AccuPyc® 1340

Gas Displacement Pycnometer Series

Calculations

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micromeritics®

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ANALYSIS

For derivation, see the Sample Volume Equation Derivation section of the AccuPyc II Series Operator Manual.

10, 100, AND 350 CM^3 UNITS

$$V_s = V_c - \frac{V_x}{\frac{P_1}{P_2 - 1}}$$

$$\rho_s = \frac{m_s}{V_s}$$

where

V_c	=	sample chamber volume
V_x	=	expansion chamber volume
V_s	=	sample volume
m_s	=	sample mass
ρ_s	=	sample density
P_1	=	gauge pressure after fill
P_2	=	gauge pressure after expansion

1 CM^3 AND 2000 CM^3 UNITS

$$V_s = V_c - V_x\left(\frac{P_1}{P_2} - 1\right)$$

$$\rho_s = \frac{m_s}{V_s}$$

where

V_c	=	sample chamber volume
V_x	=	expansion chamber volume
V_s	=	sample volume
m_s	=	sample mass
ρ_s	=	sample density
P_1	=	gauge pressure after fill
P_2	=	gauge pressure after expansion

ASPHALT DENSITY

Sample volume at 60 °F is found by multiplying the measured volume by the asphalt volume correction factor.

$$V(60) = \alpha(T)V_{\text{measured}}$$

where

$$\alpha(T) = 1.0211326242 - 3.548988118 \times 10^{4}T + 4.498813 \times 10^{-8}T^{2}$$

and T is the analysis temperature in degrees Fahrenheit.

Sample density at 60 °F is

$$\rho(60) = m/V(60)$$

Specific gravity at 60 °F is calculated by dividing the adjusted sample density by the density of water at 60 °F.

$$SG(60) = \rho(60)/\rho_{\text{H2O}}(60)$$

where

$$\rho_{\text{H2O}}(60) = 0.9990170$$

Note that the density of water at the analysis temperature is not required for this calculation.

FOAMPYC METHODS

METHOD A: COMPUTED OPEN CELL FRACTION

$$\mathrm{OpenCellPct} = \frac{\mathrm{GeomVol} - V_s - \mathrm{VolCellsCutOpen}}{\mathrm{GeomVol}} \times 100$$

$$\mathrm{ResinPlusClosedCellPct} = 100 - \mathrm{OpenCellPct}$$

If cell measure is **Chord Length**,

$$\mathrm{VolCellsCutOpen} = \mathrm{ActiveArea} \times \frac{\mathrm{ChordLength}}{1.14}$$

If cell measure is **Diameter**,

$$\mathrm{VolCellsCutOpen} = \mathrm{ActiveArea} \times \frac{\mathrm{CellDiam}}{1.4515}$$

METHOD B: MEASURED OPEN CELL FRACTION

$$\mathrm{VolCellsCutOpen} = V_s[1] - V_s[2]$$

$$\mathrm{ResinPlusClosedCellVol} = V_s[1] + \mathrm{VolCellsCutOpen}$$

$$\mathrm{OpenCellVol} = \mathrm{GeomVol} - \mathrm{ResinPlusClosedCellVol}$$

$$\mathrm{ResinPlusClosedCellPct} = \frac{\mathrm{ResinPlusClosedCellVol}}{\mathrm{GeomVol}} \times 100$$

$$\mathrm{OpenCellPct} = \frac{\mathrm{OpenCellVol}}{\mathrm{GeomVol}} \times 100$$

where

$V_s[1]$ = V_s from the first analysis (before recutting)
$V_s[2]$ = V_s from the second analysis (after recutting)
$V_s[1]$ = V_s from the first analysis (before recutting)

METHOD C: UNCORRECTED OPEN CELL FRACTION

$$\text{OpenCellVol} = \text{GeomVol} - V_S$$

$$\text{OpenCellPct} = \frac{\text{OpenCellVol}}{\text{GeomVol}} \times 100$$

METHOD D: COMPRESSIBILITY TEST

Quantities appended with [i] are for cycle i, where i goes from 1 up to the number of cycles.

$$\Delta V_{P_1}[i] = \frac{V_s[i-1] - V_s[i]}{P_1[i-1] - P_1[i]}$$

$$\Delta V_{P_2}[i] = \frac{V_s[i-1] - V_s[i]}{P_2[i-1] - P_2[i]}$$

$$\text{AvgVolChangeP1} = \text{avg}(\Delta_{P1}[i] \text{ for all included i}$$

$$\text{AvgVolChangeP2} = \text{avg}(\Delta_{P2}[i] \text{ for all included i}$$

$$\text{PctAvgVolChangeP1} = \frac{\text{AvgVolChangeP1}}{\text{GeomVol}} \times 100$$

$$\text{PctAvgVolChangeP2} = \frac{\text{AvgVolChangeP2}}{\text{GeomVol}} \times 100$$

METHOD E: FRACTURE TEST

$$\Delta\text{Vol} = V_s[3] - V_s[1]$$

$$\text{PctFracturedCells} = \frac{\Delta\text{Vol}}{\text{GeomVol}} \times 100$$

where

$V_S[1]$ = V_S for the first (prefracture) cycle
$V_S[3]$ = V_S for the third (postfracture) cycle

CALIBRATION

Volume calibration uses the ultra-precise method of separate adjustments for the offset and scale factor.

VOLUME OFFSET

$$V_c = V_{\text{celprev}} - V_{\text{sampempty}}$$

$-V_{\text{sampempty}}$ is reported as the offset in volume calibration reports.

VOLUME SCALE

$$V_c = V_{\text{celprev}} \left(\frac{V_{\text{calib}}}{V_{\text{sampball}}} \right)$$

$$V_x = V_{\text{expprev}} \left(\frac{V_{\text{calib}}}{V_{\text{sampeball}}} \right)$$

$\left(\frac{V_{\text{calib}}}{V_{\text{sampeball}}} \right)$ is reported as the scale factor in volume calibration reports.

where

V_c	=	sample chamber volume
V_{celprev}	=	previously stored cell volume
$V_{\text{sampempty}}$	=	average V_{samp} from volume offset calibration analysis (no calibration ball)
V_{calib}	=	calibration ball volume
V_{sampball}	=	average V_{samp} from volume scale calibration analysis (with calibration ball)
V_x	=	expansion chamber volume
V_{expprev}	=	previously stored expansion volume

GEOMETRIC VOLUME AND ACTIVE AREA

Geometric volume of the sample is calculated based on the sample shape; for Method A, Active area is also calculated.

CUBE

$$\mathrm{GeomVol} = \mathrm{EdgeLength}^3 \times \mathrm{NumPieces}$$

$$\mathrm{ActiveArea} = \mathrm{EdgeLength}^2 \times (6 - \mathrm{NumSkins}) \times \mathrm{NumPieces}$$

CYLINDER

$$\mathrm{GeomVol} = \pi \times \frac{\mathrm{Diam}^2}{4} \times \mathrm{Height} \times \mathrm{NumPieces}$$

$$\mathrm{ActiveArea} = [\pi \times \mathrm{Diam} \times \mathrm{Height} + \frac{\pi}{r} \times \mathrm{Diam}^2 \times (2 - \mathrm{NumSkins})] \times \mathrm{NumPieces}$$

RECTANGLE

$$\mathrm{GeomVol} = \mathrm{LongEdge} \times \mathrm{ShortEdge} \times \mathrm{RemainEdge} \times \mathrm{NumPieces}$$

$$\begin{aligned}\mathrm{ActiveArea} = [&\mathrm{LongEdge} \times \mathrm{RemainEdge} \times (2 - \mathrm{NumLargeSkins}) + \mathrm{ShortEdge} \\ &\times \mathrm{RemainEdge} \times (2 - \mathrm{NumSmallSkins}) + \mathrm{LongEdge} \times \mathrm{ShortEdge} \\ &\times (2 - \mathrm{NumRemainSkins})] \times \mathrm{NumPieces}\end{aligned}$$

PERCENT POROSITY

$$\text{percent porosity} = (\rho_s - \rho)/\rho_s$$

RESIN VOLUME

$$\mathrm{ResinVol} = \frac{m_s}{\mathrm{ResinDensity}}$$

$$\mathrm{ResinVolPct} = \frac{\mathrm{ResinVol}}{\mathrm{GeomVol}} \times 100$$

where

m_s = sample mass

RUN PRECISION

Run precision requires at least five runs. Run precision criterion is met when the sample volumes calculated for the four most recent previous runs fall within the specified error band for the current run's sample volume. The error band is a specified percentage of the nominal volume of the sample chamber (1, 10, 100, 350 and/or 2000 cm^3).

$V_s[0]$ to $V_s[4]$ are the five most recent sample volumes, $V_s[4]$ being the most recent.

$$\mathbf{ErrBand} = \mathbf{PctFullScale} \times \frac{\mathbf{V_{nominal}}}{\mathbf{100}}$$

where

$V_{nominal}$ = nominal sample cell volume

If $(|V_s[i] - V_s[4]| \leq \mathbf{ErrBand})$ for i = 0 to 3, run precision is achieved.

SPC REPORT VARIABLES

REGRESSION CHART VARIABLES

The line of best fit for the Regression Chart is calculated by the usual least squares method. [1] If there is only a single point or all *N* points have the same x-value, there can be no line of best fit in the standard form.

$$\bar{x} = \frac{\sum x_i}{N}$$

$$\bar{y} = \frac{\sum y_i}{N}$$

$$\text{Slope} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}$$

$$\text{Intercept} = \bar{y} - \text{Slope} \cdot \bar{x}$$

The coefficient of correlation for this line is also calculated in the usual way. [2]

$$\sigma_x = \sqrt{\frac{\sum (x_4 - \bar{x})^2}{N}}$$

$$\sigma_y = \sqrt{\frac{\sum (y_i - \bar{y})^2}{N}}$$

$$\text{Cov}(x, y) = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{N}$$

$$\text{Correlation Coeff} = \frac{\text{Cov}(x,y)}{\sigma_x \sigma_y}$$

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[1] *BASIC Scientific Subroutines Vol II*, by F.R. Ruckdeschel, Copyright 1981 BYTE Publications/McGraw Hill, p. 16.

[2] *Mathematical Handbook for Scientists and Engineers*, G.A. Korn and T.M. Korn, McGraw Hill, Sec. 18.4. (1968)

CONTROL CHART VARIABLES

$$\text{Mean} = \frac{\sum y_i}{N}$$

$$\text{Standard Deviation} = \sqrt{\frac{\sum (y_i - \text{Mean})^2}{N-1}}$$

$$\text{C. V.} = \frac{\text{StdDev}}{\text{Mean}}$$

$$+n\sigma = \text{Mean} + n \cdot \text{Standard Deviation}$$

$$-n\sigma = \text{Mean} - n \cdot \text{Standard Deviation}$$

SPECIFIC GRAVITY

$$\mathrm{SG} = \rho_s / rho_w$$

where

ρ_w = water density at analysis temperature

TOTAL PORE VOLUME

Total pore volume is per gram of sample.

$$\text{TotalPoreVol} = \frac{\rho_s - \rho_{\text{bulk}}}{\rho_s \times \rho_{\text{bulk}}}$$

where

ρ_{bulk} = entered bulk density

TOTAL SOLIDS CONCENTRATION

$$\mathrm{WeightPercentSolids} = \left(1 - \frac{\rho_{\mathrm{liq}}}{\rho_s}\right) \frac{\rho_{\mathrm{sol}}}{\rho_{\mathrm{sol}} - \rho_{\mathrm{liq}}} \times 100$$

where

ρ_{liq}	=	entered liquid density
ρ_{sol}	=	entered solid density
ρ_s	=	sample density