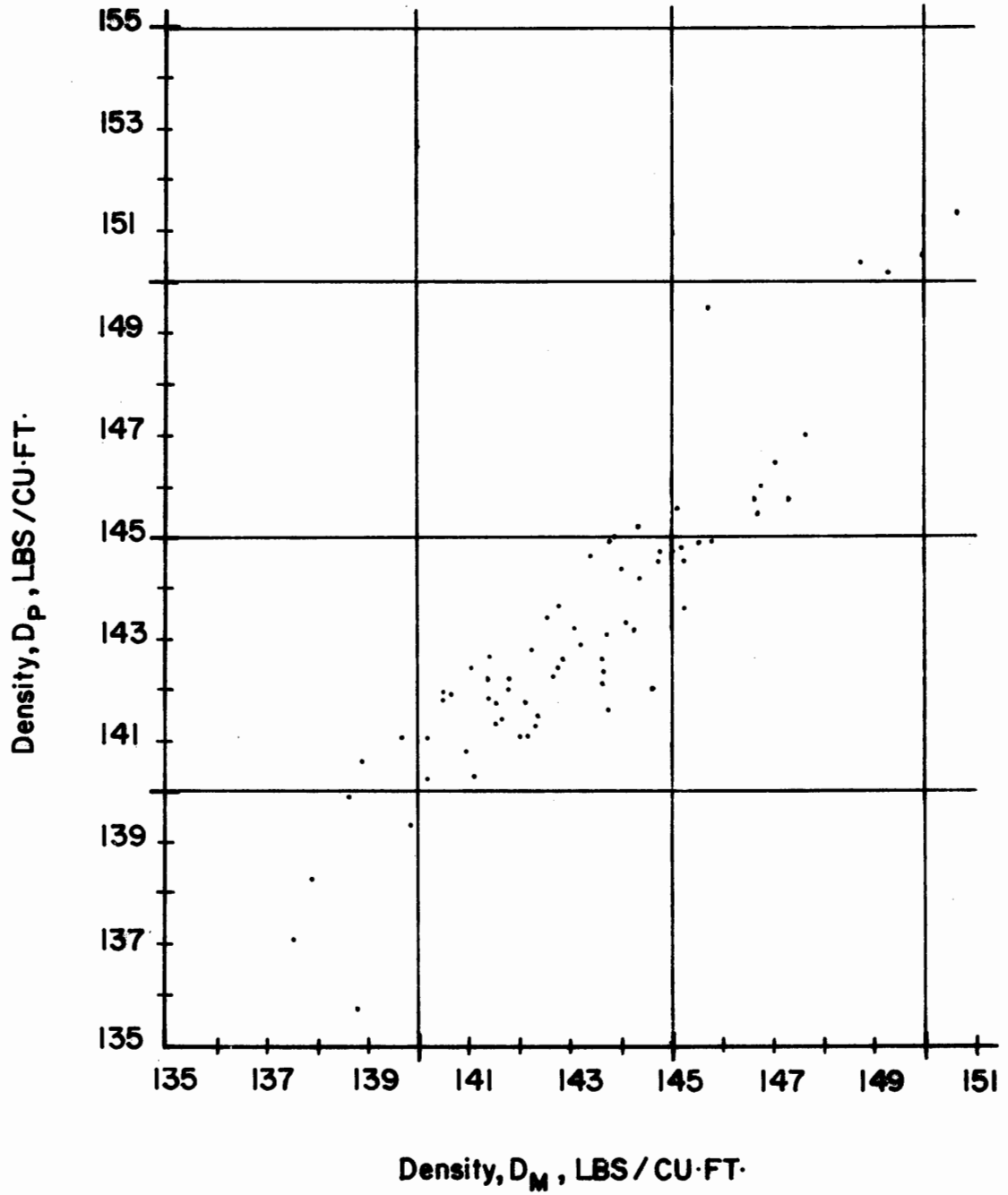


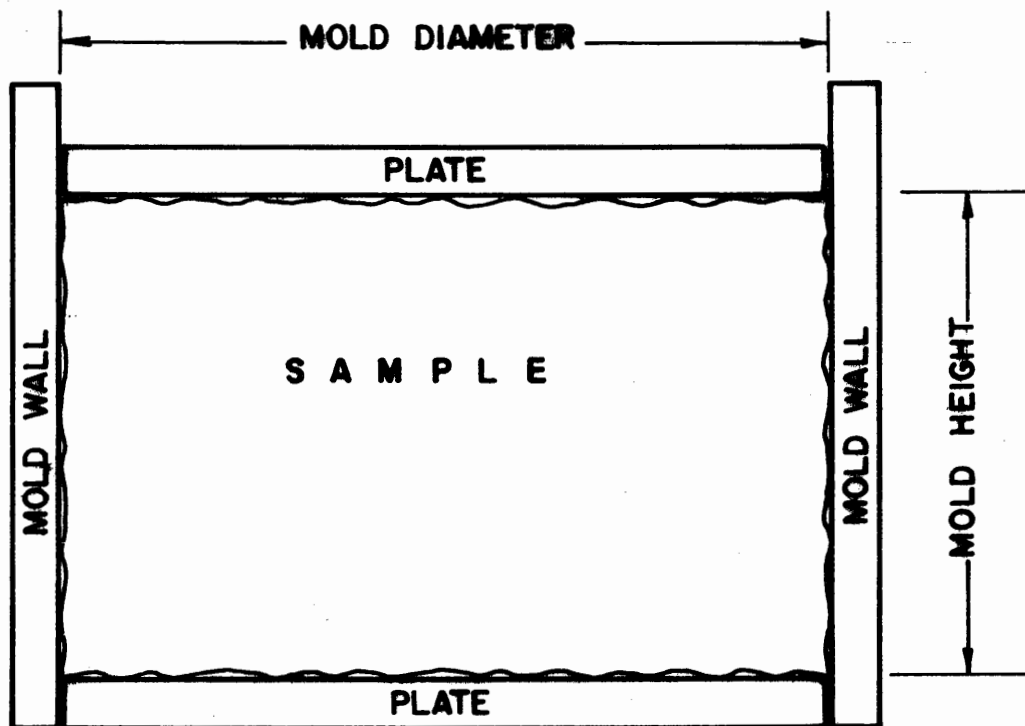
(FIG-2)  
DENSITY BASED ON SATURATED SURFACE DRY  
SAMPLE ( $D_{SS}$ )  
V-S.  
DENSITY BASED ON MOLD SIZE ( $D_M$ )



(FIG-3)

DENSITY BASED ON PLASTIC COATED  
WEIGHT ( $D_p$ )  
V.S.  
DENSITY BASED ON MOLD SIZE ( $D_M$ )

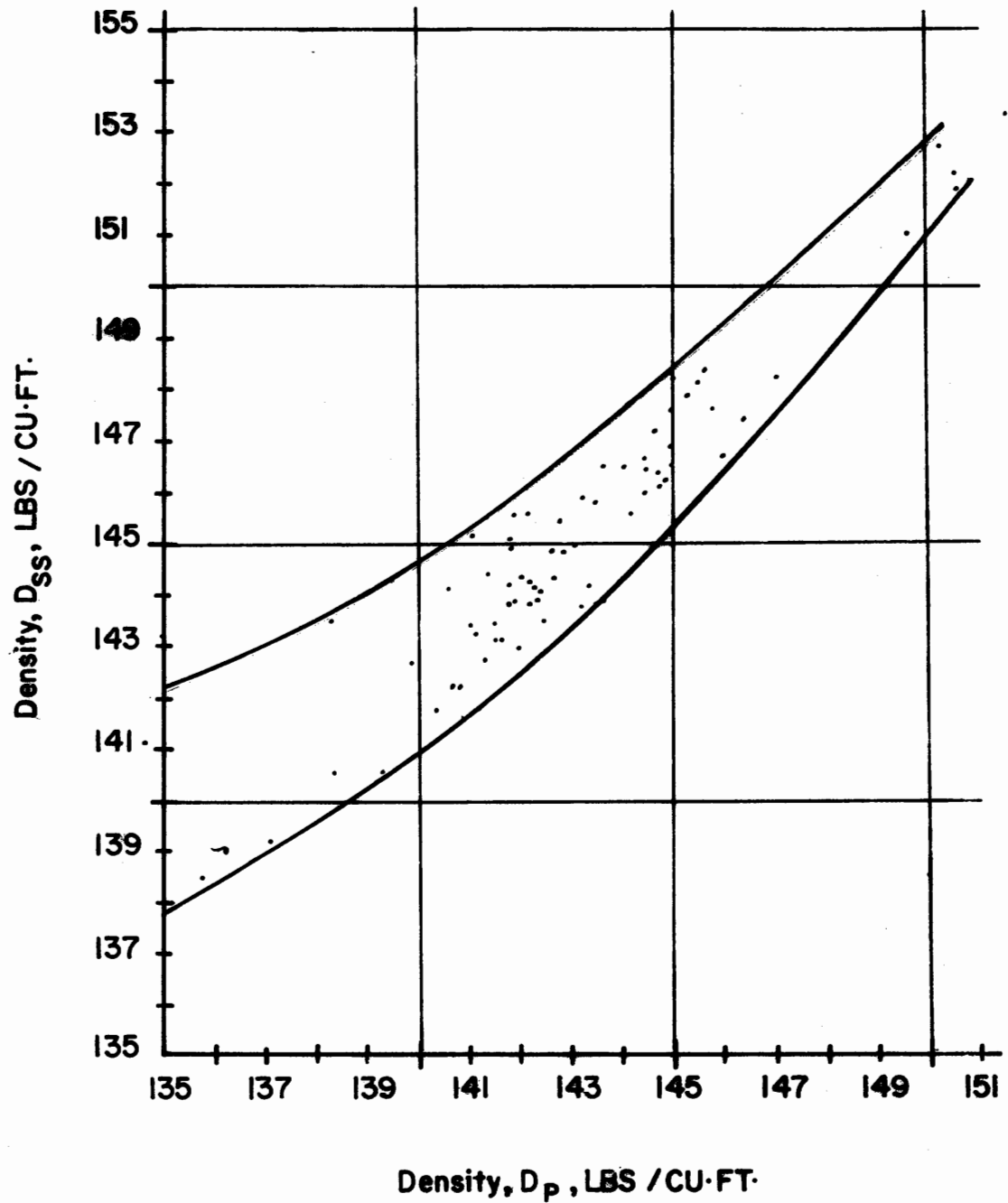




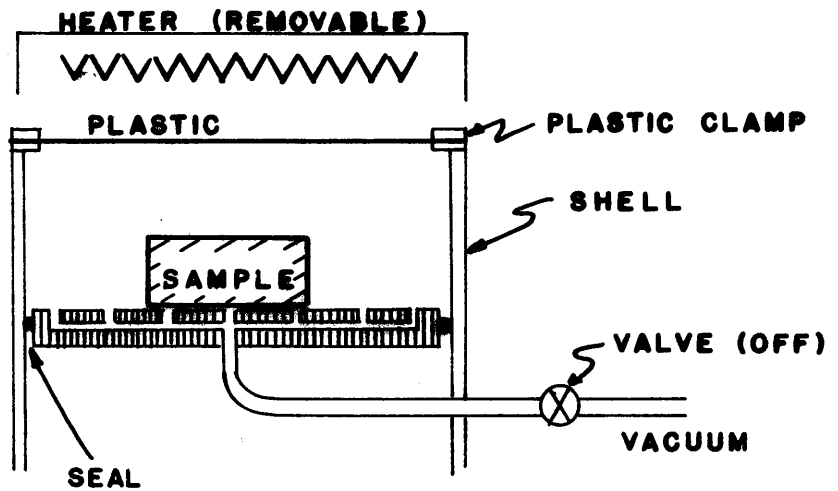
(FIG. 4)

DIAGRAMATIC SKETCH COMPARING  
SAMPLE SIZE FROM MOLD TO TRUE  
SAMPLE. MOLD MUST BE LARGER.

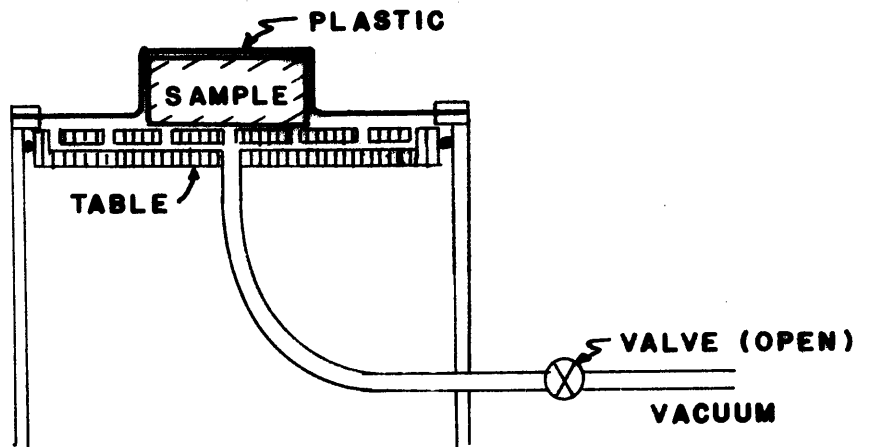
(FIG. 5)  
 DENSITY BASED ON SATURATED SURFACE  
 DRY SAMPLE ( $D_{SS}$ )  
 V.S.  
 DENSITY BASED ON PLASTIC COATED WEIGHT ( $D_p$ )



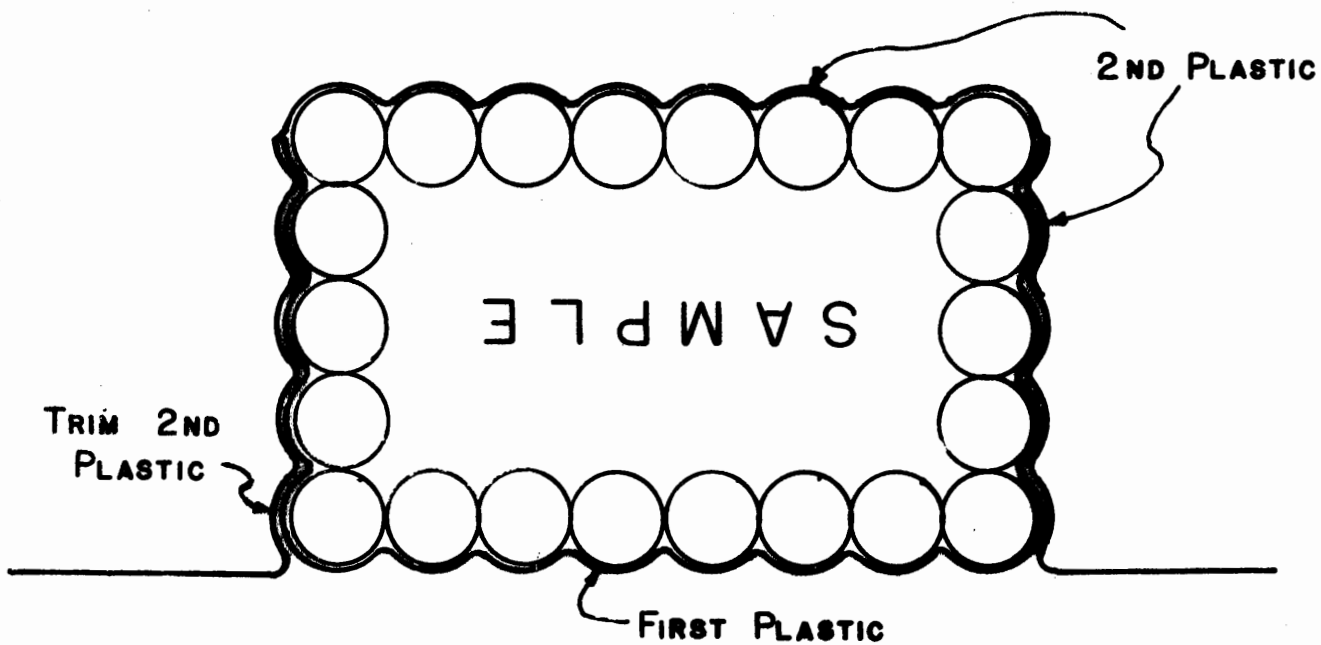
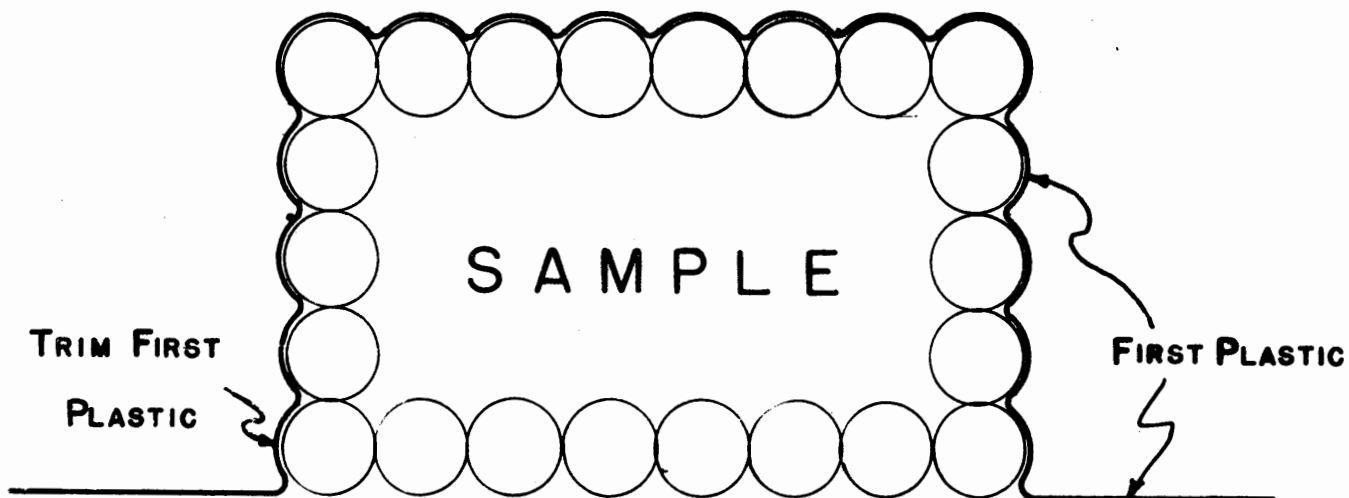
(FIG. 6)  
VACUUMFORMER



PLASTIC, SAMPLE, AND PLASTIC HEATER IN PLACE



HEATER REMOVED, PACKAGING TABLE PULLED UP AND PLASTIC MOLDED TO SAMPLE BY VACUUM



(FIG. 7)  
STEPS IN APPLYING PLASTIC TO SAMPLES