Operating Instructions for the Pine AFLS1 Rapid Angle Measurement (RAM) Kit for Superpave Gyratory Compactors

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Scope

This manual describes the proper use of the Pine AFLS1 Rapid Angle Measurement (RAM) device in conjunction with a Superpave Gyratory Compactor (SGC). This manual addresses routine operating procedures, periodic maintenance and calibration, and safety issues. It is assumed that the reader of this manual is already familiar with hot mix asphalt design and proper use of an SGC.

The Pine AFLS1 Rapid Angle Measurement Device

Copyright

Patent

Each Pine AFLS1 Rapid Angle Measurement device is marked with a nameplate which indicates the model number, serial number, and patent information.

Also marked on each Pine AFLS1 device is the date of the most recent calibration and the date for the next scheduled calibration.

The Pine AFLS1 makes use of *Invelop Load Simulation* (ILS) technology developed by Invelop Oy (Savonlinna, Finland). US and Foreign Patents applicable.

Trademarks

- *Superpave*™ is a trademark of the Strategic Highway Research Program now owned by the Transportation Research Board (Washington, DC).
- *Vaseline*® is a registered trademark of Unilever United States, Inc.
- *Rapid Angle Measurement* (RAM) is a trademark of Pine Instrument Company (Grove City, PA).

Warranty

PINE INSTRUMENT COMPANY

LIMITED WARRANTY

The Pine AFLS1 Rapid Angle Measurement device manufactured by Pine Instrument Company is warranted to be free from defects in material and workmanship for a one (1) year period from the date of shipment to the original purchaser and used under normal conditions. The obligation under this warranty is limited to replacing or repairing parts which shall upon examination disclose to Pine Instrument Company's satisfaction to have been defective. The customer may be obligated to assist Pine Instrument Company personnel in servicing our equipment. Pine will provide telephone support to guide a customer's technician to effect any needed repairs. In the event that telephone support is unsuccessful in resolving the defect, Pine Instrument Company may recommend that the device be returned to Pine Instrument Company for repair.

This warranty being expressly in lieu of all other warranties, expressed or implied and all other liabilities. All specifications are subject to change without notice.

The customer is responsible for charges associated with non-warranted repairs. This obligation includes but is not limited to travel expenses, labor, parts and freight charges.

Personal Safety

When working with the Pine AFLS1 Rapid Angle Measurement device, take heed and abide by all of the following personal safety warnings:

Operator should wear eye protection and steel toe shoes.

Do not wear loose-fitting clothing items (*i.e.*, jewelry, ties, etc.) which may be caught in moving parts. Long hair should be tied back.

Use proper lifting techniques when moving gyratory compactor molds to prevent back injury. Wear heat resistant clothing and heavy gloves when working with hot gyratory compactor molds.

Keep hands and arms away from moving parts and pinch points on both the gyratory compactor and the Rapid Angle Measurement device.

Beware of any pinch points which may develop when sliding the Calibration Tube over the Rapid Angle Measurement device.

Specifications

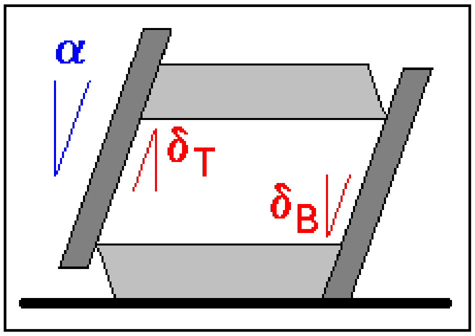
Part Number	AFLS1
Power	3 Volt Coin Type Batteries (CR2450, 3 required)**
Dimensions	Instrument: 150 mm OD x 123.5 mm H Case: 520 mm x 444 mm x 203 mm (20.5" x 17.5" x 8.0")
Weight	Instrument: 6.4 kg (14 lb) Complete Kit: 16 kg (35 lb)
Output:	Built-in Display
Measurement Range:	0.40° to 2.0°
Temperature Range:	18°C to 40°C
Contact Rings:	Pair, 44mm OD rings (0.022m eccentricity, 466.5Nm @600 kPa) Pair, 64mm OD rings (0.032m eccentricity, 678.6Nm@600 kPa) (one ring used on each end of device, top and bottom)
Calibration:	NIST traceable Calibration Tube, included (annual certification of tube is recommended)

** **The CR Lithium Coin type batteries may contain Perchlorate Material - Special handling may apply. See: www.dtsc.ca.gov/hazardouswaste/perchlorate**

Product History

One of the underlying assumptions of the Superpave mix design system is that Superpave Gyratory Compactors (SGCs) can be used to prepare laboratory compacted hot-mix asphalt (HMA) specimens in a reproducible and repeatable manner. One of the key parameters which influences compaction in an SGC is the angle of gyration.

In the early years of Superpave implementation in the United States, the angle of gyration was specified to be 1.25 ± 0.02°. This angle target was based upon a measurement of the *external angle of gyration* (α). That is, the tilt of the SGC mold was measured with respect to some external reference such as the frame of the SGC. Each SGC manufacturer provided external angle measurement tools unique to each SGC model.



At a later point in the history of Superpave, it became clear that the various approaches to measuring the external angle offered by each manufacturer might not be equivalent. As a result, compaction results from two different SGC models might differ significantly even though both were presumably calibrated to the same external angle target.

These greater than allowable differences in compaction results spurred development of new ways to measure the angle of gyration. These newer tools measured the *internal angle of gyration* (δ), which is the angle formed between the axis of the mold and an axis perpendicular to one of the end plates. Because there are two end plates, there are actually two internal angles (δ_T and δ_B). Usually, both of these internal angles are smaller than the external angle (α). This discrepancy has been attributed to deflection of the end plates with respect to the mold wall.

Each end plate (top and bottom) is supported in a different way. One plate is supported by (or perhaps even attached to) the ram, while the other plate is typically supported by the frame of the compactor. This means one plate may deflect more than the other. This causes the internal angle measured at the top (δ_T) to differ from the internal angle measured at the bottom (δ_B). The average of these two internal angles (δ_{AVG}) is called the *effective internal angle of gyration*.

Internal Angle Target

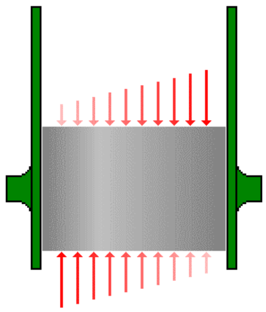
With the advent of the internal angle concept, a target internal angle, 1.16° ± 0.02°, has been established which will likely replace the external angle target, 1.25° ± 0.02°. The transition from the traditional external angle concept to the internal angle concept will take time. During the transition period, a state agency is free to continue using the traditional external angle target until such time as it is ready to switch all compactors in its jurisdiction over to the new internal angle target.

It is important to keep in mind that the internal angle concept and the external angle concept represent fundamentally different ways to measure the angle of gyration. To prevent any confusion, it is important to keep in mind the following three points:

- When a particular SGC is adjusted to the new target internal angle (1.16° ± 0.02°), the external angle measurement system for that individual SGC will most likely report an angle which is higher than 1.16° ± 0.02°. The exact discrepancy between the internal and external angle will vary from one individual SGC to another.
- When a particular SGC is adjusted to the new target internal angle (1.16° ± 0.02°), the external angle measurement system for that individual SGC will not necessarily be in the range 1.25° ± 0.02°. While this may occur (by coincidence or design) on a particular SGC model, it is not something which is required or even anticipated.
- If one SGC is adjusted to the external angle target (1.25° ± 0.02°) and another compactor is adjusted to the internal angle target (1.16° ± 0.02°), it is unreasonable to expect these two compactors to provide the same compaction effort. For this reason, it is important to convert all SGCs within a given jurisdiction to the internal angle target within a short time period. This assures both the agency and the contractor are calibrating their machines to the same angle target.

Loaded Angle Measurements

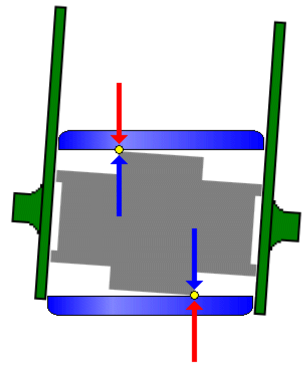
For most gyratory compactors, the angle of gyration changes depending upon how much load is placed upon the SGC frame and mold end plates. The tendency is for the angle to go down as the amount of load increases. For example, larger specimens require the compactor to "work harder," leading to more deflection of the compactor frame, the mold, and/or the end plates. And more deflection usually means a lower angle. Also, "stiff" mix designs that are more difficult to compact cause the compactor to "work harder," again leading to a lower angle of gyration.



Because the angle measurement depends upon the load placed on the compactor, it is important that the angle measurement be made under proper loading conditions. That is, the load experienced by the compactor when measuring the angle should be similar to the load experienced by the compactor when compacting an actual HMA specimen. In particular, the load should be the same as when compacting a standard Superpave specimen (150 mm OD x 115 mm H).

The principle advantage of the RAM device is its ability to mechanically induce appropriate loading conditions on the SGC while simultaneously making an internal angle measurement. While earlier internal angle measurement devices relied upon simultaneous compaction of hot mix asphalt to create the loading conditions, the RAM permits internal angle measurement without the need for hot mix asphalt. This saves a lot of time and offers more predictable load control while measuring the internal angle of gyration.

Simulated Loading



The way in which the RAM simulates an appropriate load is based upon two rings which project from the top and bottom of the RAM's chassis. These rings are not readily visible because they are covered by spring-mounted wear protection plates. When inside a gyrating SGC mold, the sole point of contact between the RAM and the mold end plates is at a single point on the outer edge of each ring. As the mold gyrates, these points of contact orbit the centerline, causing the vertical consolidation force (**F**) to be applied at a distance (**e**) away from the centerline.

This type of "off-centerline" loading is very similar to what happens when an actual hot mix asphalt specimen is compacted in an SGC mold. The distance of the applied force from the centerline (**e**) is often called the ***eccentricity***. Stiffer mixes create larger eccentricities; softer mixes create smaller eccentricities. Standard Superpave volumetric specimens generally create eccentricities between 20 mm and 35 mm.

By controlling the radius of the two rings on the RAM device, it is possible to control the loading condition (or eccentricity) experienced by the SGC. Thus, the RAM provides precise control of the load while simultaneously measuring the internal angle of gyration. For routine verification of the internal angle of gyration, the RAM is equipped with built-in 44-mm OD rings projecting from each end. These radius of these rings (22-mm) represents the eccentricity simulated by the RAM. A 22-mm eccentricity is well suited for routine SGC angle measurement.

ASTM D 7115-05 *Standard Test Method for Measurement of Superpave Gyratory Compactor (SGC) Internal Angle of Gyration Using Simulated Loading* provides the guidelines to be followed when making internal angle measurements with the AFLS1. Pine Instrument Company report #LMRR200301B describes simulated loading in more detail.

SGC Frame Rigidity

A second pair of larger rings is also provided with each RAM device. When installed on each end of the RAM device, these larger rings (64-mm OD) induce a larger load on the SGC, corresponding to an eccentricity of 32-mm. By comparing the internal angle measured using the smaller rings with the internal angle measured using the larger rings, it is possible to quantify the "rigidity" of the SGC.

A rigid SGC with a strong frame design will resist deflection as the amount of load on the SGC increases. The internal angle of gyration on such an SGC will not change very much regardless of the ring radius (eccentricity) used with the RAM device. Use of the larger rings and issues pertaining to SGC rigidity are described in more detail near the end of this manual.

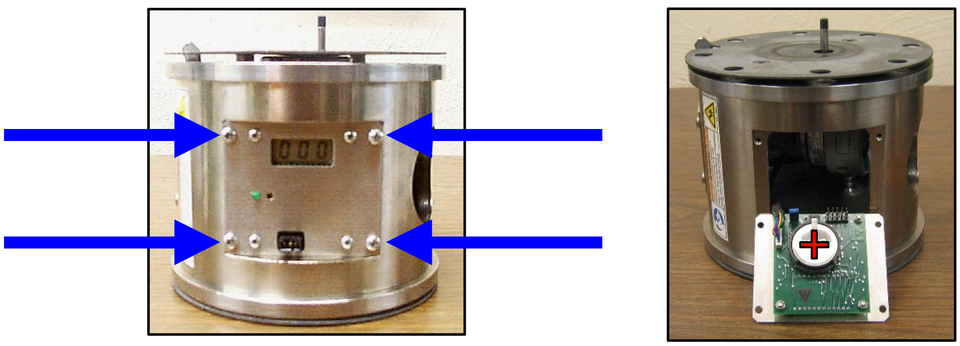
The ability to quantify SGC rigidity over a wide range of eccentricities is a unique feature of the Pine AFLS1 Rapid Angle Measurement device.

Battery Care

The estimated operational lifetime of the batteries within the RAM device is 250 hours (continuous use). Given the short amount of time required to make an internal angle measurement with the RAM device, the interval between battery replacements should be long.

 CR2450	**Replacement Batteries** There are three identical batteries inside the RAM device. They are 3V lithium watch batteries of type CR2450, available through many retail outlets or from Pine Instrument Company (part number EDL3V620). **All three batteries should be replaced at the same time**.

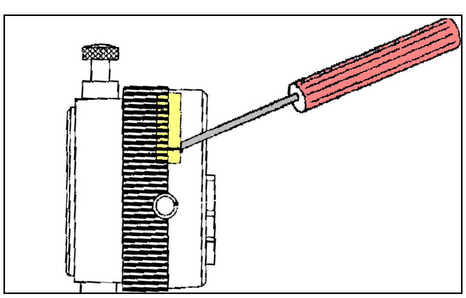
There are three batteries inside the RAM device. Two of the batteries are mounted within the digital dial gauge, and the third battery is mounted behind the main display. To change the batteries, the four screws which secure the main display must be removed.

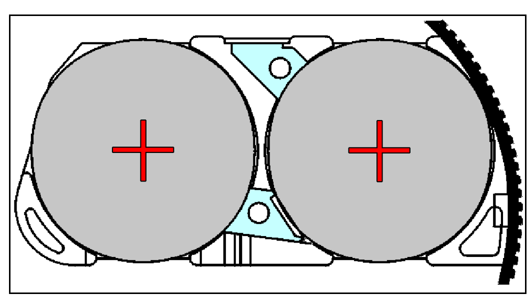


Remove the Four Large Screws to Gain Access to the Batteries

The battery mounted on the back side of the main display is readily accessible and easily changed. Pay close attention to the polarity of the battery being removed, and be certain to install the new battery with the polarity shown in the photo (above).

The two batteries located inside the dial gauge reside in a removable battery tray. This battery tray can be removed using a small screwdriver as shown below. When placing new batteries in the tray, be sure to install both of the batteries with the positive side facing upwards (as shown).

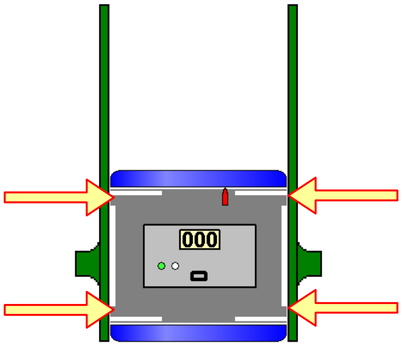




Daily Inspection and Lubrication

Before each use, check the screws on each end of the RAM to assure that they are tightened.

Routine lubrication of the Rapid Angle Measurement device is strongly recommended. The SGC mold contacts the outer diameter of the device at the top and bottom as shown below. A light lubricant, such as Vaseline®, should be used to keep the outer diameter lubricated. This lubrication should be applied before each use of the device.



In addition, a light oil should be used to lubricate the alignment probe frame where it slides in the body of the RAM device.

Cleanliness

Measuring angles to the nearest one hundredth of a degree (0.01°) requires a level of cleanliness not normally encountered in a hot mix asphalt laboratory. Even a small piece of debris can seriously alter the results of an angle measurement, so it is important to make certain that all metal surfaces on the RAM, SGC, SGC molds, and mold end plates are kept clean.

The spindle on the dial gauge probe must be kept clean. If any gummy deposits develop along or on the end of the spindle, use a dry cloth and a small amount of isopropyl alcohol (rubbing alcohol) or WD-40 to clean the spindle.

Note: **NEVER USE VASELINE ON THE INDICATOR SPINDLE !**

SGC Molds

The condition of an SGC mold can influence the angle measurement. Do not use molds which are excessively worn, deformed or have serious scratches on the inside walls. Also keep in mind that on some SGC models, the dimensions of the mold play a key role in maintaining the proper angle. If the mold height has decreased due to wear, or if a mold flange has been worn down by rollers, it might alter the angle of gyration. When in doubt, consult the SGC manufacturer regarding proper SGC mold dimensions.

Temperature

If the RAM is being used to measure the internal angle inside of heated SGC molds, then time should be allowed for the device to cool between each use. The best way to cool the RAM is to set it in front of a fan and allow ambient air to flow around and through the device. The internal temperature of the RAM must be less than 30°C before using it to measure an internal angle.

Do Not Freeze or Refrigerate!

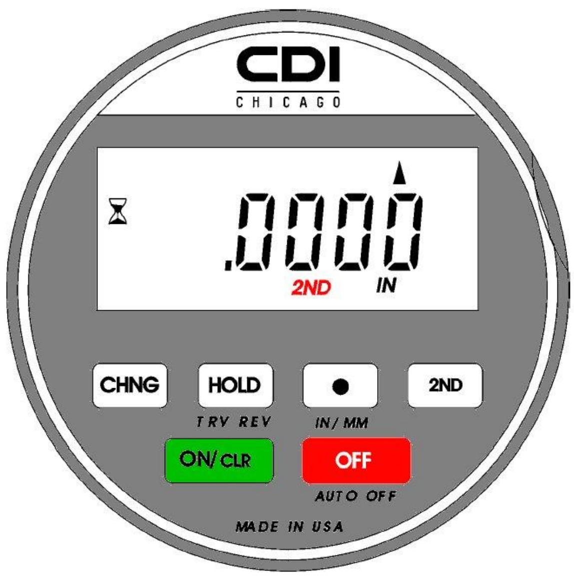
It is tempting to speed the cooling process by placing the RAM into a cold environment like a freezer. While this will cool RAM faster, the undesired consequence is water condensation inside the device. This water condensation can damage circuitry and rust metal parts. In addition, the RAM is not accurate at temperatures near freezing.

Temperature Matters

Calibrating the RAM against the Calibration Tube is valid only when both are at the same temperature! If the RAM has been in a hot mold or in a cold automobile recently, wait until both the RAM and the Calibration Tube are at room temperature (*i.e.*, typically overnight).

Turning the RAM On and Off

The dial gauge located within the RAM is used to turn the RAM on and off. The dial gauge has a green **ON/CLR** button and a red **OFF** button (see figure).



Pressing the green **ON/CLR** button turns on the RAM. Both the dial gauge display and the main display are activated at the same time.

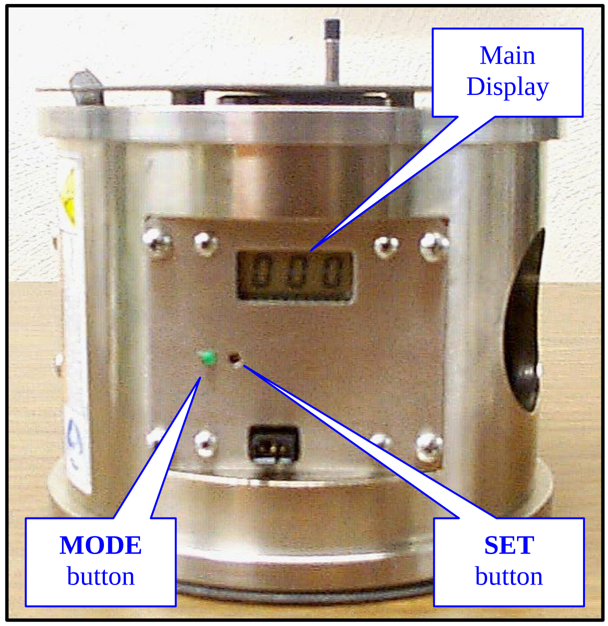
Pressing the red **OFF** button turns off the RAM. The RAM will also power off automatically after about ten minutes of idle time.

The RAM device can be reset at any time simply by turning it off and turning it back on again.

Main Display and Controls

An LCD display and two small buttons on the outside of the RAM are used to control normal operation of the device. The **MODE** button is used to cycle the device through four different operational modes as follows:

Display	Mode
-1-	Run
-2-	Diagnostics
-3-	Verify
-4-	Calibrate

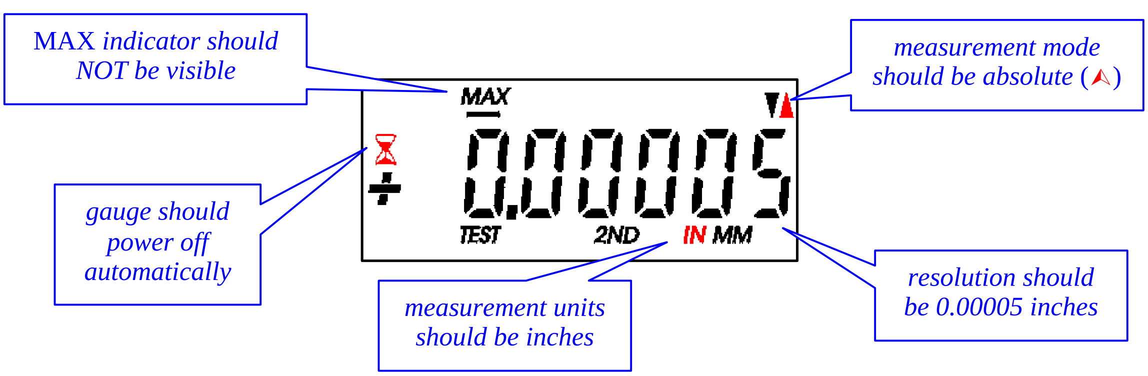


When the **MODE** button is pressed, the presently selected mode number is displayed for about two seconds. Pressing the **MODE** button again during this two second period advances to the next mode. Most of the time, the RAM is simply operated in **Run Mode** -1-, which is the mode that measures an SGC internal angle.

The **SET** button is located inside a small hole below the main display. A pen, mechanical pencil, or other small (but not sharp) object can be used to press the **SET** button. The **SET** button only used in the Diagnostics and Calibrate modes.

Dial Indicator Settings

The dial gauge located inside the RAM is shipped from the factory with the proper settings for making internal angle measurements. These settings are "locked" to prevent accidental change. If, for some reason, the dial gauge settings must be reset to their factory settings, the gauge should be configured as follows:



Internal Angle Measurement Procedure

Note: Follow ASTM D7115-05 *Standard Test Method for Measurement of Superpave Gyratory Compactor (SGC) Internal Angle of Gyration Using Simulated Loading* when making internal angle measurements with the AFLS1.

The RAM is used to rapidly measure either the top or the bottom internal angle of gyration. When measuring the top internal angle, the dial gauge probe is oriented toward the top of the SGC mold, and when measuring the bottom internal angle, the dial gauge probe is oriented toward the bottom of the mold. A complete evaluation of the internal angle usually involves taking the average of four measurements (*i.e.*, two top angles and two bottom angles). Such an evaluation can easily be accomplished in less than 30 minutes (with room temperature molds).

Preparing the Compactor

The SGC and its mold and end plates should be thoroughly cleaned and inspected for any damage. Molds or end plates that are scratched or worn should not be used for internal angle measurement. Debris present in the mold, on the mold end plates or on the ram head or SGC platen can introduce significant errors.

The SGC should be configured to gyrate at 10 times while applying a 600 kPa load. This provides time for the pressure and angle to stabilize prior to measuring the angle. Because the internal angle reported by the RAM is based upon the final five gyrations, there is little reason for using more than 10 gyrations when making a measurement. If a higher number of gyrations is used, then data from all but the final seven gyrations is simply ignored.

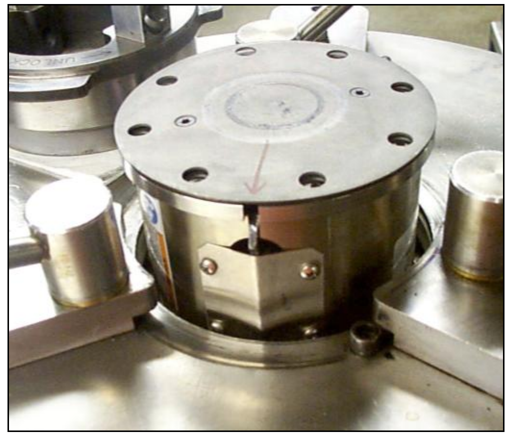
Note: A 600 kPa pressure corresponds to 10603 N for a 150-mm diameter mold.

Loading the Mold

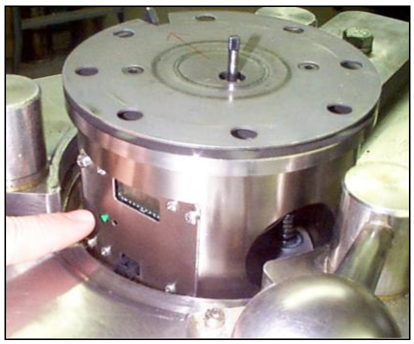
For most SGC models, the easiest way to place the RAM inside the SGC mold is to make use of the mold extruder. The extruder can be used to raise the mold bottom plate up to a position near the top of the mold. Then, the RAM can be gently placed directly on the mold bottom plate.

If the top internal angle is being measured, then the dial gauge probe must be oriented upwards. If the bottom internal angle is being measured, then the dial gauge probe is oriented toward the bottom of the mold.

RAM Oriented for Top Internal Angle



RAM Oriented for Bottom Internal Angle



Press the MODE Button Once to Set the RAM to Mode -1-
(Do This Just Before Lowering the RAM into the Mold)

Resetting the RAM

When the RAM is powered on, it is initially in **Run Mode** `-1-`. This is the mode used to measure an internal angle. A very easy way to reset the RAM prior to an internal angle measurement is to simply turn it off and then back on again.

Alternately, if it is known that the RAM is already in **Run Mode**, then the **MODE** button can be pressed once to reset the RAM. The display will momentarily show `-1-` and then it will show the internal temperature of the RAM.

Note: The internal temperature of the RAM should be less than 30°C before starting.

After the RAM is properly reset, the display should count down the timer from 30 to 0 then read `000` to indicate that the RAM is ready to begin counting gyrations.

Note:	**There is a 30 second time delay from the time the RAM is placed into Run Mode and the time the angle measurement is captured to prevent erroneous readings while the RAM is lowered into the mold and/or the mold is placed into the compaction chamber.**

Making the Measurement

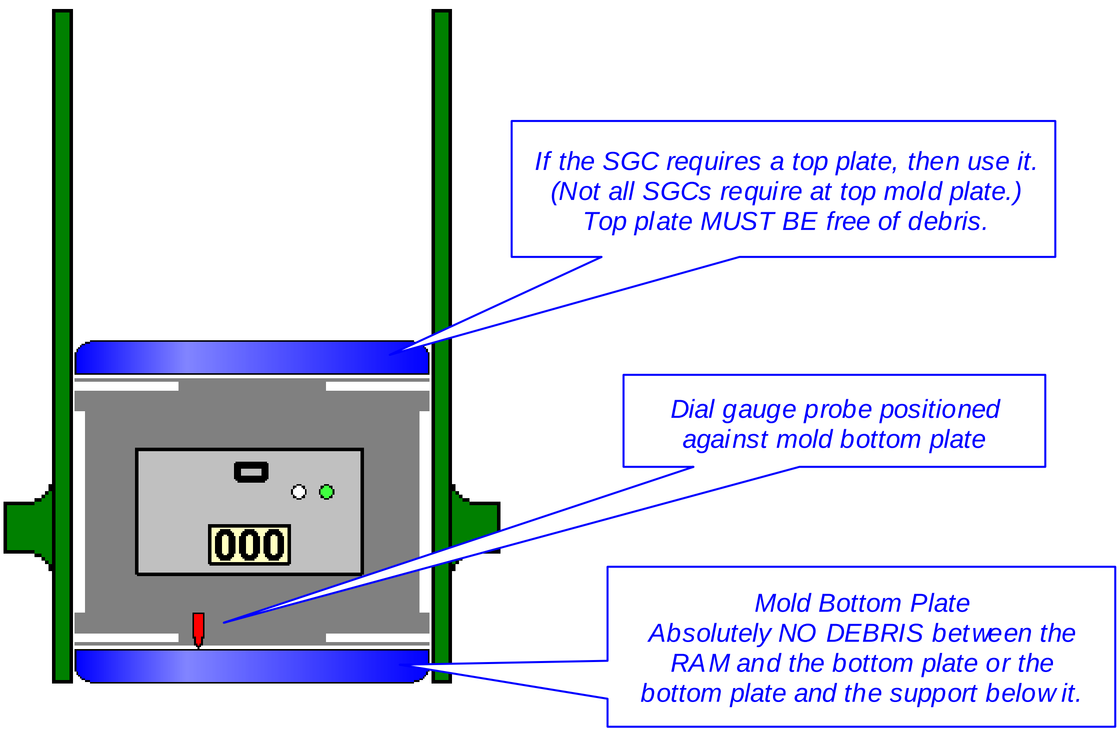
After the RAM is reset, use the extruder to gently lower the RAM down into the mold. For those SGC models requiring a top plate, be sure to place the top plate on top of the RAM prior to lowering the RAM into the mold.

Place the mold in the gyratory compactor and start the gyratory process. After the 10 gyrations are complete, use the extruder to remove the RAM from the gyratory mold.

The display on the RAM shows the internal angle measurement. The result **1.16** reported to the nearest hundredth of a degree should be flashing. If the result is not flashing, it means that the RAM did not obtain a statistically satisfactory set of angle measurements.

- The angle can be reported to the nearest 0.001° by pressing the set (recessed) button while the display is flashing. Due to display limitations, only the last three digits will be displayed without a decimal point. For example, if the measured angle is 1.214°, then the display will show **1.21**, then will show **214** after the set button is pressed.

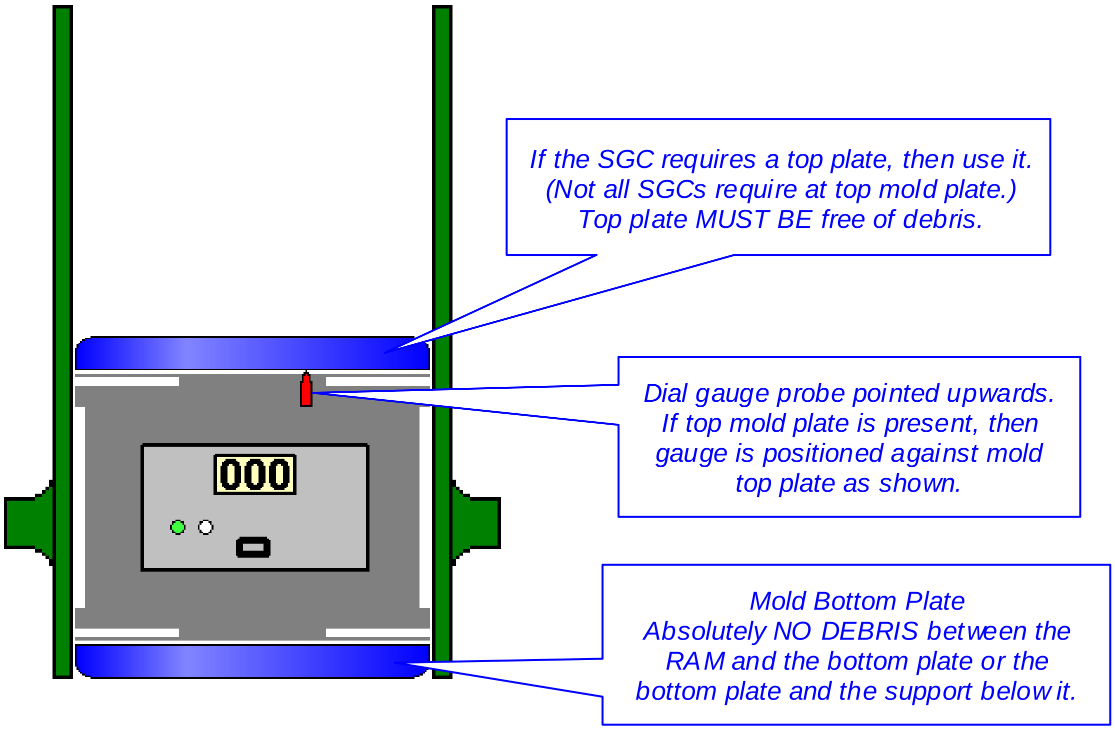
Measuring the Bottom Internal Angle of Gyration (δ_B)



- Work on a clean bench top to prevent debris from sticking to the bottom of the mold.
- Adjust compactor for 10 gyrations at 600 kPa pressure.
- Thoroughly clean the mold and mold end plates.
- Use the SGC extruder to raise mold bottom plate up near the top of the mold.
- Gently place RAM on bottom plate with dial gauge probe pointing downward.
- If required for the particular SGC being tested, place a mold top plate on top of the RAM.
- Use the extruder to slowly lower the RAM down into the mold.
- Put the loaded mold into the gyratory compactor.
- Start the compactor and gyrate the mold 10 times.
- Carefully extrude the RAM device from the mold.
- Read the internal angle from the main display on the RAM.

Never place hot mix asphalt in the mold with the Rapid Angle Measurement device!

Measuring the Top Internal Angle of Gyration (δ_T)



- Work on a clean bench top to prevent debris from sticking to the bottom of the mold.
- Adjust compactor for 10 gyrations at 600 kPa pressure.
- Thoroughly clean the mold and mold end plates.
- Use the SGC extruder to raise mold bottom plate up near the top of the mold.
- Gently place RAM on bottom plate with dial gauge probe pointing upward.
- If required for the particular SGC being tested, place a mold top plate on top of the RAM.
- Use the extruder to slowly lower the RAM down into the mold.
- Put the loaded mold into the gyratory compactor.
- Start the compactor and gyrate the mold 10 times.
- Carefully extrude the RAM device from the mold.
- Read the internal angle from the main display on the RAM.

Never place hot mix asphalt in the mold with the Rapid Angle Measurement device!

Error Conditions

If an error condition is detected during the angle measurement process, an error code appears on the main display. The following errors can occur during measurement:

E01 This error code is displayed if the RAM temperature exceeds the maximum operating temperature (40°C) at any time during the measurement. The display alternately flashes the error code and the present internal temperature **Error! Objects cannot be created from editing field codes.** of the RAM in Celsius. Allow the RAM to cool to less than 30°C before attempting another angle measurement.

E03 This error code is displayed if the angles recorded during the final five gyrations are statistically too variable to provide a reliable angle measurement. One reason that this error may occur is if the RAM and/or SGC mold is jostled a bit too much when placing the mold in the compactor. If this error occurs, reset the RAM by turning it off and on again, and then repeat the measurement.

00N If the display simply shows a small number from **001** to **005**, then the RAM did not sense enough gyrations to trigger the angle measurement process. Make sure the SGC is adjusted to perform at least 10 gyrations.

dE1 This code is displayed if the digital indicator has an Error 1 condition when Mode 1 or Mode 3 is selected. The Error 1 condition is the result of an over speed sense by the indicator. To clear this error, press the green On/Clear button on the indicator and reselect Mode 1.

dE2 This code is displayed if an Error 1 condition occurs on the digital indicator during data acquisition. This condition may result from an over speed detection as in error dE1 or it may be the result of a broken indicator. To clear this error, press the green On/Clear button on the indicator. Check indicator operation by moving the indicator probe over its travel range. If the Error 1 condition reoccurs on the indicator, the indicator is broken and must be repaired. If the indicator operates and displays displacement values properly, the error condition was likely from an over speed condition. Reset the instrument to Mode 1 and continue.

Diagnostics Mode

When the RAM is placed in **Diagnostics Mode** `-2-`, the internal values of certain operational parameters can be viewed on the main display. This mode is primarily for use by factory service personnel. To view the internal parameters, follow these directions:

- Press the **MODE** button to enter the **Diagnostics Mode** `-2-`.
- The display briefly shows the mode number `-2-` then displays the present version of the RAM firmware.
- Press the **SET** button again and it shows the internal temperature of the RAM in Celsius. If the temperature happens to be a negative number (*i.e.*, if the RAM is below freezing temperature for some reason), then the temperature reading will be flashing.
- Press the **SET** button again to view the dial indicator reading on the main display. In this case, the three most significant digits from the dial indicator should be displayed on the main display (without a decimal point). If the dial indicator reading is a negative number, then the value displayed on the main display will be flashing.
- To exit the **Diagnostics Mode**, press the mode button.

Routine Daily Verification

Before each use of the RAM (*i.e.*, on a daily basis), the RAM's internal angle measurement system should be verified using a Calibration Tube (supplied) to apply a known angle to the RAM. The Calibration Tube slides over the end of the RAM and contacts the dial gauge probe. By carefully rotating the Calibration Tube with respect to the RAM, a single "gyration" is applied to the RAM using a known internal angle.

The Calibration Tube Slides Over the Rapid Angle Measurement Device
(slide the tube over the end of the RAM with the dial gauge probe)

!	**Beware of any pinch points which may develop when sliding the Calibration Tube over the Rapid Angle Measurement device.**
!	**The larger (64.0-mm) rings should not be installed on the RAM during verification.**

Temperature Matters

Checking the RAM against the Calibration Tube is valid only when both are at the same temperature! If the RAM has been in a hot mold or in a cold automobile recently, wait until both the RAM and the Calibration Tube are at room temperature (*i.e.*, typically overnight).

Verification Procedure

- Place the RAM on a flat surface with the dial gauge probe pointing upwards and turn on the RAM. The RAM will initially be in **Run Mode** `-1-`.
- Carefully slide the Calibration Tube over the RAM and rotate it until the main display and **MODE** button are visible through the hole in the side of the Calibration Tube.
- Press the **MODE** button (twice) to enter **Verification Mode** `-3-`.
- When the `-3-` disappears, the angle reading should be `0.00` on the main display.
- Carefully rotate the Calibration Tube a full 360 degrees (in either direction) to apply a single "gyration" to the RAM device.

- When the main display is once again viewable through the hole in the side of the Calibration Tube, stop rotating the tube and wait for the angle result to be displayed.
- If the angle result on the display is within ±0.01° of the certified angle value written on the Calibration Tube, then the RAM is calibrated and functioning properly.
- Exit the **Verification Mode** by turning the RAM off and back on again.
- Repeat the verification twice. A proper verification consists of three replicates.

Turning Tip

When turning the Calibration Tube, the RAM has a tendency to turn with the tube. To prevent this from happening, slide the RAM near the edge of a table. With a small portion of the bottom of the RAM hanging off of the edge of the table, use one hand to hold the RAM in place while using the other hand to rotate the Calibration Tube.

CAUTION

Do Not Slide RAM Off Edge of Table!

How the Calibration Tube Works

The flat end surface on the inside of the Calibration Tube is slightly tilted with respect to the axis of the calibration tube. When the tube is placed over the RAM, the angle measurement apparatus is aligned with the axis of the tube, and the dial gauge probe directly contacts the tilted surface at the end of the tube. When the tube is rotated 360 degrees with respect to the RAM, the net effect is that the dial gauge probe travels up and down through one full cycle of displacement. This cycle simulates a single "gyration" where the tilt of the end plate with respect to the tube wall is known precisely. The certified angle inscribed on the top of the Calibration Tube is based on a traceable measurement of the tilt of the end surface with respect to the axis of the tube.

Calibration Mode

If more than one attempt at routine daily verification of the RAM indicates that it is out of calibration, then it is necessary to recalibrate the RAM. Do not attempt to recalibrate the RAM if unfamiliar with its normal operation. Do not attempt to recalibrate the RAM unless multiple attempts at routine verification have already failed.

Temperature Matters

Calibrating the RAM against the Calibration Tube is valid only when both are at the same temperature! If the RAM has been in a hot mold or in a cold automobile recently, wait until both the RAM and the Calibration Tube are at room temperature (*i.e.*, typically overnight).

The larger (64.0-mm) rings should not be installed on the RAM during calibration.

Calibration Procedure

- Place the RAM on a flat surface with the dial gauge probe pointing upwards and turn on the RAM. The RAM will initially be in **Run Mode** `-1-`.
- Carefully slide the Calibration Tube over the RAM and rotate it until the main display and **MODE** button are visible through the hole in the side of the Calibration Tube.
- Press the **MODE** button (thrice) to enter **Calibration Mode** `-4-`.
- When the `-4-` disappears, the main display shows three digits which should exactly match the fractional portion of the certified angle inscribed on the Calibration tube. For example, if the certified angle is 1.214°, then the display should show `214`.
- If the displayed value does not match the certified angle, then use the **SET** button to adjust the value on the main display until it matches the certified angle. Pressing the **SET** button one time will increment the displayed value by one. Holding down the **SET** button continuously causes the displayed value to increment automatically as long as the button is being pressed. The value on the display is adjustable from 100 to 300.
- After verifying that the reading on the display matches the certified angle, press the **MODE** button one time, and the display changes to `CAL`.
- While the display reads to `CAL`, rotate the calibration tube through a full 360 degrees with respect to the RAM. When a full revolution is completed, the main display will once again be visible through the hole in the tube, and a flashing `CAL` message should be visible on the display.
- To **abort** the calibration at this point, press the **MODE** button.
- To **accept** the calibration result, press the **SET** button. The message `END` will be displayed, and then the RAM automatically switches to **Verification Mode** `-3-`.

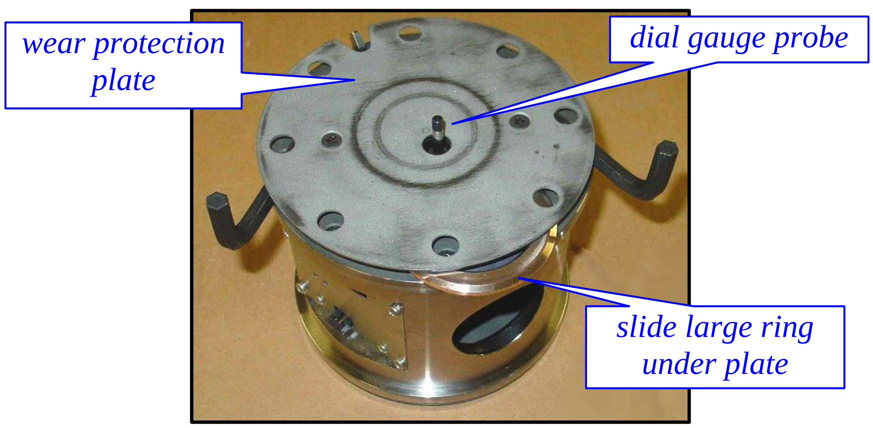
Alternate Contact Ring Installation

The contact rings integral to each end of the RAM have a diameter equal to 44.0-mm. This ring diameter creates a tilting moment which loads the SGC in a manner similar to the load induced by compaction of a typical Superpave specimen (115 mm tall x 150 mm OD). For purposes of routine SGC internal angle verification, the 44-mm contact rings should be used.

Users wishing to evaluate the internal angle of gyration under other (greater) loading conditions may install alternate larger rings on each end of the RAM. The contact diameter of these larger rings is 64.0-mm. These rings can be snapped into position on both ends of the RAM device.

Observing how the internal angle changes under different loading conditions allows the stiffness of an SGC frame to be evaluated. For example, if the internal angle does not change very much despite the additional load induced by the larger (64-mm diameter) contact rings, then this is an indication that the SGC frame is reasonably stiff. On the other hand, if the angle changes by a large amount when the load is increased, then this might be a warning that the SGC frame is relatively weak.

Always use the same ring diameter on both the top and bottom of the RAM device! Using a 44.0-mm ring on one end while using a 64.0-mm ring on the other produces erroneous results.



Note: The dial gauge probe must be carefully pushed down and out of the way in order to slide the larger ring into position.

Note: A small screwdriver (supplied) may be used to facilitate mounting and removal of the larger size rings.

Ring Installation Procedure

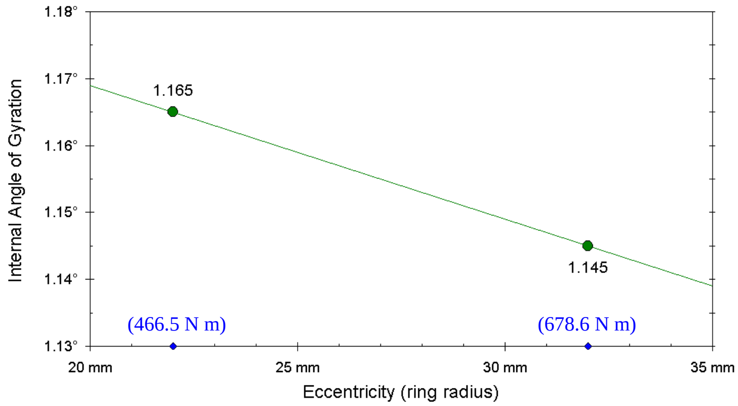
The larger diameter rings are designed to snap on to each end of the RAM. Because the spring-mounted wear protection plates on each end of the RAM must remain in place at all times, care must be taken to hold them away from the RAM while installing the larger rings. A pair of 5/16" hex wrenches (supplied) aid with this process.

- Place the RAM on a suitable work surface with the dial gauge probe pointing upwards.
- Slide the two hex wrenches underneath the wear protection plate to hold the plate away from the body of the RAM.
- Slide the large ring under the wear protection plate, center it on the end of the RAM, and snap it into place.
- Remove the hex wrenches from underneath the wear protection plate.
- Carefully flip the RAM over on to the other end (dial gauge probe pointing downwards).
- Slide the two hex wrenches underneath the wear protection plate to hold the plate away from the body of the RAM.
- Slide the large ring under the wear protection plate, center it on the end of the RAM, and snap it into place.
- Remove the hex wrenches from underneath the wear protection plate.

Once the larger rings are installed, the RAM can be used to measure the internal angle of gyration in the same manner as when using the smaller rings. The internal angle measured using larger rings is quite likely to be lower than that measured with the smaller rings.

SGC Frame Stiffness Calculation

If the internal angle is measured using the 44.0-mm rings and using the 64.0-mm rings, it is possible to quantify the “rigidity” of the SGC frame based on the slope of a plot like the one shown below. On this plot, the internal angle is plotted on the vertical axis versus the ring radius (eccentricity) on the horizontal axis. As the eccentricity increases, the internal angle decreases.



Ideally, an SGC would be infinitely rigid, meaning that no matter what load (*i.e.*, eccentricity) is experienced by the SGC, the internal angle of gyration would remain unchanged. In reality, all SGCs deflect when loaded. The greater the load, the more the deflection, and typically, the lower the angle. The RAM provides a way to quantify this behavior.

Assuming a 600 kPa vertical pressure, the following table shows the total moment created by the RAM for the two available ring sizes:

ring diameter (mm)	vertical pressure (kPa)	vertical force (newtons)	eccentricity (meters)	total moment (newton meters)
44.0	600	10603	0.022	**466.5**
64.0	600	10603	0.032	**678.6**

The SGC rigidity can be computed using the following equation,

$$\textbf{SGC Rigidity} = \frac{(\delta_{64} - \delta_{44})}{(678.6 \text{ N m} - 466.5 \text{ N m})}$$

where δ_{64} is the internal angle measured using the 64.0-mm rings, and δ_{44} is the internal angle measured using the 44.0-mm rings. For the example data shown in the plot, the SGC rigidity is computed as follows:

$$\textbf{SGC Rigidity} = \frac{(1.145° - 1.165°)}{(678.6 \text{ N m} - 466.5 \text{ N m})} = \frac{-0.02°}{212.1 \text{ N m}}$$

$$= -0.000094 \text{ degrees per newton-meter}$$

As computed above, the SGC rigidity is always a negative number, but it is convenient to drop the negative sign and simply express the rigidity as a positive number (*i.e.*, 0.000094°/N m). The *smaller* the magnitude of this number, the *stiffer (e.g.: less compliant)* the SGC frame.

The SGC Frame Rigidity

Typical standard Superpave HMA specimens (150 mm OD x 115 mm H) create an eccentricity in the range from 20 mm to 35 mm, depending on whether the mix is "soft" or "stiff". As long as an SGC has a rigid frame, the internal angle of gyration will not change very much over the entire range from "soft" to "stiff." Indeed, an ideal SGC frame would experience absolutely no deflection under load and would have an SGC rigidity equal to zero. However, a "real world" SGC frame deflects under the varying loads induced by different hot mix asphalt designs.

No two SGCs are likely to have exactly the same rigidity, but this is not a problem as long as both SGCs have similar rigidity. A pair of SGCs with similar rigidity can be adjusted so that they compact both "soft" and "stiff" mixes to the same extent, because both SGCs deflect under load in a similar manner.

However, if two SGCs have significantly different frame rigidity, it is quite impossible to adjust them so that they share the same angle of gyration over the entire range of mix stiffness. Such a pair might be adjusted to nearly the same internal angle at one eccentricity (i.e., 22 mm), but at a different eccentricity (i.e., 32 mm) the angles will not be the same. In this case, the RAM helps elucidate, but does not solve, the problem.

This predicament can be avoided either by always using SGCs with similar rigidity, or more appropriately, by addressing any mechanical issues that cause one SGC to be less rigid than the other SGC.