

## SMALL ID (< .004") OPTICAL MEASUREMENT METHOD

Traditionally, inside diameters (ID) have been measured using pin gages. Pin gages are inserted 1/16" until tight to determine the press fit ID. For most tubing sizes (ID: .005-.200"), this measurement method yields acceptable and correlatable results. However, with very small IDs (< .004") it is challenging to insert a delicate pin gage into a small tube without bending or causing damage. In these cases, pin gages don't yield acceptably accurate and repeatable results; results vary significantly from user to user and inconsistently meet the pass/fail criteria.

For small ID (.002-.004") tubing that cannot be measured with standard pin gages, K-Tube uses an optical measurement system by RAM® Optical. The high-precision RAM system allows easy focusing and part positioning. It has manual X-Y positioning control and side-mounted X-axis positioning with coarse and fine controls. It includes software with extensive functionality for general-purpose dimensional measurement. For circles and arcs, the RAM system has a feature finder that automatically measures a selected geometric shape according to specified points. This optical measurement system enables us to obtain consistent, repeatable results when using the same sample preparation and measuring technique.

### MEASUREMENT PROCESS

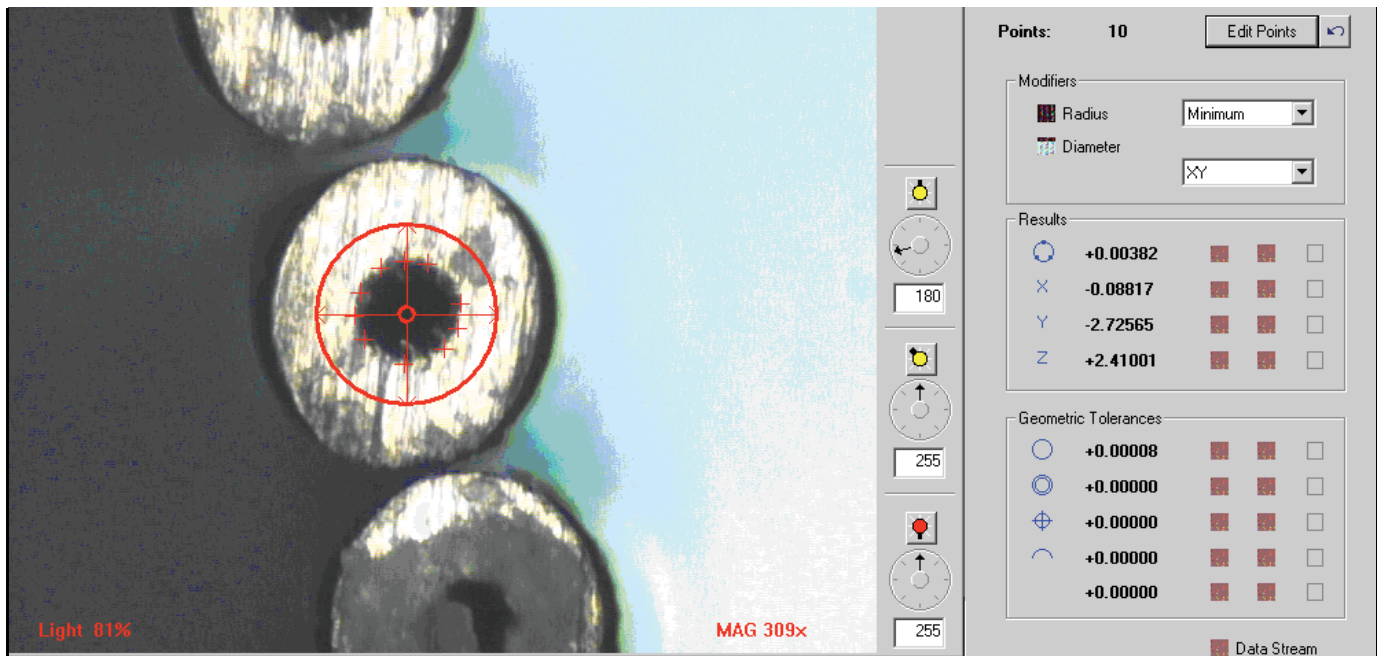
#### SAMPLE PREPARATION

1. Obtain sample tube that is 1.25" to 1.5" long and is open ended.
2. Grind and polish samples enough to measure actual ID with precision.
3. Clean tubing samples and flush ends with DI water to remove all debris from ID of tubing.
4. Dry tubing with compressed air to dislodge any remaining debris and water.
5. Inspect samples for open ends and cleanliness under a QA lab stereo microscope at 20x.

#### RAM OPTICAL MEASUREMENT

6. Position samples on RAM measurement stage perpendicular to X-Y coordinates so that the tubes are standing on end under the camera lens. A magnet is used to hold the sample vertically and straight.
7. Center image on the monitor by adjusting X-Y stage.
8. Set magnification to maximum zoom.
9. Increase illumination gradually to maximize the contrast between the tube wall and ID.
10. Adjust coarse/fine focus knobs to obtain best possible image.
11. Using the RAM's circle/arc feature finder, select three points 120 degrees apart.
12. Select "MINIMUM" on the radius modifier option to have the software calculate the minimum diameter opening of the ID. The measured ID result resembles the pin gage technique/results. See figure on back. The result displayed in this figure is +.00382" with a tolerance of .00008".

## MINIMUM DIAMETER OPENING OF ID ON RAM OPTICAL EQUIPMENT



## ANALYZED DATA FROM ACTUAL TEST RESULT

Sample Number	RAM Results (Regular Prep) <sup>1</sup>	RAM Results (Advanced Prep) <sup>2</sup>	Customer Test Results (Advanced Prep) <sup>3</sup>
1	.00320"	.00328"	.00332"
2	.00280"	.00308"	.00302"
3	.00314"	.00294"	.00306"
4	.00306"	.00308"	.00310"
5	.00304"	.00312"	.00321"
6	.00313"	.00308"	.00317"
7	.00301"	.00293"	.00302"
8	.00290"	.00314"	.00309"
9	.00309"	.00299"	.00312"
10	.00329"	.00332"	.00327"
<b>Mean</b>	<b>.003063"</b>	<b>.003096"</b>	<b>.003138"</b>
<b>STDEV</b>	<b>.000140"</b>	<b>.000129"</b>	<b>.000103"</b>

1. Regular prep: Tube is ground and polished enough to measure ID cross-section with precision.
2. Advanced prep: Tube ID cross-section is filled with epoxy, diamond cut, and polished.
3. Illumination is critical. Angles, light intensity, filtering, etc., must be correlated.

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