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DENSITY MEASUREMENTS OF CURVED FOAM
PARTS USING RADIOGRAPHIC-FILM TECHNIQUE

By W. J. Bowden

Published October 1978

Final Report

Prepared for the United States Department of Energy
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Final Report
W. J. Bowden, Project Leader

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DENSITY MEASUREMENTS OF CURVED FOAM PARTS USING RADIOGRAPHIC-FILM
TECHNIQUE

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Prepared by W. J. Bowden

A study to determine the feasibility of using film-density measurements from in-motion radiographic images to determine the density of curved parts having a nonuniform thickness indicates a measurement-accuracy range from 5 to 11 percent. Development of the fixturing and use of calibration standards are described. Using digitally controlled, regulated power supplies and fixed-geometry fixturing, part density could be determined to an estimated accuracy of 5 percent or better.

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CONTENTS

Section	Page
SUMMARY.	5
DISCUSSION	6
SCOPE AND PURPOSE.	6
ACTIVITY	6
<u>Background</u>	6
<u>Density-Measurement Theory</u>	7
<u>Fixture Fabrication</u>	9
<u>Film-Density Measurement</u>	10
<u>DXT Calibration Curve</u>	11
<u>Calculation of Part Density</u>	12
<u>Analysis of Results</u>	12
ACCOMPLISHMENTS.	17
FUTURE WORK.	18
REFERENCES	19
APPENDIX. TABULAR DATA.	20
DISTRIBUTION	50

ILLUSTRATIONS

Figure		Page
1	General Configuration of Molded Foam Part. . .	8
2	Cross Section of Penetrameter.	10
3	In-Motion Radiographic Fixture (P-97659) . . .	11
4	Schematic of In-Motion Radiographic Fixture. .	12
5	Diagram Showing Film-Density-Measurement Locations for Part and Penetrameter.	13

TABLES

Number		Page
1	DXT Versus Film Density.	14
2	Thickness Values for Selected Locations on Right-Hand Penetrameter.	15
A-1	Thickness Measurements From Segment 2 of Parts.	21
A-2	Uncorrected Film-Density Measurements From Specific Locations on Parts.	23
A-3	Uncorrected Film-Density Measurements From Specific Penetrameter Locations.	31
A-4	Normalized Film-Density Measurements From Specific Locations on Parts.	35
A-5	Normalized Film-Density Measurements From Specific Penetrameter Locations.	43
A-6	Results of Density Calculations for Segment 2 of Parts	47
A-7	Part Density Calculated by Weight-Volume Method	49

SUMMARY

This project was initiated to investigate the feasibility of using film-density measurements from radiographic images to determine the density of curved parts having a nonuniform thickness. A curved part mounted on a turntable was radiographed through a collimating slot to produce in-motion radiographs of ten polypropylene foam parts. A section was cut out of each part and divided into five segments, and the density of each segment was determined by the weight-volume method.

Film-density readings taken from a solid-polypropylene standard (penetrameter) were used to obtain a calibration curve. Film-density readings taken from the X-ray film at points corresponding to the segment locations were compared to the information from the standard to obtain density-times-thickness (DXT) values for the measurement locations. The part density then was calculated by dividing each DXT value by the thickness of the part at the point on the segment corresponding to the location at which the film density was determined.

The calculated part-density values obtained from data taken from each radiograph were compared to part-density values obtained by the weight-volume method. The results from the two methods were found to vary over a range of 5 to 11 percent. Using digitally controlled, highly regulated power supplies and fixed-geometry fixturing, part density could be determined to an estimated accuracy of 5 percent or better.

Visually determining whether the film density of the part image was between the film densities of the penetrameter images proved to be impossible. The difference in the two penetrameters represented a ± 4.5 -percent change in part density. Changes of ± 10 percent or more in the penetrameter thickness possibly could be visually detected.

DISCUSSION

SCOPE AND PURPOSE

Density variations in rectangular volumes or in solid or hollow cylindrical parts are routinely measured by the use of X-ray or gamma-ray DXT (density-times-thickness) gages. Because these gages rely on one of two factors remaining constant in order to measure changes in the other, to determine variations in part density, the part thickness must be constant. For this reason, density measurements of parts which do not have a uniform thickness are very difficult to make on a DXT gage.

This project was initiated to investigate the feasibility of using film-density measurements from radiographic images to determine the density of curved parts having a nonuniform thickness.

ACTIVITY

Background

Almost without exception, foam parts previously have been machined from solid billets or hollow cylinders of material. More recently, foam parts have been directly cast to the required shape and size. While foam billets can be easily gaged by the use of X-ray equipment, cast parts rarely have regular shapes with uniform thicknesses that permit the use of standard radiation-gaging techniques.

During 1976 and 1977, Bendix Kansas City had been endeavoring to develop a method for fabricating foam parts by an injection-molding process. To assess the progress of the development, engineering personnel wanted to determine any variation in the density of the molded parts and to obtain radiographs showing the internal structure of the foam.

Because the part that was being developed was curved and had a nonuniform cross section (Figure 1), the question immediately arose as to how density information could be obtained for parts that could not be easily measured with a standard DXT radiation gage. Since the obtaining of a radiograph was necessary for inspecting the internal structure of the part, using the same radiograph to provide density-variation data seemed to be a logical step.

Density-Measurement Theory

The method described in this report for determining the density of a foam part utilizes data obtained from radiographic-film images of both the part and a calibration standard (penetrameter) that is radiographed along with the part. From a knowledge of the thickness and density of the penetrameter, a calibration curve can be established to show DXT-versus-film-density values. Using this curve, film-density readings obtained from the part can be converted to equivalent DXT values. Dividing these values by part-thickness measurements made at locations on the part corresponding to the locations at which the film-density readings were taken provides calculations of the part density.

X-ray radiation is attenuated by material in its path in the exponential manner described by the following equation:

$$I = I_0 \epsilon^{-\mu t}; \quad (1)$$

where

I_0 = level of radiation striking the material;

I = level of radiation after being attenuated by the material;

ϵ = 2.718281828;

μ = linear-absorption coefficient; and

t = material thickness (in cm).

Equation 1 can be modified by dividing the linear-absorption coefficient by the material density to obtain the mass-absorption coefficient. Restated, the equation then becomes

$$I = I_0 \epsilon^{-m(\rho t)}, \quad (2)$$

where

$m = \frac{\mu}{\rho}$ = mass-absorption coefficient, and

ρ = material density.

The mass absorption of a material varies according to the wavelength of the energy striking its surface.¹ The wavelength of the X-radiation that is generated is a function of the anode voltage of the X-ray tube. From Equation 2, variations in the

Figure 1. General Configuration of Molded Foam Part

mass absorption (X-ray-tube anode voltage), material density, or material thickness will change the amount of radiation that is absorbed by the material in the X-ray beam. By maintaining a constant X-ray-tube anode voltage, only density and thickness remain as variables in radiation gaging or in the imaging of a radiograph.

Assuming that solid polypropylene and polypropylene foam have the same chemistry, the mass-absorption coefficient is the same for both. When the X-ray attenuation for a certain thickness of one material is the same as the attenuation for a certain thickness of the other material,

$$I_{\text{solid}} = I_{\text{foam}}, \quad (3)$$

$$I_0 e^{-\mu(\text{solid}) t_{\text{solid}}} = I_0 e^{-\mu(\text{foam}) t_{\text{foam}}}, \quad (4)$$

and

$$\mu_{\text{solid}} t_{\text{solid}} = \mu_{\text{foam}} t_{\text{foam}}. \quad (5)$$

From the application of Equation 3, an X-ray film showing simultaneous exposures of the solid polypropylene and polypropylene foam would register the same film density for both images, and the DXT value of the solid polypropylene would equal that of the foam. A solid polypropylene calibration standard therefore can be used to obtain a film-density-versus-DXT curve representing a foam material. The use of a solid standard is preferred to that of a foam standard because the density of the solid material is considerably more uniform than the density of foam (Figure 2).

Using the density and thickness of the solid polypropylene standard together with the film densities taken at the locations of the thickness measurements, linear, exponential, and logarithmic curve fits were applied to obtain by trial-and-error the best curve fit. The curve-fitting was done with a programmable calculator. The best fit was found to be of the following type:

$$Y = ae^{bx}; \quad (6)$$

where

Y = DXT value;

a = a constant;

b = a constant; and

x = film density.

The following values were determined for the a and b constants by the calculator:

$a = 3.513286679$; and

$b = -1.122455244$.

The curve fit was found to be 0.995.

Fixture Fabrication

For convenience in reading the X-ray film, and to provide a means of maintaining the X-ray beam normal to both the part and the film, an in-motion radiographic fixture was developed (Figures 3 and 4).

The cross section of the polypropylene foam part was shaped somewhat like the airfoil of an airplane wing, and it was curved as though the wing were built with a concave spar. Placing the

Figure 2. Cross Section of Penetrameter

part on edge on a rotating table in such a manner that the center of the table was at the radius of the concave surface provided a pivoting of the part in front of the X-ray tube. The X-ray beam was passed through a vertical slot so that only a narrow section of the remaining beam impinged on the part to expose the film placed along the curved back surface of the part.

A precision rotating table was mounted on a fixture plate by the Nondestructive Testing Laboratory and geared to a reversible, variable-speed motor. The motor controls were modified to automatically reverse the rotational direction at the end of 170 degrees of travel. A backlash spring was used to keep gear chatter from affecting the motion of the table.

An aluminum plate, large enough to prevent X-rays from striking the film, was backed with lead and mounted on the base of the fixture in front of the turntable. A machined slot, 5.537 mm wide by 152.4 mm high (0.218 by 6.0 inches), in the plate was centered in front of the table so that a line passing through the slot normal to the plane of the plate would pass through the rotational center of the table.

A supporting structure was attached to the table to hold the part, the X-ray film, and two solid-polypropylene standards. The standards were mounted at each end of the support.

Film-Density Measurement

Film density was measured by the use of a quantalog densitometer. This device compares the intensity of the transmitted light (I) to the intensity of the source (I_0), as indicated by the following equation.

$$\text{Film Density} = \log_{10} \left(\frac{I_0}{I} \right). \quad (7)$$

Selected locations on the X-ray film were measured and recorded. The left-hand portion of Figure 5 shows the locations on the X-ray film where film-density readings were taken. This section of film coincides with the section cut out of the part which was

Figure 3. In-Motion Radiographic Fixture

divided into five segments. The right-hand portion of Figure 5 shows a section of film containing the penetrameter image. Film-density readings were taken along the center line of the penetrameter in the same locations as the rows shown for the part. Although only one penetrameter image is shown in the diagram, the other penetrameter image also was marked and measured in a similar manner.

DXT Calibration Curve

The use of film-density measurements for determining part density requires generating a curve from the image of the penetrameter standard in each radiograph. The right-hand standard was used to obtain a curve showing density-times-thickness (DXT) versus film

Figure 4. Schematic of In-Motion Radiographic Fixture

density. Values for the curve are shown in Table 1. DXT values were calculated using 0.908 g/cm^3 for the density of solid polypropylene. This value was obtained by the weight-volume method.

The ten film-density readings obtained for each position on the penetrameter were averaged. These average values then were used with the thickness values shown in Table 2 to generate the curve.

Calculation of Part Density

To calculate the density of the part at a point corresponding to a film-density-reading location on the part, the film-density value is first substituted into Equation 6 to determine the DXT value. The DXT value then is divided by the thickness of the part (in cm) at the film-density-measurement location to provide the density at that particular location (in g/cm^3).

Analysis of Results

Ten parts were X-rayed according to the previously described procedure, and the film was processed. After all parts had been radiographed, a 25.4-mm-wide (1 inch) section to the right of the part center line (viewing the concave surface) was machined from each part, and the large section was subdivided into five segments. The density of each segment was determined by the weight-volume method using water-immersion, weights, and an analytical balance. The thickness of Segment 2 then was measured at 16 positions for each part (Table A-1).

Figure 5. Diagram Showing Film-Density-Measurement Locations for Part (Left) and Penetrameter (Right)

The portion of each X-ray film corresponding to the 25.4-mm (1 inch) section of the part that was removed for the density measurement was marked to show the five segments that were cut from each section. Segments 1 through 4 were further marked into 6.35-mm (0.250 inch) squares. Segments 2 through 4 contained 16 squares each, and Segment 1 contained 20 squares. Film-density measurements were taken with a densitometer at the center of each of the squares, using conventional operating procedures (Table A-2).

Table 1. DXT Versus Film
Density

DXT Value*	Film-Density Value
0.1743	2.56
0.3054	2.24
0.4357	1.93
0.5749	1.64
0.7208	1.44
0.8545	1.28
0.9910	1.13
1.1024	1.03
1.1186	1.00
1.1186	1.00
1.1174	1.00
1.0994	1.00

*Density of solid polypropylene
= 0.908 g/cm³.

Each penetrameter image was marked to correspond to the part-segment rows, 1 through 4. Film-density measurements then were taken along both sides of the center line of the penetrameter image at each row (Table A-3).

The film density is inversely proportional to the product of the part density and the part thickness. Thus if the thickness is constant, the variations in the film density are a measure of the part density. Under these conditions, an area where the film is darker (having a higher film density) than the other portions of the film (having a lower film density) indicates that the corresponding part location has less density than the other portions of the part. If both the part thickness and density vary, interpreting the X-ray film becomes impossible unless techniques are used to provide comparison standards of known thickness and density in each film. For this evaluation, comparison standards were included in each radiograph.

Table 2. Thickness Values
for Selected
Locations on
Right-Hand
Penetrameter

Location*	Thickness (cm)
4A	0.1920
4E	0.3363
4I	0.4798
4M	0.6332
3A	0.7938
3E	0.9411
3I	1.0914
3M	1.2141
2A	1.2319
2E	1.2319
2I	1.2306
2M	1.2108

*Refer to Figure 5 for
diagram of measurement
locations.

Film-density variations of the penetrameter images from film-to-film are an indication of variation in the parameters controlling the imaging and processing of the films. Imaging variables include X-ray-tube voltage adjustment, voltage regulation, current adjustment, and current regulation, together with accuracy of exposure time, distance from film to focal spot (X-ray tube), and control of the film-manufacturing process. Processing variables in the use of an automatic processor include the mixing of the chemicals, replenishment of the developer, temperature of the water and chemicals, and the action of the film-transport system within the processor.

The total variation in all of the combined variables must be limited to ± 2.0 percent to maintain a variation no greater than ± 0.05 film-density units at a film density of 2.50 units. There-

fore, in an effort to normalize the variability from film-to-film, the film-density readings from each of the ten films were shifted by whatever number of film-density units necessary to adjust Segment 2 of the right-hand penetrameter to a film density of 1.00. The values obtained are shown in Tables A-4 and A-5.

A comparison of results from the two solid polypropylene penetrameters indicated that even though they were shaped on a tape-controlled machine, the one which was intended to be 10-percent thicker at all points actually was thinner at each end than the thin penetrameter. Hence, the film-density readings at Positions 4A, 4E (every time), and 1Q (part of the time) of the left-hand (thicker) penetrameter were higher than corresponding readings from the right-hand penetrameter.

Position 4M was reported to be higher in film density than the corresponding point on the right-hand penetrameter for two out of the ten films. At the position where these measurements were taken, there was no reversal of the penetrameter dimensions. Therefore, part or all of the variation had to be attributed to the previously mentioned lack of precise control of the imaging and processing variables. In order for the part density to be obtained as described in this report, variations in all of the variables must be minimized.

To illustrate how part density was determined using film density and part thickness, the density for each of the 16 locations in Segment 2 were calculated for each part and listed in Table A-6. The weight-volume density values for Segments 1 through 4 are listed for each part in Table A-7.

The resulting density values for each segment, when averaged, were from 5.84 to 20.3 percent lower than the values obtained from the weight-volume calculations for the same segment. If the 25-3-12 film had not been included, the range would have been from 5.84 to 11.07 percent, and the average of the remaining films would have been 8.37 percent less than the value obtained by the weight-volume method.

Included in the deviation in the calculated density values is the error in measuring the part thickness at locations corresponding to the film-density measurements. For Segment 2, a ± 0.254 -mm (± 0.010 inch) error in the thickness measurement is equivalent to a ± 1.2 -percent deviation in the part density.

By using available in-plant X-ray machines with improved alignment techniques and a more precise method of part-thickness measurement, the part-density measurement error could be reduced to an estimated ± 5.0 percent. Further improvement would require

the use of highly regulated, digitally set power supplies for the X-ray tube in order to obtain and maintain a uniform, repeatable X-ray beam.

The two penetrameters, which proved to have a thickness difference of 9 percent in Segment 2 (the goal was 10 percent), were included in each film in hope that their different film densities would indicate whether the film density of the part was less than one of the penetrameters and greater than the other. Then, if the acceptance limits for the part were ± 5 percent, the film reader could determine by observation whether the part density was within the specified limits.

The difference in film density corresponding to the ± 4.5 -percent dimensional difference in the part was so slight that the possibility of detecting a change of this magnitude was negated. Using the techniques and equipment that were employed in this investigation, the chance that a change of ± 10 percent would be visually discerned is marginal.

A further consideration in using the described method for determining part density is the large amount of data that would be required for each part, and the data reduction that would be necessary to calculate the results. Part quantities in excess of a relatively small number could require a considerable amount of inspection time, thus making the inspection cost per part rather high when compared to the cost of parts that could be measured by a radiation-density gage. The cost might be justified, however, if the part could not be measured by any other means. This, of course, would require a management decision to justify the expense, and it in no way alters the accuracy of the described method.

ACCOMPLISHMENTS

The results of this investigation indicate that part density can be measured from X-ray film to an accuracy of 8 ± 3 percent using available equipment and standard radiographic procedures, provided that a method is available for measuring the thickness of the part at the point corresponding to the location on the X-ray film where the film density is measured.

Using digitally controlled, highly regulated power supplies and fixed-geometry fixturing, part density could be determined to an estimated accuracy of 5 percent or better.

FUTURE WORK

Should the technique described in this report for determining part density be further pursued, improved fixturing to provide a fixed X-ray-tube-to-part geometry would be required. A power supply providing a high degree of both voltage and current regulation should be used to energize the X-ray tube, and an improved means of measuring the part thickness should be devised. If these improvements cannot be made, the recommendation is offered that no further work be done in this field.

REFERENCES

¹Robert C. McMasters, editor, *Nondestructive Testing Handbook*.
New York: Ronald Press, 1959, p 18-32 through 18-40.

Appendix
TABULAR DATA

Table A-1. Thickness Measurements From Segment 2 of Parts

Location*	Thickness of Part Indicated				
	25-1-8 (cm)	25-2-7 (cm)	25-2-8 (cm)	25-3-5 (cm)	25-3-7 (cm)
A	2.09550	2.10312	2.09296	2.00914	2.10312
B	2.09296	2.10566	2.09042	2.01168	2.10312
C	2.09296	2.10566	2.08788	2.01168	2.10058
D	2.08534	2.10312	2.08534	2.00914	2.08788
E	2.11328	2.11836	2.10820	2.00914	2.11836
F	2.11074	2.11836	2.10566	2.01422	2.11836
G	2.10566	2.11836	2.10058	2.01422	2.11582
H	2.10566	2.11382	2.07772	2.01422	2.11074
I	2.09042	2.10312	2.09042	1.99644	2.10312
J	2.09550	2.10312	2.08280	1.99898	2.10312
K	2.09550	2.10312	2.08534	2.00406	2.10058
L	2.09550	2.10312	2.07772	2.00406	2.09550
M	2.03962	2.01930	2.02438	1.94564	2.03200
N	2.03200	2.03454	2.01930	1.95580	2.04470
O	2.02692	2.02692	2.01930	1.95834	2.03200
P	2.02692	2.02692	2.02184	1.95326	2.03200
	25-3-8	25-3-9	25-3-10	25-3-11	25-3-12
A	2.09042	2.08788	2.08280	2.07264	2.05740
B	2.09042	2.08534	2.07772	2.06248	2.05740
C	2.08534	2.08280	2.07518	2.06248	2.05232
D	2.08280	2.08280	2.07264	2.05994	2.05232
E	2.10566	2.10312	2.09296	2.07772	2.06756
F	2.10312	2.10058	2.09042	2.07518	2.06502
G	2.09804	2.09550	2.08788	2.07264	2.06248
H	2.09550	2.09296	2.08534	2.07010	2.05994
I	2.08534	2.08534	2.07264	2.06248	2.05232
J	2.08280	2.08788	2.07772	2.05994	2.05232
K	2.08534	2.08026	2.07772	2.05740	2.05232

Table A-1 Continued. Thickness Measurements From Segment 2 of Parts

Location*	Thickness of Part Indicated				
	25-3-8 (cm)	25-3-9 (cm)	25-3-10 (cm)	25-3-11 (cm)	25-3-12 (cm)
L	2.08280	2.07772	2.06756	2.05740	2.05232
M	2.02946	2.03200	2.00914	1.99644	1.98882
N	2.02692	2.01676	2.01422	1.99898	1.98374
O	2.02692	2.02184	2.00914	2.00152	1.98120
P	2.02438	2.01676	2.00914	1.99898	1.98374

*Refer to Figure 5 for diagram of measurement locations.

Table A-2. Uncorrected Film-Density Measurements From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-1-8	A	1.32	1.07	1.54	2.96
	B	1.30	1.06	1.53	2.96
	C	1.34	1.07	1.52	2.93
	D	1.35	1.08	1.54	2.93
	E	1.44	1.06	1.40	2.42
	F	1.47	1.07	1.36	2.48
	G	1.47	1.06	1.36	2.43
	H	1.50	1.07	1.38	2.46
	I	1.62	1.04	1.24	2.05
	J	1.62	1.05	1.21	2.07
	K	1.62	1.04	1.24	2.07
	L	1.64	1.09	1.24	2.09
	M	1.85	1.05	1.12	1.74
	N	1.86	1.06	1.17	1.73
	O	1.82	1.06	1.13	1.73
	P	1.84	1.06	1.14	1.73
	Q	2.46			
	R	2.45			
	S	2.46			
	T	2.44			
25-2-7	A	1.36	1.14	1.67	3.27
	B	1.36	1.14	1.65	3.28
	C	1.34	1.16	1.66	3.28
	D	1.40	1.16	1.65	3.28
	E	1.54	1.13	1.42	2.70
	F	1.56	1.10	1.48	2.69
	G	1.55	1.13	1.47	2.65
	H	1.54	1.12	1.52	2.70

Table A-2 Continued. Uncorrected Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-2-7	I	1.72	1.11	1.31	2.21
	J	1.72	1.11	1.32	2.23
	K	1.71	1.11	1.29	2.21
	L	1.70	1.15	1.34	2.22
	M	1.91	1.10	1.23	1.88
	N	1.94	1.12	1.20	1.88
	O	1.91	1.13	1.22	1.92
	P	1.92	1.16	1.20	1.90
	Q	2.55			
	R	2.57			
	S	2.54			
	T	2.54			
25-2-8	A	1.43	1.18	1.69	3.26
	B	1.40	1.18	1.68	3.22
	C	1.41	1.16	1.66	3.24
	D	1.42	1.16	1.66	3.22
	E	1.57	1.14	1.50	2.68
	F	1.57	1.16	1.51	2.65
	G	1.56	1.17	1.49	2.67
	H	1.55	1.16	1.50	2.68
	I	1.72	1.12	1.34	2.21
	J	1.79	1.11	1.36	2.21
	K	1.74	1.13	1.37	2.22
	L	1.75	1.14	1.38	2.22
	M	1.94	1.13	1.25	1.89
	N	1.95	1.13	1.26	1.91
	O	1.92	1.12	1.29	1.93
	P	1.93	1.14	1.26	1.91

Table A-2 Continued. Uncorrected Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-2-8	Q	2.58			
	R	2.60			
	S	2.59			
	T	2.58			
25-3-5	A	1.33	1.09	1.55	3.01
	B	1.33	1.15	1.57	3.04
	C	1.37	1.07	1.63	3.00
	D	1.34	1.13	1.64	3.07
	E	1.49	1.12	1.42	2.52
	F	1.48	1.11	1.39	2.50
	G	1.51	1.10	1.46	2.51
	H	1.50	1.14	1.43	2.51
	I	1.66	1.06	1.33	2.10
	J	1.66	1.10	1.25	2.10
	K	1.66	1.12	1.28	2.11
	L	1.70	1.15	1.29	2.12
	M	1.87	1.13	1.16	1.81
	N	1.87	1.13	1.18	1.79
	O	1.87	1.13	1.14	1.78
	P	1.88	1.17	1.16	1.83
	Q	2.45			
	R	2.45			
	S	2.44			
	T	2.50			
25-3-7	A	1.20	1.00	1.44	2.80
	B	1.19	0.98	1.48	2.83
	C	1.17	0.99	1.44	2.80
	D	1.17	0.99	1.46	2.81

Table A-2 Continued. Uncorrected Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-7	E	1.33	0.96	1.27	2.34
	F	1.34	1.00	1.25	2.36
	G	1.34	0.99	1.27	2.34
	H	1.32	0.96	1.29	2.34
	I	1.47	0.97	1.15	1.99
	J	1.48	0.99	1.15	1.96
	K	1.49	0.97	1.16	1.96
	L	1.49	0.95	1.15	1.98
	M	1.66	0.97	1.03	1.66
	N	1.69	0.97	1.05	1.64
	O	1.66	1.02	1.05	1.69
	P	1.68	0.99	1.05	1.66
	Q	2.24			
	R	2.24			
	S	2.24			
	T	2.24			
25-3-8	A	1.24	1.01	1.46	2.95
	B	1.24	1.01	1.48	2.94
	C	1.23	1.02	1.49	2.92
	D	1.25	1.02	1.48	2.91
	E	1.35	1.00	1.31	2.41
	F	1.34	1.00	1.30	2.41
	G	1.35	1.02	1.35	2.44
	H	1.42	1.01	1.33	2.43
	I	1.52	0.98	1.26	2.04
	J	1.54	0.98	1.18	2.04
	K	1.52	1.00	1.19	2.05
	L	1.52	0.98	1.17	2.06

Table A-2 Continued. Uncorrected Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-8	M	1.73	1.04	1.08	1.69
	N	1.72	1.00	1.07	1.74
	O	1.72	1.00	1.09	1.70
	P	1.74	1.00	1.07	1.72
	Q	2.27			
	R	2.28			
	S	2.27			
	T	2.29			
25-3-9	A	1.31	1.07	1.56	3.11
	B	1.31	1.06	1.59	3.12
	C	1.31	1.06	1.58	3.11
	D	1.31	1.08	1.58	3.13
	E	1.43	1.03	1.43	2.58
	F	1.48	1.05	1.42	2.60
	G	1.44	1.05	1.42	2.58
	H	1.45	1.08	1.41	2.60
	I	1.59	1.03	1.23	2.14
	J	1.61	1.04	1.29	2.18
	K	1.60	1.05	1.27	2.14
	L	1.61	1.05	1.29	2.13
	M	1.79	1.05	1.17	1.81
	N	1.82	1.04	1.17	1.85
	O	1.81	1.05	1.16	1.81
	P	1.81	1.06	1.17	1.83
	Q	2.41			
	R	2.43			
	S	2.42			
	T	2.40			

Table A-2 Continued. Uncorrected Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-10	A	1.31	1.11	1.56	3.03
	B	1.31	1.09	1.55	3.09
	C	1.33	1.12	1.59	3.10
	D	1.32	1.13	1.61	3.06
	E	1.44	1.05	1.39	2.51
	F	1.48	1.05	1.41	2.53
	G	1.50	1.10	1.40	2.58
	H	1.48	1.10	1.39	2.53
	I	1.61	1.04	1.24	2.13
	J	1.64	1.04	1.27	2.14
	K	1.64	1.07	1.30	2.15
	L	1.65	1.07	1.29	2.15
	M	1.83	1.06	1.13	1.80
	N	1.81	1.06	1.17	1.83
	O	1.84	1.08	1.19	1.84
	P	1.84	1.07	1.20	1.85
	Q	2.43			
	R	2.45			
	S	2.47			
	T	2.47			
25-3-11	A	1.27	1.10	1.53	3.00
	B	1.28	1.08	1.56	2.99
	C	1.30	1.07	1.57	2.99
	D	1.29	1.10	1.54	3.00
	E	1.43	1.04	1.36	2.46
	F	1.43	1.05	1.38	2.47
	G	1.43	1.05	1.39	2.48
	H	1.43	1.06	1.39	2.44

Table A-2 Continued. Uncorrected Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-11	I	1.55	1.04	1.20	2.04
	J	1.60	1.05	1.25	2.04
	K	1.65	1.02	1.25	2.05
	L	1.58	1.04	1.28	2.04
	M	1.76	1.04	1.15	1.78
	N	1.79	1.05	1.13	1.75
	O	1.77	1.08	1.14	1.75
	P	1.77	1.07	1.11	1.74
	Q	2.39			
	R	2.41			
	S	2.39			
	T	2.40			
25-3-12	A	1.30	1.08	1.56	3.06
	B	1.32	1.09	1.56	3.02
	C	1.32	1.10	1.56	3.01
	D	1.36	1.10	1.53	3.04
	E	1.46	1.07	1.40	2.49
	F	1.47	1.06	1.40	2.48
	G	1.47	1.05	1.41	2.56
	H	1.48	1.12	1.44	2.54
	I	1.64	1.12	1.24	2.11
	J	1.62	1.06	1.24	2.09
	K	1.61	1.06	1.29	2.10
	L	1.62	1.08	1.26	2.10
	M	1.81	1.08	1.15	1.80
	N	1.82	1.05	1.14	1.82
	O	1.81	1.07	1.14	1.79
	P	1.84	1.06	1.17	1.82

Table A-2 Continued. Uncorrected Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-12	Q	2.43			
	R	2.44			
	S	2.44			
	T	2.44			

*Refer to Figure 5 for diagram of part segments and measurement locations.

**Values shown are from densitometer.

Table A-3. Uncorrected Film-Density Measurements From Specific Penetrameter Locations

Location*	Film Density** for Penetrameter Exposed With Indicated Part					
	25-1-8		25-2-7		25-2-8	
	Left	Right	Left	Right	Left	Right
4A	2.78	2.45	2.92	2.65	2.88	2.72
4E	2.28	2.13	2.40	2.30	2.35	2.33
4I	1.91	1.86	1.94	1.94	1.95	2.04
4M	1.61	1.55	1.62	1.64	1.62	1.73
3A	1.37	1.35	1.39	1.46	1.41	1.49
3E	1.18	1.18	1.22	1.29	1.21	1.32
3I	1.04	1.04	1.09	1.14	1.07	1.18
3M	0.94	0.96	0.98	1.03	0.97	1.06
2A	0.91	0.96	0.92	1.01	0.93	1.02
2E	0.91	0.96	0.92	1.01	0.92	1.03
2I	0.91	0.96	0.92	1.00	0.92	1.02
2M	0.91	0.97	0.92	1.00	0.93	1.03
1A	1.20	1.24	1.22	1.31	1.22	1.36
1E	1.39	1.42	1.42	1.48	1.38	1.55
1I	1.57	1.61	1.60	1.66	1.56	1.74
1M	1.74	1.76	1.80	1.84	1.76	1.92
1Q	2.40	2.27	2.42	2.37	2.40	2.44

Table A-3 Continued. Uncorrected Film-Density Measurements From
Specific Penetrameter Locations

Location*	Film Density** for Penetrameter Exposed With Indicated Part					
	25-3-5		25-3-7		25-3-8	
	Left	Right	Left	Right	Left	Right
4A	2.66	2.62	2.55	2.42	2.67	2.41
4E	2.21	2.28	2.13	2.14	2.16	2.12
4I	1.81	1.98	1.75	1.84	1.79	1.82
4M	1.52	1.67	1.48	1.55	1.50	1.56
3A	1.33	1.46	1.25	1.37	1.27	1.33
3E	1.14	1.28	1.08	1.19	1.10	1.19
3I	1.01	1.13	0.95	1.05	0.97	1.04
3M	0.91	1.03	0.85	0.95	0.88	0.95
2A	0.88	1.00	0.82	0.91	0.85	0.92
2E	0.88	1.00	0.82	0.90	0.84	0.91
2I	0.88	1.00	0.82	0.90	0.84	0.91
2M	0.88	1.00	0.82	0.91	0.84	0.91
1A	1.17	1.29	1.06	1.17	1.13	1.18
1E	1.35	1.46	1.24	1.32	1.30	1.35
1I	1.54	1.67	1.40	1.48	1.48	1.51
1M	1.72	1.83	1.55	1.64	1.66	1.66
1Q	2.34	2.37	2.13	2.14	2.24	2.16

Table A-3 Continued. Uncorrected Film-Density Measurements From
Specific Penetrameter Locations

Location*	Film Density** for Penetrameter Exposed With Indicated Part					
	25-3-9		25-3-10		25-3-11	
	Left	Right	Left	Right	Left	Right
4A	2.76	2.58	2.38	2.51	2.52	2.50
4E	2.24	2.25	2.01	2.18	2.10	2.17
4I	1.84	1.95	1.64	1.88	1.72	1.82
4M	1.56	1.62	1.42	1.58	1.46	1.56
3A	1.33	1.42	1.21	1.38	1.26	1.36
3E	1.17	1.25	1.04	1.22	1.08	1.20
3I	1.02	1.09	0.93	1.08	0.94	1.06
3M	0.92	0.99	0.83	0.97	0.86	0.97
2A	0.87	0.95	0.81	0.95	0.82	0.93
2E	0.86	0.96	0.80	0.94	0.82	0.93
2I	0.86	0.94	0.80	0.93	0.82	0.93
2M	0.87	0.96	0.80	0.95	0.82	0.94
1A	1.14	1.26	1.05	1.25	1.04	1.25
1E	1.32	1.43	1.22	1.44	1.22	1.42
1I	1.48	1.62	1.39	1.58	1.39	1.58
1M	1.67	1.80	1.54	1.75	1.53	1.76
1Q	2.30	2.30	2.11	2.26	2.12	2.25

Table A-3 Continued. Uncorrected Film-Density Measurements From
Specific Penetrameter Locations

Location*	Film Density** for Penetrameter Exposed With Indicated Part					
	25-3-12					
	Left	Right	Left	Right	Left	Right
4A	2.58	2.17				
4E	2.16	1.91				
4I	1.76	1.65				
4M	1.47	1.42				
3A	1.26	1.22				
3E	1.09	1.07				
3I	0.96	0.95				
3M	0.88	0.86				
2A	0.85	0.83				
2E	0.84	0.82				
2I	0.85	0.82				
2M	0.84	0.82				
1A	1.08	1.04				
1E	1.24	1.18				
1I	1.42	1.34				
1M	1.58	1.47				
1Q	2.16	1.92				

*Refer to Figure 5 for diagram of measurement locations.

**Values shown are from densitometer.

Table A-4. Normalized Film-Density Measurements From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-1-8	A	1.36	1.11	1.58	3.00
	B	1.34	1.10	1.57	3.00
	C	1.38	1.11	1.56	2.97
	D	1.39	1.12	1.58	2.97
	E	1.48	1.10	1.44	2.46
	F	1.51	1.11	1.40	2.52
	G	1.51	1.10	1.40	2.47
	H	1.54	1.11	1.42	2.50
	I	1.66	1.08	1.28	2.09
	J	1.66	1.09	1.25	2.11
	K	1.66	1.08	1.28	2.11
	L	1.68	1.13	1.28	2.13
	M	1.89	1.09	1.16	1.78
	N	1.90	1.10	1.21	1.77
	O	1.86	1.10	1.17	1.77
	P	1.88	1.10	1.18	1.81
	Q	2.50			
	R	2.49			
	S	2.50			
	T	2.48			
25-2-7	A	1.36	1.14	1.67	3.27
	B	1.36	1.14	1.65	3.28
	C	1.39	1.16	1.66	3.28
	D	1.40	1.16	1.65	3.28
	E	1.54	1.13	1.42	2.70
	F	1.56	1.10	1.48	2.69
	G	1.55	1.13	1.47	2.65
	H	1.54	1.12	1.52	2.70

Table A-4 Continued. Normalized Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-2-7	I	1.72	1.11	1.31	2.21
	J	1.72	1.11	1.32	2.23
	K	1.71	1.11	1.29	2.21
	L	1.70	1.15	1.34	2.22
	M	1.91	1.10	1.23	1.88
	N	1.94	1.12	1.20	1.88
	O	1.91	1.13	1.22	1.92
	P	1.92	1.16	1.20	1.90
	Q	2.55			
	R	2.57			
	S	2.54			
	T	2.54			
25-2-8	A	1.40	1.15	1.66	3.23
	B	1.37	1.15	1.65	3.19
	C	1.38	1.13	1.63	3.21
	D	1.39	1.13	1.63	3.19
	E	1.54	1.11	1.47	2.65
	F	1.54	1.13	1.48	2.62
	G	1.53	1.14	1.46	2.64
	H	1.52	1.13	1.47	2.65
	I	1.69	1.09	1.31	2.18
	J	1.76	1.08	1.33	2.18
	K	1.71	1.10	1.34	2.19
	L	1.72	1.11	1.35	2.19
	M	1.91	1.10	1.25	1.86
	N	1.92	1.10	1.23	1.88
	O	1.89	1.09	1.26	1.90
	P	1.90	1.11	1.23	1.83

Table A-4 Continued. Normalized Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-2-8	Q	2.55			
	R	2.57			
	S	2.56			
	T	2.55			
25-3-5	A	1.33	1.09	1.55	3.01
	B	1.33	1.15	1.57	3.04
	C	1.37	1.07	1.63	3.00
	D	1.34	1.13	1.64	3.07
	E	1.49	1.12	1.42	2.52
	F	1.48	1.11	1.39	2.50
	G	1.51	1.10	1.46	2.51
	H	1.50	1.14	1.43	2.51
	I	1.66	1.06	1.33	2.10
	J	1.66	1.10	1.25	2.10
	K	1.66	1.12	1.28	2.11
	L	1.70	1.15	1.29	2.12
	M	1.87	1.13	1.16	1.81
	N	1.87	1.13	1.18	1.79
	O	1.87	1.13	1.14	1.78
	P	1.88	1.17	1.16	1.83
	Q	2.45			
	R	2.45			
	S	2.44			
	T	2.50			
25-3-7	A	1.30	1.10	1.54	2.90
	B	1.29	1.08	1.58	2.93
	C	1.27	1.09	1.54	2.90
	D	1.27	1.09	1.56	2.91

Table A-4 Continued. Normalized Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-7	E	1.43	1.06	1.37	2.44
	F	1.44	1.10	1.35	2.46
	G	1.44	1.09	1.37	2.44
	H	1.42	1.06	1.39	2.44
	I	1.57	1.07	1.25	2.09
	J	1.58	1.09	1.25	2.06
	K	1.59	1.07	1.26	2.06
	L	1.59	1.05	1.25	2.08
	M	1.76	1.07	1.13	1.76
	N	1.79	1.07	1.15	1.74
	O	1.76	1.12	1.15	1.79
	P	1.78	1.09	1.15	1.76
	Q	2.34			
	R	2.34			
	S	2.34			
	T	2.34			
25-3-8	A	1.33	1.10	1.55	3.04
	B	1.33	1.10	1.57	3.03
	C	1.32	1.11	1.58	3.01
	D	1.34	1.11	1.57	3.00
	E	1.44	1.09	1.40	2.50
	F	1.43	1.09	1.39	2.50
	G	1.44	1.11	1.44	2.53
	H	1.41	1.10	1.42	2.52
	I	1.61	1.07	1.35	2.13
	J	1.63	1.07	1.27	2.13
	K	1.61	1.09	1.28	2.14
	L	1.61	1.07	1.26	2.15

Table A-4 Continued. Normalized Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-8	M	1.82	1.03	1.17	1.78
	N	1.81	1.09	1.16	1.85
	O	1.81	1.09	1.18	1.79
	P	1.83	1.09	1.16	1.81
	Q	2.36			
	R	2.37			
	S	2.36			
	T	2.38			
25-3-9	A	1.36	1.12	1.61	3.16
	B	1.36	1.11	1.64	3.17
	C	1.36	1.11	1.63	3.16
	D	1.36	1.13	1.63	3.18
	E	1.48	1.08	1.48	2.63
	F	1.53	1.10	1.47	2.65
	G	1.49	1.10	1.47	2.63
	H	1.50	1.13	1.46	2.65
	I	1.64	1.08	1.28	2.19
	J	1.66	1.09	1.34	2.23
	K	1.65	1.10	1.32	2.19
	L	1.66	1.10	1.34	2.18
	M	1.84	1.10	1.22	1.86
	N	1.87	1.09	1.22	1.90
	O	1.86	1.10	1.21	1.86
	P	1.86	1.10	1.22	1.88
	Q	2.46			
	R	2.48			
	S	2.47			
	T	2.45			

Table A-4 Continued. Normalized Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-10	A	1.37	1.17	1.62	3.09
	B	1.37	1.15	1.61	3.15
	C	1.39	1.18	1.65	3.16
	D	1.38	1.19	1.67	3.12
	E	1.50	1.11	1.45	2.57
	F	1.54	1.11	1.47	2.59
	G	1.56	1.16	1.46	2.64
	H	1.54	1.16	1.45	2.59
	I	1.67	1.10	1.30	2.19
	J	1.70	1.10	1.33	2.20
	K	1.70	1.13	1.36	2.21
	L	1.71	1.13	1.35	2.21
	M	1.89	1.12	1.19	1.86
	N	1.87	1.12	1.23	1.89
	O	1.90	1.14	1.25	1.90
	P	1.90	1.13	1.26	1.91
	Q	2.49			
	R	2.51			
	S	2.53			
	T	2.53			
25-3-11	A	1.34	1.17	1.60	3.07
	B	1.35	1.15	1.63	3.06
	C	1.37	1.14	1.64	3.06
	D	1.36	1.17	1.61	3.07
	E	1.50	1.11	1.43	2.53
	F	1.50	1.12	1.45	2.54
	G	1.50	1.12	1.46	2.55
	H	1.50	1.13	1.46	2.51

Table A-4 Continued. Normalized Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-11	I	1.62	1.11	1.27	2.11
	J	1.67	1.12	1.32	2.11
	K	1.72	1.09	1.32	2.12
	L	1.65	1.11	1.35	2.11
	M	1.83	1.11	1.22	1.85
	N	1.86	1.12	1.20	1.82
	O	1.84	1.15	1.21	1.82
	P	1.84	1.14	1.18	1.81
	Q	2.46			
	R	2.48			
	S	2.46			
	T	2.47			
25-3-12	A	1.48	1.26	1.74	3.24
	B	1.50	1.27	1.74	3.20
	C	1.50	1.28	1.74	3.19
	D	1.54	1.28	1.71	3.22
	E	1.64	1.25	1.58	2.67
	F	1.65	1.24	1.58	2.66
	G	1.65	1.23	1.59	2.74
	H	1.66	1.30	1.62	2.72
	I	1.82	1.30	1.42	2.29
	J	1.80	1.24	1.42	2.27
	K	1.79	1.24	1.47	2.28
	L	1.80	1.26	1.44	2.28
	M	1.99	1.26	1.33	1.98
	N	2.00	1.23	1.32	2.00
	O	1.99	1.25	1.32	1.97
	P	2.02	1.24	1.35	2.00

Table A-4 Continued. Normalized Film-Density Measurements
From Specific Locations on Parts

Part	Location*	Film Density** for Indicated Segment*			
		1	2	3	4
25-3-12	Q	2.61			
	R	2.62			
	S	2.62			
	T	2.62			

*Refer to Figure 5 for diagram of part segments and measurement locations.

**Original, unnormalized values were from densitometer.

Table A-5. Normalized Film-Density Measurements From Specific Penetrameter Locations

Location*	Film Density** for Penetrameter Exposed With Indicated Part					
	25-1-8		25-2-7		25-2-8	
	Left	Right	Left	Right	Left	Right
4A	2.82	2.49	2.92	2.65	2.85	2.69
4E	2.32	2.17	2.40	2.30	2.32	2.30
4I	1.95	1.90	1.94	1.94	1.92	2.01
4M	1.65	1.59	1.62	1.64	1.59	1.70
3A	1.41	1.39	1.39	1.46	1.38	1.46
3E	1.22	1.22	1.22	1.29	1.18	1.29
3I	1.08	1.08	1.09	1.14	1.04	1.15
3M	0.98	1.00	0.98	1.03	0.94	1.03
2A	0.95	1.00	0.92	1.01	0.90	0.99
2E	0.95	1.00	0.92	1.01	0.89	1.00
2I	0.95	1.00	0.92	1.00	0.89	0.99
2M	0.95	1.01	0.92	1.00	0.90	1.00
1A	1.24	1.28	1.22	1.31	1.19	1.33
1E	1.43	1.46	1.42	1.48	1.35	1.52
1I	1.61	1.65	1.60	1.66	1.53	1.71
1M	1.78	1.80	1.80	1.84	1.73	1.89
1Q	2.44	2.31	2.42	2.37	2.37	2.41

Table A-5. Continued. Normalized Film-Density Measurements From
Specific Penetrameter Locations

Location*	Film Density** for Penetrameter Exposed With Indicated Part					
	25-3-5		25-3-7		25-3-8	
	Left	Right	Left	Right	Left	Right
4A	2.66	2.62	2.65	2.52	2.76	2.50
4E	2.21	2.28	2.23	2.24	2.25	2.21
4I	1.81	1.98	1.85	1.94	1.88	1.91
4M	1.52	1.67	1.98	1.65	1.59	1.65
3A	1.33	1.46	1.35	1.47	1.36	1.42
3E	1.14	1.28	1.18	1.29	1.19	1.28
3I	1.01	1.13	1.05	1.15	1.06	1.13
3M	0.91	1.03	0.95	1.05	0.97	1.04
2A	0.88	1.00	0.92	1.01	0.94	1.01
2E	0.88	1.00	0.92	1.00	0.93	1.00
2I	0.88	1.00	0.92	1.00	0.93	1.00
2M	0.88	1.00	0.92	1.01	0.93	1.00
1A	1.17	1.29	1.16	1.27	1.22	1.27
1E	1.35	1.46	1.34	1.42	1.39	1.44
1I	1.54	1.67	1.50	1.58	1.57	1.60
1M	1.72	1.83	1.65	1.74	1.75	1.75
1Q	2.34	2.37	2.23	2.24	2.33	2.25

Table A-5 Continued. Normalized Film-Density Measurements From
Specific Penetrameter Locations

Location*	Film Density** for Penetrameter Exposed With Indicated Part					
	25-3-9		25-3-10		25-3-11	
	Left	Right	Left	Right	Left	Right
4A	2.81	2.63	2.44	2.57	2.59	2.57
4E	2.29	2.30	2.07	2.24	2.17	2.24
4I	1.89	2.00	1.70	1.94	1.79	1.89
4M	1.61	1.67	1.48	1.64	1.53	1.63
3A	1.38	1.47	1.27	1.44	1.33	1.43
3E	1.22	1.30	1.10	1.28	1.15	1.27
3I	1.07	1.14	0.99	1.14	1.01	1.13
3M	0.97	1.04	0.89	1.03	0.93	1.04
2A	0.92	1.00	0.87	1.01	0.89	1.00
2E	0.91	1.01	0.86	1.00	0.89	1.00
2I	0.91	0.99	0.86	0.99	0.89	1.00
2M	0.92	1.00	0.86	1.01	0.89	1.01
1A	1.19	1.31	1.11	1.31	1.11	1.32
1E	1.37	1.48	1.28	1.50	1.29	1.49
1I	1.53	1.67	1.45	1.64	1.46	1.65
1M	1.72	1.85	1.60	1.81	1.60	1.83
1Q	2.35	2.35	2.17	2.32	2.19	2.32

Table A-5 Continued. Normalized Film-Density Measurements From
Specific Penetrameter Locations

Film Density** for Penetrameter Exposed With Indicated Part						
25-3-12						
Location*	Left	Right	Left	Right	Left	Right
4A	2.76	2.35				
4E	2.34	2.09				
4I	1.94	1.83				
4M	1.65	1.60				
3A	1.44	1.40				
3E	1.27	1.25				
3I	1.14	1.13				
3M	1.06	1.04				
2A	1.03	1.01				
2E	1.02	1.00				
2I	1.03	1.00				
2M	1.02	1.00				
1A	1.26	1.22				
1E	1.42	1.36				
1I	1.60	1.52				
1M	1.76	1.65				
1Q	2.34	2.10				

*Refer to Figure 5 for diagram of measurement locations.

**Original, unnormalized values were from densitometer.

Table A-6. Results of Density Calculations for Segment 2* of Parts

Location*	Calculated Density for Part Indicated				
	25-1-8 (g/cm ³)	25-2-7 (g/cm ³)	25-2-8 (g/cm ³)	25-3-5 (g/cm ³)	25-3-7 (g/cm ³)
A	0.482	0.465	0.462	0.514	0.486
B	0.488	0.464	0.462	0.480	0.497
C	0.483	0.454	0.473	0.525	0.492
D	0.479	0.454	0.474	0.492	0.495
E	0.484	0.467	0.479	0.497	0.490
F	0.479	0.482	0.469	0.502	0.482
G	0.485	0.467	0.465	0.507	0.489
H	0.480	0.473	0.476	0.485	0.506
I	0.500	0.481	0.494	0.535	0.503
J	0.493	0.481	0.502	0.511	0.491
K	0.499	0.481	0.490	0.499	0.503
L	0.472	0.459	0.486	0.482	0.516
M	0.507	0.506	0.505	0.508	0.520
N	0.503	0.491	0.506	0.505	0.517
O	0.504	0.493	0.512	0.505	0.492
P	0.504	0.471	0.500	0.484	0.509
Average	0.490	0.474	0.485	0.502	0.499
Standard Deviation	0.011	0.015	0.017	0.015	0.012
Density, Weight/Volume	0.533	0.533	0.539	0.542	0.532
Percent Deviation	8.07	11.07	10.02	7.38	6.20
	25-3-8	25-3-9	25-3-10	25-3-11	25-3-12
A	0.489	0.479	0.454	0.456	0.415
B	0.489	0.485	0.465	0.469	0.410
C	0.485	0.485	0.450	0.474	0.407
D	0.485	0.474	0.446	0.459	0.407

Table A-6 Continued. Results of Density Calculations for
Segment 2* of Parts

Location*	Calculated Density for Part Indicated				
	25-3-8 (g/cm ³)	25-3-9 (g/cm ³)	25-3-10 (g/cm ³)	25-3-11 (g/cm ³)	25-3-12 (g/cm ³)
E	0.491	0.497	0.483	0.486	0.418
F	0.491	0.487	0.483	0.482	0.423
G	0.482	0.488	0.458	0.482	0.428
H	0.488	0.472	0.458	0.477	0.396
I	0.507	0.501	0.493	0.490	0.398
J	0.508	0.495	0.492	0.485	0.426
K	0.496	0.491	0.476	0.502	0.426
L	0.508	0.492	0.478	0.491	0.416
M	0.545	0.503	0.497	0.506	0.429
N	0.510	0.513	0.496	0.500	0.445
O	0.510	0.506	0.486	0.483	0.436
P	0.511	0.507	0.492	0.489	0.440
Average	0.500	0.492	0.474	0.483	0.420
Standard Deviation	0.016	0.012	0.017	0.014	0.014
Density, Weight/Volume	0.531	0.531	0.531	0.529	0.527
Percent Deviation	5.84	7.34	10.73	8.70	20.30

*Refer to Figure 5 for diagram of measurement locations.

Table A-7. Part Density Calculated by Weight-Volume Method

Segment*	Calculated Density for Part Indicated				
	25-1-8 (g/cm ³)	25-2-7 (g/cm ³)	25-2-8 (g/cm ³)	25-3-5 (g/cm ³)	25-3-7 (g/cm ³)
1	0.594	0.588	0.586	0.575	0.589
2	0.533	0.533	0.539	0.542	0.532
3	0.548	0.553	0.547	0.547	0.556
4	0.610	0.614	0.612	0.604	0.620
Segment*	25-3-8	25-3-9	25-3-10	25-3-11	25-3-12
	(g/cm ³)	(g/cm ³)	(g/cm ³)	(g/cm ³)	(g/cm ³)
1	0.587	0.587	0.580	0.588	0.582
2	0.531	0.531	0.531	0.529	0.527
3	0.544	0.546	0.548	0.546	0.533
4	0.615	0.616	0.606	0.606	0.608

*Refer to Figure 5 for diagram showing location of part segments.

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X-RAY POLE FIGURE ANALYSIS

By D. M. Jarboe
and
D. E. Lacey

Published September 1978

Final Report
D. M. Jarboe, Project Leader

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