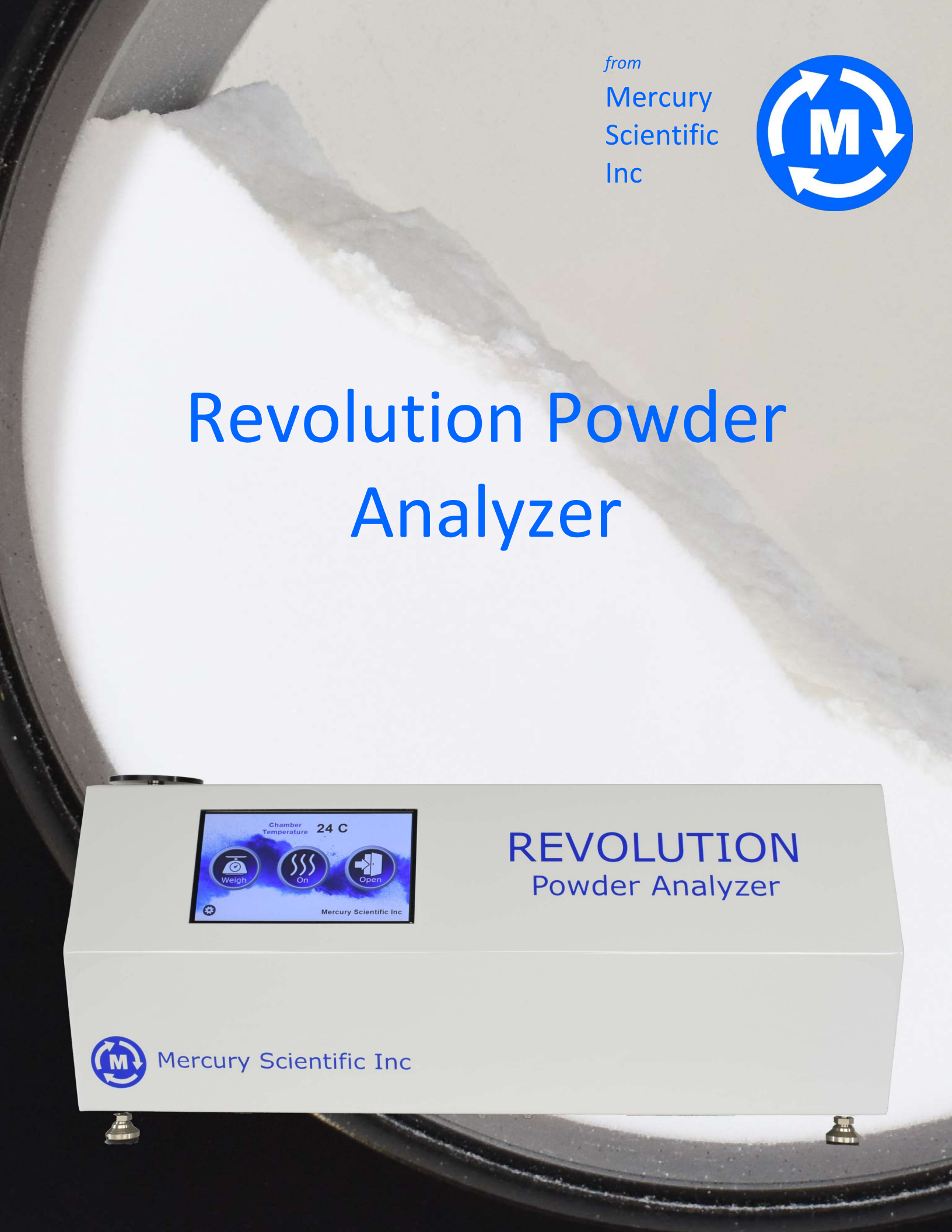
*from*

Mercury Scientific Inc

# Revolution Powder Analyzer



The Revolution Powder Analyzer measures the flow properties of powders by taking and analyzing images of powder as it flows in a rotating drum.


measure sample


load drum

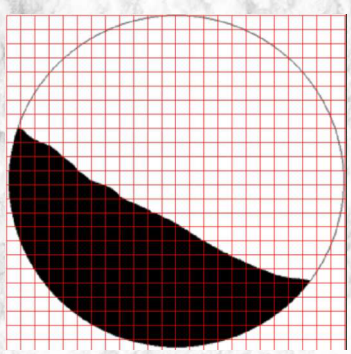
put drum in analyzer


analyze flow properties

The instrument is very easy to use. A measured volume of test powder is collected using the provided sample cup. The sample is then loaded into the sample drum and the drum is placed inside the instrument on two rollers in front of a machine vision camera. The drum is back or front lighted depending on the measurements required. The test is started and images of the sample powder are taken with the camera and are analzyzed using image analysis software as the drum turns or vibrates. The analysis software locates the powder and measures several powder parameters automatically for every image.

**Properties Measured For Each Image**

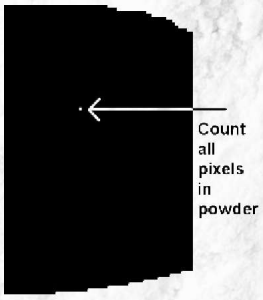
| | |
|---|---|
| Energy Level (mJ,mJ/kg) | Surface Fractal |
| Full Angel (deg) | Half Angle (deg) |
| Volume (cm3) | Density (g/cm3) |
| Curvature (cm) | Linearity |



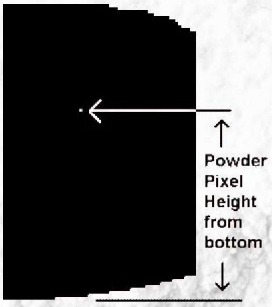
A digital image is made of pixels with different grey levels. The image is converted to a binary image with only black and white pixels for analysis.

The potential energy level of the sample powder is calculated by summing the potential energy level represented by each powder pixel. The energy level of each pixel is calculated using the height of the pixel from the bottom of the drum and the powder mass in the projected volume of each pixel. The projected mass is determined using the total volume of the powder and the sample weight.

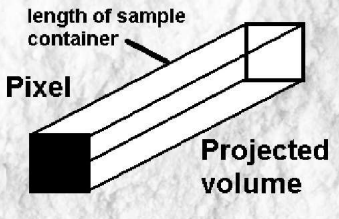

binary image



single powder pixel



pixel height



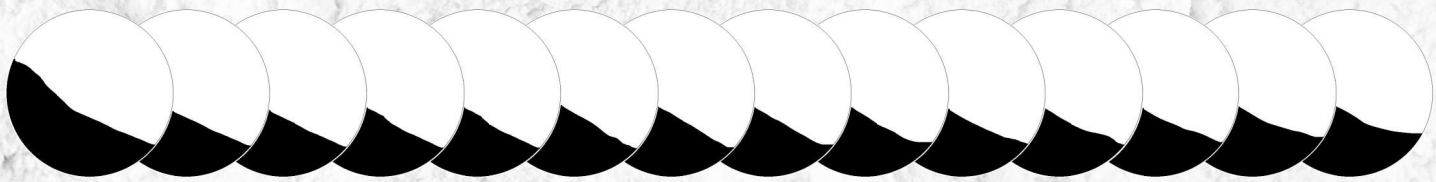
projected pixel volume

$$\boldsymbol{Potential\ Energy\ (J)} = \sum_{n=0}^{n=\#powder\ pixels} \boldsymbol{(Pixel\ Height\ (m))(Pixel\ Mass\ (kg))(9.8\ (m/s^2)}$$

**Powder Flow Properties measured over time**

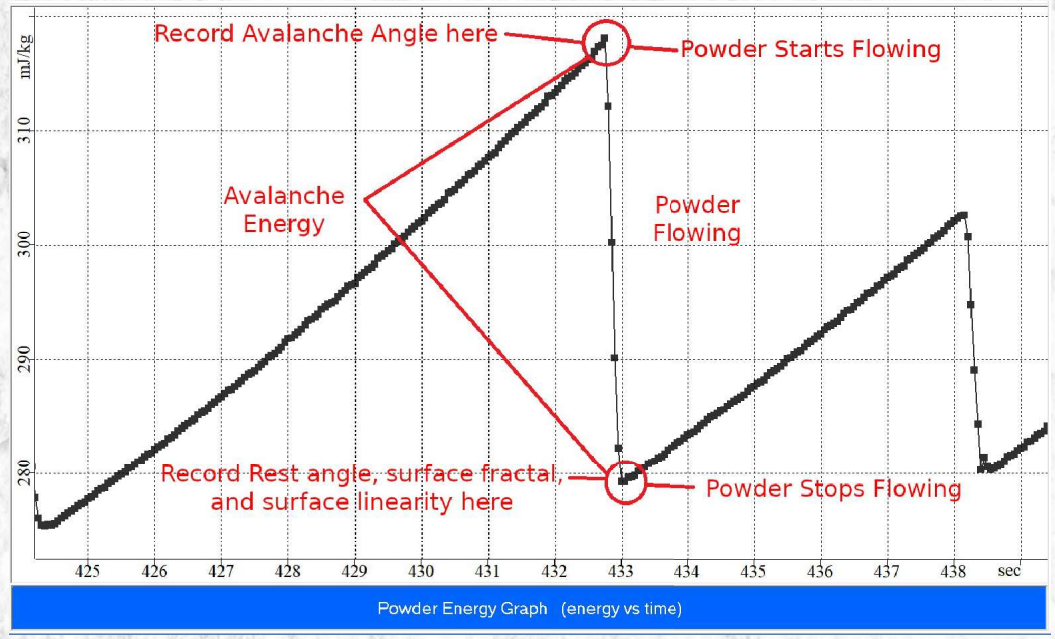
Avalanche Energy (mJ)
Break Energy (mJ)
Avalanche Angle (deg)
Rest Angle (deg)
Yield Strength (Pa)
Surface Fractal
Dynamic Density (g/cm3)
Cohesion (Pa)
Flow Speed (mm/s)
Energy (mJ)
Volume Fraction
Avalanche Curvature (cm)

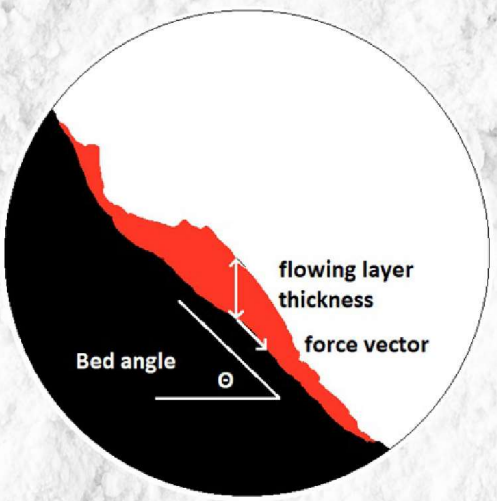
The Revolution takes images of the sample powder over time at up to 500 images per second at precise intervals. This allows the software to determine when the powder changes behavior. Measurements are made when the powder starts flowing, during flow,and when the powder stops flowing. 5,000 to 10,000 images are taken per test.



Using the powder energy value of each image, the Revolution software detects when the test powder starts flowing in the drum by a drop in energy and records the avalanche angle and break energy values. The rest energy and rest angle are recorded when the powder stops flowing. The avalanche energy is the energy released by an avalanche and is the difference between the break and rest energies. The surface fractal and surface linearity are recorded when the powder stops flowing as a new surface is created.

Each black point in the graph represents the energy level in one image. Energy increases when the powder does not flow and moves up due to the drum rotation. Energy decreases when the powder flows down the drum. The circles illustrate transition points in the behavior of the test powder.




Cohesion and flow speed are measured while the powder is flowing. Flow speed is measured by clocking the powder wave as it moves in the drum. The analyzer also measures the thickness of the flowing layer as the powder flows. This thickness along with the density of the powder bed and the angle of the powder bed is used to calculate the cohesive forces holding the powder particles together.

$$Cohesion(Pa) = Flowing\ Layer\ thickness * Bed\ density * 9.8 * sin(Bed\ Angle)$$

The Revolution software uses the basic measurements to perform several types of tests:

**Flow Test**
Test the powder at one rotation speed. Lower speeds are more sensitive to small changes in the sample powder.

**Multi-Flow Test Test**
Test powder at multiple rotation speeds to study the stability of the powder with energy.

**Packing Test**
Vibrate the drum and measure powder volume and bed strength changes.

**Fluidization Test**
Rotate drum at high speed to determine fluidization potential.

**Static Charge Test**
Study powder tribo-charging properties using a static sensor to measure static on test drum.
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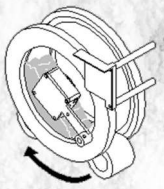
Static Sensor

**Example Flow Test Data**

| Result | Ti64 Used | Ti64 50/50 | Ti64 Virgin | 316L Used | 316L 50/50 | 316L Virgin |
|---|---|---|---|---|---|---|
| Avalanche Energy | 8.6 mJ/kg | 10.8 mJ/kg | 12.6 mJ/kg | 13.3 mJ/kg | 19.7 mJ/kg | 27.9 mJ/kg |
| Break Energy | 24.3 mJ/kg | 26.1 mJ/kg | 28.2 mJ/kg | 36.3 mJ/kg | 47.3 mJ/kg | 60.4 mJ/kg |
| Dynamic Density | 2.59 g/cc | 2.55 g/cc | 2.42 g/cc | 4.29 g/cc | 4.19 g/cc | 4.12 g/cc |
| Avalanche Angle | 32.0 deg | 32.9 deg | 38.6 deg | 41.4 deg | 46.6 deg | 50.9 deg |
| Yield Strength | 52.3 Pa | 66.1 Pa | 81.7 Pa | 174.7 Pa | 253.7 Pa | 336.5 Pa |
| Cohesion | 27.4 Pa | 33.0 Pa | 49.8 Pa | 93.3 Pa | 221.6 Pa | 343.1 Pa |
| Volume Fraction | 0.585 | 0.576 | 0.546 | 0.534 | 0.521 | 0.513 |

The above data is for metal powders used in an AM printer. The results demonstrate that the flow test of the Revolution can distinguish between the virgin, used and blended samples for both sample materials even when the difference between the materials is very small. Additionally, the fifty-fifty blended sample data is in the middle between the virgin and used materials.Generally, the lower the values for the flow values the better the flowability except for flow speed and dynamic density. Dynamic density increases with flowability because the powder particles can flow around each other ans create a bed with less air space.

**Specifications**

Rotation Rate: 0.1 to 200 rpm
Imaging Rate: 1 to 500 frames per second
Temperature: ambient to 250C (optional heating)
Sample Size: 8cm$^3$ to 500cm$^3$ (TYP 25cm$^3$, 100 cm$^3$)
Vibration: frequency and amplitude control

Voltage: 100-240V,
Current: Control 3 Amps, Temp Option 4 Amps
Software: Windows 11
Ports: 1 USB control, 1 USB3 Camera
Dimensions: 23"L x 11"W x 11"H (59 x 27 x 27 cm)

Mercury Scientific Inc. manufacturers instruments that test powder properties in Newtown CT USA. Products include the Evolutuon Powder Tester and Volution Shear tester for static flow (Unconfined Yield Strength) measurements and the SpreadStation for spreadability measurments.

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