Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures

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Section 1
Overview

Effective dates: November 2004–September 2007.

Use this test method to determine the theoretical maximum specific gravity (commonly referred to as 'Rice' gravity) of a bituminous mixture. The theoretical maximum specific gravity of a bituminous mixture is the bulk specific gravity of that mixture when compacted to the point of zero air voids. Use the specific gravity obtained to calculate the percent air voids and percent voids in mineral aggregates (VMA) contained in compacted samples as described in "Tex-207-F, Determining Density of Compacted Bituminous Mixtures." The theoretical maximum specific gravity is also used to calculate the effective specific gravity (G_e) of aggregates as described in "Tex-204-F, Design of Bituminous Mixtures."

Use Part I to perform the test using a small or wide-mouthed glass pycnometer with a metal pycnometer cap or the side arm flask.

Use Part II to perform the test using the 4500 mL metal vacuum pycnometer and vibrating table.

Use Part III to perform the test using the wide-mouthed glass pycnometer and a neoprene stopper.

NOTES: Sizes and dimensions for pycnometer and related accessories are approximate. Actual sizes and dimensions may vary if comparable results can be achieved.

Refer to the following table when using Superpave Specifications instead of standard TxDOT specifications. Replace the TxDOT nomenclature with the Superpave nomenclature when required.

Nomenclatures	
TxDOT Nomenclature	**Superpave Nomenclature**
G_e = Effective Specific Gravity of Aggregates	G_{se}
G_r = Theoretical maximum specific gravity	G_{mm}
G_{rc} = Theoretical maximum specific gravity corrected for water absorption during test	G_{mm}

Use the following table to achieve sample size requirements.

Sample Size	
Nominal Maximum Size of Aggregate In Mixture, mm (in.)	**Minimum Weight of Sample, g (lb)**
25.0 (1)	2500 (5.5)
19.0 (3/4)	2000 (5.5)
12.5 (1/2)	1500 (3.3)
9.5 (3/8)	1000 (2.2)
4.75 (No.4)	500 (1.1)

Units of Measurement

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

Section 2

Part I, Using Hand-held Glass Pycnometer

Use this procedure to measure the theoretical maximum specific gravity of bituminous mixtures using a hand-held glass pycnometer with a metal pycnometer cap.

Apparatus

Use the following apparatus:

- ♦ heavy-walled glass pycnometer
  - 1/2 gal. (2 L) fruit jar is recommended (may use either the small or large mouthed jars)
  - 68 fl. oz. (2000 mL) side-arm flask may be used in lieu of the ½ gal. (2 L) fruit jar (optional)
  - use a 135 fl. oz. (4000 mL) side-arm flask to handle large samples (optional)
  - the pycnometer must have the strength and seals to withstand and hold an essentially complete vacuum
  - epoxy a small piece of No. 50 (300 µm) sieve wire mesh inside an extra pycnometer top to prevent loss of fine material from the flask during the test
- ♦ vacuum hoses, connections, tapered stoppers and valves suitable to apply and control the specified vacuum level within the assembly. A vacuum flask or moisture trap needs to be in line between the vacuum pump and the glass pycnometer to prevent water vapor from entering the vacuum pump.
- ♦ manometer, or vacuum gauge, able to determine the level of pressure (vacuum) within the assembly.
  - do not keep a manometer in the system during routine testing, because a sudden vacuum loss can break it.
  - use the manometer to qualify vacuum pumps and water aspirators and check the accuracy of vacuum gauges.
- ♦ vacuum pump or water aspirator to evacuate air from the assembly.
  - it must be able to reduce residual pressure to 2.0 in. (50 mm) Hg or less before completion of the evacuation process of the procedure (see 'Notes' located at the end of this test procedure).
  - a quick check to determine the adequacy of a vacuum source is possible without the use of a manometer, should the vacuum gauge reading be questioned.
  - place water in the vacuum flask at slightly above 102°F (38°C) so that the water will be at 102°F (38°C) at the time the maximum degree of evacuation is achieved by the vacuum source.
  - begin applying vacuum.

- if the vacuum source is capable of causing a vigorous boil to occur in water at 102°F (38°C) or less, the residual pressure within the system is 2.0 in. (50 mm) Hg or less and the vacuum source meets the requirements for this test method.

- ♦ balance readable to 0.1 g and accurate to 0.5 g
- ♦ wide-mouth funnel
- ♦ masonry trowel and flat scoop
- ♦ small suction bulb
- ♦ sample-splitter or quartering machine
- ♦ mercury thermometer marked in 0.5°C (1°F) divisions or digital thermometer capable of measuring the temperature specified in the test procedure
- ♦ air circulating fan
- ♦ large, flat-bottom pans
- ♦ vacuum flasks of any capacity found suitable to condense water vapor and trap moisture to protect vacuum pump. (optional)
- ♦ rubber pad, or similar cushioning material
- ♦ gloves
- ♦ stopwatch or timer.

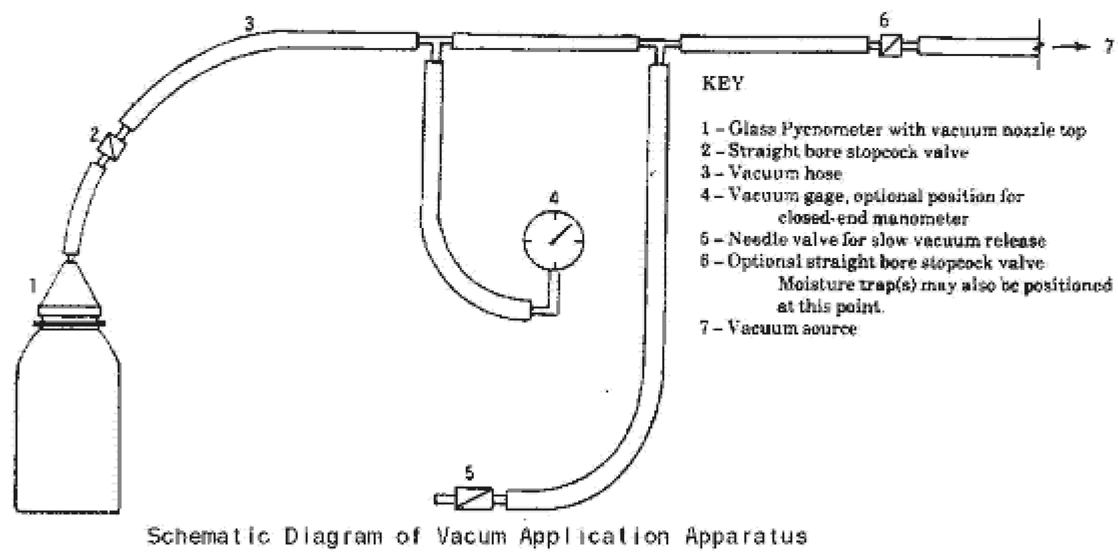

Figure 1. Schematic Diagram of Vacuum Application Apparatus

Calibrating Pycnometer

Follow these steps to calibrate the pycnometer to assure that it is of definite and constant volume.

Calibrating Pycnometer

Step	Action
1	Perform these calibration steps each day that the pycnometer is used.
2	Inspect the pycnometer for cracks and deep or excessive scratches, because the glass will be subjected to large stresses when the interior pressure is lowered. The pycnometer must have good threads and a rim free from cracks or nicks.
3	♦ Clean the pycnometer and fill the jar to the top with clean tap water. ♦ Do not use water that contains minerals.
4	Seat the gasket firmly in place inside the metal pycnometer cap and screw the cap snugly on the pycnometer.
5	♦ Completely fill the pycnometer and metal cap with water. ♦ If using an Erlenmeyer flask, fill until the side arm begins dripping.
6	Determine the water temperature. ♦ A water temperature of 77 ± 1°F (25 ± 0.5°C) is a standard calibration and test temperature. ♦ Use other water temperatures when accurate control of the water temperature at 77 ± 1°F (25 ± 0.5°C) is not practical. ♦ The water temperatures used during the pycnometer calibration and the final weighing of the pycnometer containing evacuated mixture must be within 2°F (1°C).
7	Roll the pycnometer to remove air trapped under the lid.
8	Use the suction bulb to finish filling the pycnometer with water, leaving a rounded bead of water on top of the cap.
9	Dry the pycnometer, including under the rim of the cap and inspect for leaks. ♦ If there are no leaks, proceed to Step 10. ♦ If the pycnometer leaks water: • place a piece of fine grain Carborundum cloth on a smooth, solid plane surface and pour a small amount of turpentine on the cloth; • smooth and true the rim by rotating the pycnometer on the Carborundum cloth; • apply force and continue the grinding action until the rim of the pycnometer is perfectly smooth. • Repeat Steps 8 and 9 until the leak stops.
10	Weigh the pycnometer filled with water to the nearest 0.1 g and record the weight as ‘D’ under ‘Calculations.’

Procedure

Follow these steps to determine theoretical maximum specific gravity.

Obtaining Theoretical Maximum Specific Gravity

Step	Action
1	Obtain a representative sample.
2	Place sample in a large flat pan and warm in an oven until it becomes workable.
3	♦ Heat sample to the minimum temperature and for the least amount of time necessary to separate the mix into individual aggregate particles. ♦ If the theoretical maximum specific gravity is to be used in the calculation of laboratory molded density, cure the sample at the same temperature and for the same length of time as the sample used for molding.
4	♦ Use a circular motion with a masonry trowel, while exerting downward pressure to roll the aggregate and effectively break apart individual coated aggregates. ♦ It is important to separate the aggregates, particularly the fine material, to the greatest extent possible without fracturing particles in the process.
5	If the aggregate larger than 3/4 in. (19.0 mm) was removed from the laboratory molded specimens, then sieve aggregate larger than 3/4 in. (19.0 mm) out of the sample. NOTE: If a Rice Gravity is needed to calculate the percent density of road cores for mixes that contain aggregate larger than 3/4 in. (19.0 mm), then perform an additional Rice Gravity without removing the aggregate larger than 3/4 in. (19.0 mm).
6	♦ Reduce the mix to a minimum of 1000 g using a quartering machine or by thoroughly blending the material and taking small portions from several places from the entire area of the pan. ♦ Larger samples improve test accuracy, particularly when testing mixtures with large maximum aggregate sizes. Larger samples may be tested a portion at a time, as proper agitation of the sample is difficult when the pycnometer is overfilled.
7	Alternative 1 for determining the weight of the sample: ♦ Weigh the prepared sample at room temperature to the nearest 0.1 g. ♦ Record the weight as ‘A’ under ‘Calculations.’ ♦ Use the wide-mouth funnel to transfer the weighed sample into the pycnometer. ♦ Take care not to lose any of the material. ♦ Proceed to Step 9.
8	Alternative 2 for determining the weight of the sample: ♦ Fill the pycnometer approximately one third full with water at approximately the temperature used for calibration. This helps prevent cracking the jar when adding the sample. ♦ Place the wide-mouth funnel in the jar and place these components on the scale. ♦ Zero out or tare the scale. ♦ After the sample has cooled to room temperature, pour the sample into the jar. ♦ Record the weight as ‘A’ under ‘Calculations’. ♦ Remove the wide-mouth funnel from the jar and then remove the jar from the scale and proceed to Step 9.
9	Cover the sample with water at approximately the temperature used for calibration. ♦ As some cooling can occur during the evacuation procedure, a water temperature a few degrees above that used for calibration may help provide the desired water temperature at the time of weighing the evacuated pycnometer. ♦ The water level must be adequate to submerge the entire sample (by approximately 1 in. [2.5 cm]) yet not be so high as to cause water to be siphoned into the vacuum lines during the test.

Obtaining Theoretical Maximum Specific Gravity

Step	Action
10	Attach the vacuum hose attachment to the glass pycnometer and turn on the vacuum or water aspirator and lower the residual pressure within the system to 2.0 in. (50 mm) Hg. This equates to a vacuum gauge reading of 27.9 in (710 mm) Hg at normal sea level atmospheric pressure.
11	Start the stopwatch or timer, immediately proceed to Step 12.
12	Close the twist cock valve located immediately above the pycnometer, and manually agitate the pycnometer contents for 15 to 30 seconds.
13	♦ Stop the agitation and reopen the twist cock valve. ♦ The contents of the pycnometer will be subjected to a partial vacuum and entrapped air will be removed. ♦ Leave the twist cock open until a total of approximately 60 seconds has elapsed from the time the stopwatch was started.
14	♦ Repeat Steps 12 and 13 in approximately 60 second cycles. ♦ The process will take between 5 and 20 minutes. NOTE: Water can be sucked into the aggregate, so the minimum time required to remove air from the sample is best.
15	After completing the required vacuum time, turn the vacuum or water aspirator off and gradually release the vacuum by using the bleed valve.
16	Disconnect the vacuum line from the pycnometer. (This step is optional if the vacuum hose is attached to a metal cap that is used for all pycnometer jars.)
17	Remove the pycnometer top from the pycnometer.
18	♦ Add water as needed to both adjust the water temperature and fill the pycnometer to the rim of the glass jar. ♦ Screw on the same metal cap used during calibration and completely fill with water. ♦ A sidearm flask will not be completely filled.
19	♦ Manually roll the pycnometer to check for any remaining air. ♦ Allow it to be dispelled. ♦ Prevent bubbles from the surface from contacting the sample.
20	Check the water temperature. It must be within 2°F (1°C) of the calibration temperature.
21	Use the suction bulb to finish filling the pycnometer with water, leaving a rounded bead of water on top of the cap
22	Dry the pycnometer, including under the rim of the cap and inspect for leaks. ♦ If there are no leaks, proceed to Step 23. ♦ If the pycnometer leaks water: • place a piece of fine grain Carborundum cloth on a smooth, solid plane surface and pour a small amount of turpentine on the cloth; • smooth and true the rim by rotating the pycnometer on the Carborundum cloth; • apply force and continue the grinding action until the rim of the pycnometer is perfectly smooth. ♦ Repeat Steps 21 and 22 until the leak stops.
23	♦ Weigh the pycnometer filled with sample and water. ♦ Record the weight to the nearest 0.1 g as E under 'Calculations.'
24	Use steps 25-33 if water is absorbed by the aggregate during the test. ♦ This can occur when the surfaces of any absorptive aggregate are not completely coated or coated very thinly with asphalt. ♦ This problem may be increased when highly effective vacuum pumps are used and if the samples are exposed to this vacuum for an excessive time.

Obtaining Theoretical Maximum Specific Gravity	
Step	**Action**
	♦ Very porous aggregates, such as lightweight aggregates, are particularly prone to absorb water during this test.
25	Tare a large flat pan.
26	♦ Pour the contents of the pycnometer into the pan. ♦ Rinse particles clinging to the wall of the pycnometer into the pan.
27	Decant the water from the pan over a 75 µm (No. 200) sieve, taking care to avoid loss of any of the sample.
28	♦ Tilt the sample pan to further drain water to the bottom and place in front of an electric fan to remove surface moisture. ♦ Set the fan so that it will not cause movement of the fine particles of the mixture.
29	Remove water draining to the bottom of the pan with a suction bulb.
30	Stir the sample intermittently with a trowel until the sample is almost surface dry.
31	♦ Increase the drying cycle to 15 minute intervals, stirring for two minutes every interval. ♦ Weigh after every other stirring. ♦ When the loss in mass is 0.5 g or less, the sample is considered to be surface dry. ♦ Record this weight as A_{sd}.
32	Verify the validity of the end-point by drying for an additional 30-minute period when practical.
33	♦ If a loss greater than 0.5 g occurs, continue drying until the new end-point is reached. ♦ Record this new value as A_{sd} under ‘Calculations.’

Calculations

Use the following calculations to determine theoretical maximum specific gravity.

- ♦ Theoretical Maximum Specific Gravity:

$$G_r = \frac{A}{D + A - E}$$

Where:

- G_r = Theoretical maximum specific gravity
- A = Weight (grams) of dry sample in air
- D = Weight (grams) of calibrated pycnometer filled with water
- E = Weight (grams) of pycnometer containing sample and filled with water to the calibration level.

- ♦ Theoretical Maximum Specific Gravity (corrected for water absorption during test):

$$G_{rc} = \frac{A}{D + A_{sd} - E}$$

Where:

- G_{rc} = Theoretical maximum specific gravity corrected for water absorption during test
- A_{sd} = Weight (grams) of surface dry sample in air
- D = Weight (grams) of calibrated pycnometer filled with water
- E = Weight (grams) of pycnometer containing sample and filled with water to the calibration level.

Section 3

Part II, Using a Metal Vibratory Pycnometer

Use this procedure to measure the theoretical maximum specific gravity of bituminous mixtures using a metal vibratory pycnometer.

Apparatus

Use the following apparatus:

- ♦ 150 fl. oz. (4500 mL) metal vacuum pycnometer with a clear poly (methyl methacrylate) (PMMA) lid (for applying vacuum). Humbolt H-1750, Gilson SC-16 or equal
- ♦ vibrating table. Humbolt H-1755, Gilson SGA-5RT or equal
- ♦ vacuum hoses, connections, tapered stoppers and valves suitable to apply and control the specified vacuum level within the assembly. A vacuum flask or moisture trap needs to be inline between the vacuum pump and the metal vacuum pycnometer to prevent water vapor from entering the vacuum pump.
- ♦ manometer, or vacuum gauge, able to determine the level of pressure (vacuum) within the assembly.
  - do not keep a manometer in the system during routine testing, because a sudden vacuum loss can break it.
  - use the manometer to qualify vacuum pumps and water aspirators and check the accuracy of vacuum gauges.
- ♦ vacuum pump or water aspirator to evacuate air from the assembly
  - it must be able to reduce residual pressure to 2.0 in. (50 mm) Hg or less before completion of the evacuation process of the procedure (see 'Notes' at the end of this test procedure).
  - a quick check to determine the adequacy of a vacuum source is possible without the use of a manometer, should the vacuum gauge reading be questioned.
  - place water in the vacuum flask at slightly above 102°F (38°C) so that the water will be at 102°F (38°C) at the time the maximum degree of evacuation is achieved by the vacuum source.
  - begin applying vacuum.
  - if the vacuum source is capable of causing a vigorous boil to occur in water at 102°F (38°C) or less, the residual pressure within the system is 2.0 in. (50 mm) Hg or less and the vacuum source meets the requirements for this test method.
- ♦ balance readable to 0.1 g and accurate to 0.5 g
- ♦ masonry trowel and flat scoop
- ♦ sample-splitter or quartering machine

- mercury thermometer marked in 1°F (0.5°C) divisions or digital thermometer capable of measuring the temperature specified in the test procedure
- air circulating fan
- large, flat-bottom pans
- vacuum flasks of any capacity found suitable to condense water vapor and trap moisture to protect vacuum pump. (optional)
- stopwatch or timer
- gloves
- water bath, for calibration of metal pycnometer and for immersing the metal pycnometer and sample in water, while suspended. Should be equipped with an overflow outlet for maintaining a constant water level.

Calibrating Metal Vacuum Pycnometer

Follow these steps to calibrate the pycnometer to assure that it is of definite and constant volume.

Calibrating Pycnometer

Step	Action
1	Perform these calibration steps each day that the pycnometer is used.
2	Prepare and calibrate the metal pycnometer as follows, to assure that it is of definite and constant volume.
3	Determine the water temperature. ♦ A water temperature of 77 ± 1°F (25 ± 0.5°C) is a standard calibration and test temperature. ♦ Use other water temperatures when accurate control of the water temperature at 77 ± 1°F (25 ± 0.5°C) is not practical. ♦ The water temperatures used during the pycnometer calibration and the final weighing of the pycnometer containing evacuated mixture must be within 2°F (1°C).
4	Tare the scale with the weighing apparatus suspended in water. NOTE: Equip the scale with a suitable apparatus to permit weighing the metal pycnometer with sample while suspended in water.
5	Submerge the metal pycnometer in water by placing it into the waterbath at an angle. This will prevent any air from becoming entrapped under the bottom of the metal pycnometer. Hang the metal pycnometer from the weighing apparatus and allow the scale to stabilize.
6	♦ Weigh and record the weight to the nearest 0.1 g. ♦ Record weight as 'D' under 'Calculations.'

Procedure

Follow these steps to determine the theoretical maximum specific gravity.

Obtaining Theoretical Maximum Specific Gravity

Step	Action
1	Obtain a representative sample. Minimum sample size requirements are given in the 'Sample Size' table.
2	Place sample in a large flat pan and warm in an oven until it becomes workable.
3	♦ Heat sample to the minimum temperature and for the least amount of time necessary to separate the mix into individual aggregate particles. ♦ If the theoretical maximum specific gravity is to be used in the calculation of laboratory molded density, cure the sample at the same temperature and for the same length of time as the sample used for molding.
4	♦ Use a circular motion with a masonry trowel, while exerting downward pressure to roll the aggregate and effectively break apart individual coated aggregates. ♦ It is important to separate the aggregates, particularly the fine material, to the greatest extent possible without fracturing particles in the process.
5	If the aggregate larger than 3/4 in. (19.0 mm) was removed from the laboratory molded specimens, then sieve aggregate larger than 3/4 in. (19.0 mm) out of the sample. NOTE: If a Rice Gravity is needed to calculate the percent density of road cores for mixes that contain aggregate larger than 3/4 in. (19.0 mm), then perform an additional Rice Gravity without removing the aggregate larger than 3/4 in. (19.0 mm).
6	♦ Reduce the mix using a quartering machine or by thoroughly blending the material and taking small portions from several places from the entire area of the pan to achieve a sample size that shall conform to the requirements in the ‘Sample Sizes’ table.
7	Alternative 1 for determining the weight of the sample: • Weigh the prepared sample at room temperature to the nearest 0.1g. • Record the weight as ‘A’ under ‘Calculations’. • Transfer the weighed sample into the metal pycnometer. • Take care not to lose any of the material. • Proceed to Step 9.
8	Alternative 2 for determining the weight of the sample: ♦ Fill the metal pycnometer approximately one third full with water at approximately the temperature used for calibration. ♦ Place the metal pycnometer on the scale. ♦ Zero out or tare the scale. ♦ After the sample has cooled to room temperature, pour the sample into the metal pycnometer. ♦ Record the weight as ‘A’ under ‘Calculations’. ♦ Remove the metal pycnometer from the scale and proceed to Step 9.
9	Cover the sample with water at approximately the temperature used for calibration. ♦ As some cooling can occur during the evacuation procedure, a water temperature a few degrees above that used for calibration may help provide the desired water temperature at the time of weighing the evacuated pycnometer. ♦ The water level must be adequate to submerge the entire sample (by approximately 1 in. [2.5 cm]) yet not be so high as to cause water to be siphoned into the vacuum lines during the test.
10	♦ Place the flat plexiglass vacuum lid with O-ring on the metal pycnometer and place on vibrating table. ♦ Clamp to hold in place. ♦ Turn on the vacuum pump or water aspirator and lower the residual pressure within the system to

Obtaining Theoretical Maximum Specific Gravity

Step	Action
	2.0 in. (50 mm) Hg pressure. This equates to a vacuum gauge reading of 27.9 in. (710 mm) Hg at normal sea level atmospheric pressure.
11	Turn the vibrating table on and maintain the residual pressure and agitation for 10 to 15 minutes. ♦ Water can be sucked into the aggregate, so the minimum time required to remove air from the sample is best. ♦ If the mix looks lightly coated or the aggregate is absorptive, use 10 minutes. ♦ If the mix looks well coated and has a thick film of asphalt, use 15 minutes.
12	♦ After the 10 to 15 minutes of agitation and evacuation, turn the vibrating table off, turn the vacuum or water aspirator off and gently release the vacuum. ♦ Remove the metal pycnometer from the vibrating table and then remove the flat plexiglas vacuum lid.
13	Check the water temperature. It must be within 2°F (1°C) of the calibration temperature.
14	Tare the scale with the weighing apparatus suspended in water
15	Submerge the metal pycnometer with sample in water by placing it into the waterbath at an angle. This will prevent any air from becoming entrapped under the bottom of the metal pycnometer. Hang the metal pycnometer from the weighing apparatus and allow the scale to stabilize
16	♦ Weigh and record the weight to the nearest 0.1 g. ♦ Record weight as E under 'Calculations.'
17	Use steps 18-26 if water is absorbed by the aggregate during the test. ♦ This can occur when the surfaces of any absorptive aggregate are not completely coated or coated very thinly with asphalt. ♦ This problem may be increased when highly effective vacuum pumps are used and if the samples are exposed to this vacuum for an excessive time. ♦ Very porous aggregates, such as lightweight aggregates, are particularly prone to absorb water during this test.
18	Tare a large flat pan
19	♦ Pour the contents of the pycnometer into the pan. ♦ Rinse particles clinging to the wall of the pycnometer into the pan.
20	Decant the water from the pan over a No. 200 (75 µm) sieve, taking care to avoid loss of any of the sample.
21	♦ Tilt the sample pan to further drain water to the bottom and place in front of an electric fan to remove surface moisture. ♦ Set the fan so that it will not cause movement of the fine particles of the mixture.
22	Remove water draining to the bottom of the pan with a suction bulb.
23	Stir the sample intermittently with a trowel until the sample is almost surface dry.
24	♦ Increase the drying cycle to 15 minute intervals, stirring for two minutes every interval. ♦ Weigh after every other stirring. ♦ When the loss in mass is 0.5 g or less, the sample is considered to be surface dry. ♦ Record this weight as A_{sd}.
25	Verify the validity of the end-point by drying for an additional 30-minute period when practical.
26	♦ If a loss greater than 0.5 g occurs, continue drying until the new end-point is reached. ♦ Record this new value as A_{sd} under 'Calculations.'

Use the following table to achieve sample size requirements.

Sample Size	
Nominal Maximum Size of Aggregate In Mixture, mm (in.)	**Minimum Mass of Sample, g**
25.0 (1)	2500
19.0 (3/4)	2000
12.5 (1/2)	1500
9.5 (3/8)	1000
4.75 (No.4)	500

Calculations

Use the following calculations to determine theoretical maximum specific gravity.

- Theoretical Maximum Specific Gravity:

$$G_r = \frac{A}{D + A - E}$$

Where:

- G_r = Theoretical maximum specific gravity
- A = Weight (grams) of dry sample in air
- D = Weight (grams) of calibrated pycnometer submerged in water
- E = Weight (grams) of pycnometer containing sample while submerged in water

- Theoretical Maximum Specific Gravity (corrected for water absorption during test):

$$G_{rc} = \frac{A}{D + A_{sd} - E}$$

Where:

- G_{rc} = Theoretical maximum specific gravity corrected for water absorption during test
- A_{sd} = Weight (grams) of surface dry sample in air
- D = Weight (grams) of calibrated pycnometer submerged in water
- E = Weight (grams) of pycnometer containing sample while submerged in water

Section 4

Part III, Using a Wide-Mouth Hand-held Glass Pycnometer

Use this procedure to measure the theoretical maximum specific gravity of bituminous mixtures using a wide-mouth hand-held glass pycnometer and a neoprene stopper.

Apparatus

Use the following apparatus:

- heavy-walled, wide-mouthed glass pycnometer
  - a 1/2 gal. (2 L) fruit jar is recommended
  - the pycnometer must have the strength and seals to withstand and hold an essentially complete vacuum
- No. 15 neoprene stopper with a ¼ inch copper tube inserted through it
- vacuum hoses, connections, tapered stoppers and valves suitable to apply and control the specified vacuum level within the assembly. A vacuum flask or moisture trap needs to be in line between the vacuum pump and the glass pycnometer to prevent water vapor from entering the vacuum pump.
- manometer, or vacuum gauge, able to determine the level of pressure (vacuum) within the assembly.
  - do not keep a manometer in the system during routine testing, because a sudden vacuum loss can break it.
  - use the manometer to qualify vacuum pumps and water aspirators and check the accuracy of vacuum gauges.
- vacuum pump or water aspirator to evacuate air from the assembly.
  - it must be able to reduce residual pressure to 2.0 in. (50 mm) Hg or less before completion of the evacuation process of the procedure (see 'Notes' at the end of this test procedure).
  - a quick check to determine the adequacy of a vacuum source is possible without the use of a manometer, should the vacuum gauge reading be questioned.
  - place water in the vacuum flask at slightly above 102°F (38°C) so that the water will be at 102°F (38°C) at the time the maximum degree of evacuation is achieved by the vacuum source.
  - begin applying vacuum.
  - if the vacuum source is capable of causing a vigorous boil to occur in water at 102°F (38°C) or less, the residual pressure within the system is 2.0 in. (50 mm) Hg or less and the vacuum source meets the requirements for this test method.
- balance readable to 0.1 g and accurate to 0.5 g
- wide-mouth funnel

- masonry trowel and flat scoop
- sample-splitter or quartering machine
- mercury thermometer marked in 1°F (0.5°C) divisions or digital thermometer capable of measuring the temperature specified in the test procedure
- air circulating fan
- large, flat-bottom pans
- vacuum flasks of any capacity found suitable to condense water vapor and trap moisture to protect vacuum pump. (optional)
- rubber pad, or similar cushioning material
- gloves
- stopwatch or timer
- water bath, for calibration of wide-mouthed glass pycnometer jar and for immersing the wide-mouthed glass pycnometer jar and sample in water, while suspended. Should be equipped with an overflow outlet for maintaining a constant water level.

Calibrating Pycnometer

Follow these steps to calibrate the wide-mouth glass pycnometer to assure that it is of definite and constant volume.

Calibrating Pycnometer

Step	**Action**
1	Perform these calibration steps each day that the pycnometer is used.
2	Inspect the pycnometer for cracks and deep excessive scratches, because the glass will be subjected to large stresses when the interior pressure is lowered. The pycnometer must have a rim free from cracks and nicks.
3	Determine the water temperature. ♦ A water temperature of 77 ± 1°F (25 ± 0.5°C) is a standard calibration and test temperature. ♦ Use other water temperatures when accurate control of the water temperature at 77 ± 1°F (25 ± 0.5°C) is not practical. ♦ The water temperatures used during the pycnometer calibration and the final weighing of the pycnometer containing evacuated mixture must be within 2°F (1°C).
4	Tare the scale with the weighing apparatus suspended in water. NOTE: Equip the scale with a suitable apparatus to permit weighing the wide-mouth glass pycnometer with sample while suspended in water.
5	Submerge the wide-mouth glass pycnometer in water by placing it into the waterbath at an angle. This will prevent any air from becoming entrapped under the concave bottom of the glass pycnometer. Hang the glass pycnometer from the weighing apparatus and allow the scale to stabilize.
6	Weigh the pycnometer to the nearest 0.1 g and record the weight as 'D' under **Error! Bookmark not defined.**

Procedure

Follow these steps to determine the theoretical maximum specific gravity.

Obtaining Theoretical Maximum Specific Gravity

Step	Action
1	Obtain a representative sample.
2	Place sample in a large flat pan and warm in an oven until it becomes workable.
3	♦ Heat sample to the minimum temperature and for the least amount of time necessary to separate the mix into individual aggregate particles. ♦ If the theoretical maximum specific gravity is to be used in the calculation of laboratory molded density, cure the sample at the same temperature and for the same length of time as the sample used for molding.
4	♦ Use a circular motion with a masonry trowel, while exerting downward pressure to roll the aggregate and effectively break apart individual coated aggregates. ♦ It is important to separate the aggregates, particularly the fine material, to the greatest extent possible without fracturing particles in the process.
5	If the aggregate larger than 3/4 in. (19.0 mm) was removed from the laboratory molded specimens, then sieve aggregate larger than 3/4 in. (19.0 mm) out of the sample. NOTE: If a Rice Gravity is needed to calculate the percent density of road cores for mixes that contain aggregate larger than 3/4 in. (19.0 mm), then perform an additional Rice Gravity without removing the aggregate larger than 3/4 in. (19.0 mm).
6	♦ Reduce the mix to a minimum of 1000 g using a quartering machine or by thoroughly blending the material and taking small portions from several places from the entire area of the pan. ♦ Larger samples improve test accuracy, particularly when testing mixtures with large maximum aggregate sizes. Larger samples may be tested a portion at a time, as proper agitation of the sample is difficult when the pycnometer is overfilled.
7	Alternative 1 for determining the weight of the sample: ♦ Weigh the prepared sample at room temperature to the nearest 0.1 g. ♦ Record the weight as 'A' under 'Calculations.' ♦ Use the wide-mouth funnel to transfer the weighed sample into the pycnometer. ♦ Take care not to lose any of the material. ♦ Proceed to Step 9.
8	Alternative 2 for determining the weight of the sample: ♦ Fill the pycnometer approximately one third full with water at approximately the temperature used for calibration. This helps prevent cracking the jar when adding the sample. ♦ Place the wide-mouth funnel in the jar and place these components on the scale. ♦ Zero out or tare the scale. ♦ After the sample has cooled to room temperature, pour the sample into the jar. ♦ Record the weight as 'A' under 'Calculations.' ♦ Remove the wide-mouth funnel from the jar and remove the jar from the scale and proceed to Step 9.
9	Cover the sample with water at approximately the temperature used for calibration. ♦ As some cooling can occur during the evacuation procedure, a water temperature few degrees above that used for calibration may help provide the desired water temperature at the time of weighing the evacuated pycnometer. ♦ The water level must be adequate to submerge the entire sample (by approximately 1 in. [2.5 cm]) yet not be so high as to cause water to be siphoned into the vacuum lines during the test.

Obtaining Theoretical Maximum Specific Gravity	
Step	**Action**
10	♦ Place the neoprene stopper on top of the wide-mouth glass pycnometer with the copper tubing facing outside the pycnometer. ♦ The stopper lies on top of the pycnometer. Do not attempt to place the stopper into the pycnometer. The copper tubing lies flush with the bottom of the neoprene stopper. ♦ Turn on the vacuum pump or water aspirator and lower the residual pressure within the system to 2.0 in. (50 mm) Hg pressure. This equates to a vacuum gauge reading of 27.9 in. (710 mm) Hg at normal sea level atmospheric pressure. ♦ Vacuum pressure will hold the neoprene stopper in place, do not attempt to secure neoprene stopper prior to applying the vacuum pressure. ♦ Do not attempt to agitate sample until the specified vacuum has been achieved.
11	Start the stopwatch, or timer, and immediately proceed to Step 12.
12	Close the twist cock valve located immediately above the pycnometer, and manually agitate the pycnometer contents for 15 to 30 seconds.
13	♦ Stop the agitation and reopen the twist cock valve. ♦ The contents of the pycnometer will be subjected to a partial vacuum and entrapped air will be removed. ♦ Leave the twist cock open until a total of approximately 60 seconds has elapsed from the time the stopwatch or timer was started.
14	♦ Repeat Steps 12 and 13 in approximately 60 second cycles. ♦ The process will take between 5 and 20 minutes. NOTE: Water can be sucked into the aggregate, so the minimum time required to remove air from the sample is best.
15	After completing the required vacuum time, turn the vacuum or water aspirator off and gradually release the vacuum by using the bleed valve.
16	Disconnect the vacuum line from the pycnometer. (This step is optional if the vacuum hose is attached to the same neoprene stopper used for all pycnometer jars.)
17	Remove the neoprene stopper from the pycnometer.
18	Check the water temperature. It must be within 2°F (1°C) of the calibration temperature.
19	Tare the scale with the weighing apparatus suspended in water. NOTE: Equip the scale with a suitable apparatus to permit weighing the wide-mouth glass pycnometer with sample while suspended in water.
20	Submerge the wide-mouth glass pycnometer in water by placing it into the waterbath at an angle. This will prevent any air from becoming entrapped under the concave bottom of the glass pycnometer. Hang the glass pycnometer from the weighing apparatus and allow the scale to stabilize.
21	Weigh the pycnometer to the nearest 0.1 g and record the weight as 'E' under 'Calculations.'
22	Use steps 23-31 if water is absorbed by the aggregate during the test. ♦ This can occur when the surfaces of any absorptive aggregate are not completely coated or coated very thinly with asphalt. ♦ This problem may be increased when highly effective vacuum pumps are used and if the samples are exposed to this vacuum for an excessive time. ♦ Very porous aggregates, such as lightweight aggregates, are particularly prone to absorb water during this test.
23	Tare a large flat pan.
24	♦ Pour the contents of the pycnometer into the pan. ♦ Rinse particles clinging to the wall of the pycnometer into the pan.

Obtaining Theoretical Maximum Specific Gravity	
Step	**Action**
25	Decant the water from the pan over a No. 200 (75 µm) sieve, taking care to avoid loss of any of the sample.
26	♦ Tilt the sample pan to further drain water to the bottom and place in front of an electric fan to remove surface moisture. ♦ Set the fan so that it will not cause movement of the fine particles of the mixture.
27	Remove water draining to the bottom of the pan with a suction bulb.
28	Stir the sample intermittently with a trowel until the sample is almost surface dry.
29	♦ Increase the drying cycle to 15 minute intervals, stirring for two minutes every interval. ♦ Weigh after every other stirring. ♦ When the loss in mass is 0.5 g or less, the sample is considered to be surface dry. ♦ Record this weight as ‘A_{sd}’ under 'Calculations.'
30	Verify the validity of the end-point by drying for an additional 30-minute period when practical.
31	♦ If a loss greater than 0.5 g occurs, continue drying until the new end-point is reached. ♦ Record this new value as ‘A_{sd}’ under ‘Calculations.’

Calculations

Use the following calculations to determine theoretical maximum specific gravity.

♦ Theoretical Maximum Specific Gravity:

$$G_r = \frac{A}{D + A - E}$$

Where:

- G_r = Theoretical maximum specific gravity
- A = Weight (grams) of dry sample in air
- D = Weight (grams) of calibrated pycnometer submerged in water
- E = Weight (grams) of pycnometer containing sample while submerged in water

♦ Theoretical Maximum Specific Gravity (corrected for water absorption during test):

$$G_{rc} = \frac{A}{D + A_{sd} - E}$$

Where:

- G_{rc} = Theoretical maximum specific gravity corrected for water absorption during test
- A_{sd} = Weight (grams) of surface dry sample in air
- D = Weight (grams) of calibrated pycnometer submerged in water
- E = Weight (grams) of pycnometer containing sample while submerged in water

Test Record Forms

Link to the ‘Theoretical Maximum Specific Gravity Worksheet’ in Excel.

Notes

Values for G_r and G_{rc} are rarely equal, even when no water absorption occurs. The determination of the surface dry condition is usually, to some degree, inaccurate because moisture commonly contained inside fine aggregate conglomerates. For this reason some values will tend to indicate more correction than is justified. The decision on which value to use must be based on the following factors:

- ♦ Aggregate potential for water absorption:
  - other factors being equal, if the average aggregate water absorption is lower than accepted parameters during mixture design, the probability for absorption during this test is diminished.
- ♦ Asphalt film thickness:
  - mixtures with high asphalt contents will rarely require absorption correction
  - high vacuum levels applied to highly absorptive aggregates may overcome this factor
  - lean mixtures will often require correction.
- ♦ Number of fractured aggregates:
  - some absorption will always occur when uncoated aggregate is exposed to vacuum saturation procedures
  - consider both the number of these particles and their potential for absorption.
- ♦ Vacuum level applied:
  - other factors being equal, highly effective vacuum pumps will cause more water absorption than less effective pumps or water aspirators.
- ♦ Difference between G_r and G_{rc} values:
  - as the difference between G_r and G_{rc} values increases, confidence that significant water absorption has occurred also increases
  - make corrections when values vary by more than 1.0%
  - corrections of less than 0.3% are usually insignificant and are believed to exist only because of the inadequacy of the correction procedure
  - base decisions concerning variations between G_r and G_{rc} ranging from 0.3 to 1.0% on the first four factors
  - the percentage difference is calculated as:

$$\frac{G_r - G_{rc}}{G_{rc}} \times 100 = \%$$

Wear protective gloves when handling the glass pycnometer during the vacuum process.

When using a vacuum pump to create a partial vacuum on the sample contained in the pycnometer, close the system for periods of time during the test by closing the valve in the line leading from the vacuum pump. This will protect the pump from water vapors and it can be turned off if necessary. Restart the pump and reopen the valve when leaks in the system cause the absolute pressure to rise above 2.0 in. (50 mm) Hg.

For Part I, thorough agitation of the pycnometer during removal of air from the sample is important. It must be vigorous enough to cause individual movement of all particles within the sample. Hold the pycnometer in both hands, partially inverted, and roll vigorously back and forth by twisting the wrists. Tap lightly against the rubber mat after the rolling action, but do not impact on a hard surface.

Vacuum sources applying absolute pressure considerably below 2.0 in. (50 mm) Hg may reach the end-point more quickly than less effective pumps.

Treat mix used to determine 'Rice' gravities used in the calculation to determine molded density identically to mix used for molding.

The vacuum pump or water aspirator must be able to reduce the residual pressure in the system to 2.0 in. (50 mm) Hg or less before the completion of the air evacuation process of the procedure. This equates to a vacuum gauge reading (absolute vacuum) of 27.9 in. (710 mm) Hg or more at normal sea level atmospheric pressure. When a gauge is used, it is necessary to use a mercury manometer to establish the point on a vacuum gauge that equates to 2.0 in. (50 mm) Hg of residual pressure.

- ♦ this can be accomplished by pulling a residual vacuum of 2.0 in. (50 mm) Hg as read on a mercury manometer that is placed in line with the vacuum gauge.
- ♦ at this point, make a mark on the vacuum gauge and use this point as the minimum vacuum that must be pulled.
    - vacuum gauges are not as precise as manometers and as such the vacuum gauge should be calibrated with a manometer on a regular basis.

Section 5

Archived Versions

The following archived versions of "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures" are available:

- 227-0899 for the test procedure effective August 1999 through October 2004.