CAMSIZER®

Dynamic Image Analysis
ISO 13322-2 conform

Measuring the Size and Shape of Frac Sand and other Proppants

Webinar Presentation
Friday, March 9th, 2012

Speaker: Dipl.-Ing. Gert Beckmann
Retsch Technology GmbH

Host: Ian Treviranus
HORIBA Scientific Inc.

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Abstract

Measuring the Size and Shape of Frac Sand and other Proppants

The size and shape of frac sands and other proppants plays a critical role in keeping fractures open and at the desired conductivity.
Learn how the CAMSIZER has greatly improved the accuracy and speed of proppant analysis.
This information will be useful for any petroleum engineer or proppant supplier referencing ISO 13503-2 or API RP 56/58/60 standards.

This Webinar will cover the following topics:

* Faster, more accurate size measurement
* Reporting sphericity and roundness
* Objective results in only 3 minutes
* Example measurement results

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Benefits for the Proppant Industry

- Instead of size measurement with sieve shaker and shape analysis by visual inspection you can do a CAMSIZER analysis of both in a much shorter time

- Reproducible results because of high statistics and accurate calibration

- Measuring easily in compliance of API specifications of grain size (90%), oversize and dust (<1%), roundness and sphericity and measure the dust content before and after the crush resistance test

- Measure the increase of layer coating thickness and change of roundness because of the resin coating of sand grains or ceramic proppants

- Also possible:
  Measuring diameter and length of extrudates

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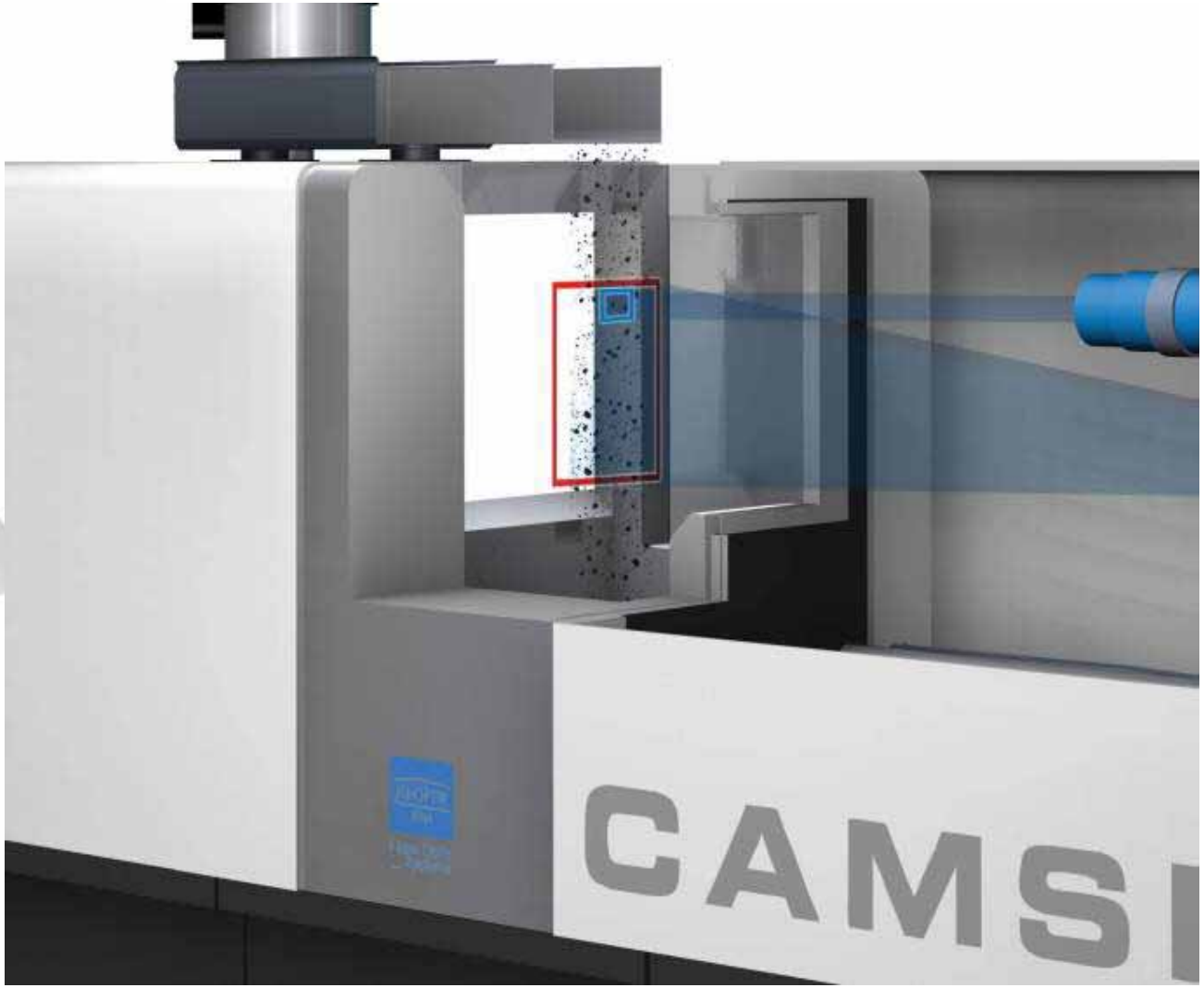
Measuring Principle



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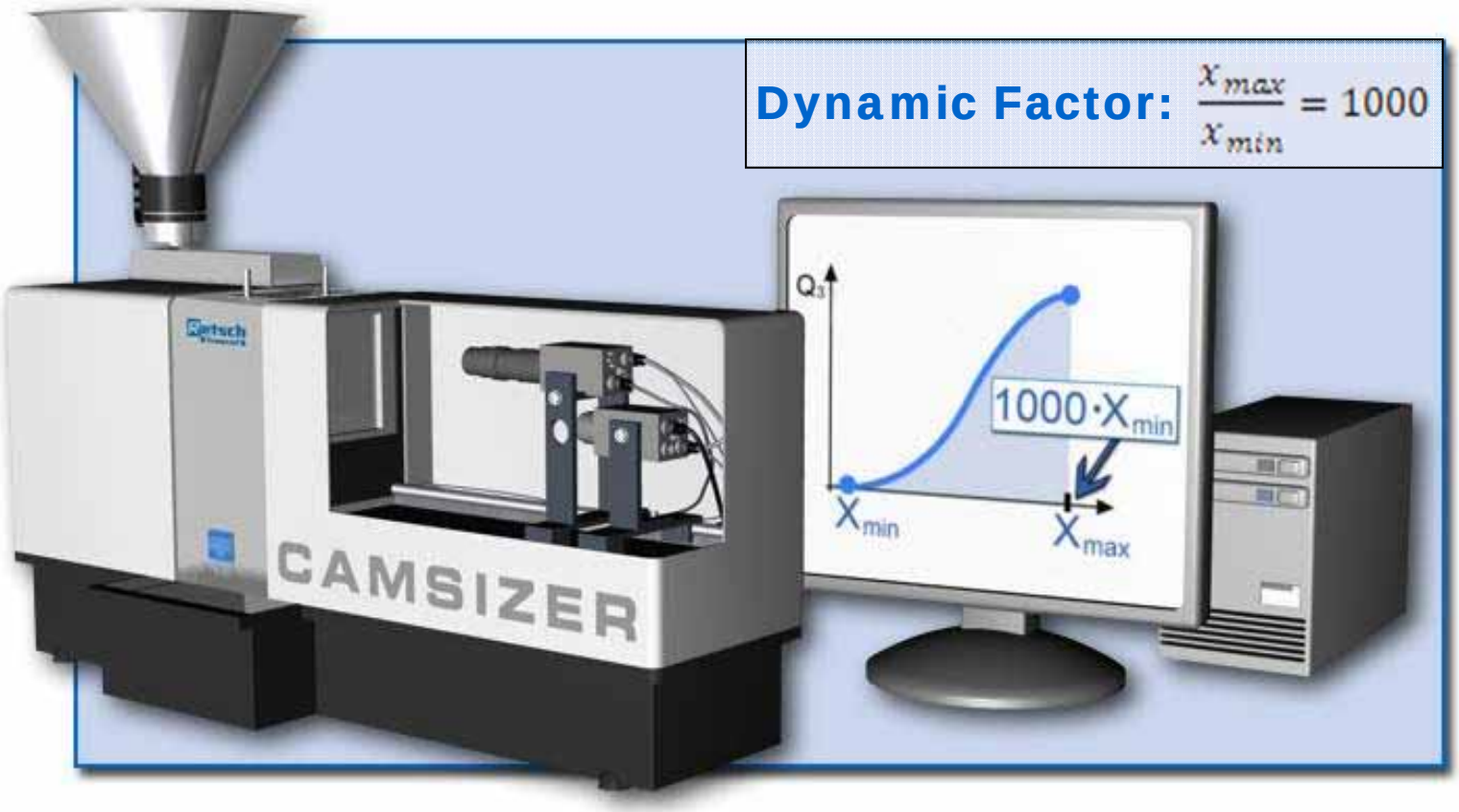
CAMSIZER Principle (Two Cameras)



Advantages

- Precise full-frame images
- Wide dynamic range: 30µm to 30mm

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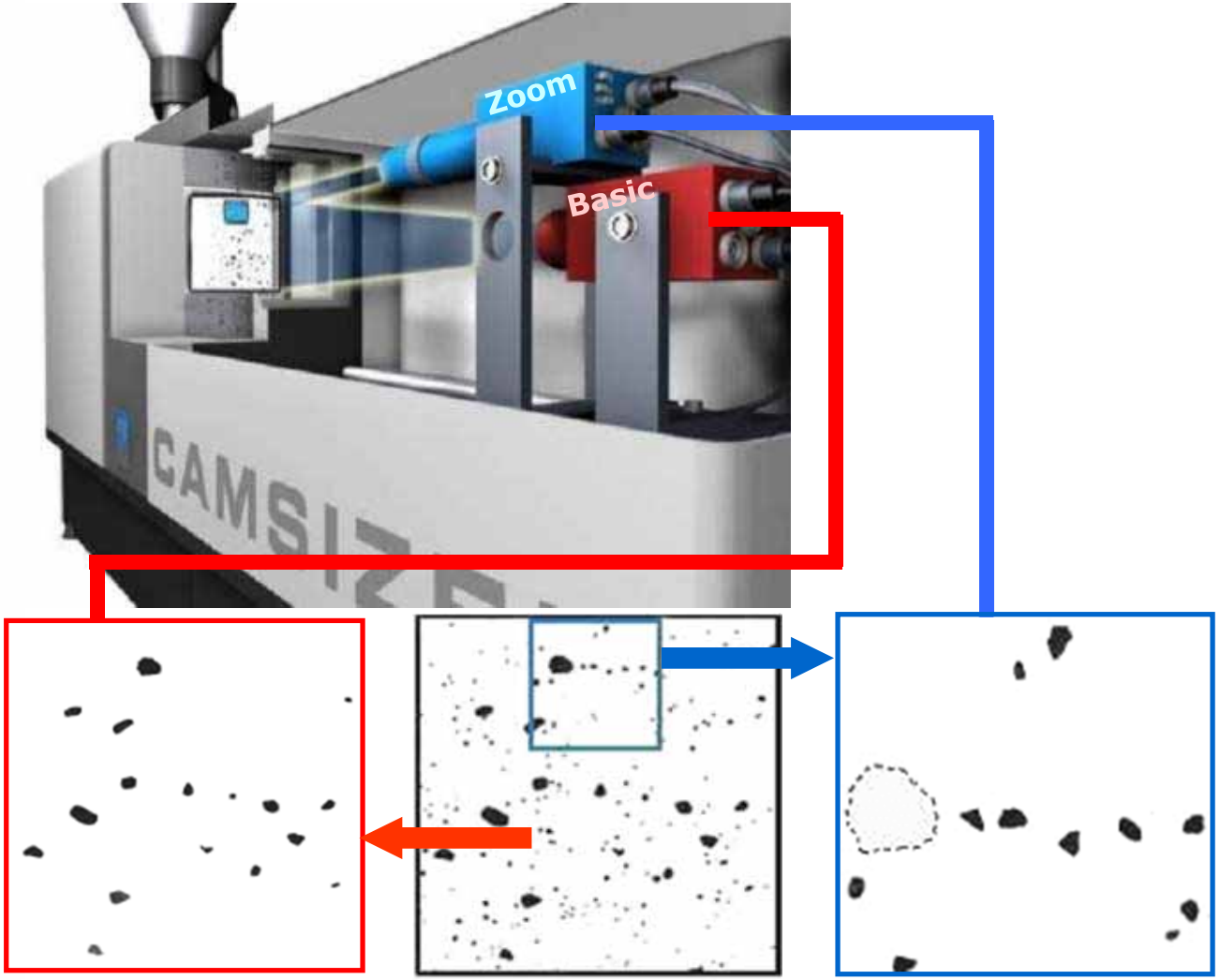
Two-Camera-System



Basic-Camera

Zoom-Camera

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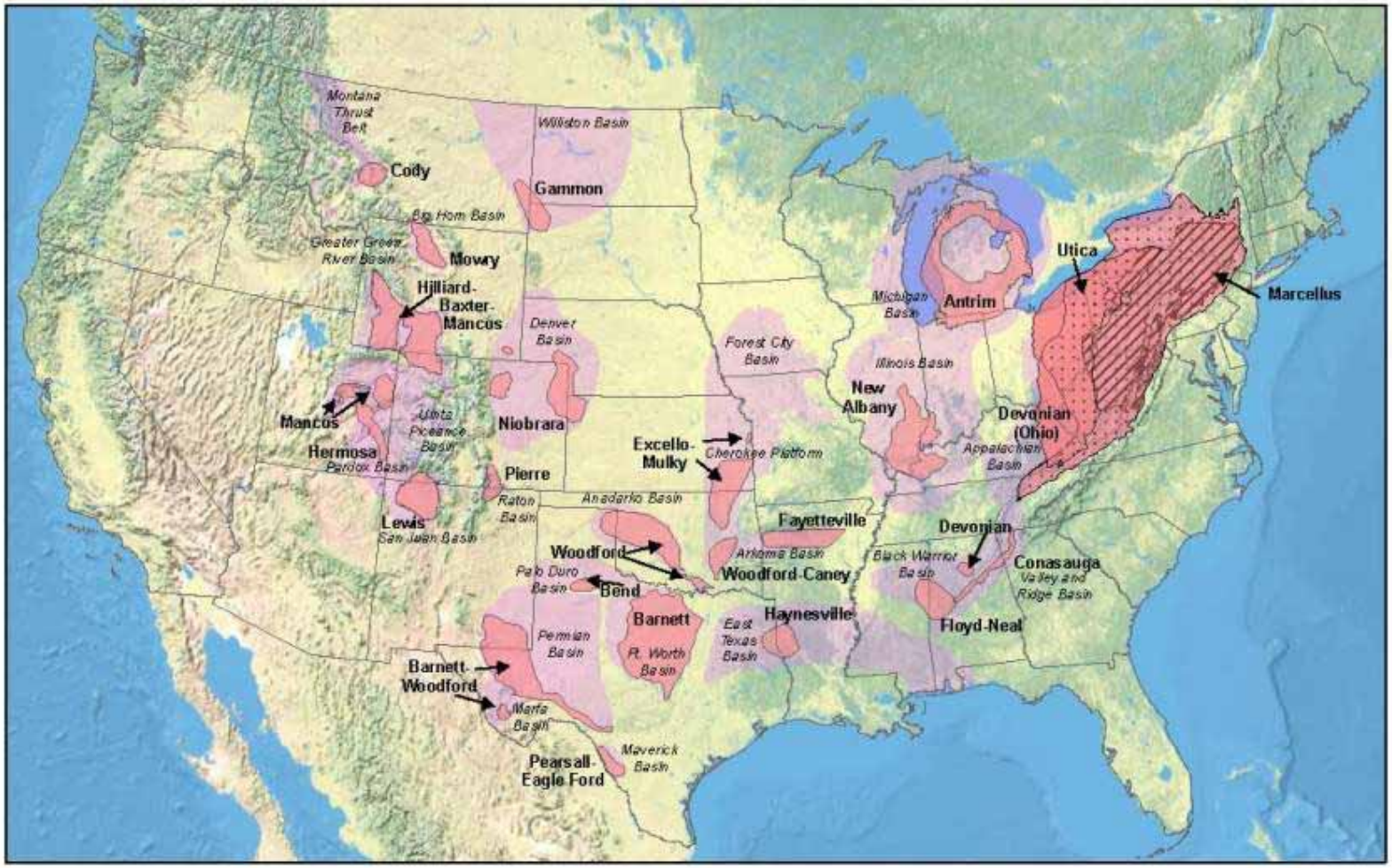

United States Shale Gas Plays

www.eia.doe.gov
Energy Information Administration
Office of Oil and Gas

Shale Gas Plays
Basins

Stacked Appalachian Plays
Marcellus
Utica
Devonian (OH shale)

November 2008
Miles
0 150 300 600

N

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Oil and Gas Exploration

Workers at the drill hole of the rig

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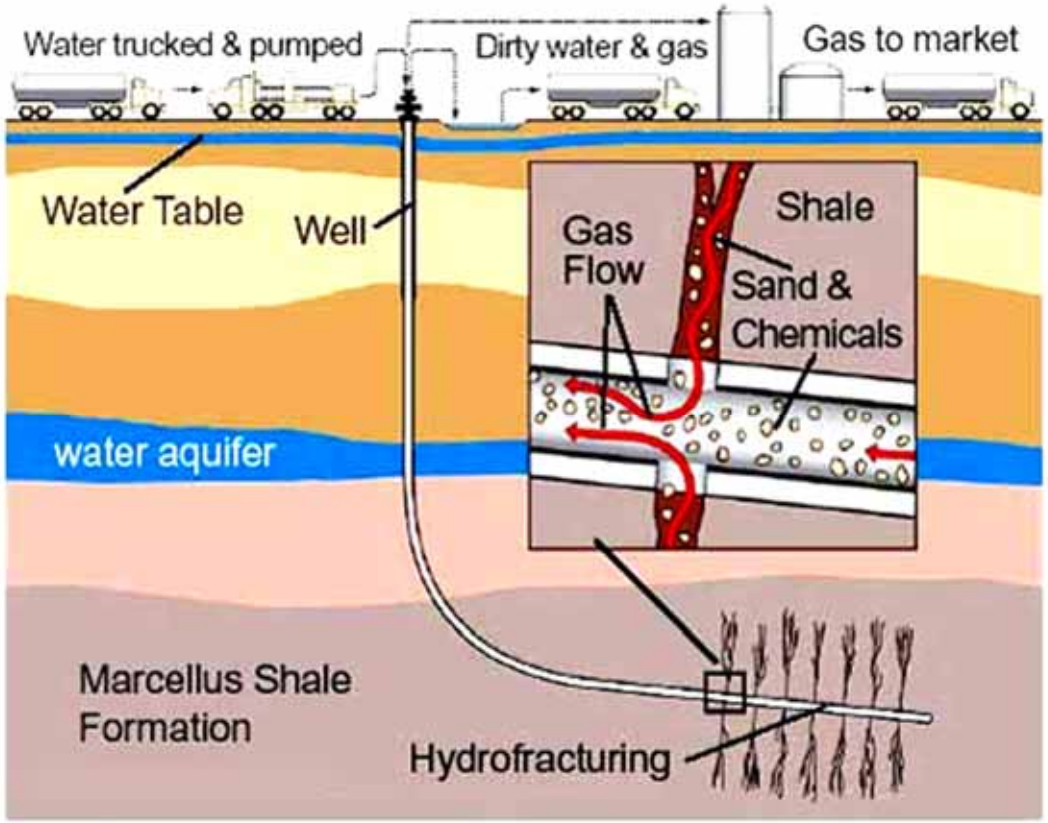
Oil and Gas Exploration



Principle draft of modern and effective oil and gas exploration

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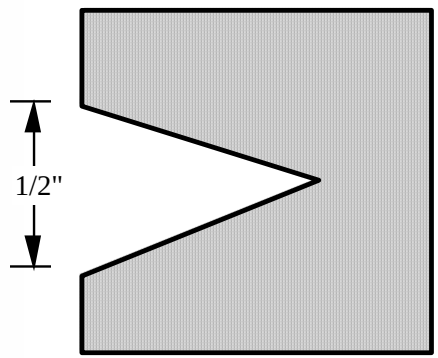
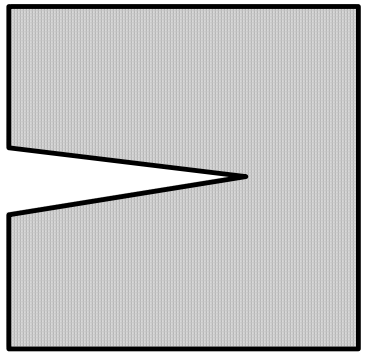
Propped Frac & Acid Frac

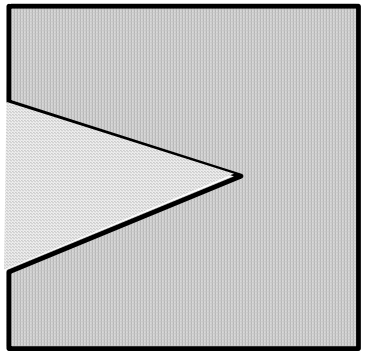
open fracture during job (frac width = w_f)

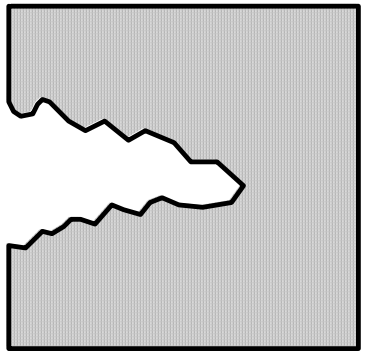




fracture tends to close once the pressure has been released

proppant used to prop the frac open





acid etched frac walls

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Different Types of Proppants

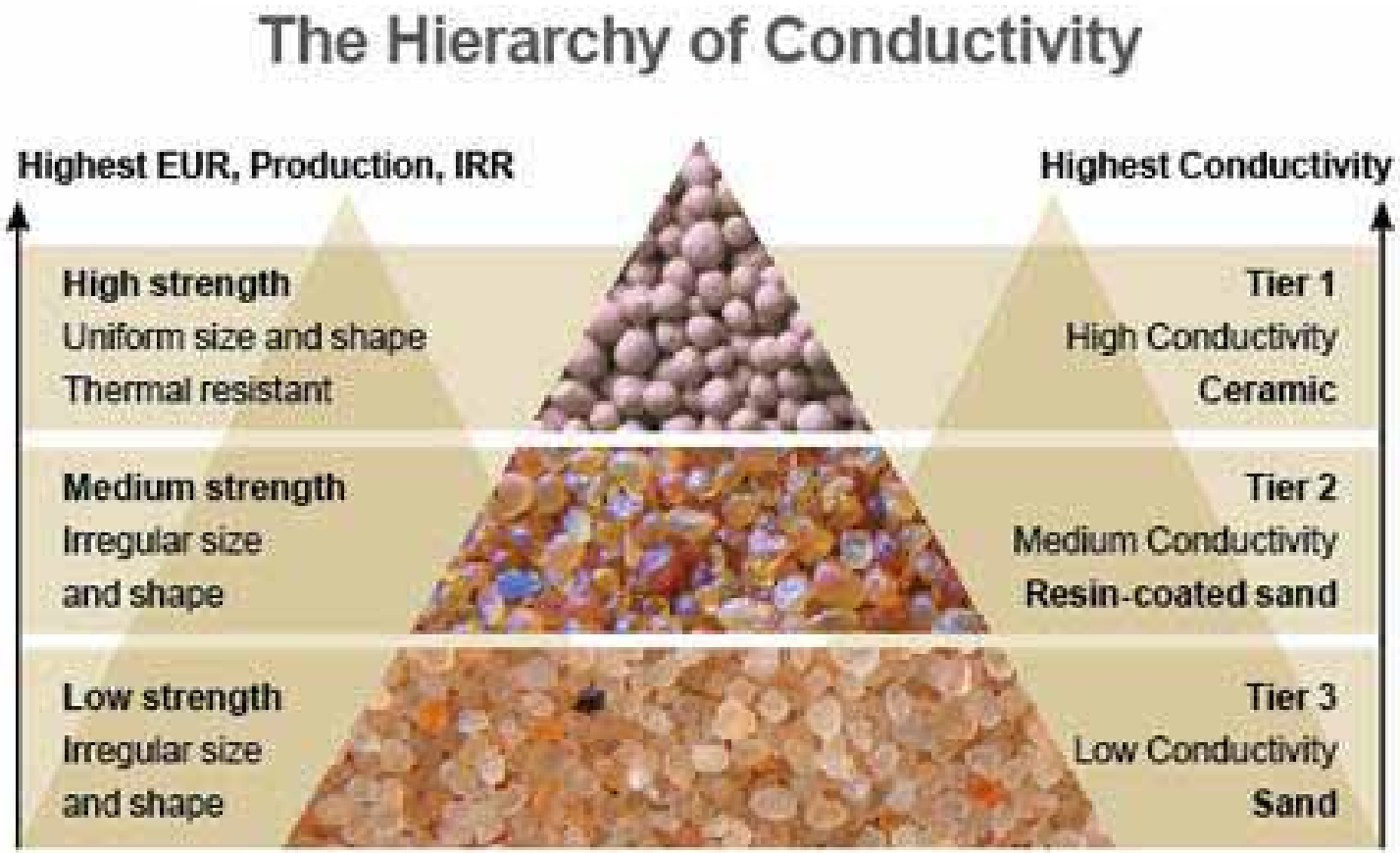

Image courtesy of CARBO Ceramics
*original located here:
http://www.carboceramics.com/hierarchy_of_conductivity/

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Different Types of Proppants

Frac Sand (<6,000psi)

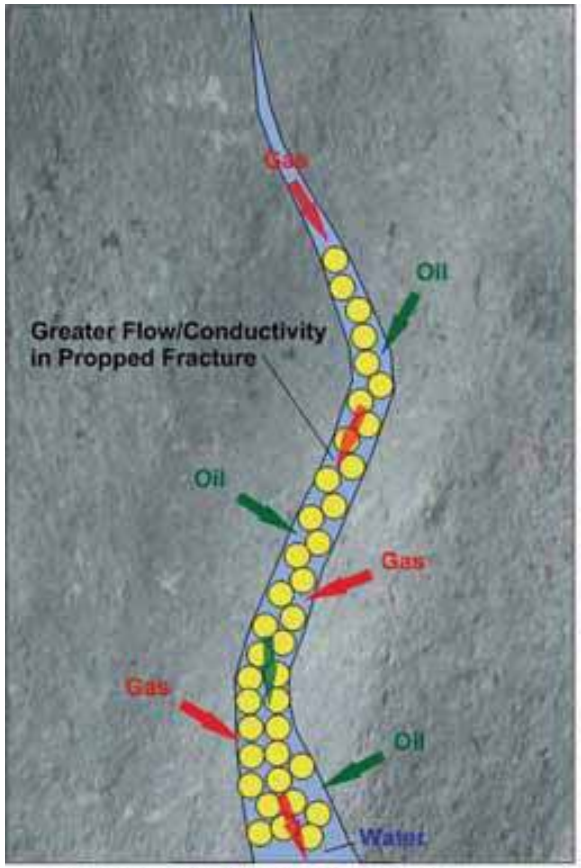
- Jordan
- Ottawa
- Brady

Resin-Coated Frac Sand (<8,000psi)

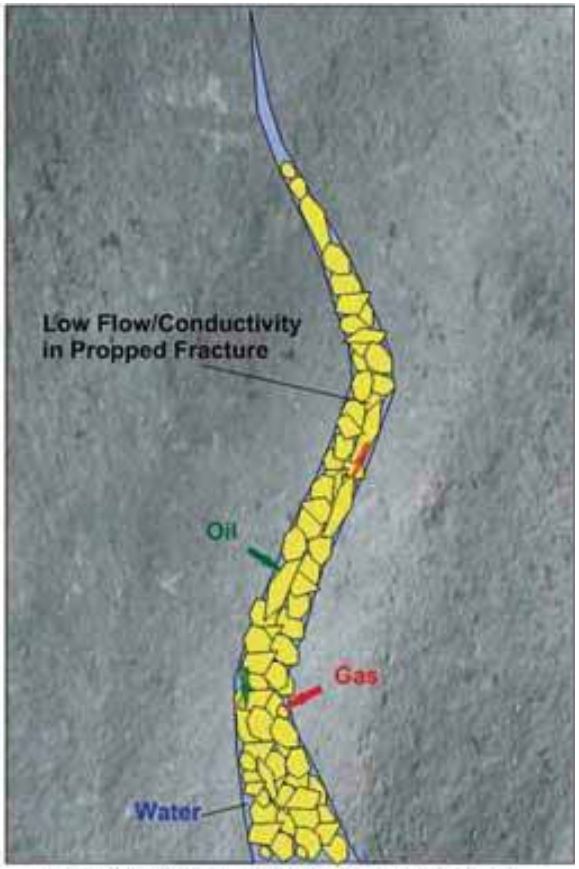
- Cureable
- Precured

Intermediate Strength Ceramics (<10,000psi)

High Strength Ceramics (<15,000psi)



a. Well Rounded Ceramic Proppant



b. Poorly Sorted Angular Proppant Sand

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Different Principles to increase the Oil and Gas Conductivity

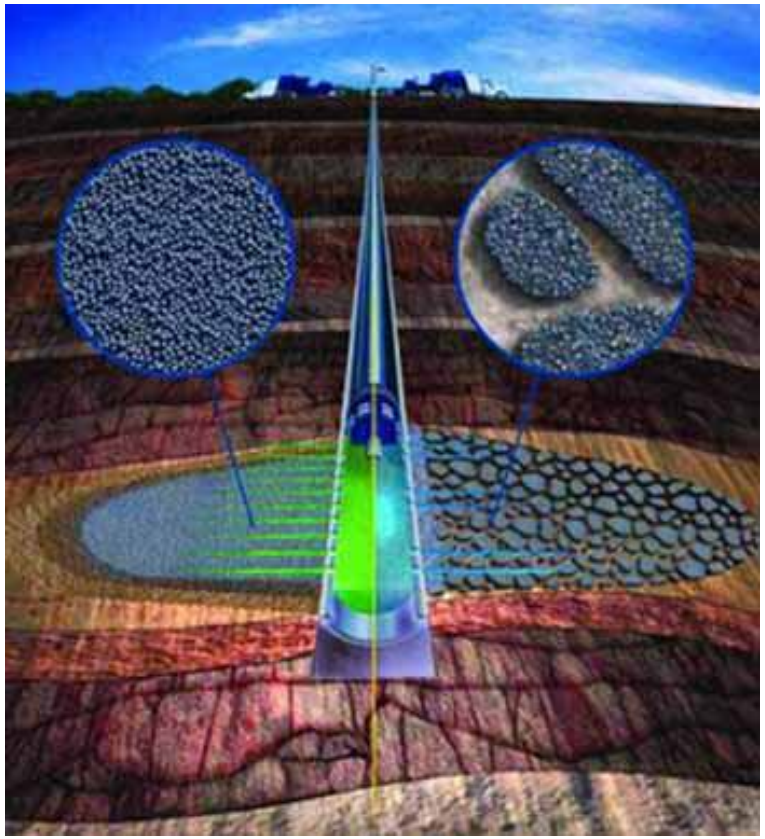

Image courtesy of Schlumberger
*original located here:
http://www.slb.com/

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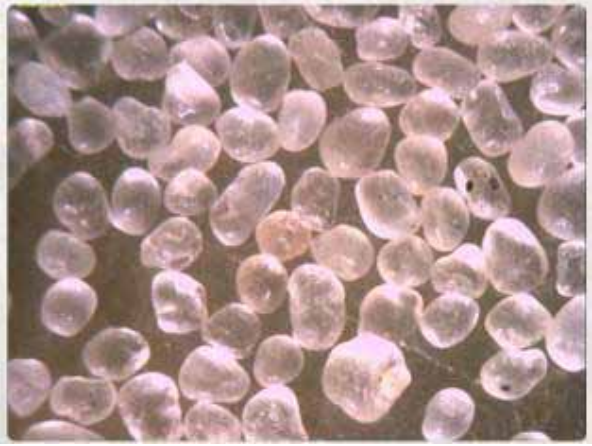
Natural Sand Proppants (Brown and White)



Resin Coated Sand Proppant

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Loading Facility of Sand Proppant Trucks

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Unloading of a Proppant Railcar

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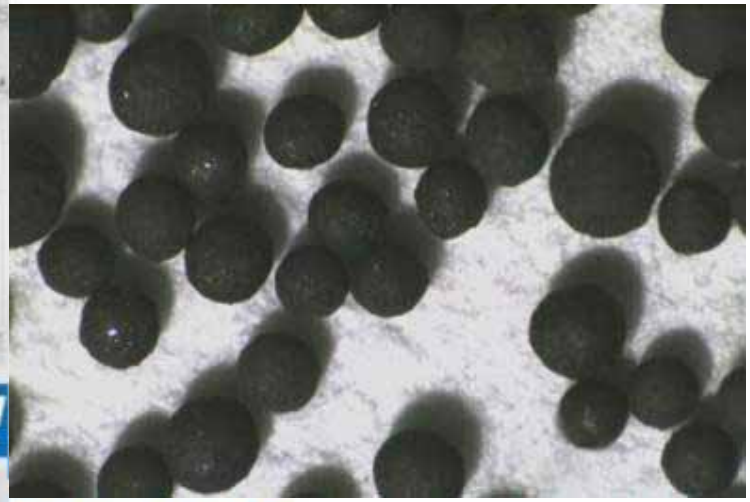
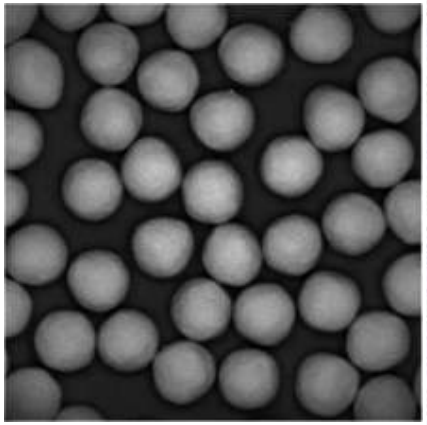
Ceramic Proppants





Ceramic Proppants

20/40

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Resin Coated Ceramic Proppant

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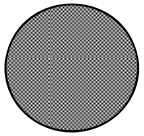
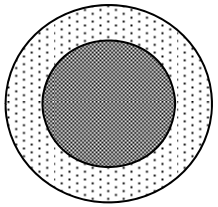
High Strength and High Roundness Resin Coated Proppants

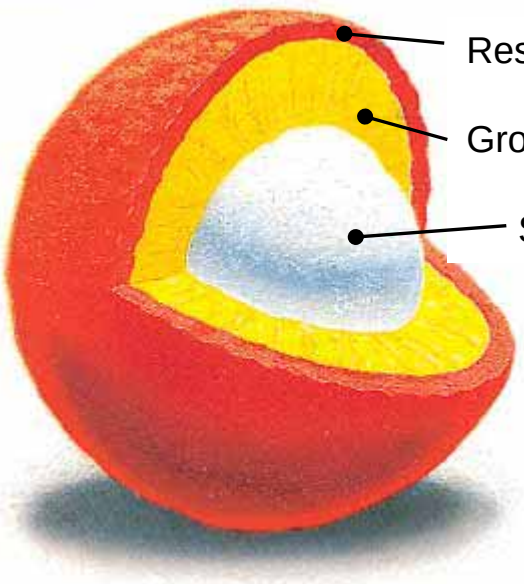
- Ceramic Core
- Growth of Ceramic Proppant during production process
- Resin Coating

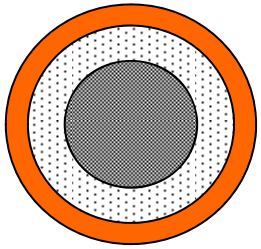


Starting Core



Growth of Ceramic Proppant





Resin Coating

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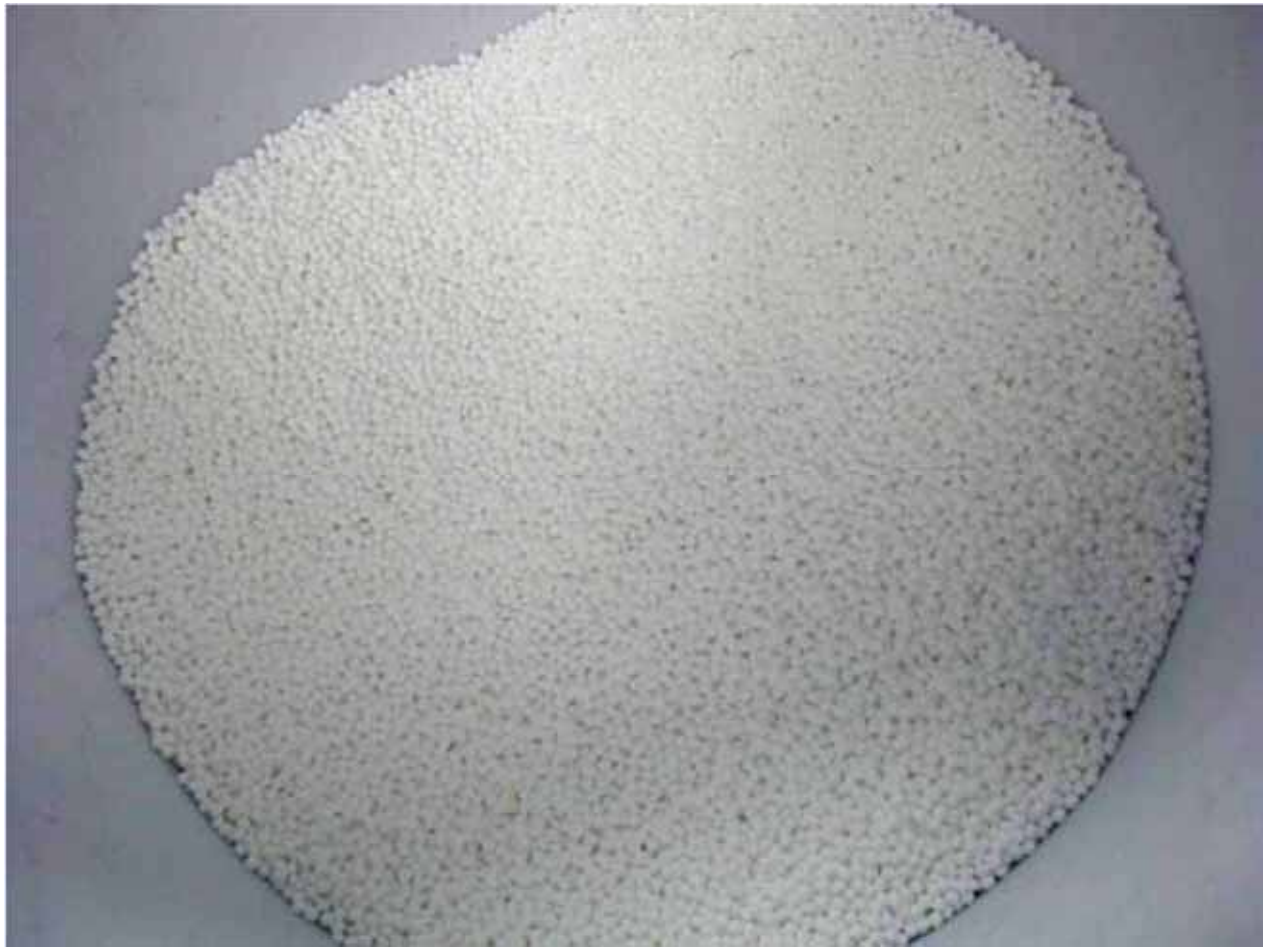
Measurement (Start)



Ceramic Proppant

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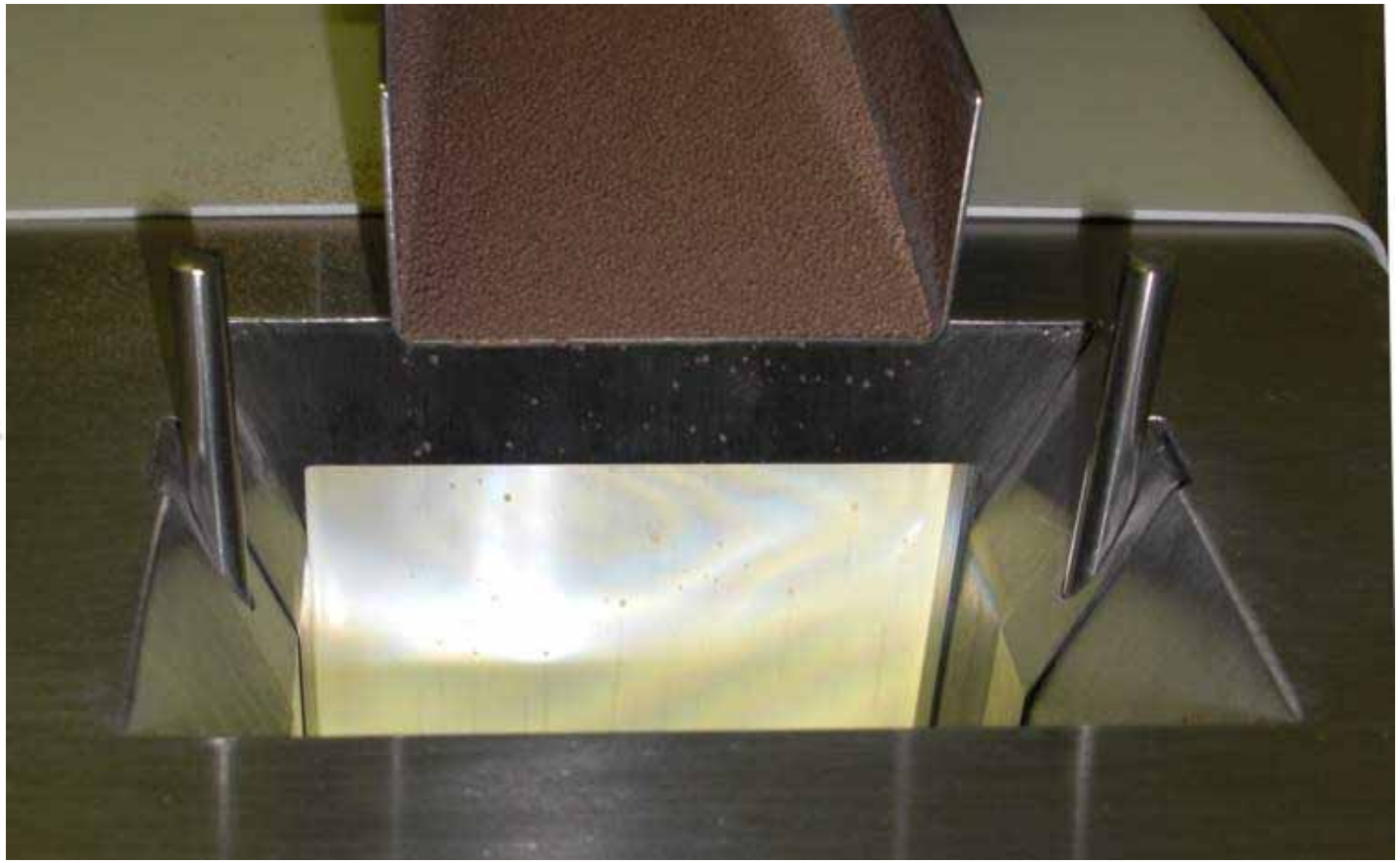
CAMSIZER Measurement



Ceramic Proppant

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CAMSIZER Measurement (End)

Ceramic Proppant

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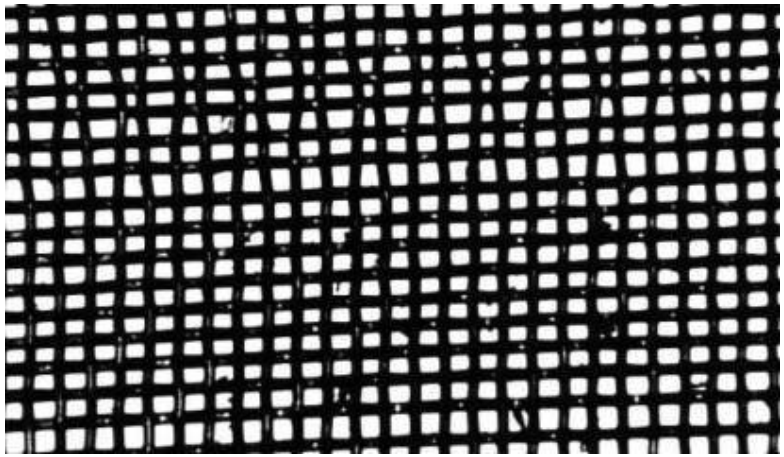
Comparison of Methods: Sieving

Advantages

- robust and industrial-suited
- easy handling
- references available from user



Worn out sieves

Disadvantages

- high amount of time and work
- low resolution,
  small number of investigatable classes
- limited sample amount
- no shape analysis possible

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Typical Grain Sizes of Proppants

Figure 1. Some recognised size classes for proppant sands (adapted from Hoagberg & Koerner-Moore)

Mesh #	8/12	10/20	20/40	70/140
Screen size (mm)	2.38-1.68	2.00-0.84	0.84-0.42	210-105μ
US standard sieves	6	8	16	40
	8	10	20	70
	10	16	30	100
	12	20	40	140
	16	30	50	200
	pan	pan	pan	pan

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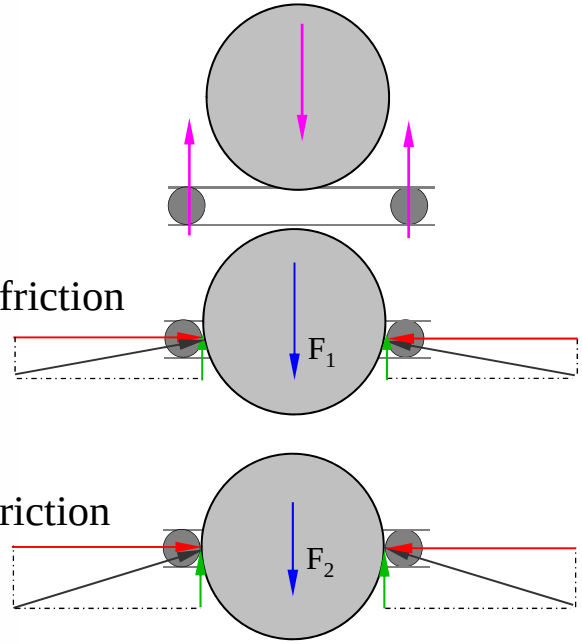
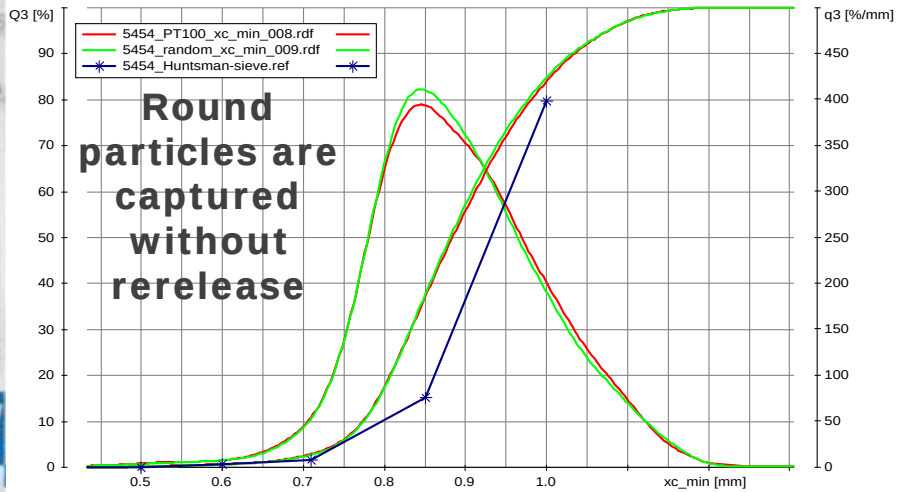
Sieving problems (here Overloading)

1. Move

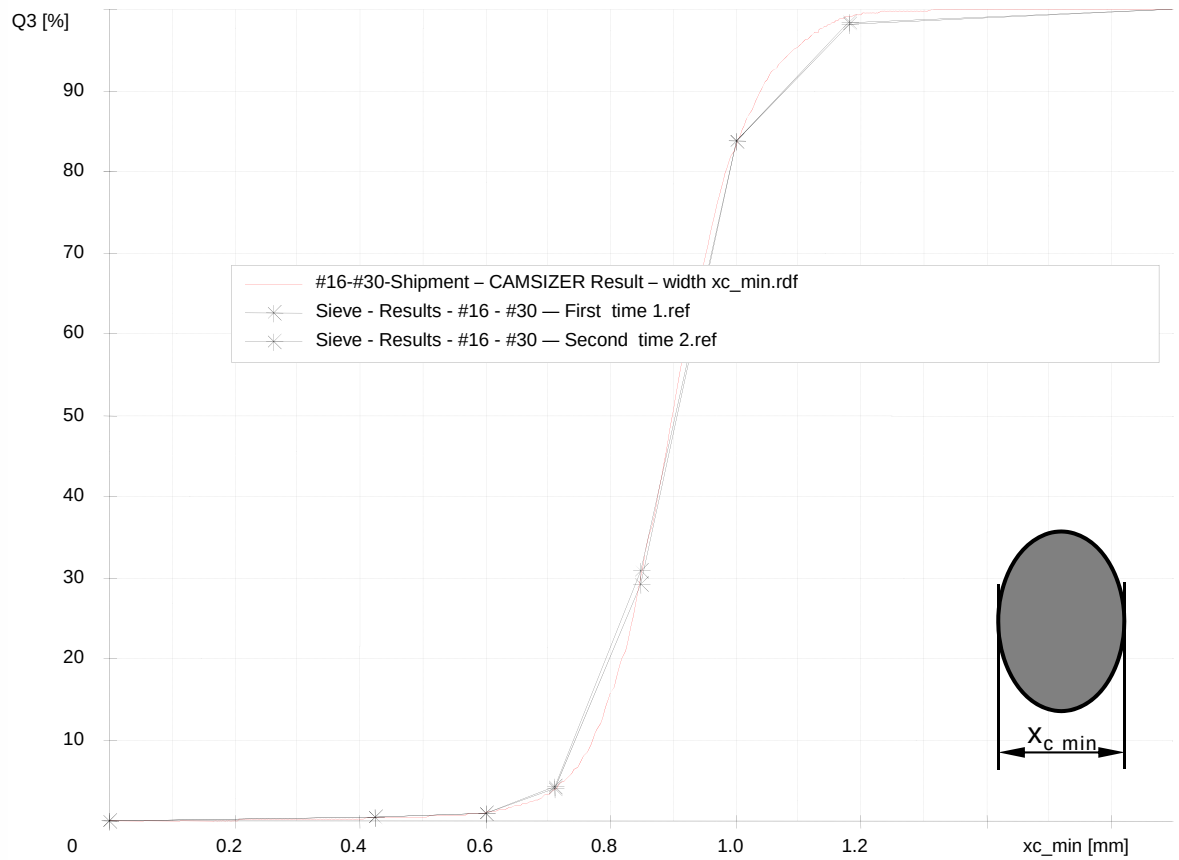
2. Sliding friction

3. Static friction





Sieve Correlation ⇔ CAMSIZER of Natural Brown Sand



Comparison of sieve (* **black**) and CAMSIZER data **(red).**
The agreement is excellent. The CAMSIZER measurement can directly replace the sieve analysis, without changing the product specifications.

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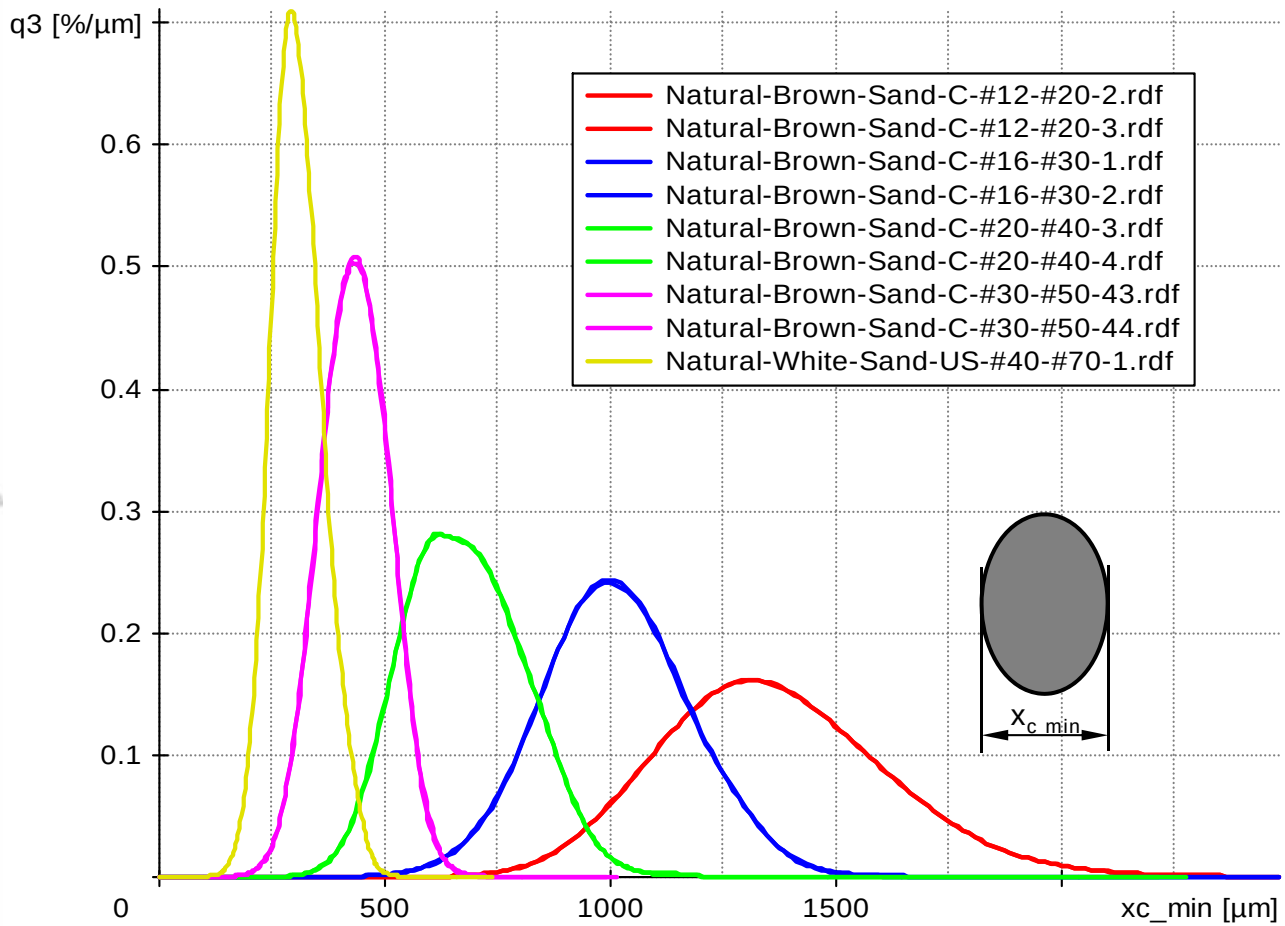
CAMSIZER Results of Different Natural (Sand) Proppants



Size analysis of 5 different natural sand proppant samples (**#12/20**, **#16/30**, **#20/40** and **#30/50**). Each sample was measured twice. The repeatability is excellent. One sample of white sand **#40/70** is shown for comparison.

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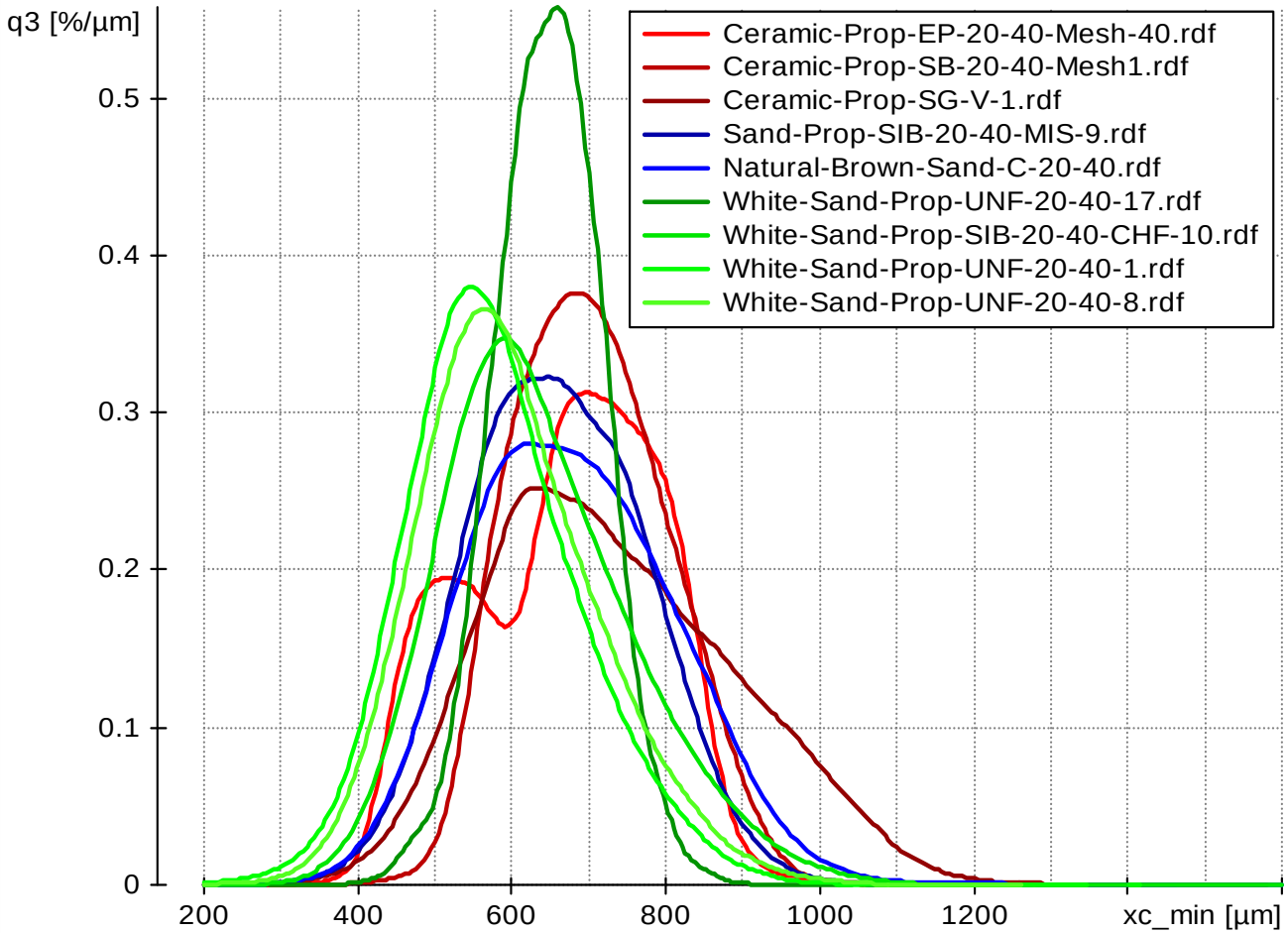
Grain Size Comparison



Size analysis of 9 different proppant (sand and ceramics) samples (#20/40). Some have wider, some have more narrow size distributions. One ceramic proppant sample had a bimodal distribution (**red "Ceramic-Prop-EP-20-40-Mesh-40"**).

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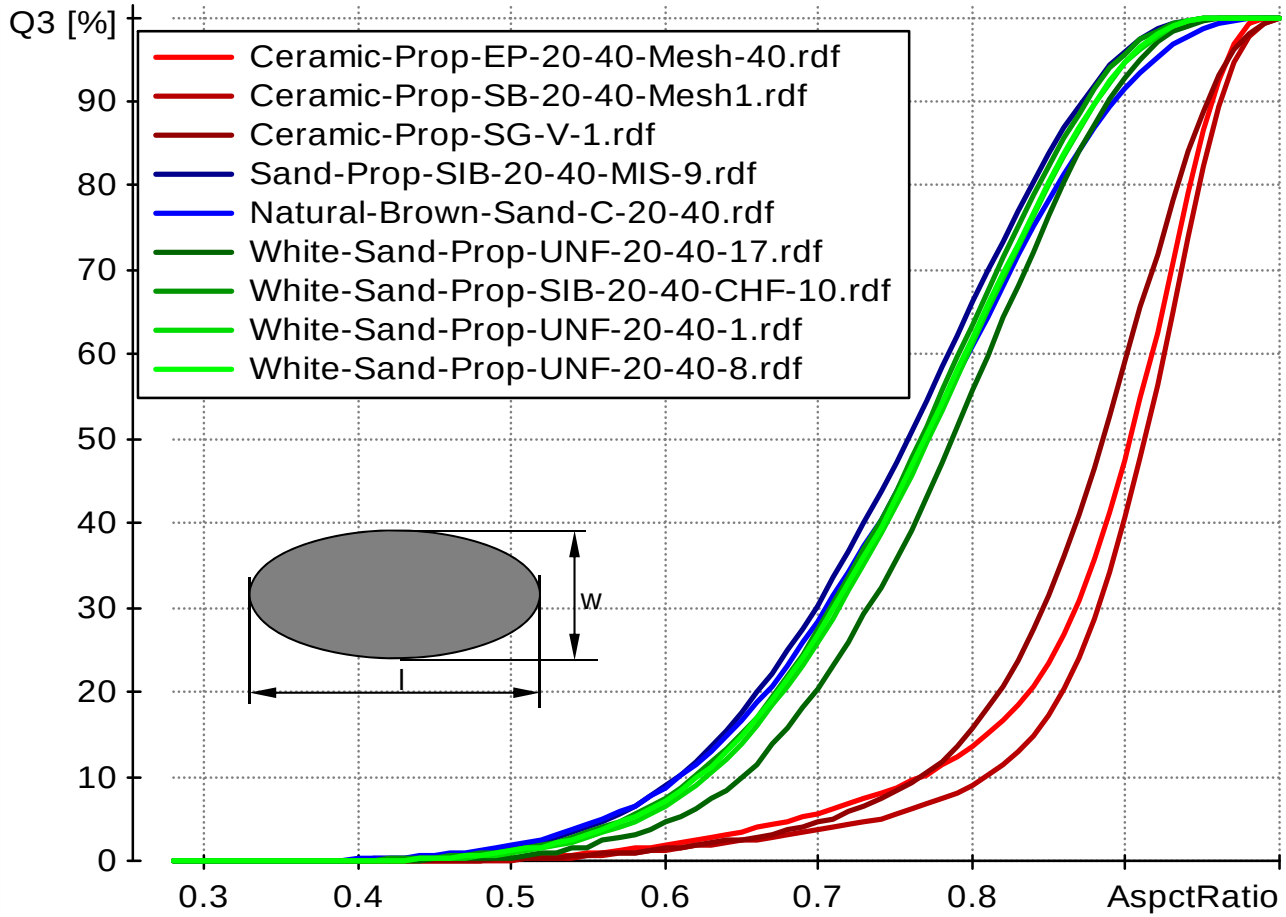
Shape Comparison



Shape comparison between natural **sand proppants** and **ceramic proppants**. There are two clearly different ranges of Aspect Ratio (Krumbein's Sphericity). Analysis of other shape parameters are possible as well (Convexity for ceramic bead twins, Symmetry for good and broken ceramic beads, Krumbein's Roundness etc.)

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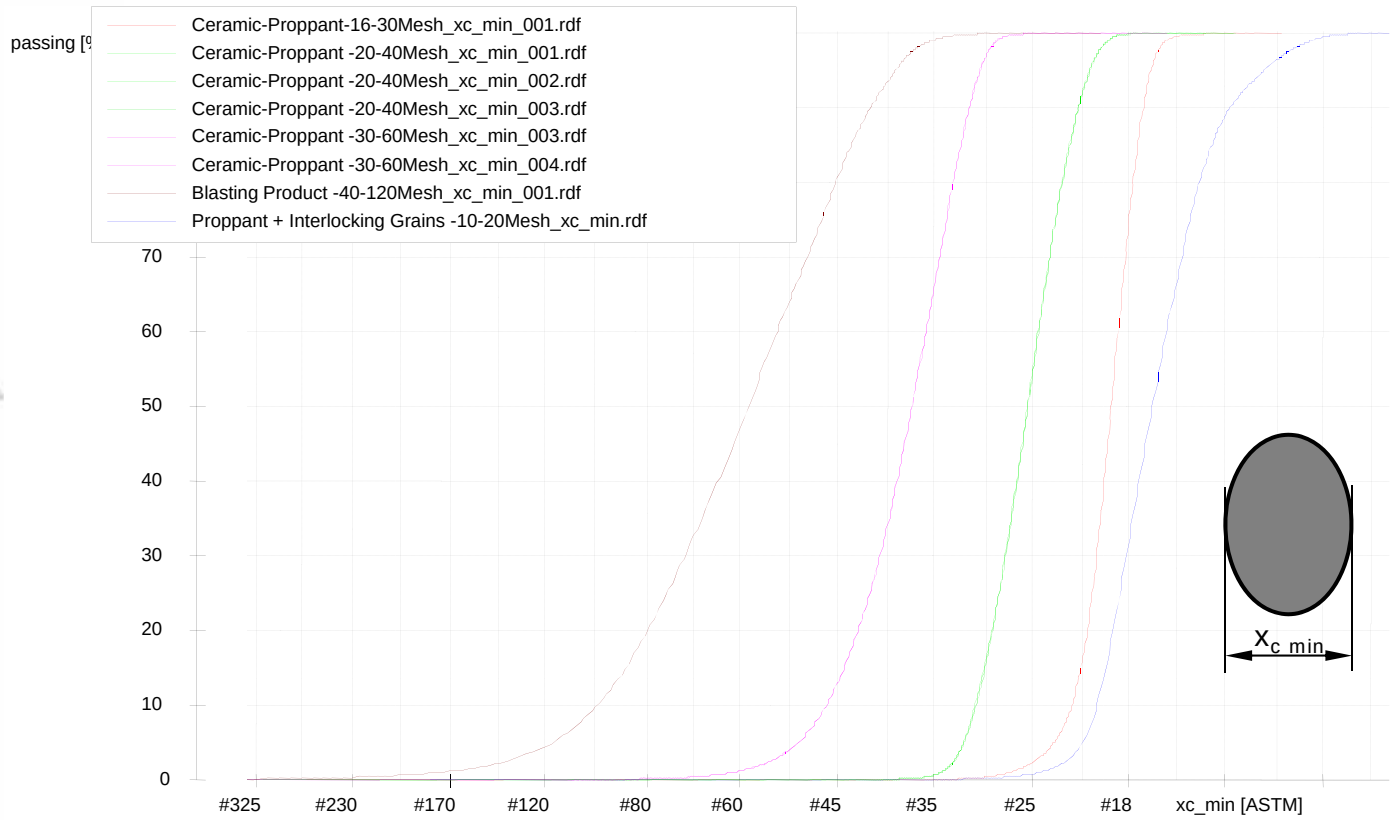
Grain Size Analysis of Ceramic Proppants



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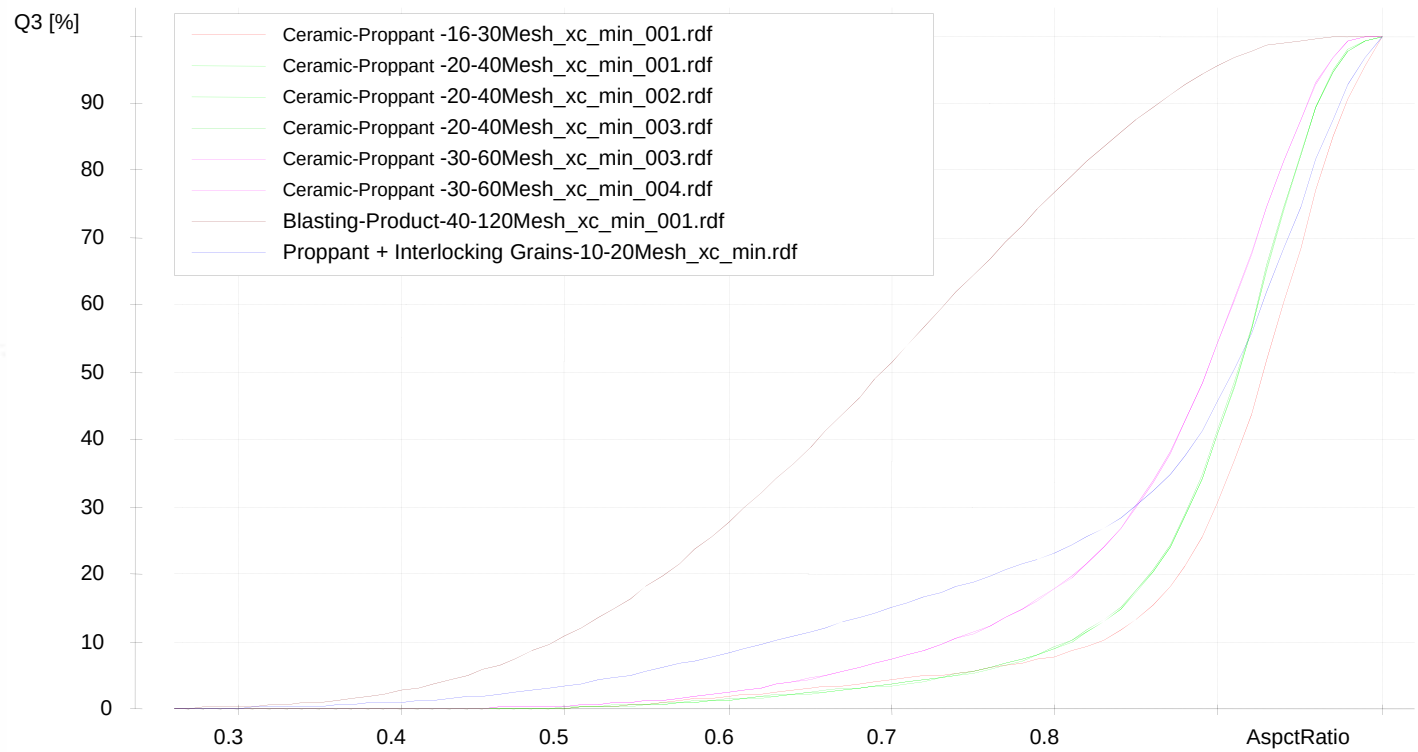
Shape Analysis of Ceramic Proppants



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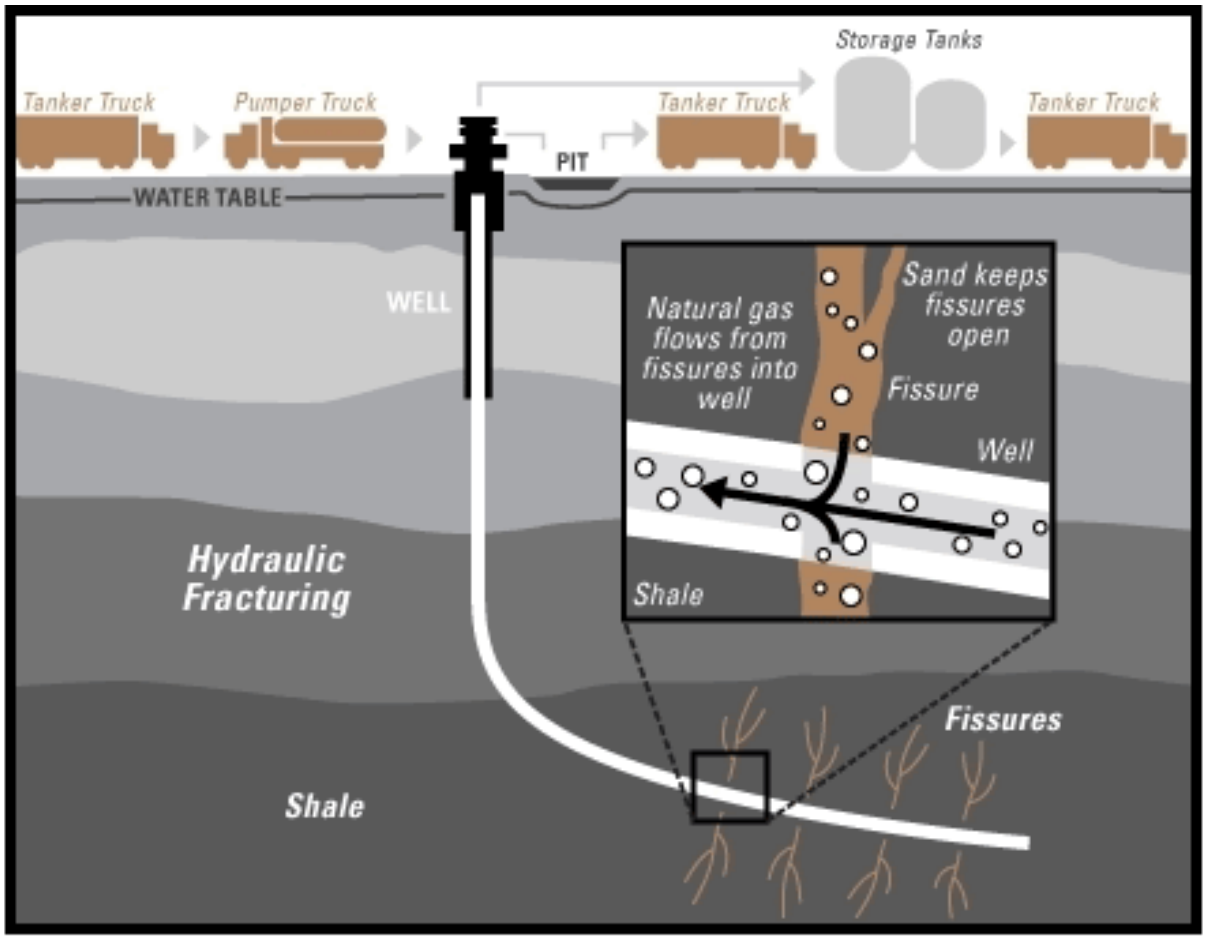
Hydraulic Fracturing



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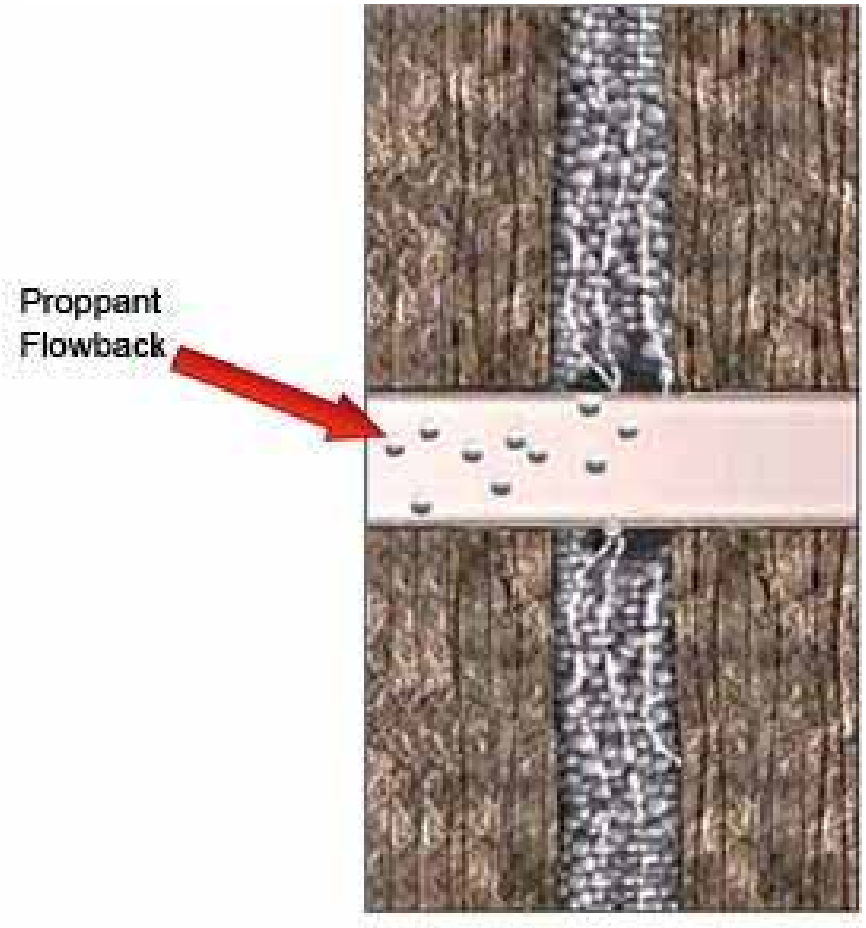
Proppant Flowback



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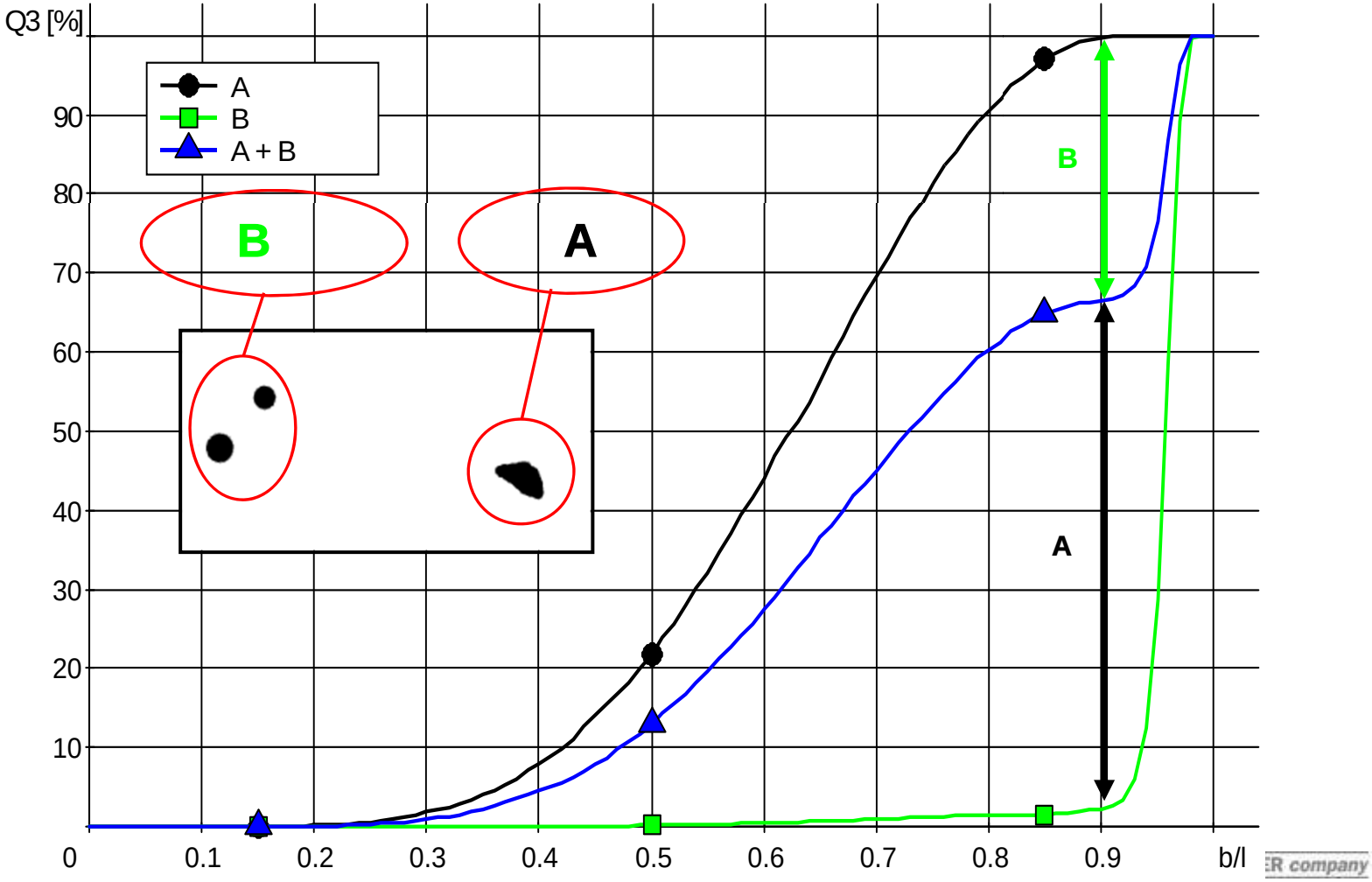
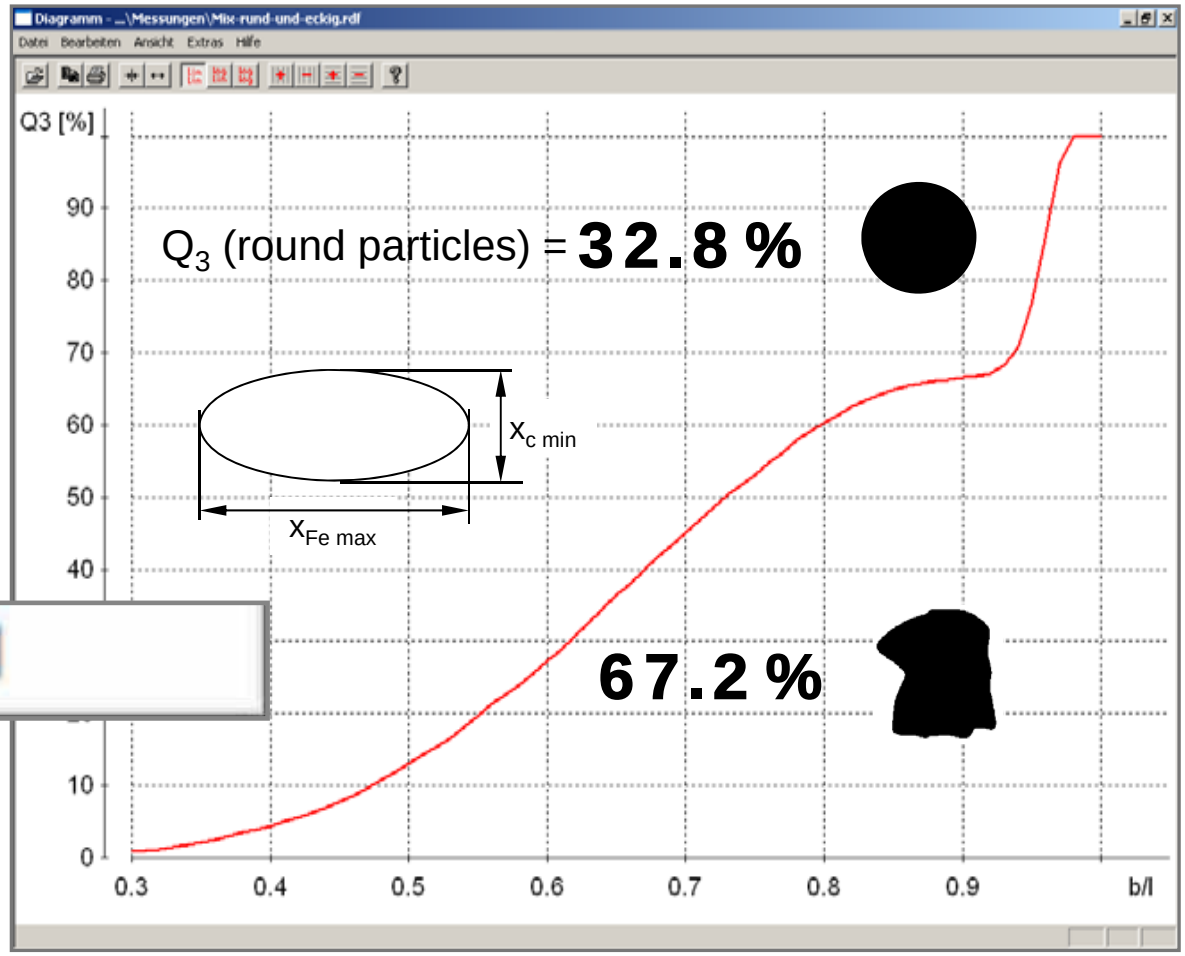
Ceramic Proppant with Interlocking Particles

Amounts of Proppant Beads and crushed interlocking particles in a mixture



Ceramic Proppant with Interlocking Particles

CAMSIZER can find the mixing ratio of Proppant Beads and Angular Interlocking Grains



1-Q3 (b/l=0.9) = 32.8 %

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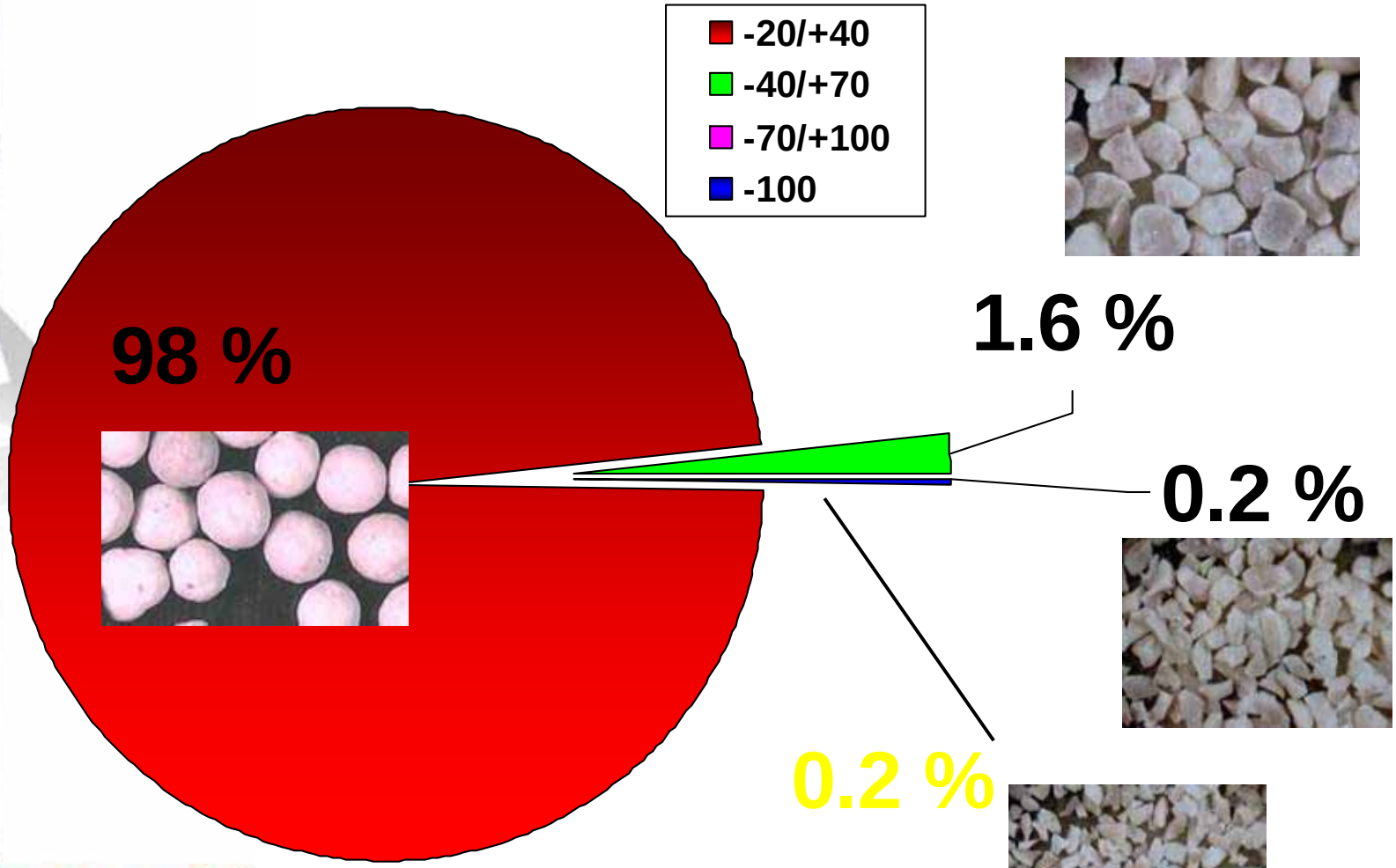
Fines Migration & Plugging



Ceramic Prop after API single cycle crush test at 6000 psi

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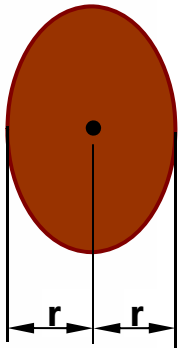
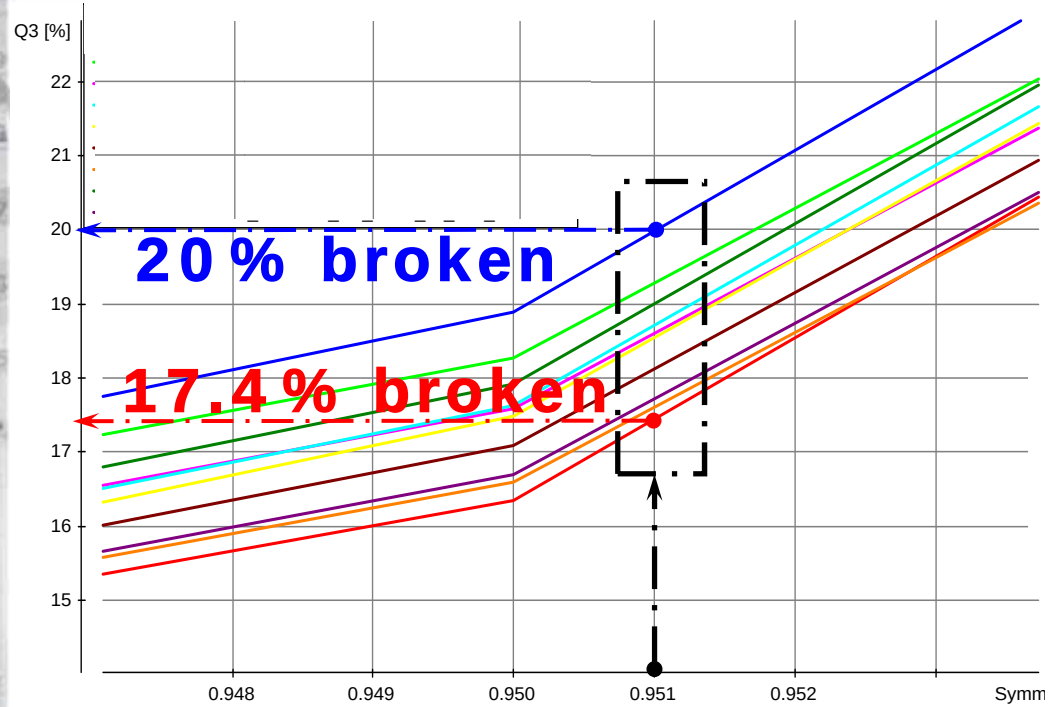
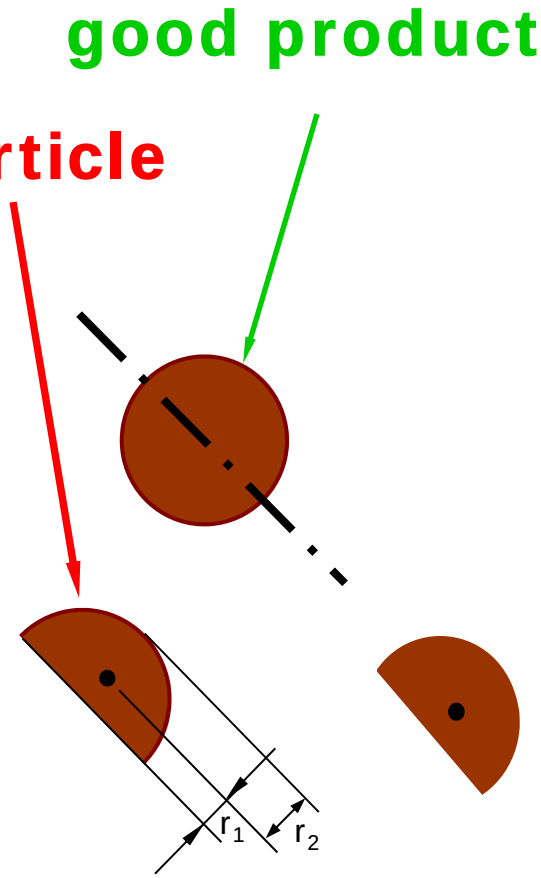
CAMSIZER – Advantages Measuring Broken Beads







Symmetry $\sim \min\left(\frac{r_1}{r_2}\right)$

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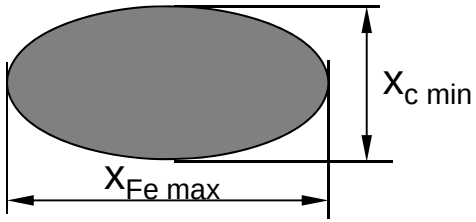
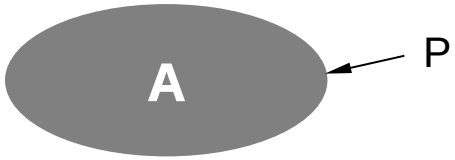
Particle Shape

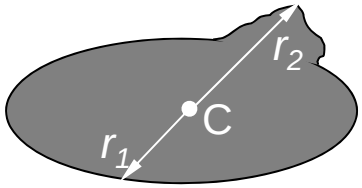
- **Breadth- / Length-ratio**



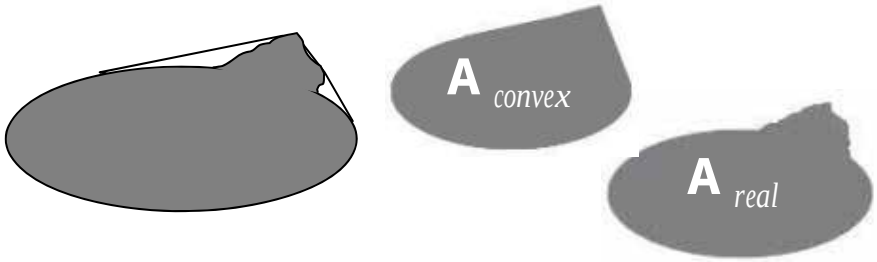
- **Roundness**



- **Symmetry**



- **Convexity**



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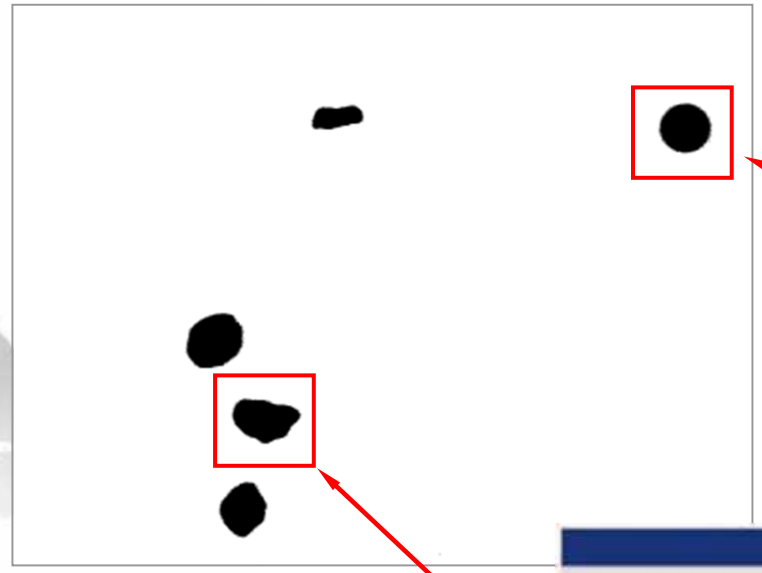
Optical Process Control

analysis for size and shape



x-values in mm

Nr=0 , d=2.148 ,

xFe_min=2.148 , xFe=2.203 , xFe_max=2.241 ,
xMa_min=2.134 , xMa=2.199 , xMa_max=2.241 ,
xc_min=2.148 , xc=2.200 , xc_max=2.241 ,

Symm=0.9827 , b/l=0.9480 ,
SPHT=0.9818 ,
Convex=0.9997 ,

OK

x-values in mm

Nr=0 , d=1.966 ,

xFe_min=1.970 , xFe=2.546 , xFe_max=3.063 ,
xMa_min=1.889 , xMa=2.419 , xMa_max=3.047 ,
xc_min=1.966 , xc=2.419 , xc_max=3.060 ,

Symm=0.9289 , b/l=0.6361 ,
SPHT=0.9066 ,
Convex=0.9995 ,

OK

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Solutions in Particle Sizing

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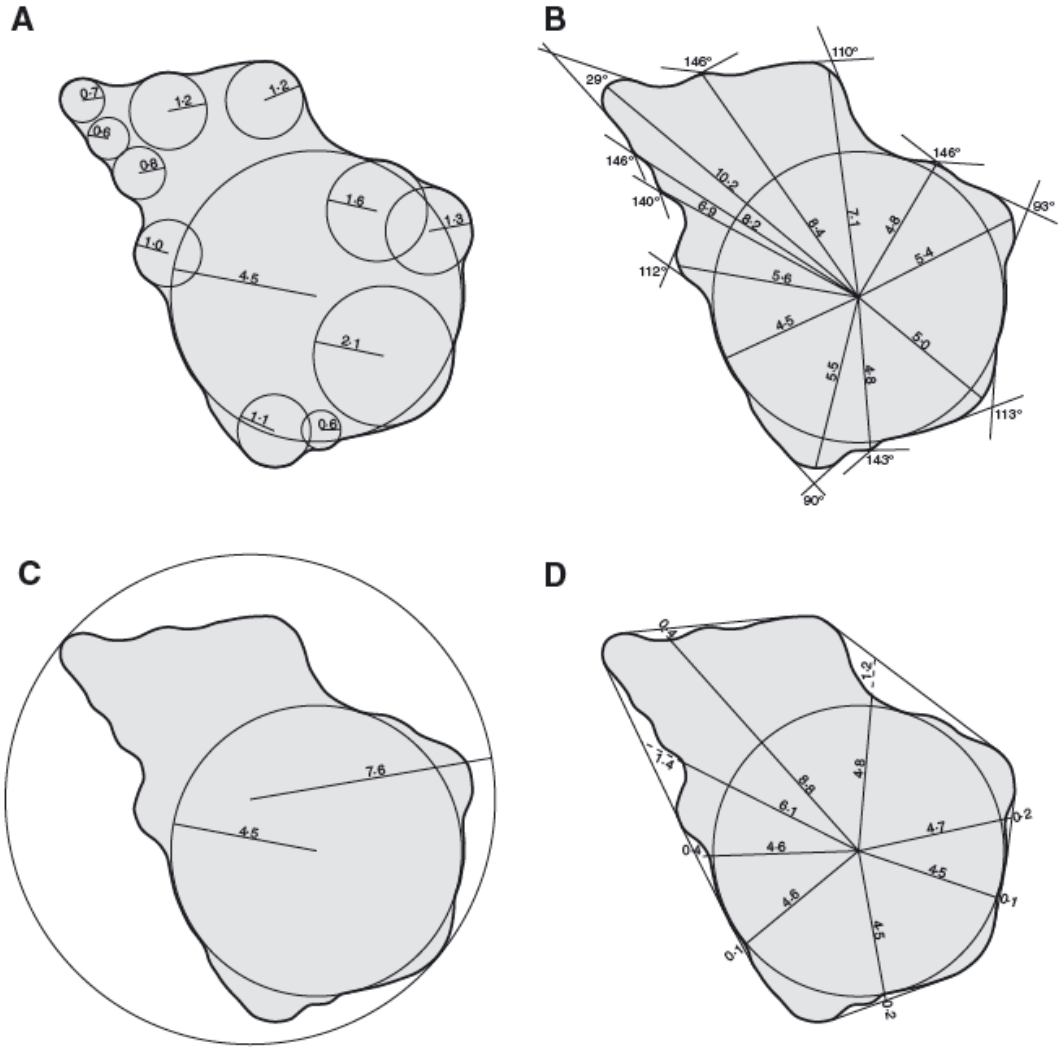


Fig. 14. Diagrams illustrating the measurements made for determination of: (A) particle roundness (Wadell, 1932); (B) angularity (Lees, 1964a); (C) circularity (Riley, 1941); and (D) irregularity (this paper). See text for further explanation. The same particle is also illustrated in Fig. 1.

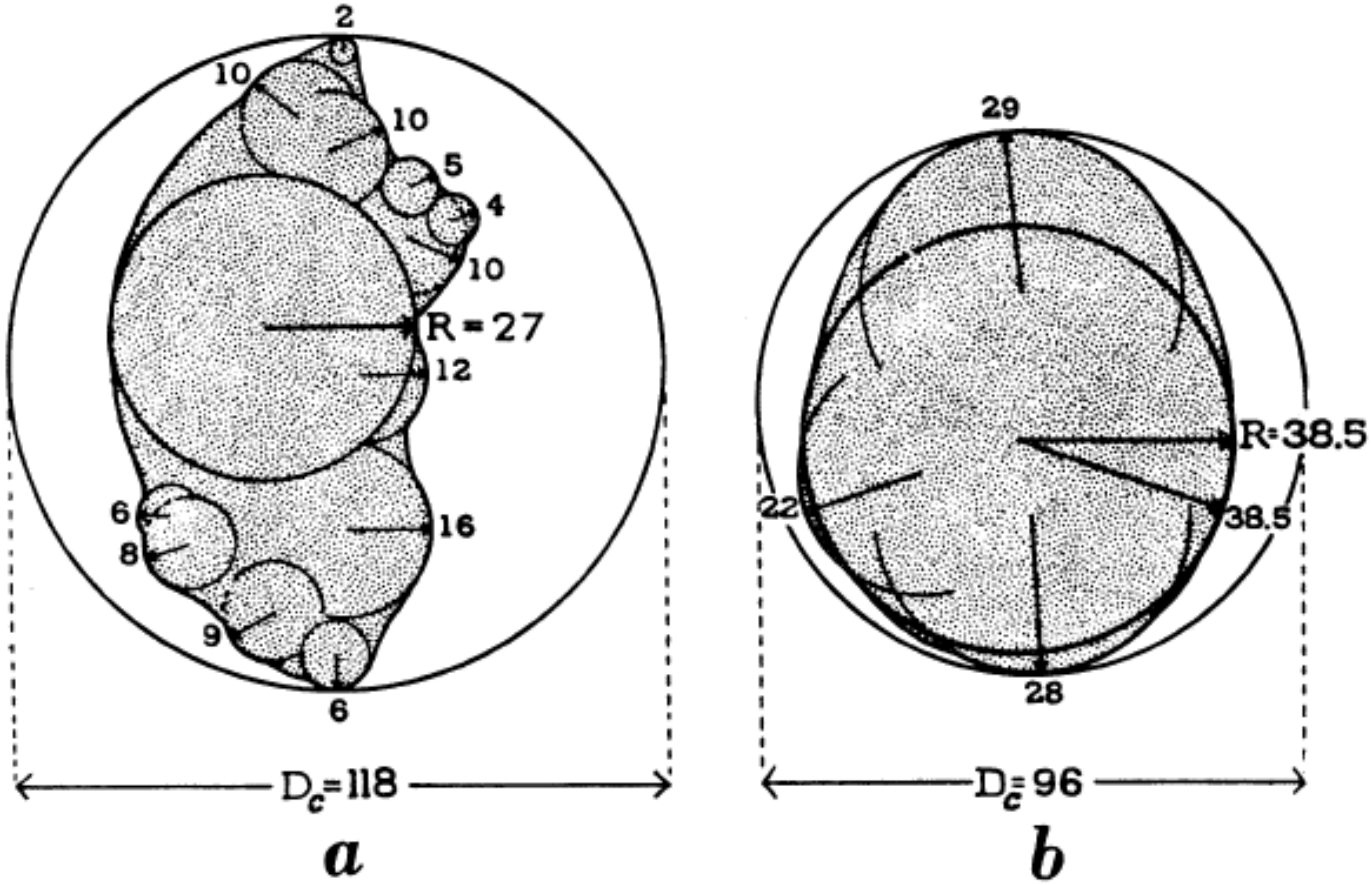
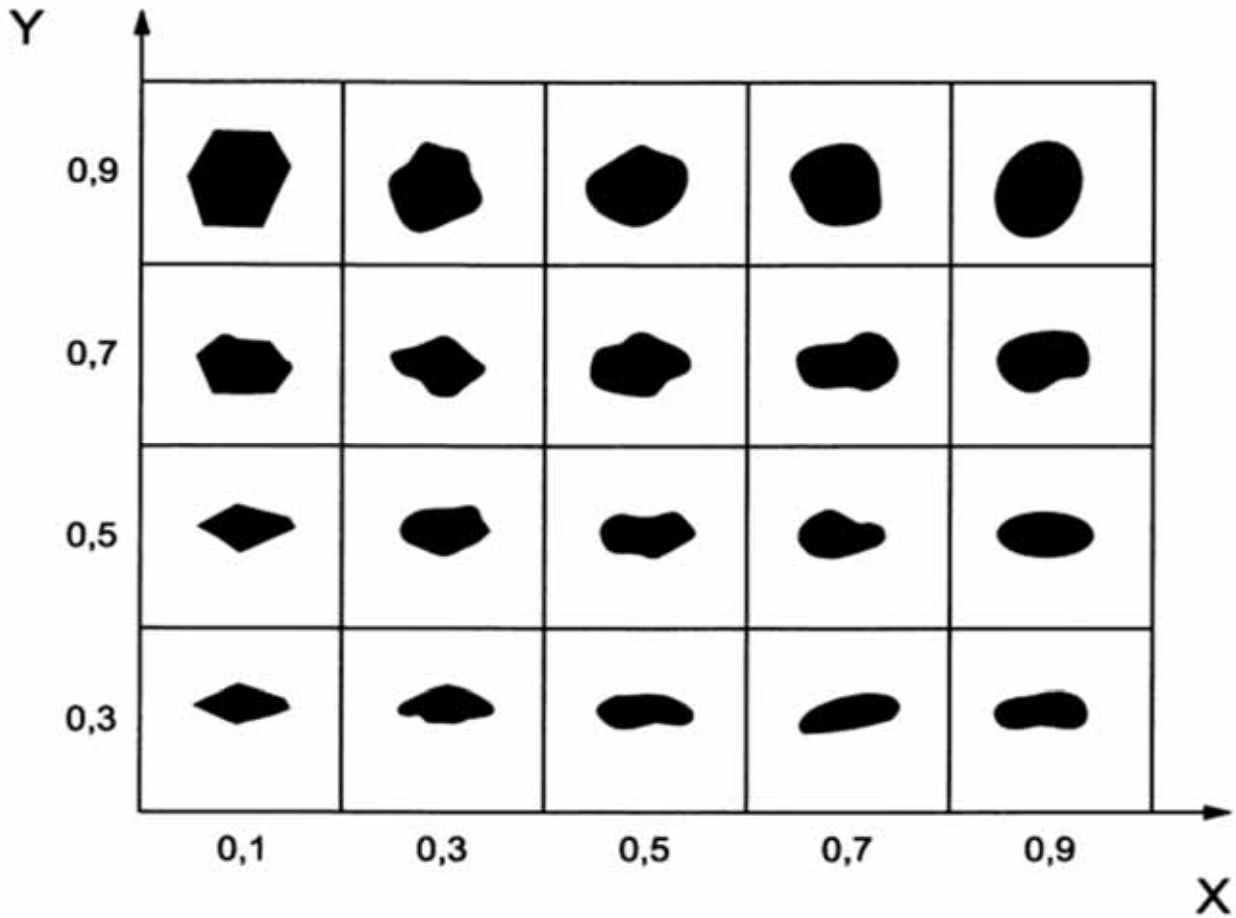


FIG. 2.—Camera lucida drawings, *a*, of a grain retained on the 0.125-mm. sieve, *b*, of a grain retained on the 0.061-mm. sieve. (The figures give the dimensions in millimeters.)

Visual Inspection and Comparison with Krumbein's Chart



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AutoSampler

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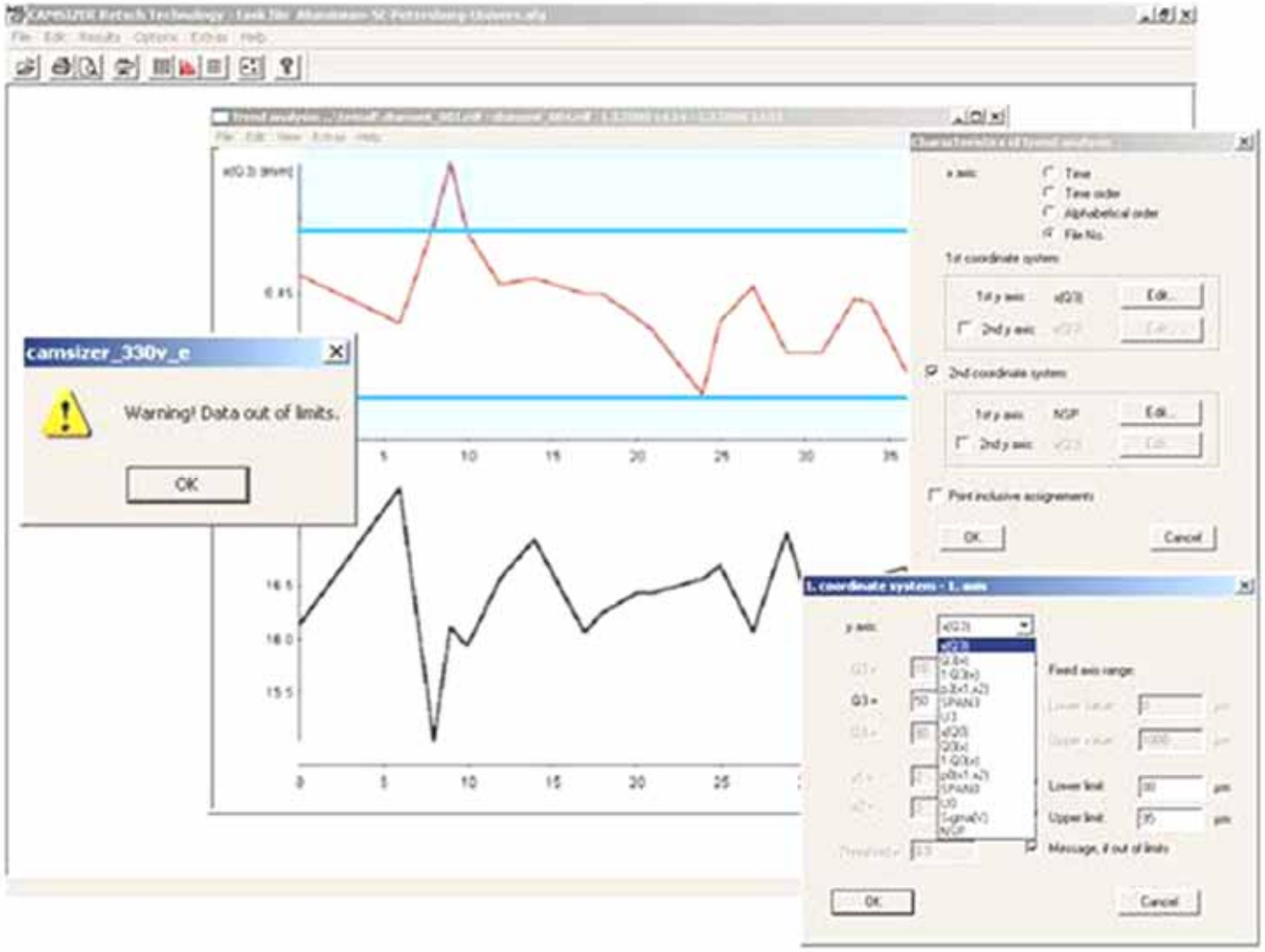
Trend Analysis



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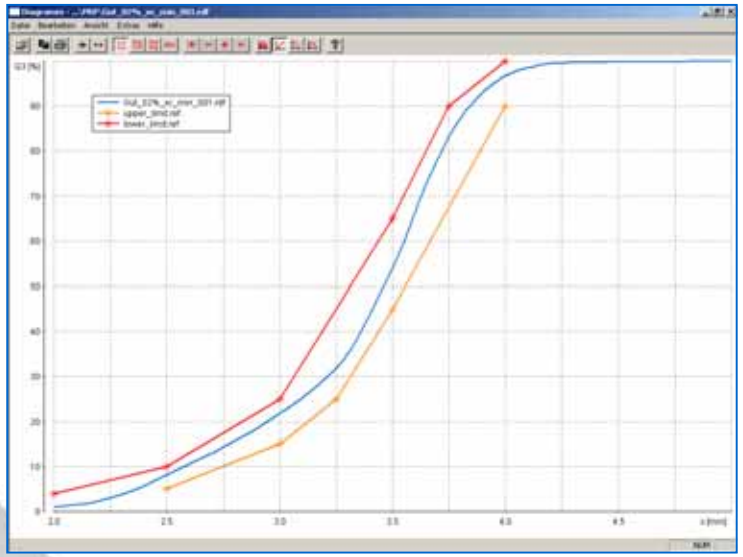
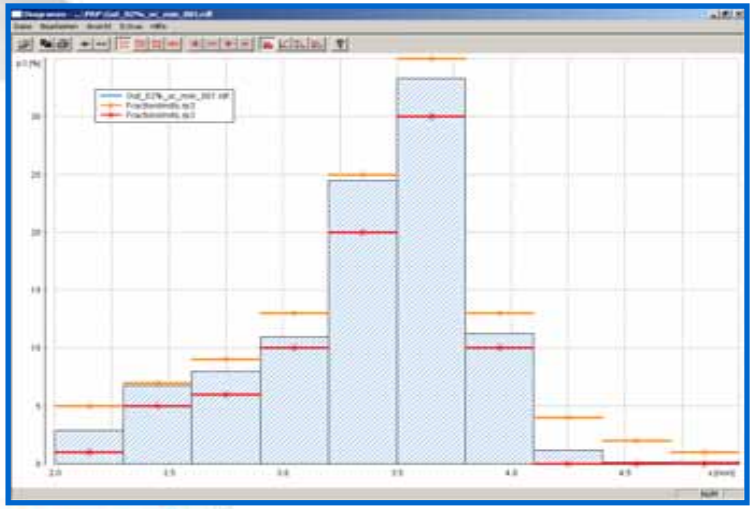
Quality Control



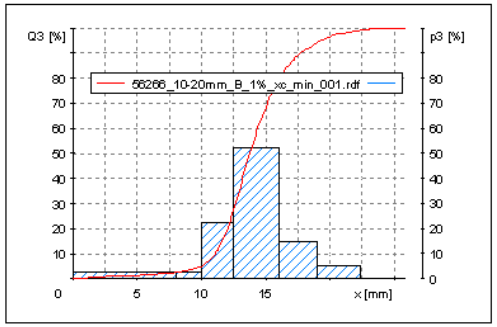


CAMSIZER® Retsch TECHNOLOGY

Reg. 56266; 10-20mm

Company:	Mavit as (Skanlab)
User:	T. Pruschitzki
Result file:	C:\...MSIZER-SkanLab-Denmark\CAMDATM\axit-Coarse\56266_10-20mm_B_1%_xc_min_001.rdf
Task file:	C:\...n-5-GB\CAMSIZER-SkanLab-Denmark\CAMSYS\RT841_Skanlab_Letklinker10-20_B_1%.afg
Time:	3.11.2005 , 9:09 , duration 38 min 2 s at 1.0 % covered area, image rate 1:2 and 60 mm feeder
Particle model:	min(x:c)
No. of particles:	CCD-B = 452560 , CCD-Z not active
Fitting:	no
Material:	Letklinker
Comment:	Druckluft, 60mm Rinne; Bildrate 1:2

Size class	[mm]	p3 [%]	Q3 [%]	SPHT3	b/l3	PDO
0.000 -	0.063	0.000	0.000	0.726	0.507	0
0.063 -	8.000	2.529	2.529	0.831	0.681	449853
8.000 -	10.000	2.542	5.071	0.907	0.739	231
10.000 -	12.500	22.160	27.231	0.922	0.761	951
12.500 -	16.000	51.976	79.207	0.933	0.800	1288
16.000 -	19.000	14.945	94.152	0.939	0.811	194
19.000 -	22.400	5.069	99.221	0.944	0.837	39
> 22.400		0.779	100.000	0.945	0.864	4



Characteristics

Q3 [%]	x [mm]
10.0	11.083
50.0	13.740
90.0	17.692
SPAN3 =	0.481
U3 =	1.297
Sv =	0.521 / mm

Mean value SPHT3 = 0.927
Mean value b/l3 = 0.785

>90% within specification => API conform

User

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Maintenance-Free by Venturi-Flushing

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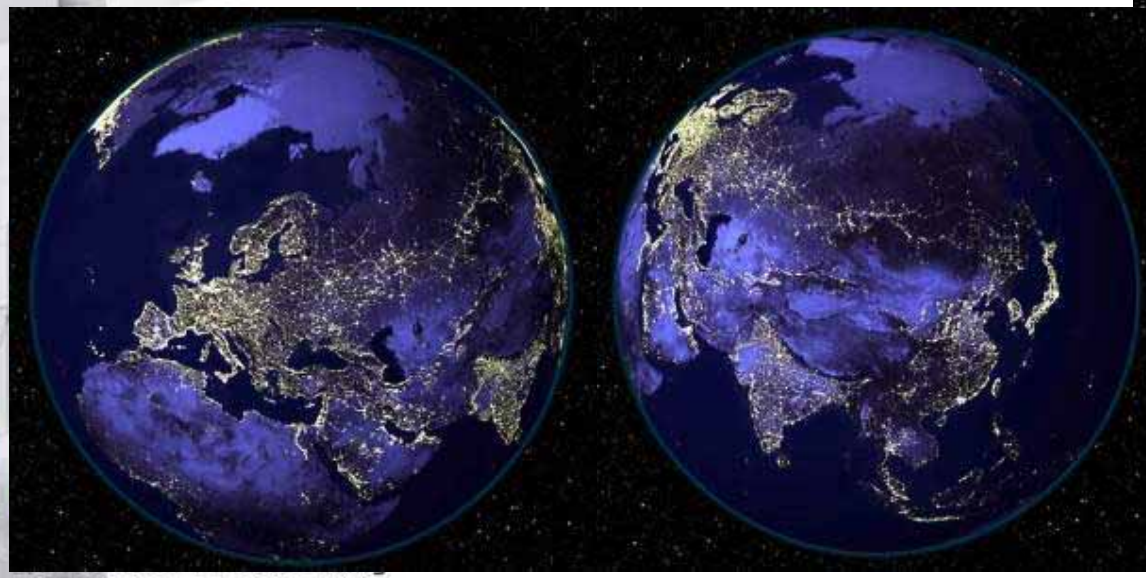
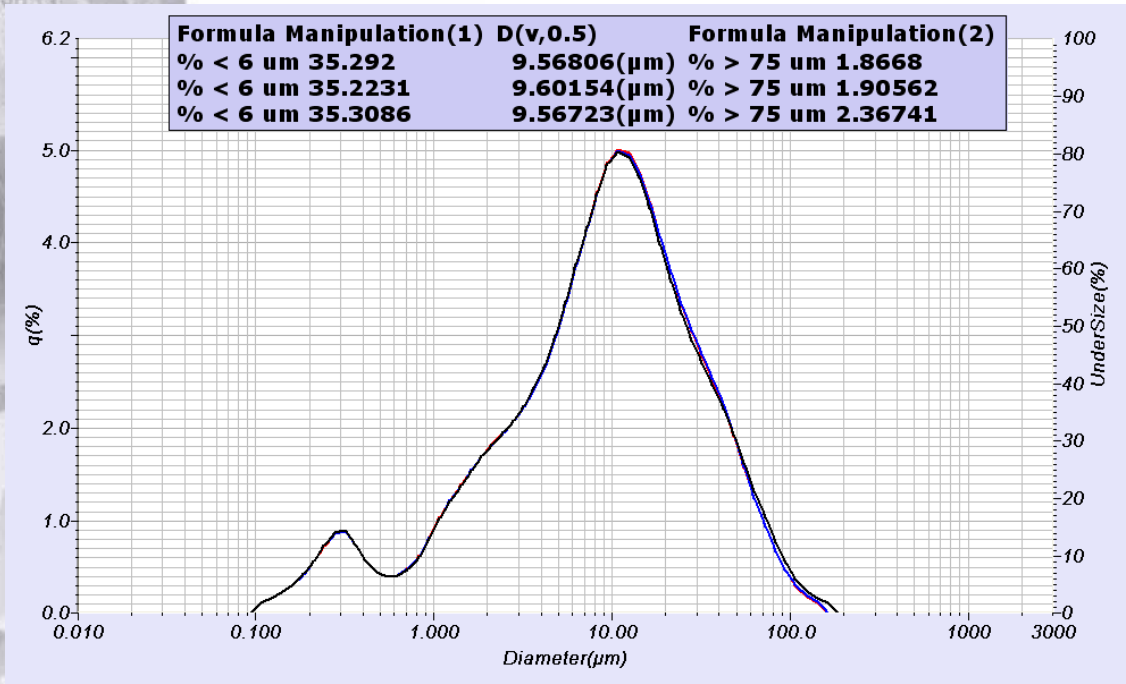
12 Years CAMSIZER

~ 600 installed CAMSIZER Instruments worldwide:
Nearly on all continents
For many applications / industries:
API conformity, Brown sand, Ceramic proppants, Extrudates, Grains, Proppants, Resin coated proppants, Sand, White sand .....



Particle Size of Drilling Fluid



LA-950

Sample Name	File Name	D(v,0.1)	D(v,0.5)	D(v,0.9)
Drilling Mud Sampling 2	200911301126035.NGB	1.211	9.568	38.269
Drilling Mud Sampling 2	200911301126036.NGB	1.212	9.602	38.490
Drilling Mud Sampling 2	200911301127037.NGB	1.211	9.567	39.830
Average		1.211	9.579	38.863
Std. Dev.		0.001	0.020	0.845
CV (%)		0.048	0.208	2.174
ISO 13320-1 (20.0, 15.0, 20.(		PASSED	PASSED	PASSED

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Solutions in Particle Sizing

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Surface Area

Size, shape and specific surface area (SSA) affect catalyst performance

Measure SSA using BET: SA-9600

- Flowing gas BET method
- Low price,operating costs, maintenance
- Easy to use, fastest measurement time
- No vacuum system required
- Single or multi-point
- Up to three samples simultaneously

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Petroleum Analysis

Many instruments to measure the quality of oils, fuels, etc.
SLFA-20 ASTM D4294 for crude

MESA-6000 ASTM D7220 for low ppm sulfur and chlorine

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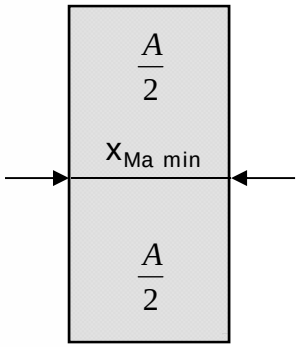
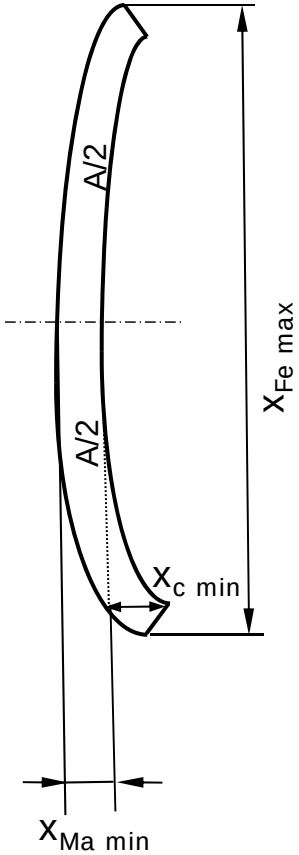
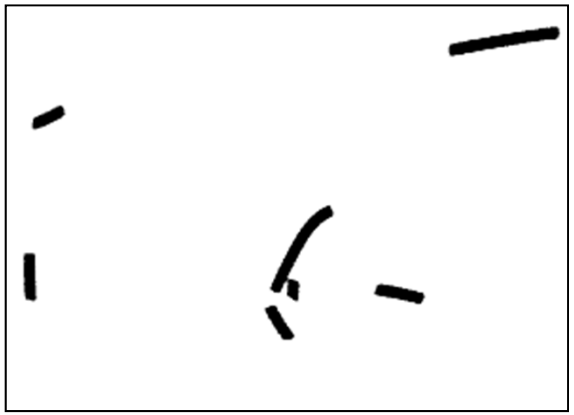
CAMSIZER

for elongated particles (extrudates)







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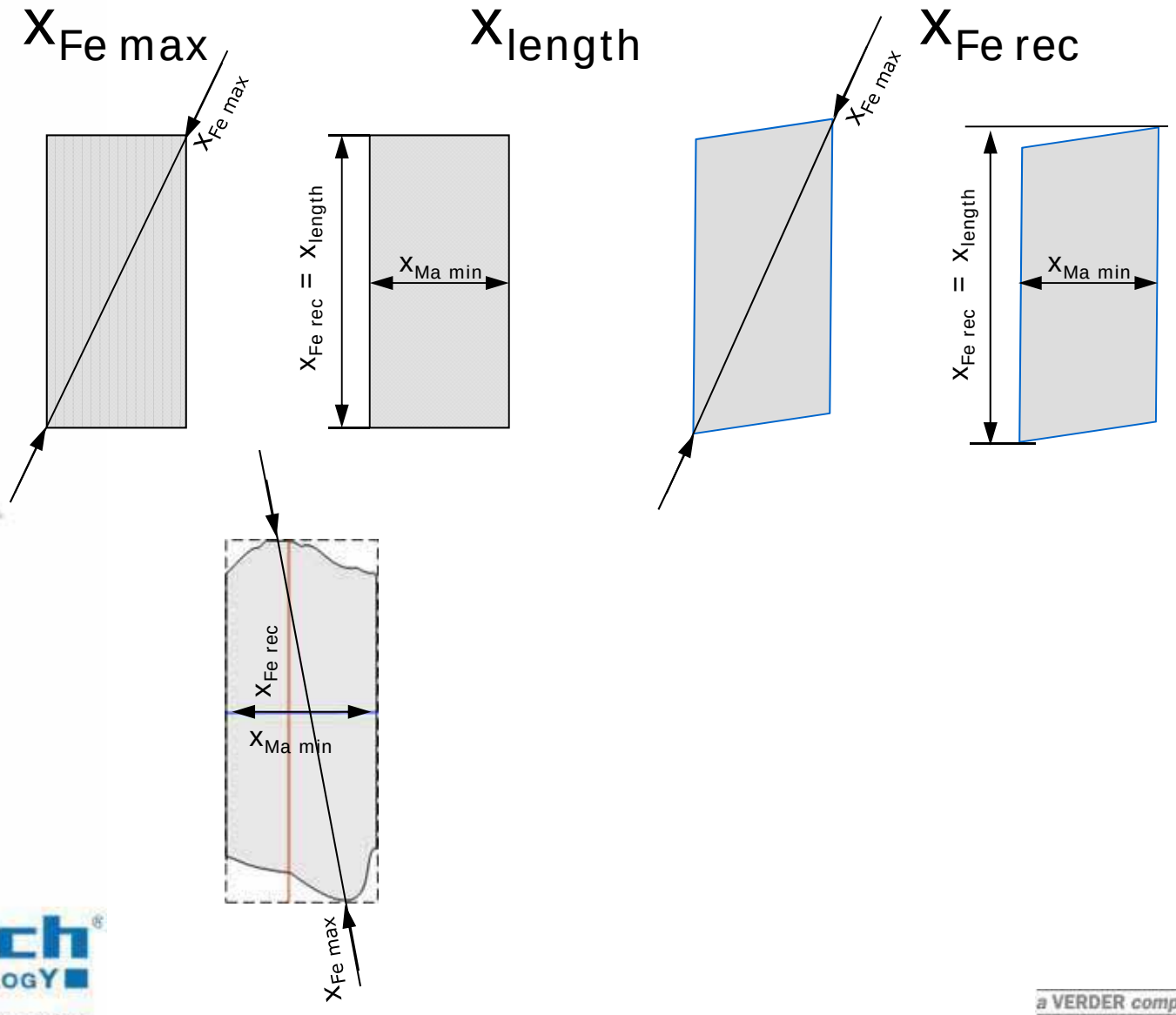
CAMSIZER® length definitions
for elongated particles (extrudates)



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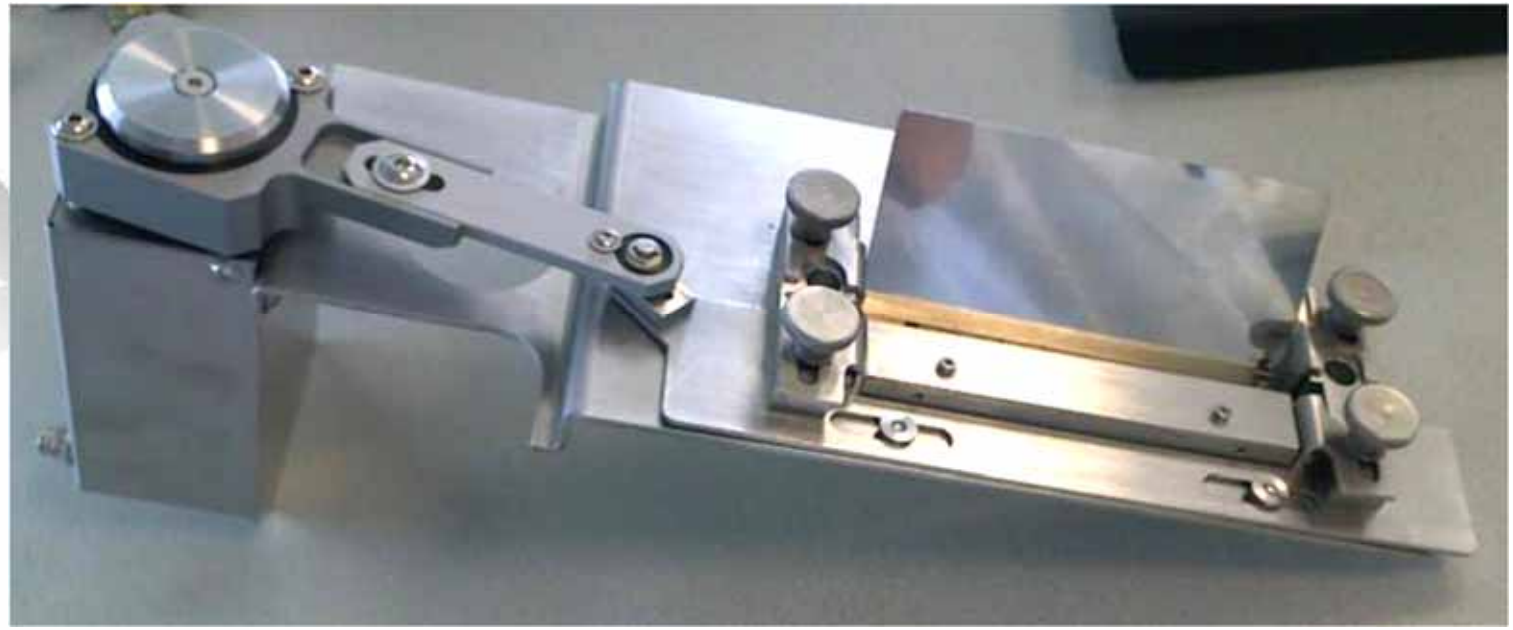

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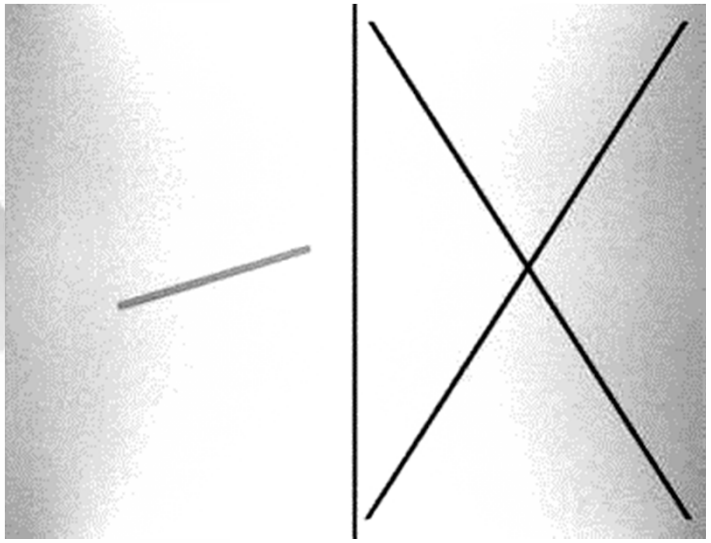
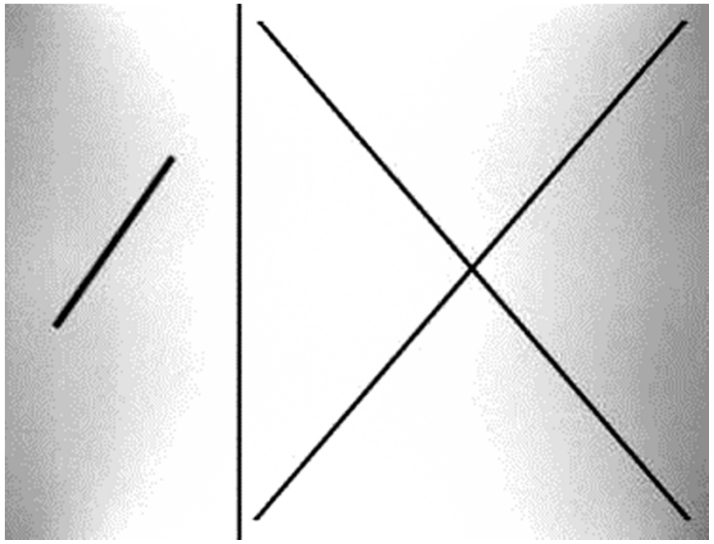
Length + Diameter of Implants

Length measurement x_{length} ~ 26mm

Diameter measurement Ø ~ 0.85mm



validation and test
1. with plastic and
2. steel cylinders



measurements of produced implants (release time 1 month)

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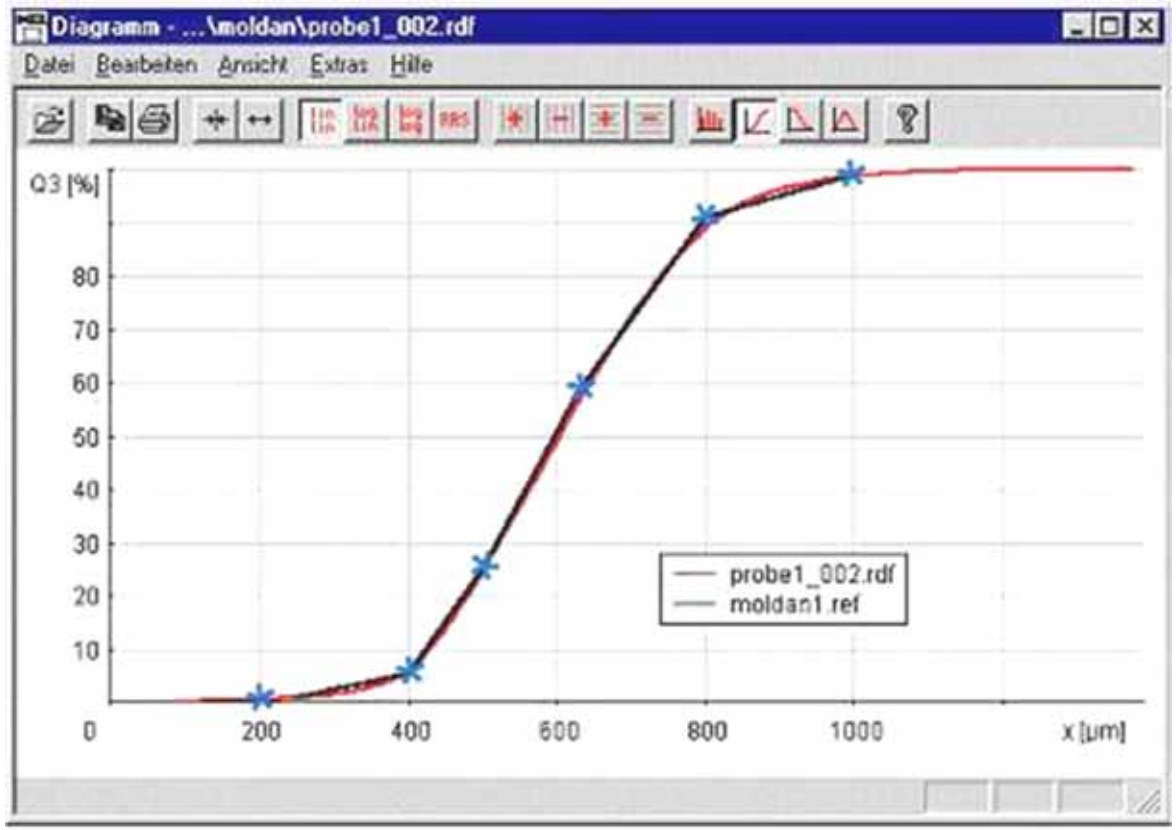
Fitting of CAMSIZER result to Sieving



fitted result

CAMSIZER-measurement **x** (**red**)
to sieving ***** (**blue**)

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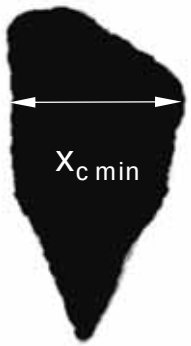
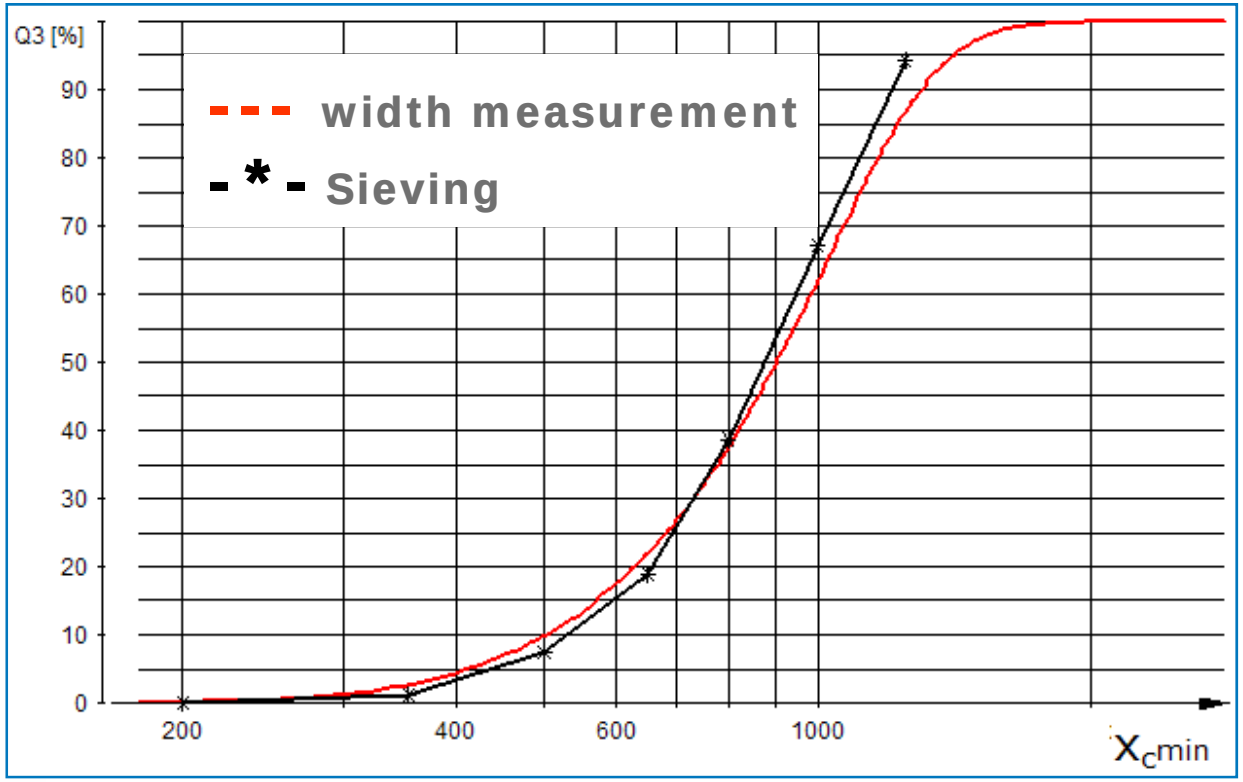
Digital Image Processing
Measuring of Width ⇔ Sieving

$x_{c\,min}$
"width"





comparison

CAMSIZER-measurement $x_{c\,min}$ (**red**)
and sieving * (**black**)

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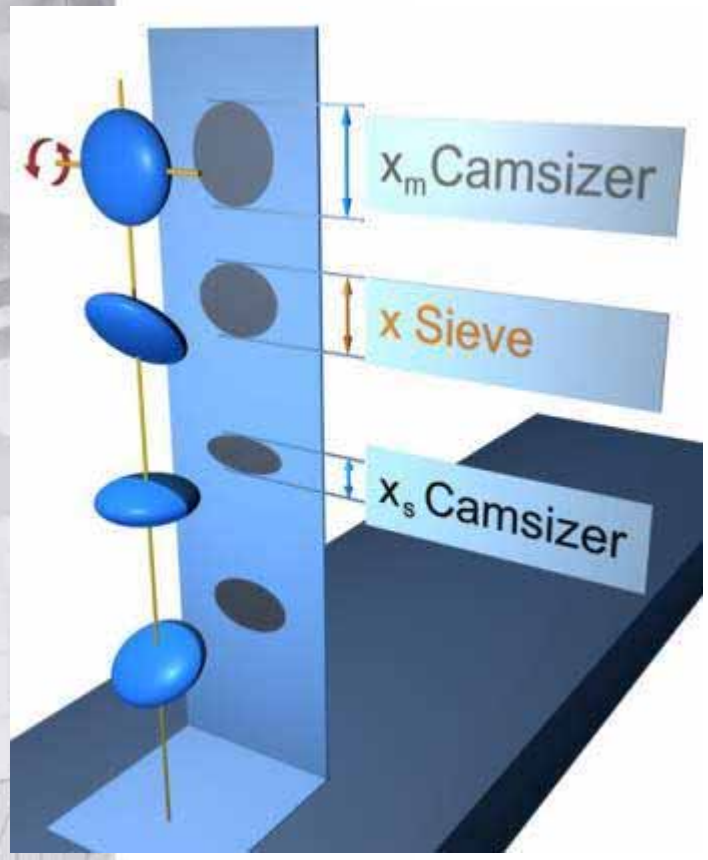
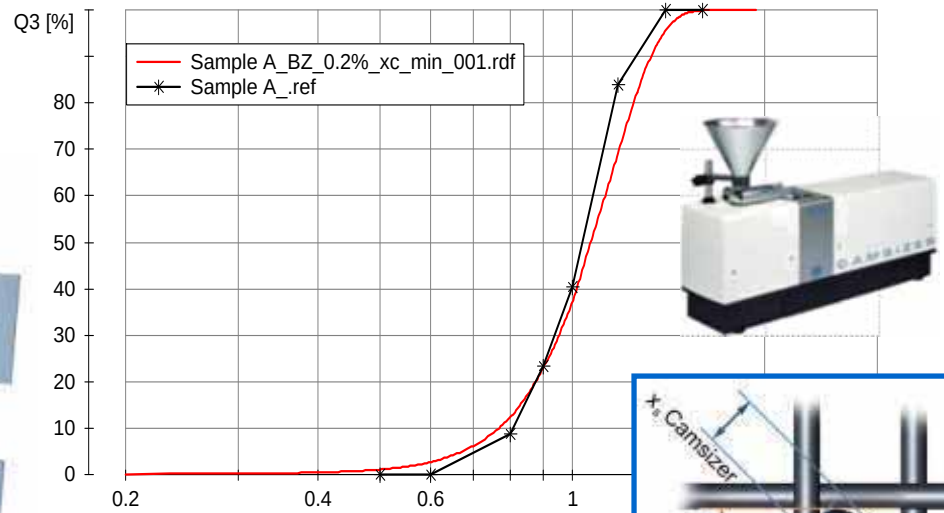
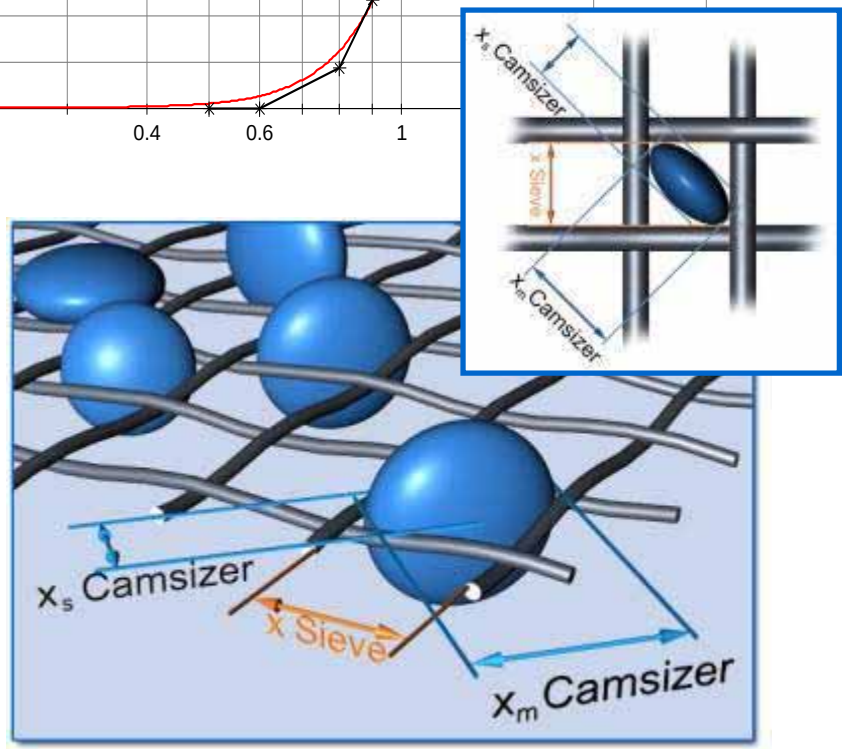
Digitale Imaging ⇔ Sieving







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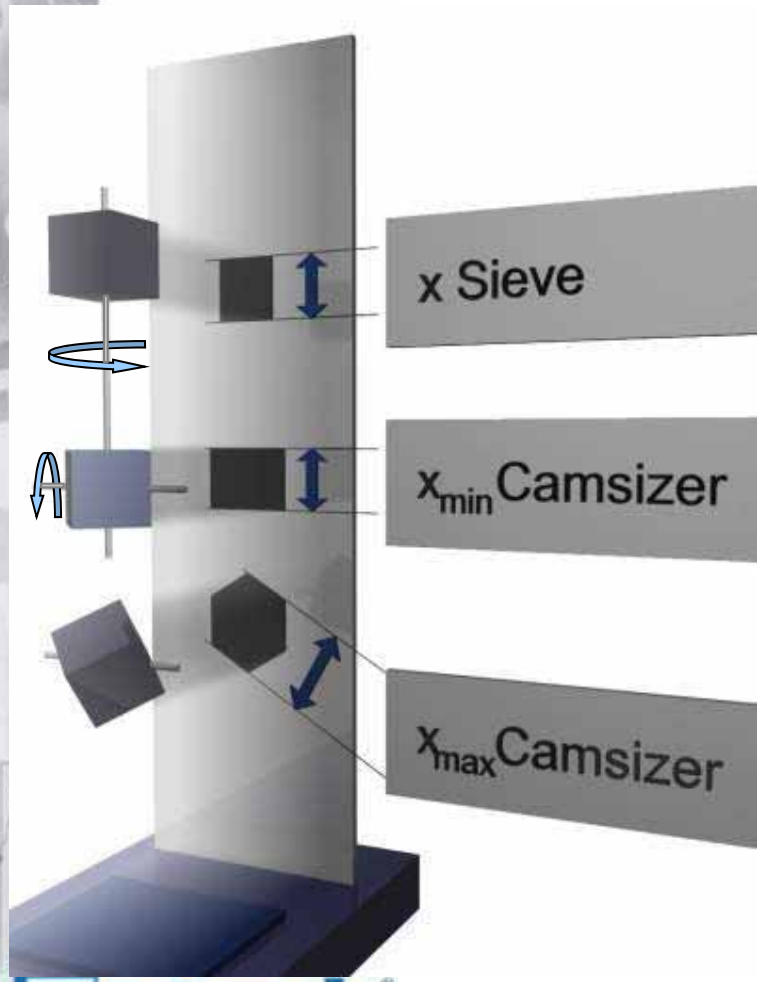
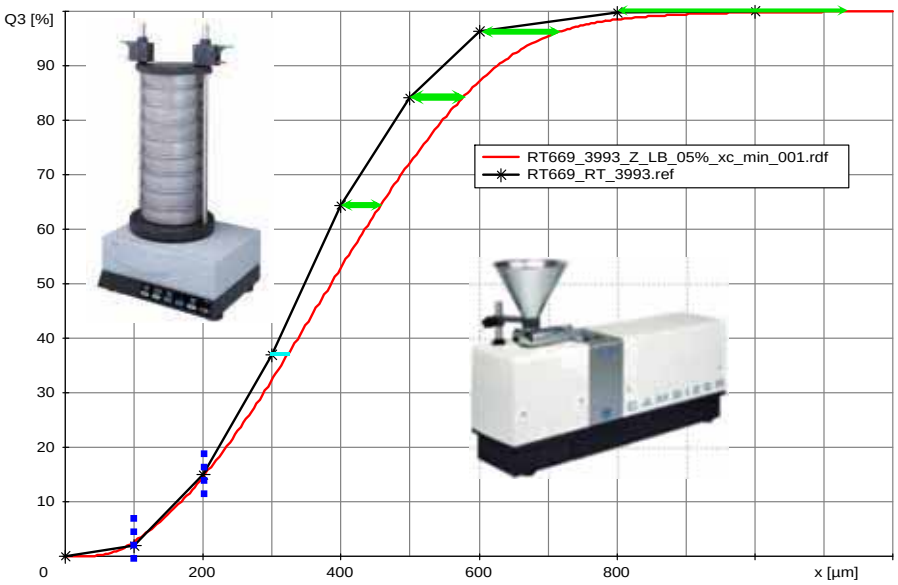
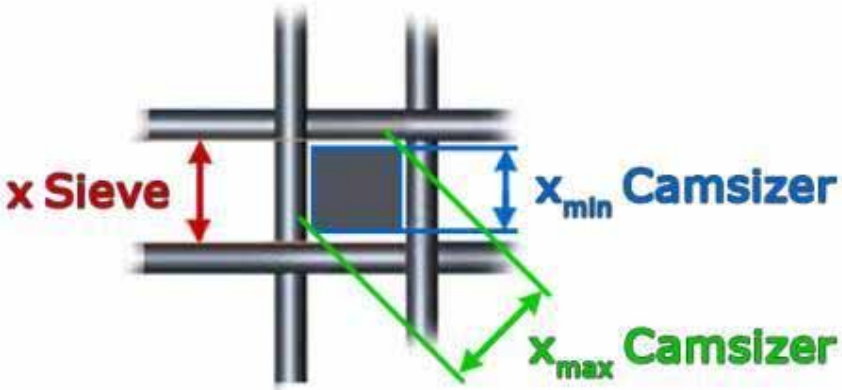
Digital Imaging ⇔ Sieving
Cubes / Angular Particles







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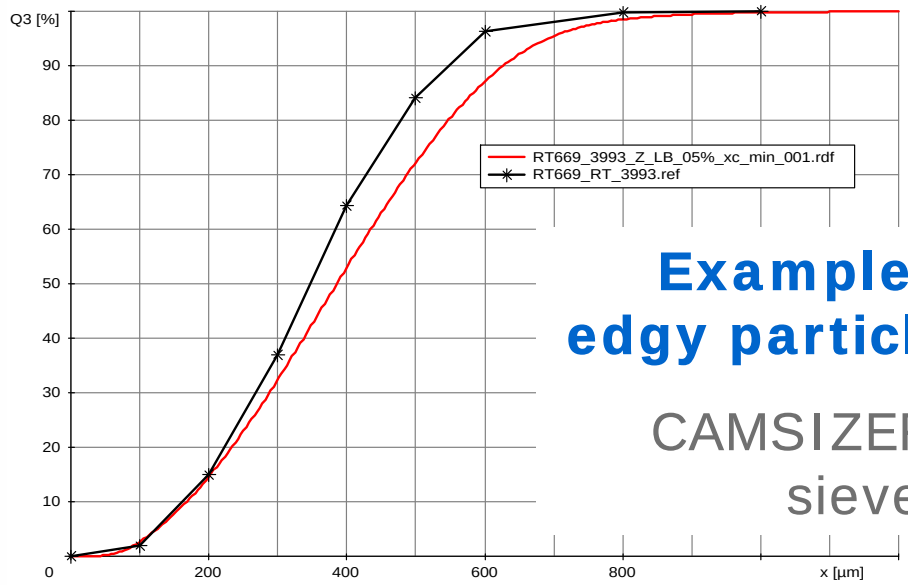
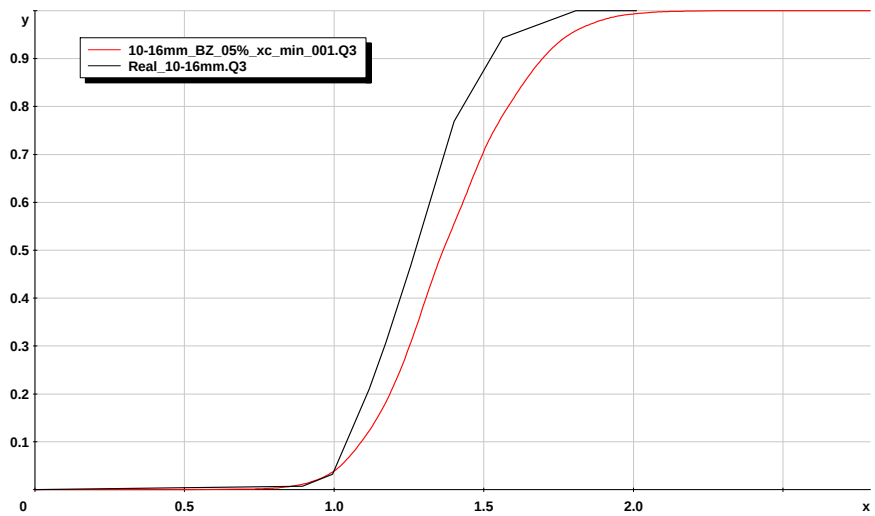
Digital Imaging ⇔ Sieving



Examples of samples with edgy particles without fitting

CAMSIZER-result $x_{c\ min}$ (**red**)
sieve analysis * (**black**)



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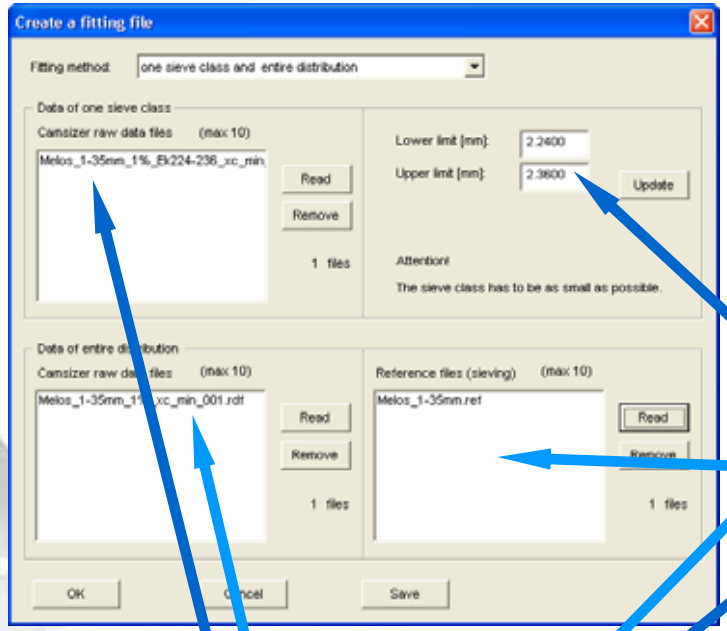
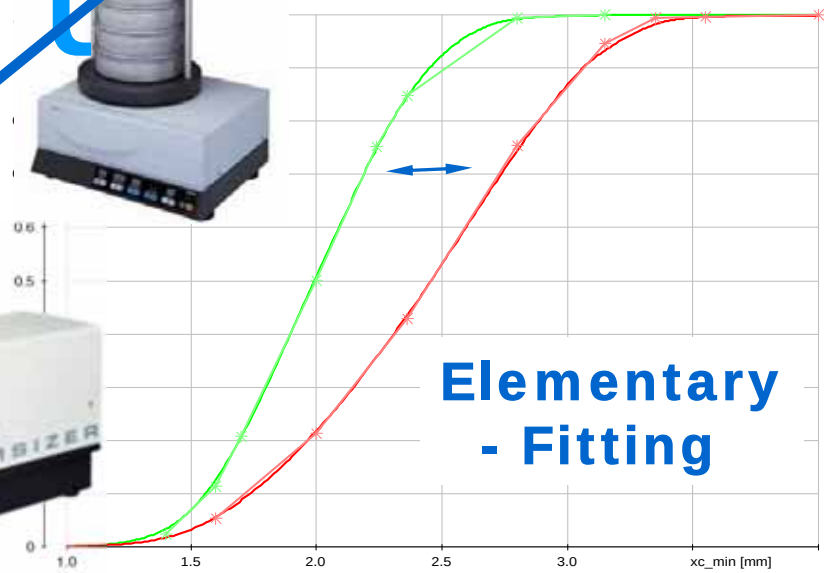
Digital Imaging ⇔ Sieving

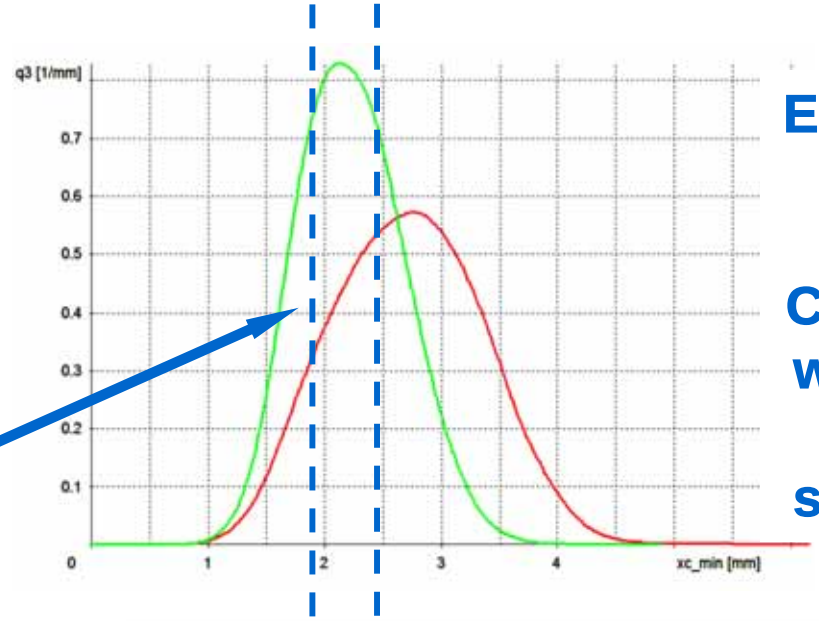


New elementary fitting with **single (narrow) sieve class** and **entire distribution**

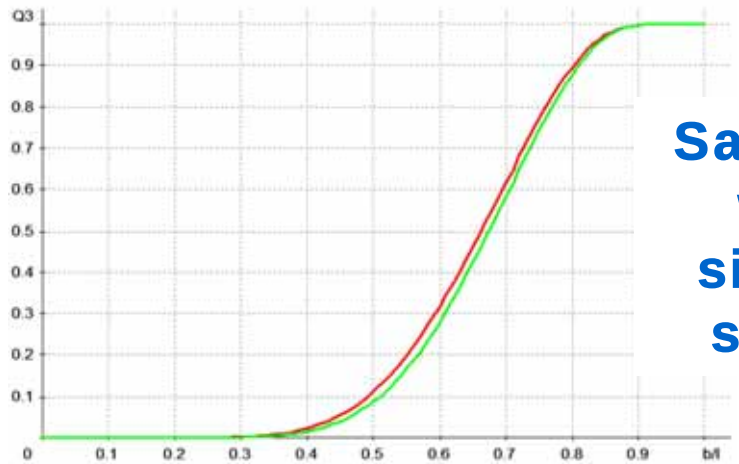


Elementary - Fitting

Digital Imaging ⇔ Sieving



Elementary fitting = Sieve Correlation with single (narrow) sieve class



Samples with similar shape

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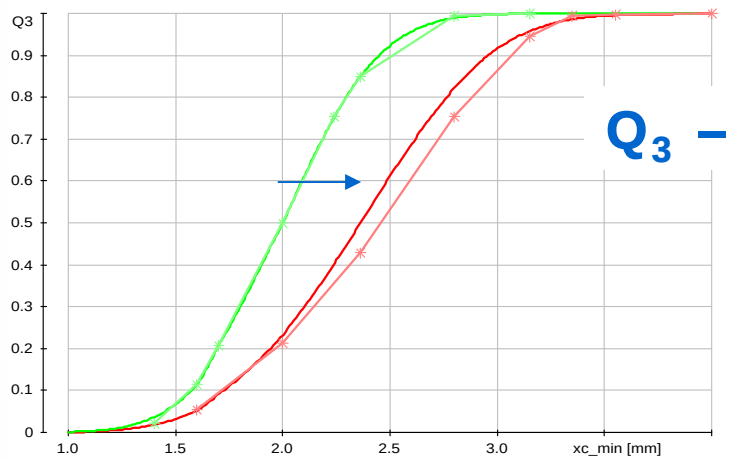
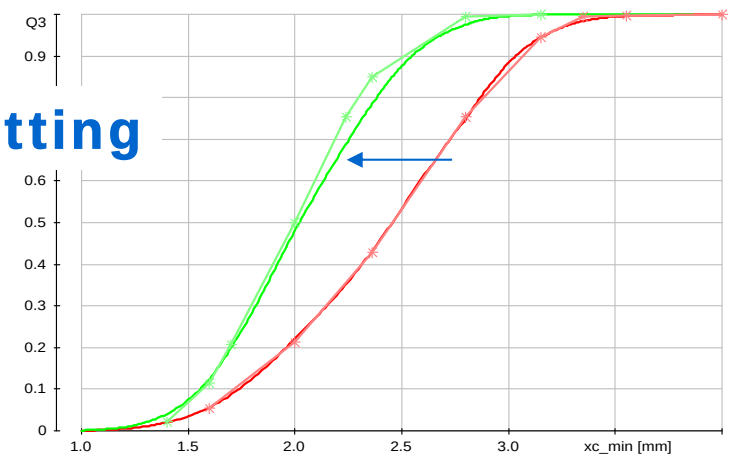
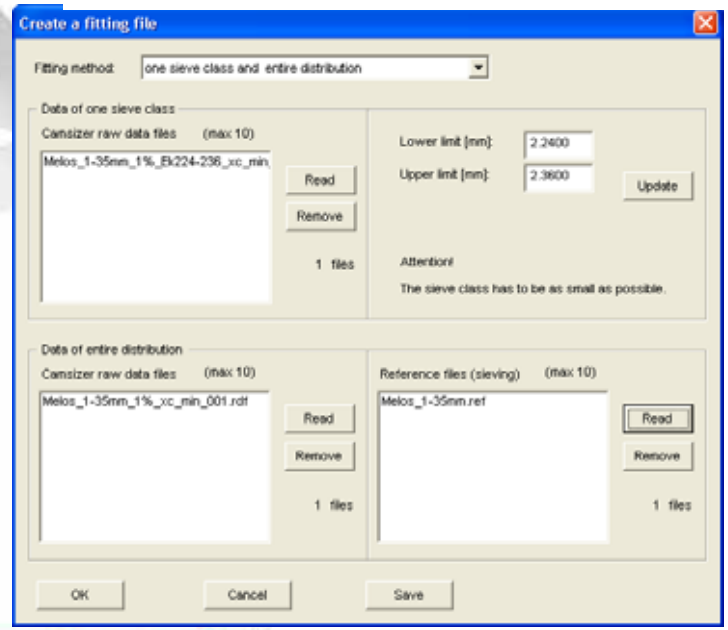
Digital Imaging ⇔ Sieving

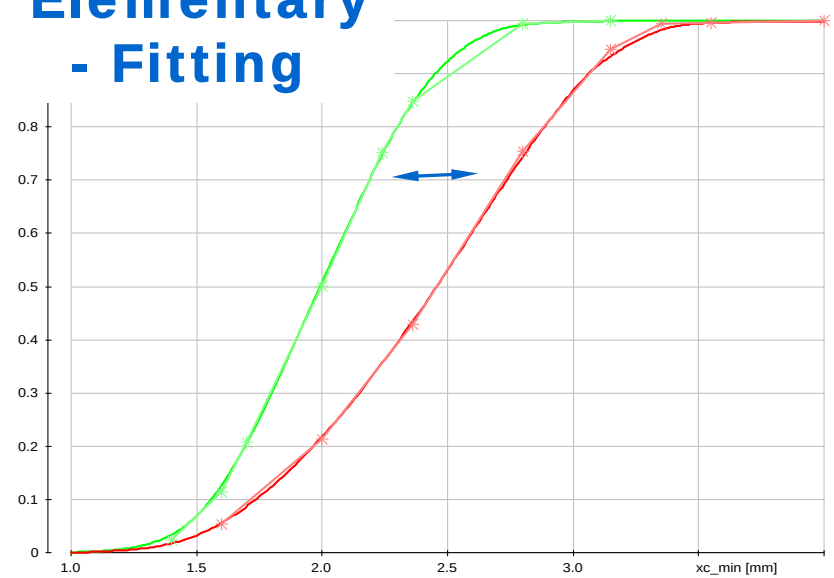


Q_3 – Fitting





Elementary - Fitting



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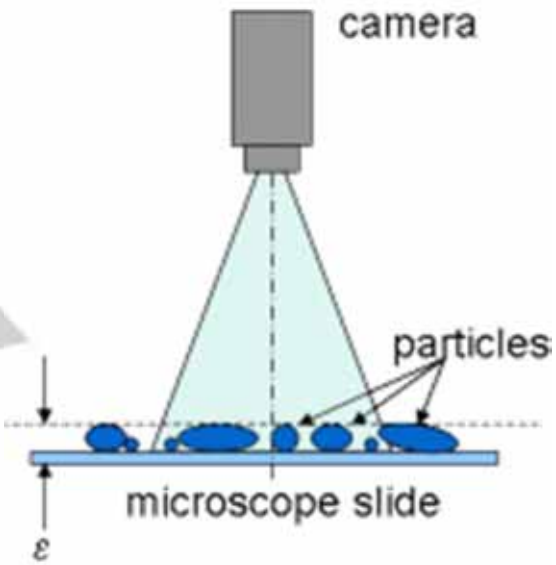
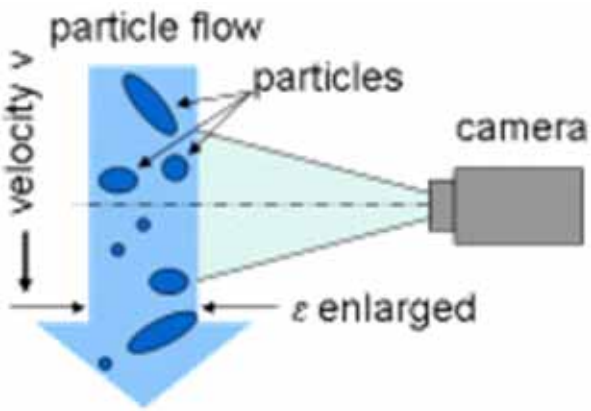
Comparison between Static ⇔ Dynamic Image Analysis



ISO 13322-1



ISO 13322-2

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Slides Shown During the Q&A Session Sampling

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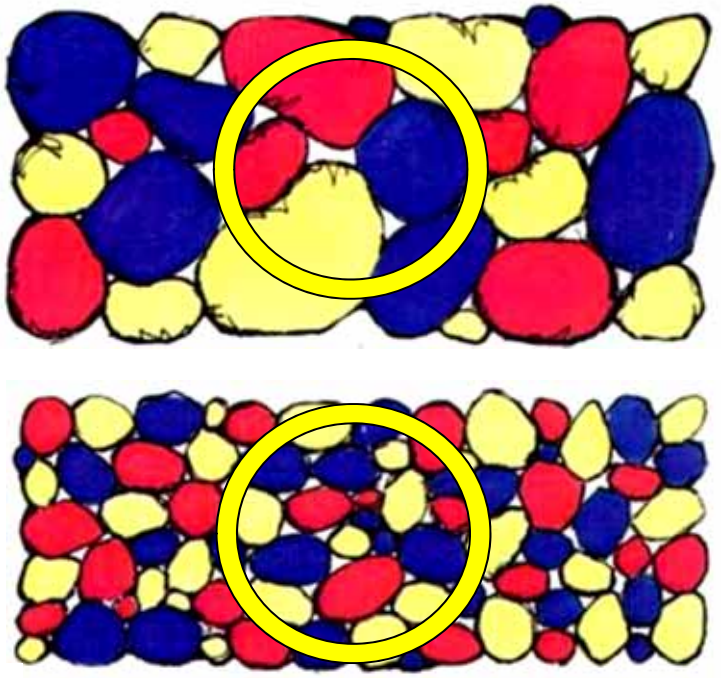
Sample Quantity in Mass or Volume in Relation to the Particle Size

ISO 13322-1

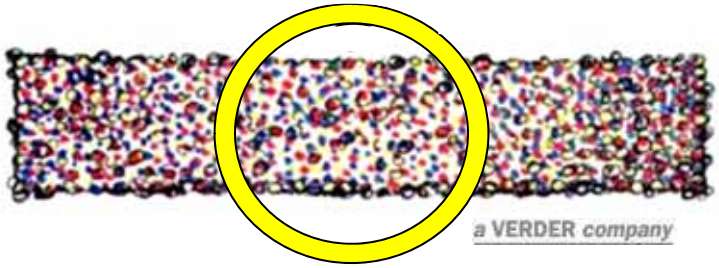
Tables 1 to 3 list, as a function of the geometric standard deviation σ_g of the test powder, the number of particles to be measured, N, the median particle size of a cumulative mass distribution, $x_{50,3}$, the Sauter Diameter, $\bar{x}_{1,2}$, and the average mass diameter, $\bar{x}_{3,0}$, for the precision, respectively, δ = 0,05, 0,1 and 0,2. Here, the confidence coefficient probability, P, is equal to 0,95.

Table 1- Number of particles to be measured N, δ = 0,05, p = 0,95

δ	σ_g	$x_{50,3}$	$\bar{x}_{1,2}$	$\bar{x}_{3,0}$
0,05	1,10	585	389	131
	1,15	1 460	934	294
	1,20	2 939	1 808	528
	1,25	5 223	3 103	843
	1,30	8 526	4 920	1 247
	1,35	13 059	7 355	1 750
	1,40	19 026	10 504	2 363
	1,45	26 617	14 457	3 096
	1,50	36 007	19 295	3 956
	1,55	47 358	25 093	4 952
	1,60	60 811	31 919	6 092



A Sufficient Sample Quantity is Based on the **Number** of Particles



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Additional Slides to better explain Sampling and Sample Splitting

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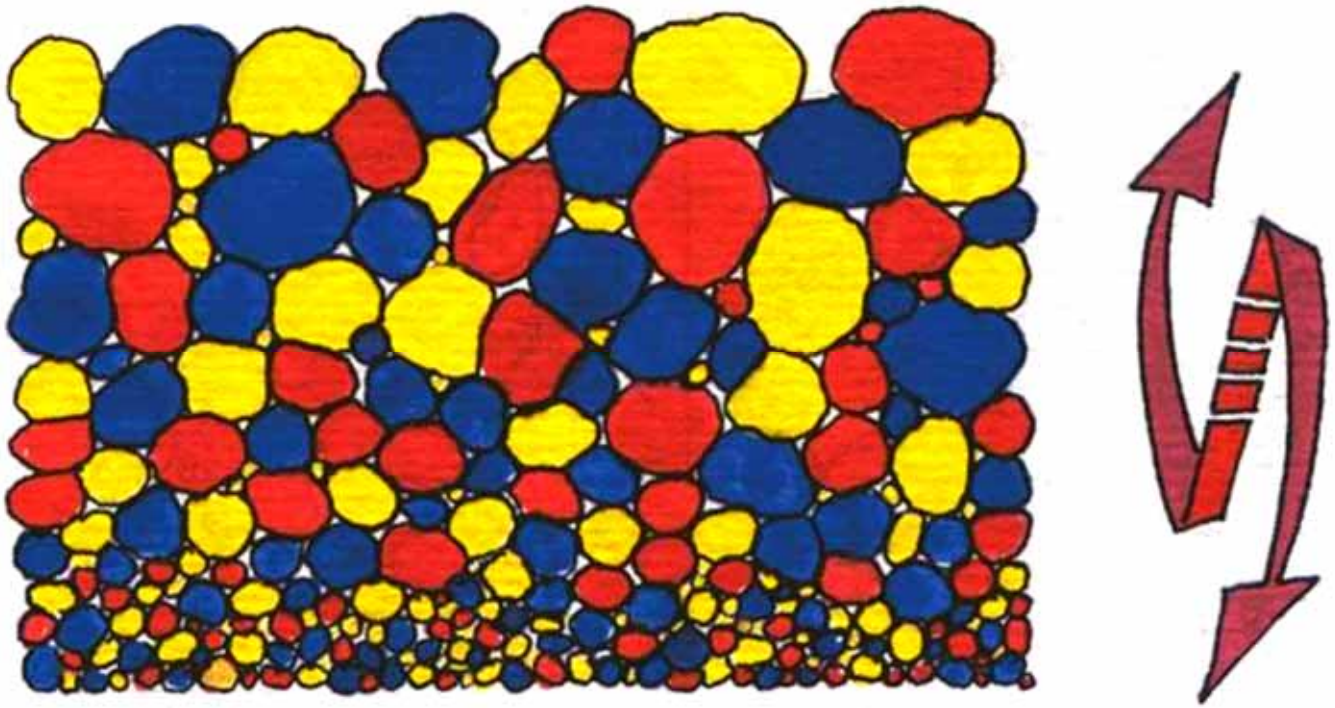
Separation of fine and coarse particles

Separation happens during

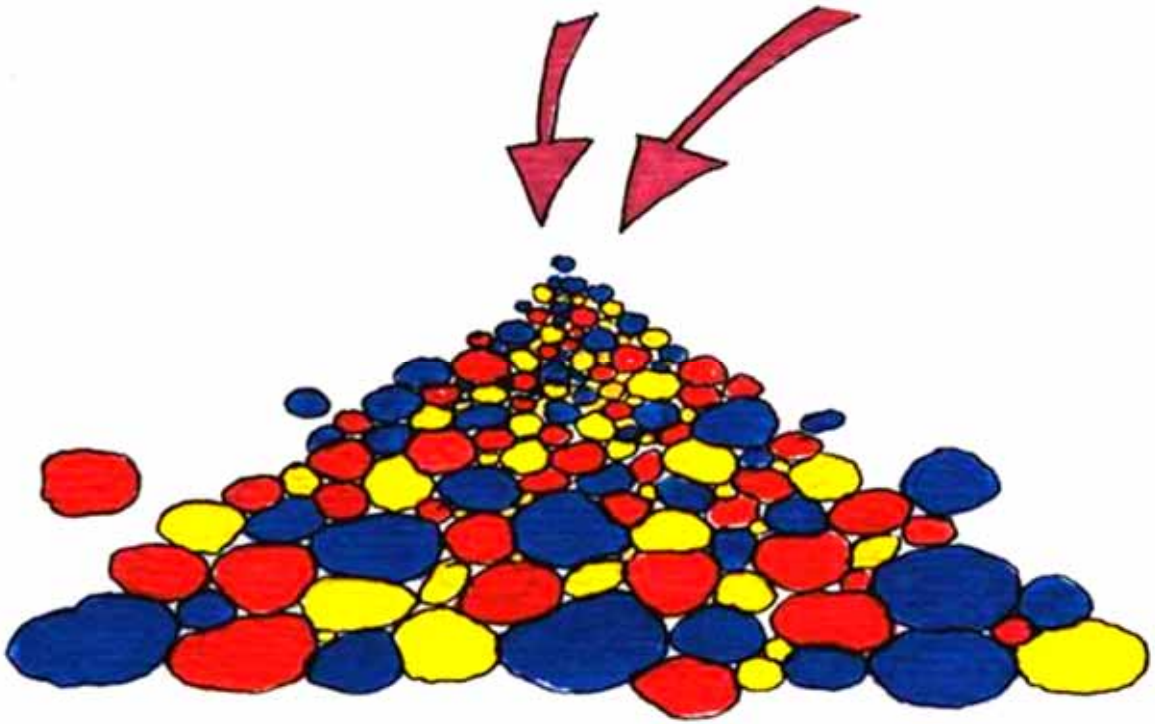
- Transport processes (container, train and truck)
- Feeding processes (funnels, vibration feeders, belts)
- and Storage (bulk pile, silo)



Separation of fine and coarse particles

Segregation (separation by size) happens during

- Filling processes (silo)
- Feeding processes (bulk pile)
- Accumulation of fines in the middle of the pile



Different Fertilizer Product Types, Different Production Methods, as well as Different Sizes and Shapes

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Sample Splitting

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Sample Splitting

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Sample Splitting

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Sample Splitting

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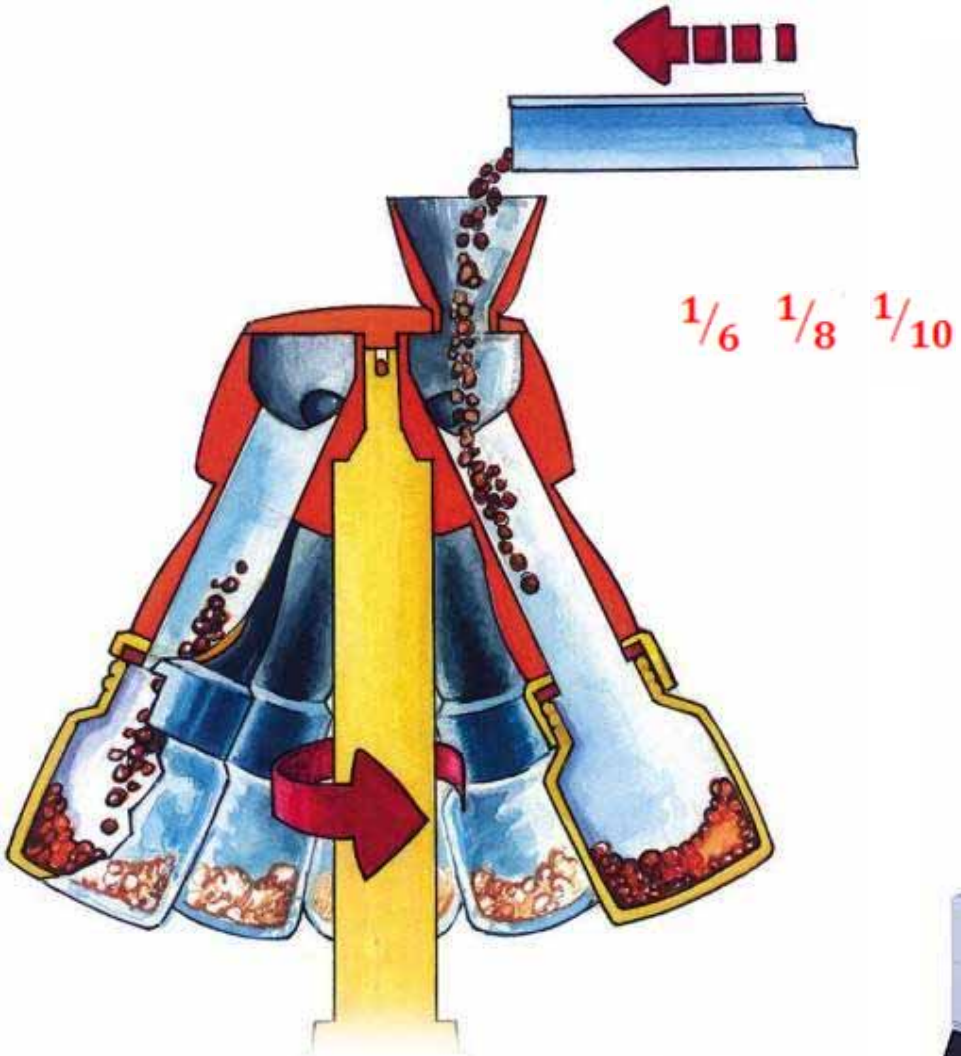
Sample Splitting



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Additional Slides to better explain the CAMSIZER Technology

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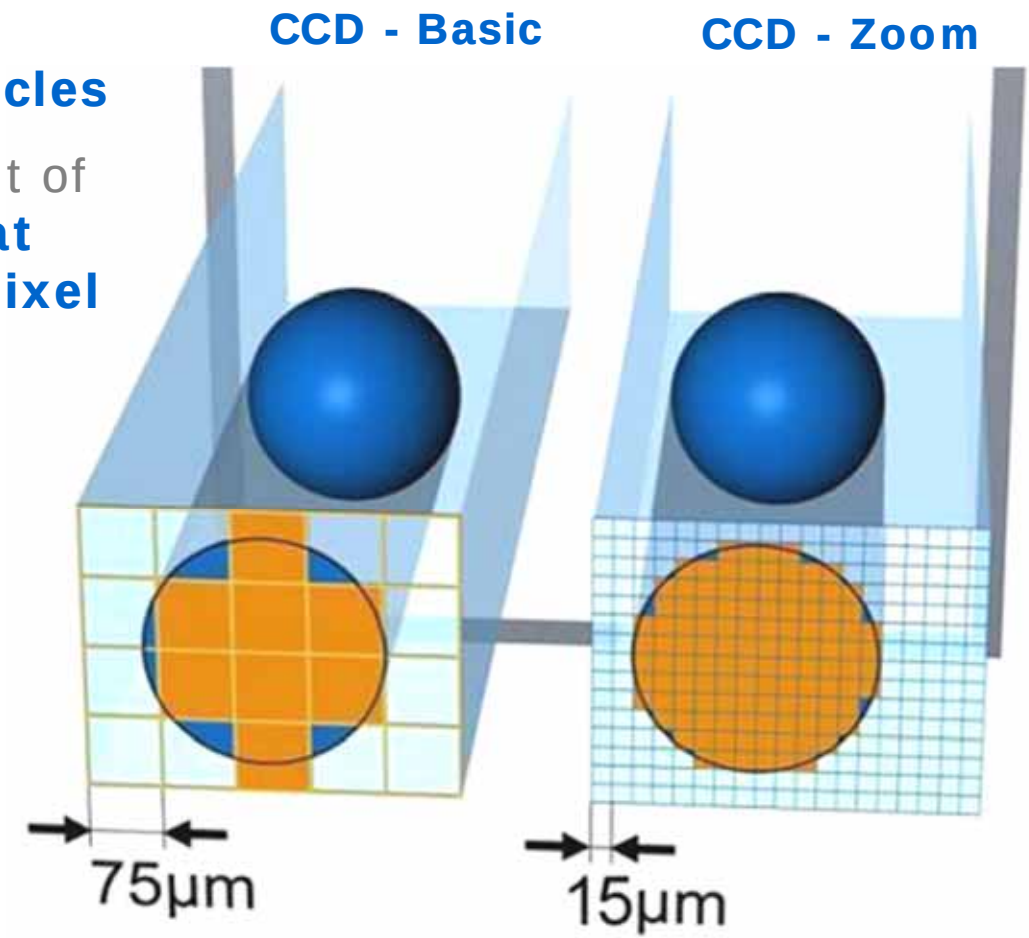
Resolution

Detection of particles

One pixel is element of a projection when **at least half of the pixel** is covered.



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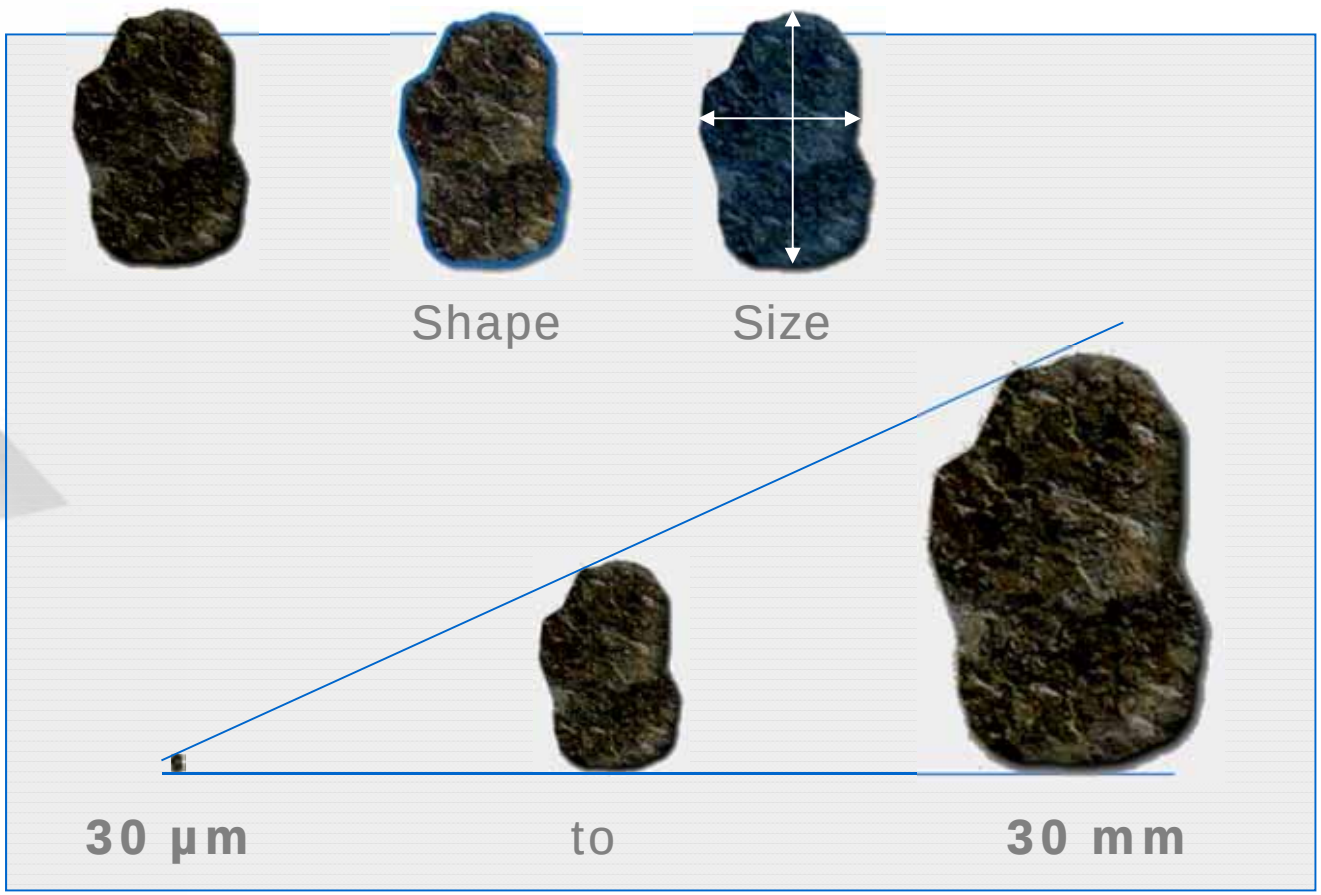
Range of use



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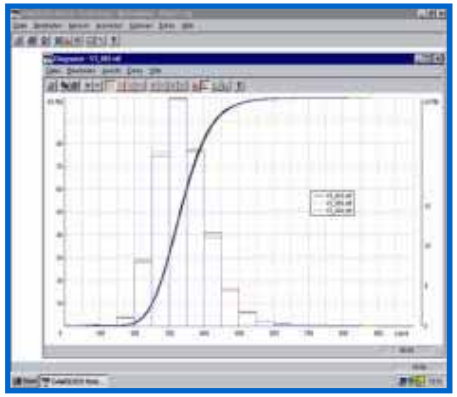
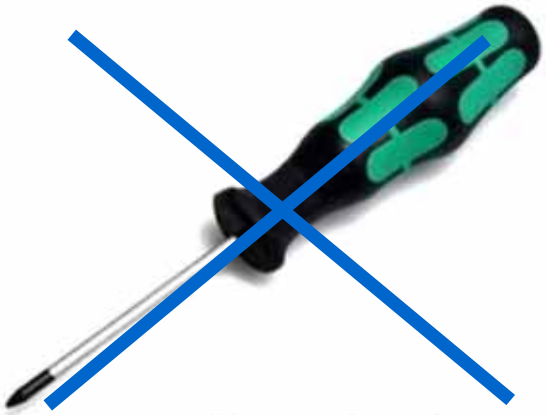
Advantages

fast



reproducible

precise



maintenance-free & robust

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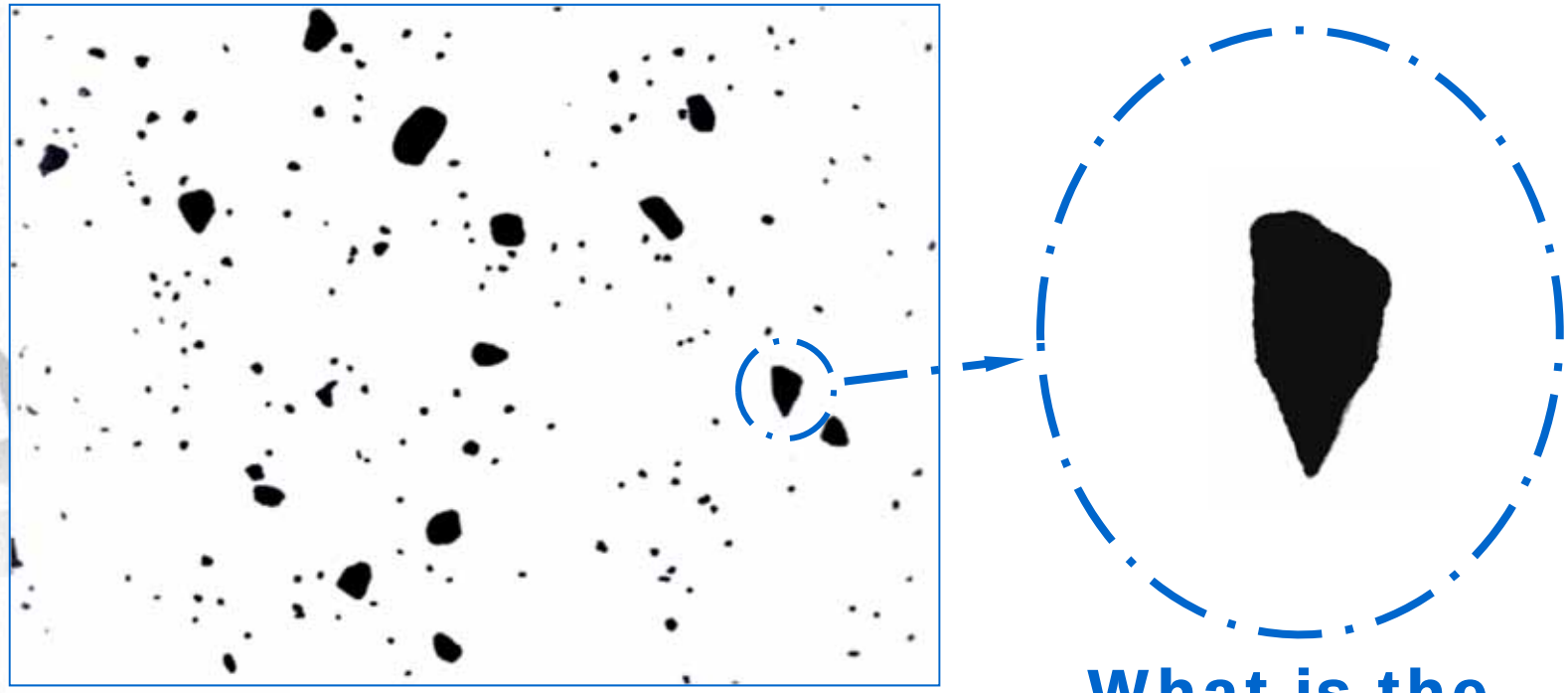
Particle Size



What is the size of this particle?

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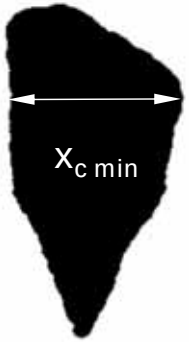
Particle Size

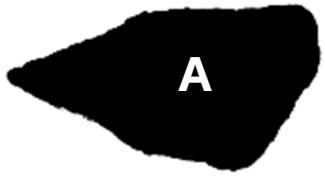
$x_{c\,min}$

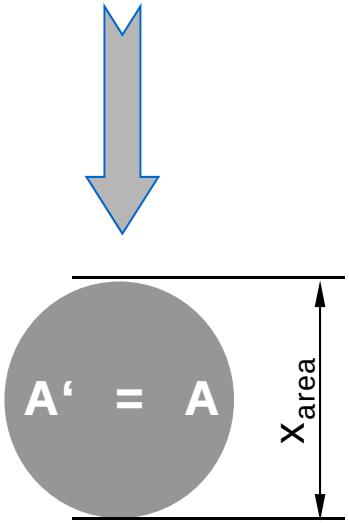
"width"



x_{area}

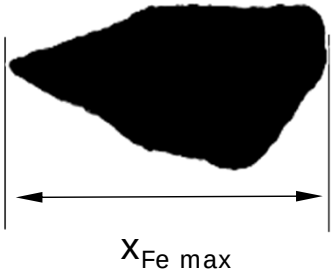
"diameter over projection surface"





$x_{Fe\,max}$

"length"



CAMSIZER results are compatible with sieve analysis

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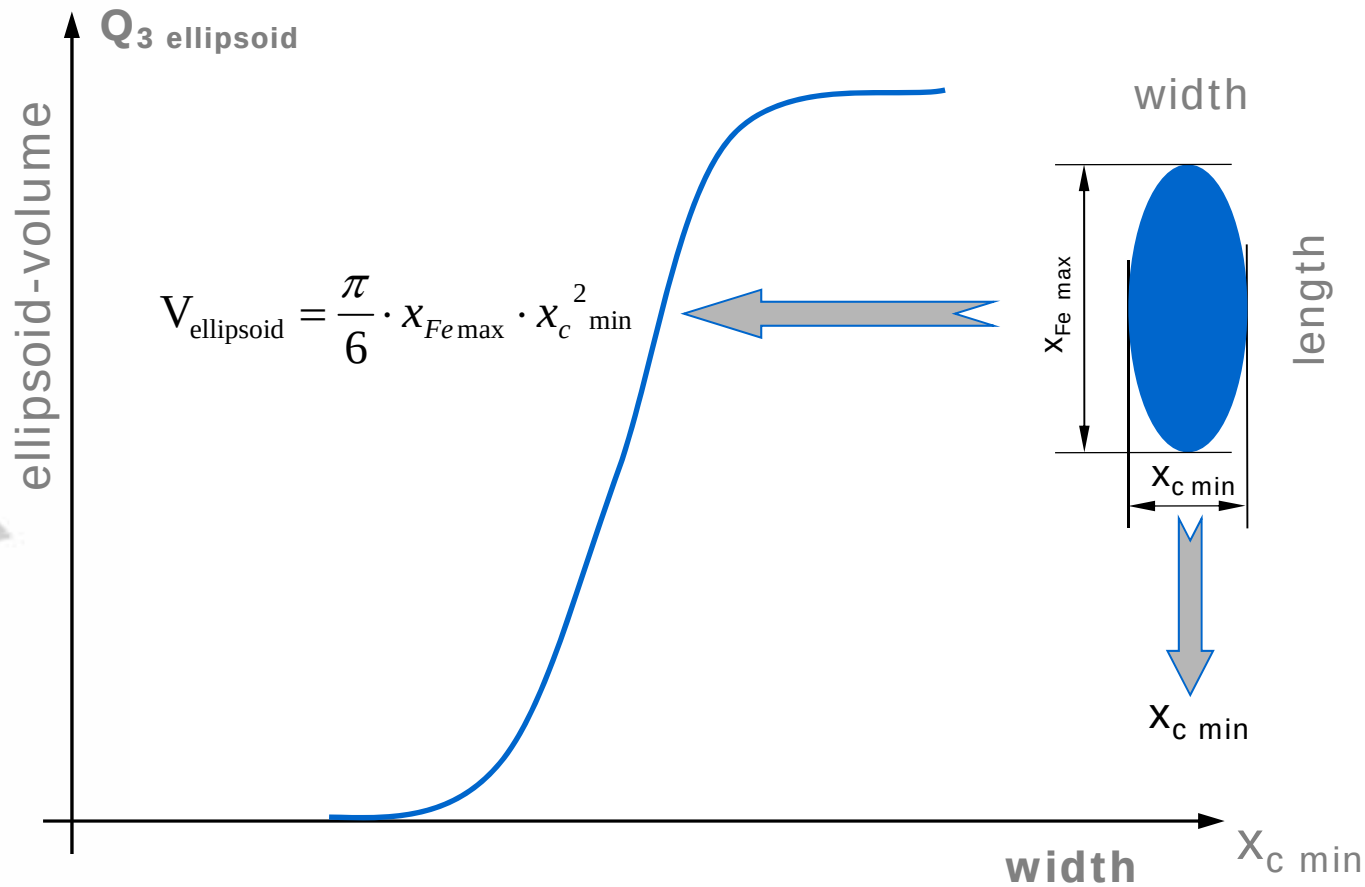
Volume Definition



$$V_{ellipsoid} = \frac{\pi}{6} \cdot x_{Fe\,max} \cdot x_c^{\,2}{}_{min}$$

Ellipsoid model leads to better results

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Additional Slides to better explain the Dispersion Technology (against static charged particles)

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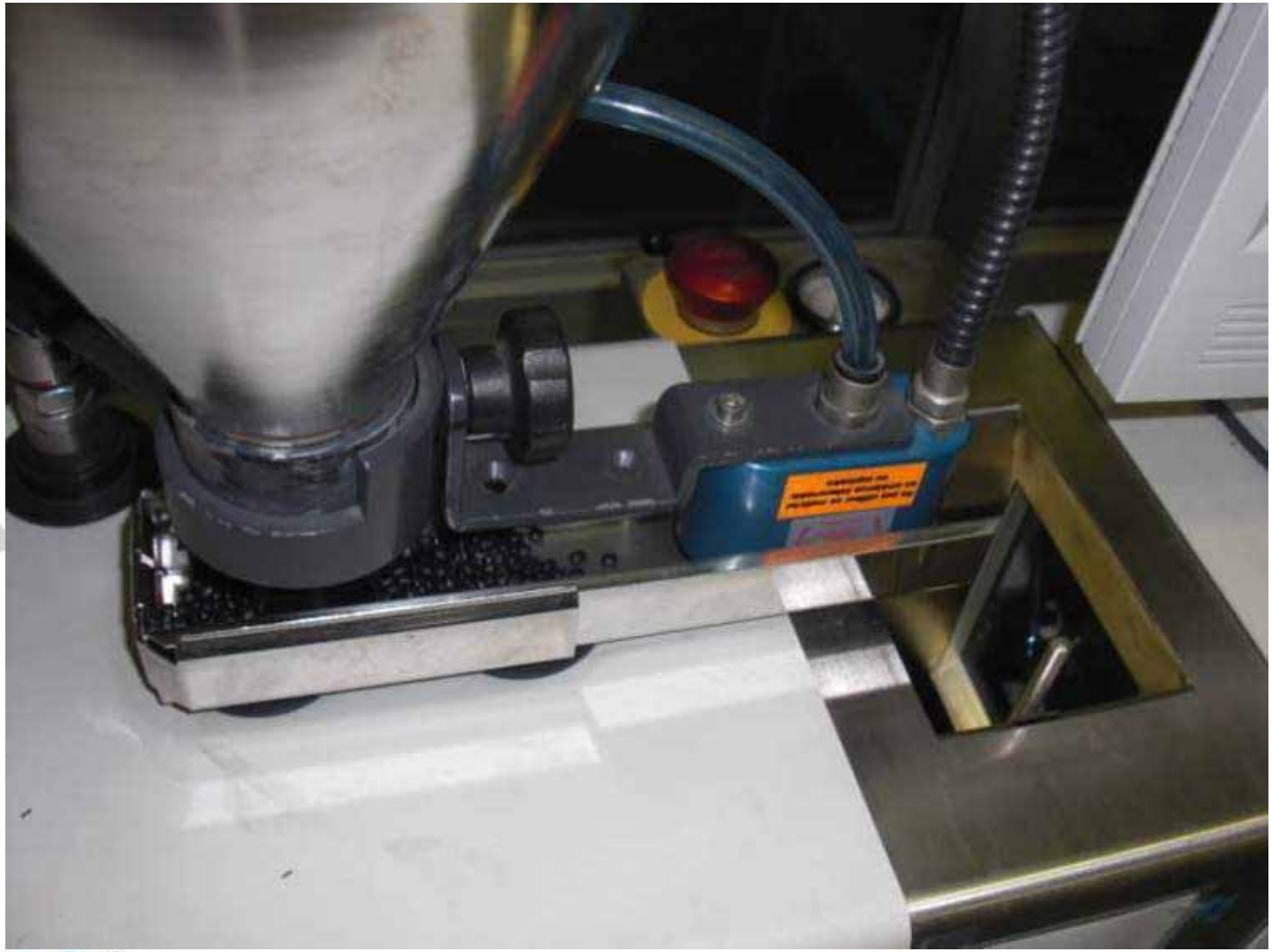
Size, Shape & Density Measurement of Charged Coated Resin Beads using an Electric High Voltage Ionizer



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How to separate the dust part from the granules to measure these single dispersed?

Dispersion of coated granules with Ultrasonic or ALU-C Aeroxide

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Additional Slides to better explain the Basics of the used Parameters and the Calibration of the Instrument

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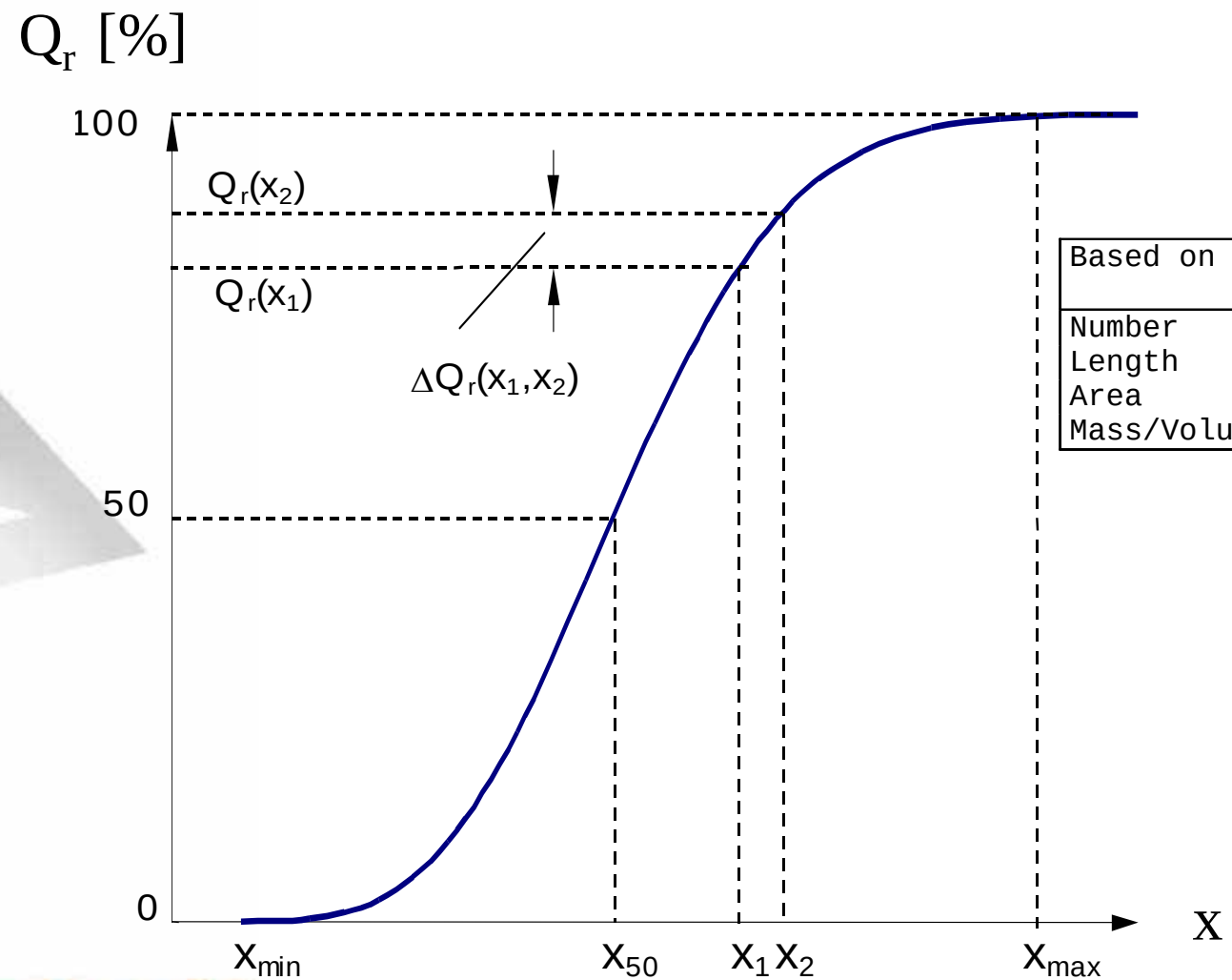
Particle Distributions

Cumulative distribution Q_r



Based on	Index r
Number	0
Length	1
Area	2
Mass/Volume	3

median

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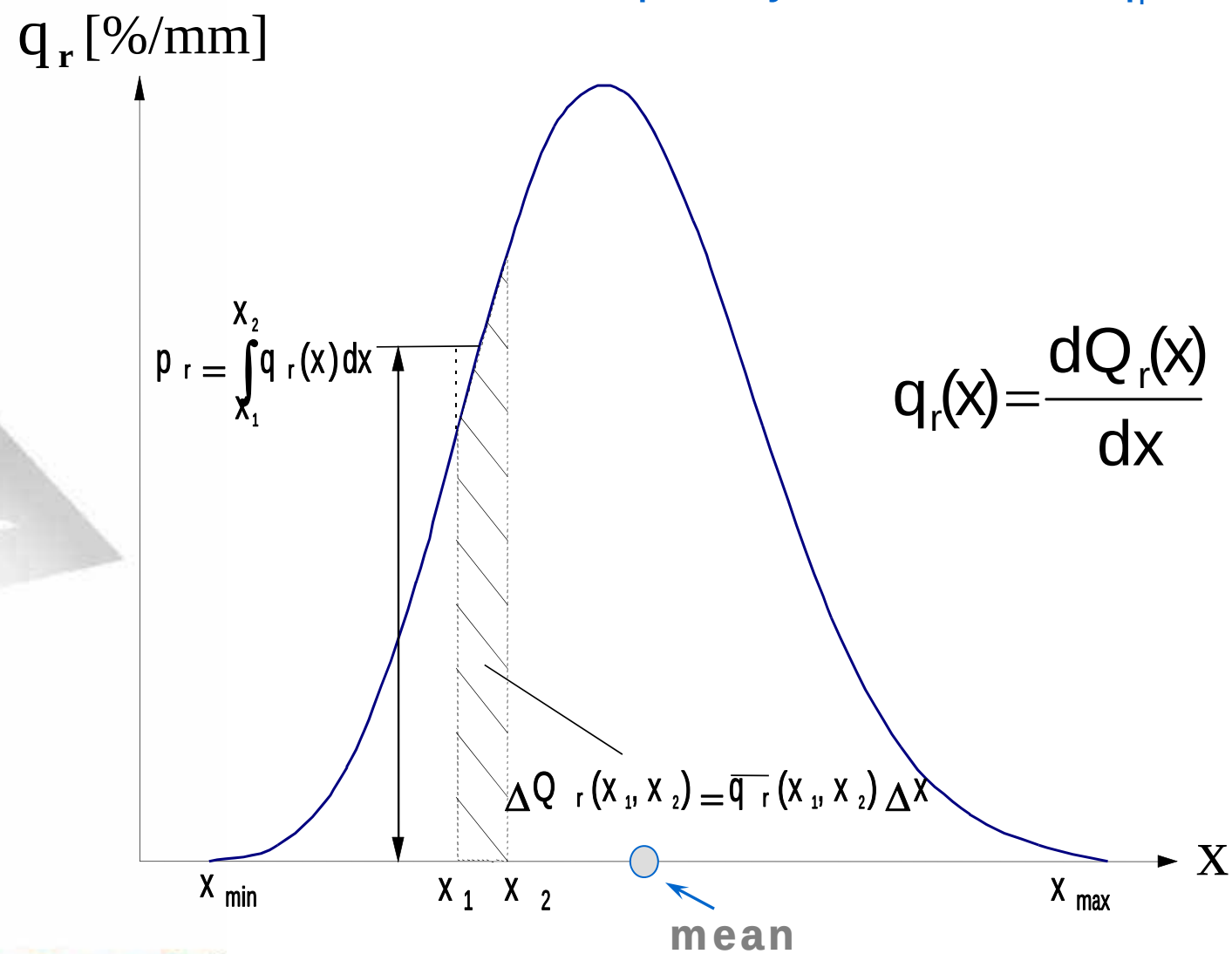
Particle Distributions

Frequency distribution q_r



$$q_r(x) = \frac{dQ_r(x)}{dx}$$

Mv(x): mean value of x, determined from the distribution of all particles

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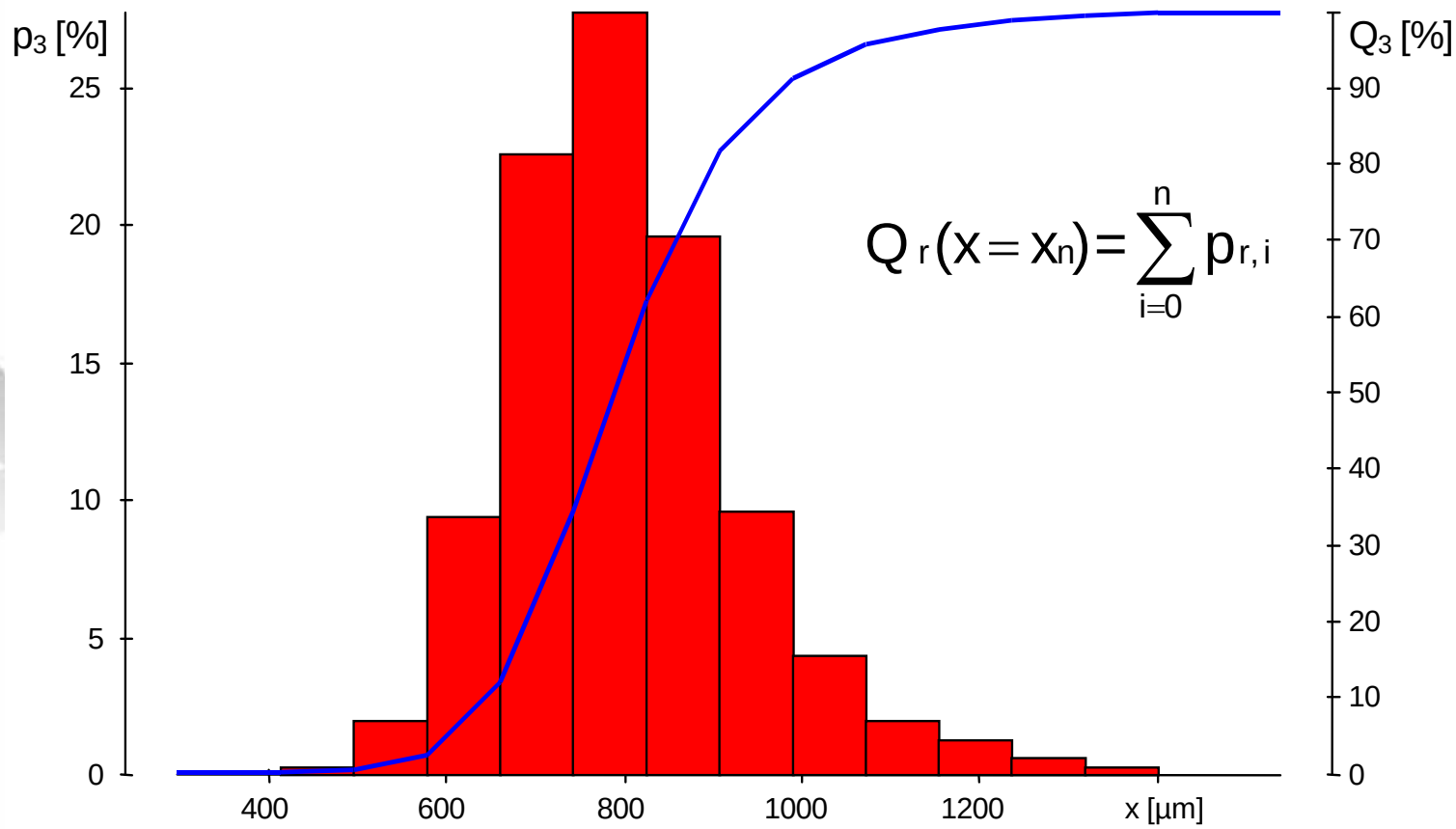
Particle Distributions

Histogram fractions p_r



$$Q_r(x = x_n) = \sum_{i=0}^{n} p_{r,i}$$

n is the number of the fraction

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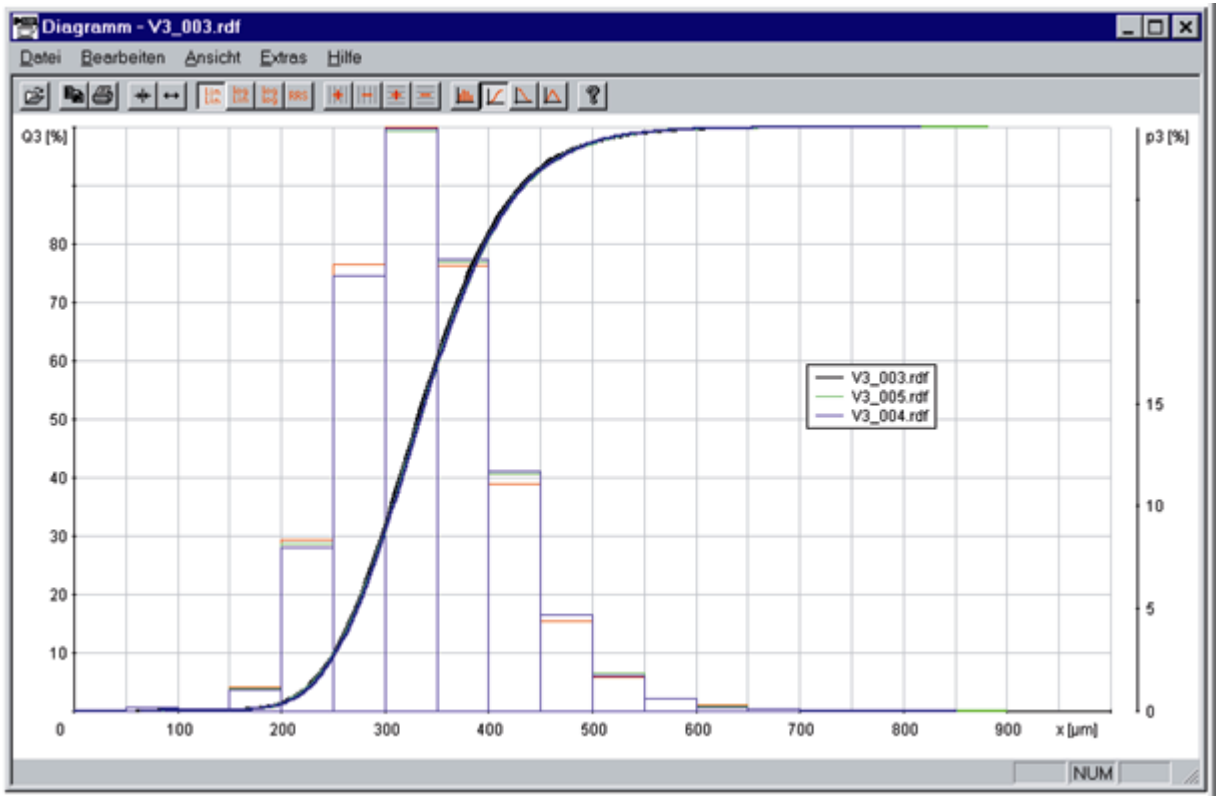
Reproducibility



Calibration with traceable standard

=> Absolute accuracy

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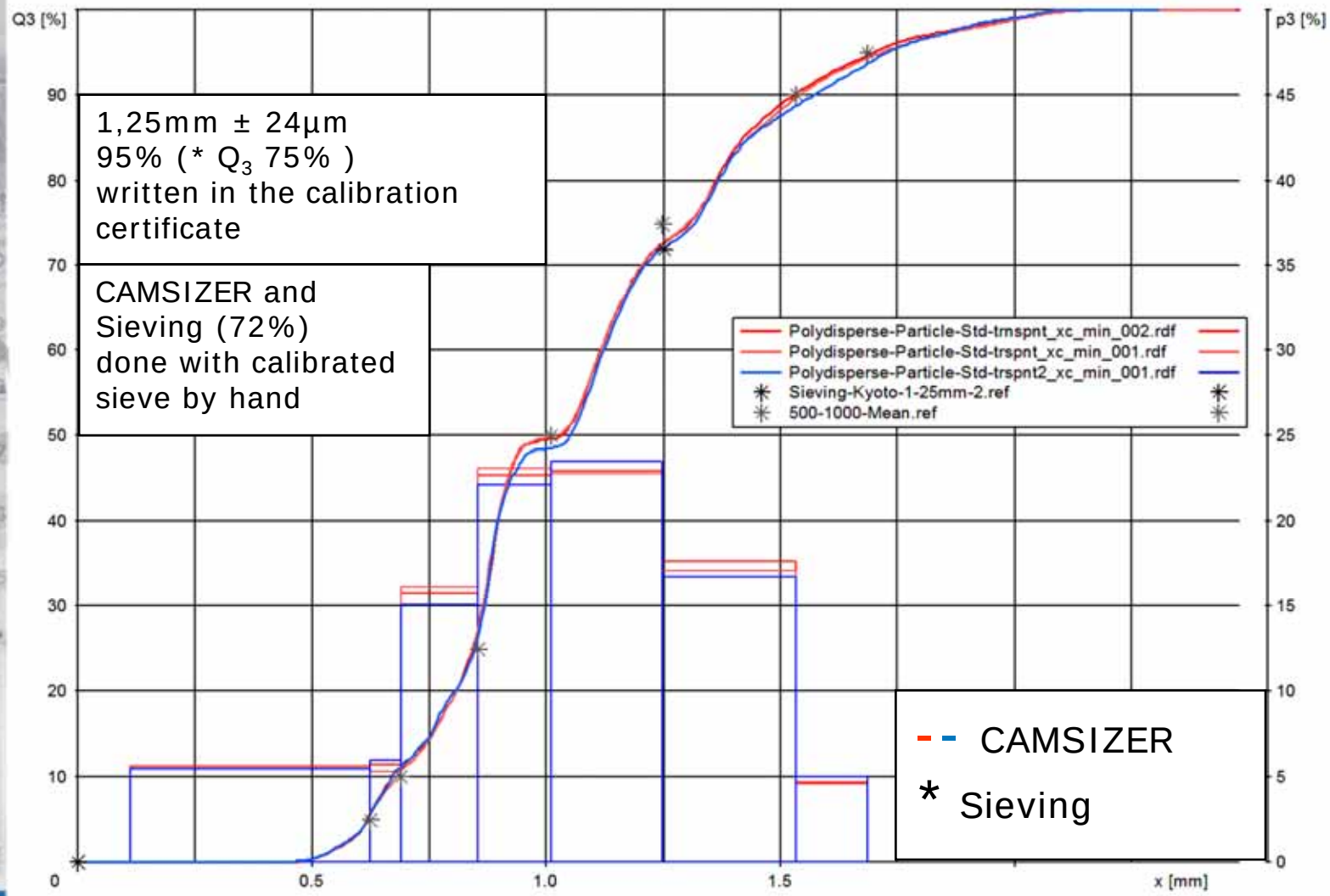
Glass Bead-Standard 500µm – 2000µm



1,25mm ± 24µm
95% (* Q_3 75%)
written in the calibration certificate

CAMSIZER and Sieving (72%) done with calibrated sieve by hand

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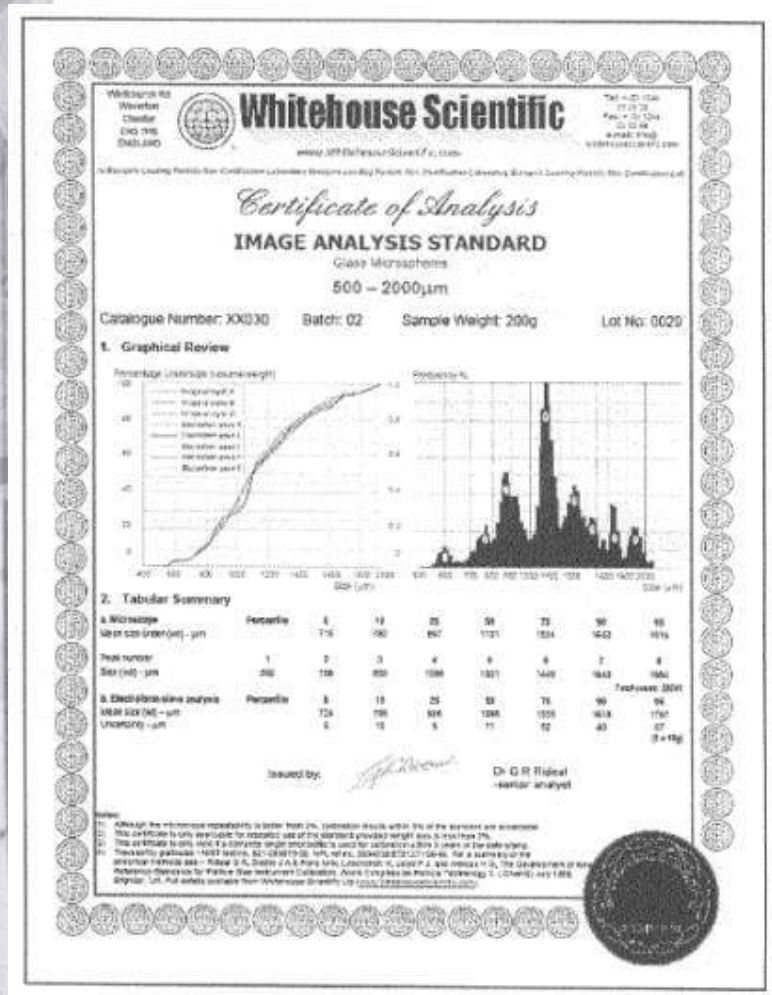
Whitehouse Standard XX030



Whitehouse Scientific

Certificate of Analysis

IMAGE ANALYSIS STANDARD

Glass Microspheres

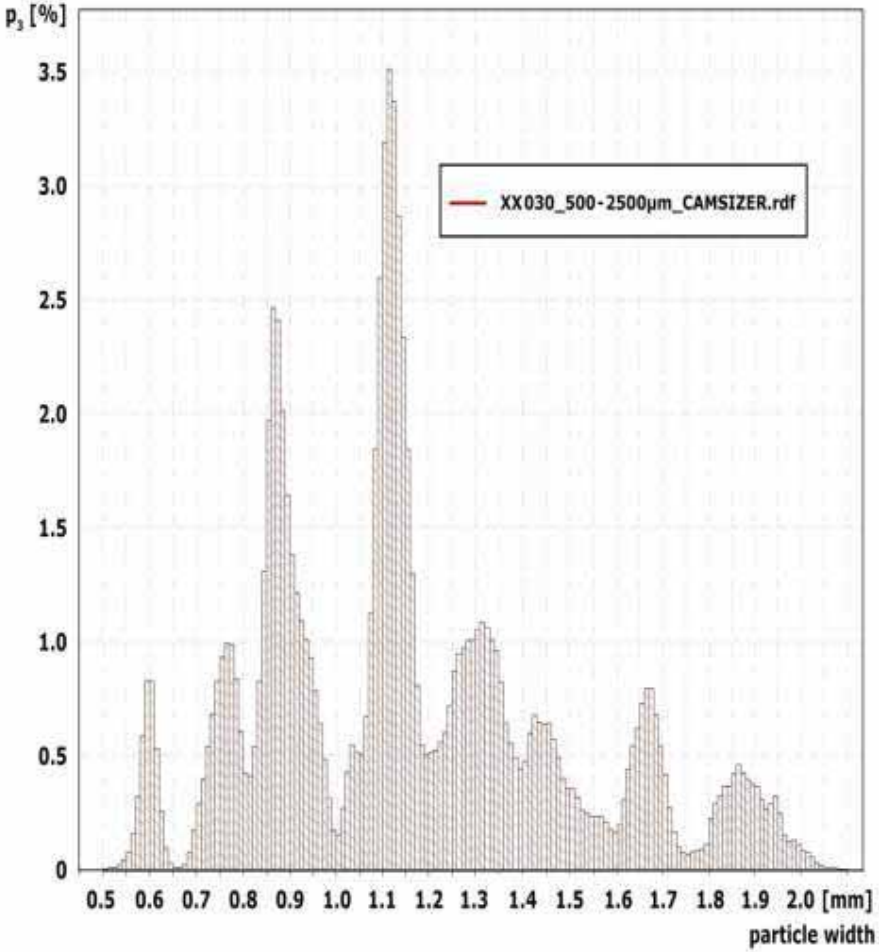
500 – 2000µm

Catalogue Number: XX030 Batch: 02 Sample Weight: 200g Lot No: 0020

1. Graphical Review

2. Tabular Summary

Issued by: Dr G R Tidbal



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