Mixing and Agglomeration in Eirich Mixers

22. – 23. November, 2016
PFI - Building
Gl∅shaugen, Trondheim

Welcome!

Marcus Müller

EIRICH

The Pioneer in
Material Processing

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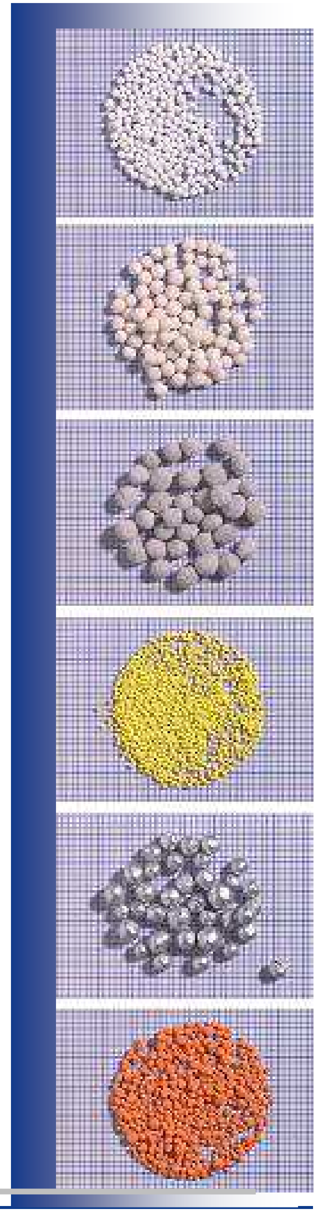
AGENDA:

1. **Solid mixing**
   1. **Theory of solid mixing**
   2. **Homogeneity**
2. **Build-up agglomeration**
   1. **Particle size distribution**
   2. **Moisture**



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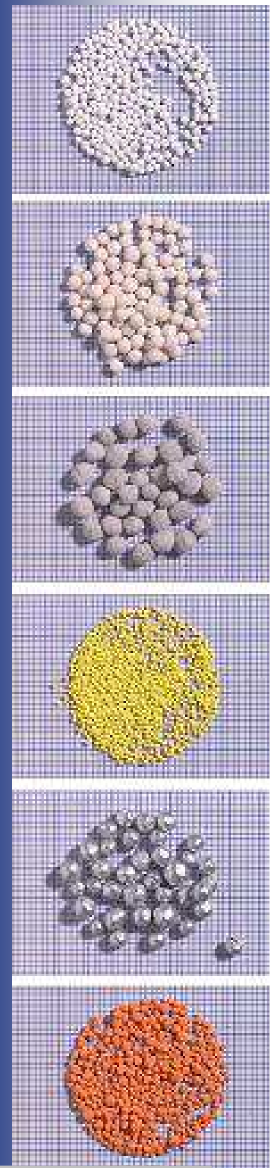

Mixing:

1. Process of thoroughly combining different materials to produce a homogenous mix
2. Mixing is a critical process
3. Quality of the final product attributes depend on the mixing performance

Poor Mixing:

1. Non homogenous product lacking consistency in chemical composition, colour, flavour, reactivity
2. Failed batches
3. Loss of high value product
4. Cost of poor mxing estimated as US $ 100 million per year!

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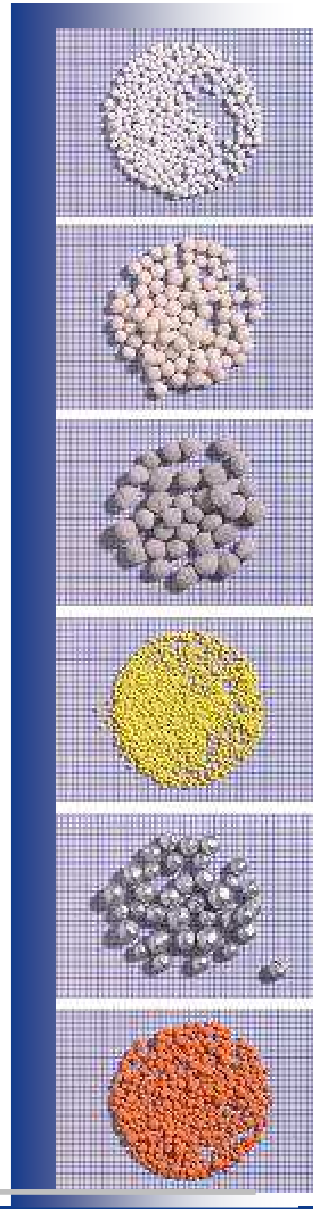
Reasons for Poor Mixing:

1. **Lack of understanding of material characteristics**
2. **Inadequate, inaccurate definition of mixing objectives**
3. **Incorrect selection of mixer**
4. **Wrong scale - up techniques**
5. **Limited knowledge on mixing equipment design, parameters**



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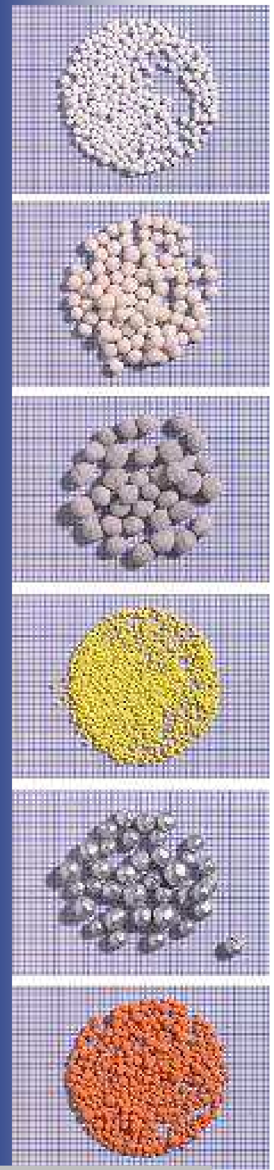
Mechanisms of Solid Blending

1. Diffusion Blending
2. Convection Blending
3. Shear Blending

These three mechanisms occur to varying extents depending on the type of mixers, blenders and the characteristics of the solids to be blended!



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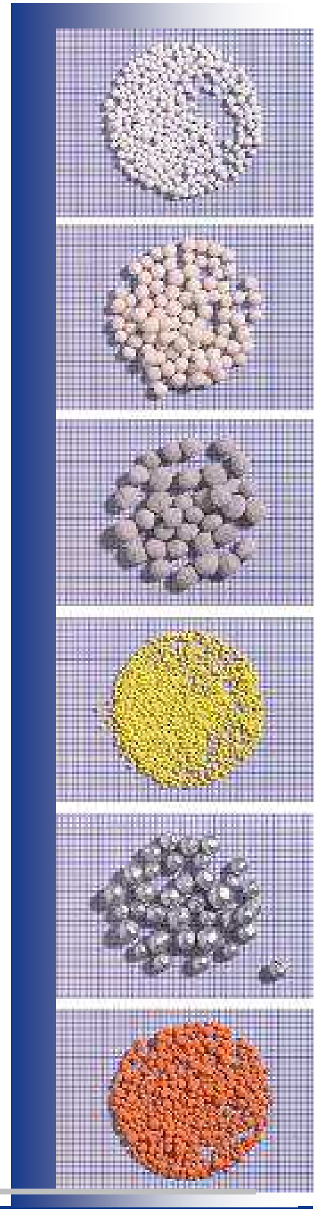
Mechanisms of Solid Blending

Diffusion Blending

- **Diffusion blending is characterized by small scale random motion of solid particles**
- **Blender movements increase the mobility of the individual particles and promote diffusive blending**
- ***Diffusion blending occurs where the particles are distributed* over a freshly developed interface**
- **In the absence of segregation effects, the diffusive blending will in time lead to a high degree of homogeneity**
- **Tumbler blenders like the double cone blenders, v-blenders function by diffusion mixing**



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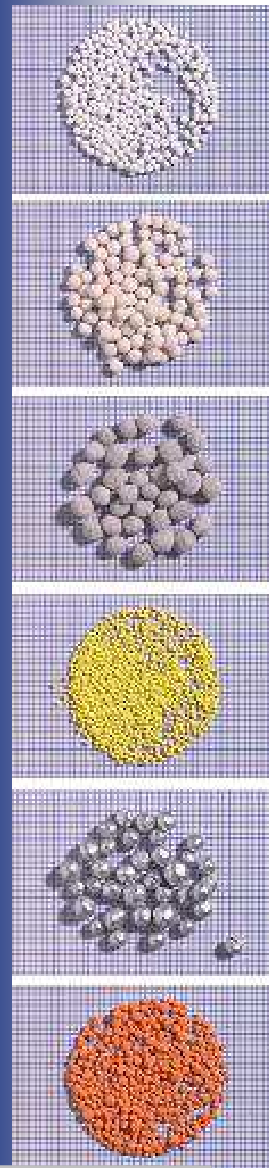
Mechanisms of Solid Blending

Convection Blending

- Convection blending is characterized by large scale random motion of solid particles
- In convection blending, groups of particles are rapidly moved from one position to another due to the action of a mixing agitator or cascading of material within a tumbler blender
- The blending of solids in ribbon blenders, paddle blenders, plow mixers is mainly a resuld of convection mixing



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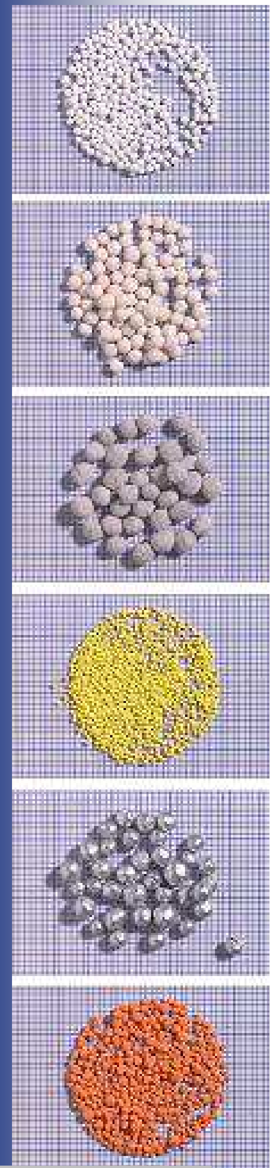
Mechanisms of Solid Blending

Shear Blending

1. Shear blending is the high intensity impact or splitting of the bed of material to disintegrate agglomerates or overcome cohesion

2. Shear blending is very effective at producing small-scale uniformity generally on a localized basis

3. Blenders with a high speed chopper blades, intensifiers are an example of shear blending.



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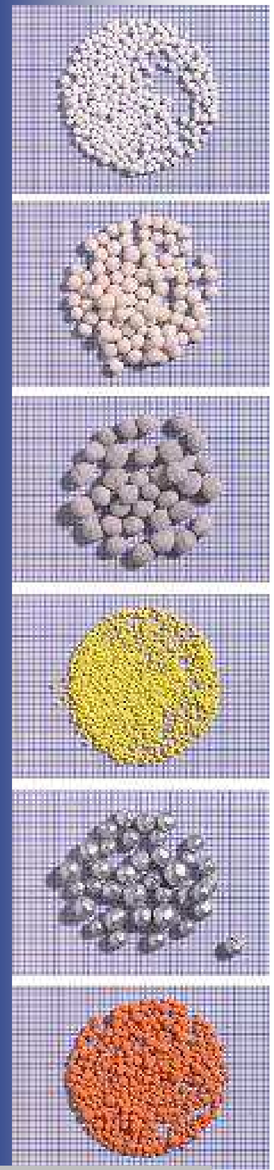
Theory of Mixing

1. Moving of particles which are different in one or more properties or characteristics (particle size, particle shape, moisture, chemistry, density, reactivity....)
2. Moving of particles in one closed process room
3. The aim is to achieve a homogeneous distribution of the particles in the process room
4. Different parts of the material must move with different velocities
5. The whole content must move with different velocities



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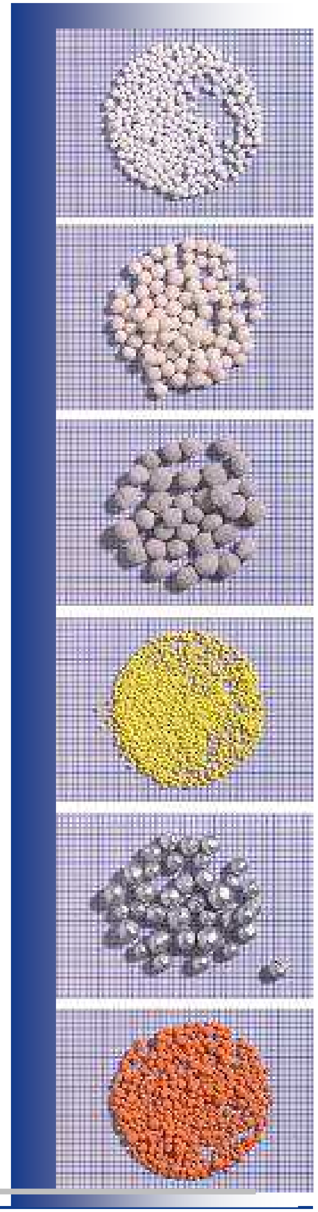
Theory of Mixing

- Simultaneous macro and micro mixing
- Macro mixing = exchange of bigger parts of the material between the streaming lines
- Micro mixing = change of neighbouring particles

Impulse forces destroy adhesive strength in order to segregate the material



Mixing Technology

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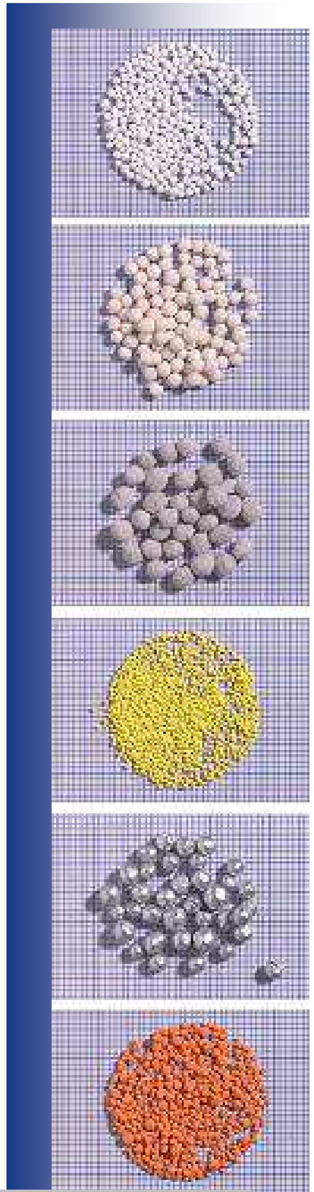
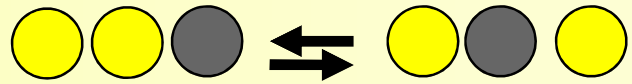
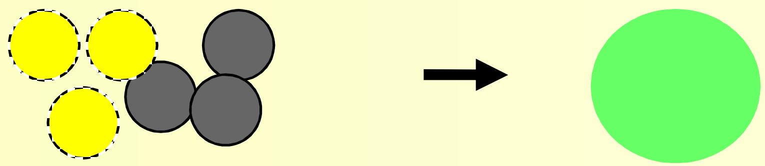


- **Distributive Mixing**
  no input of shearing energy



- **Dispersive Mixing**
  high input of shearing energy



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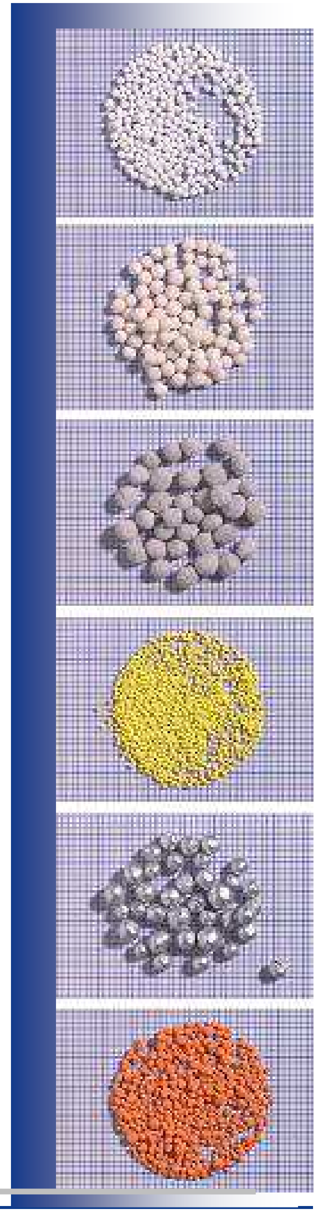

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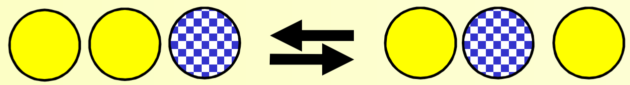
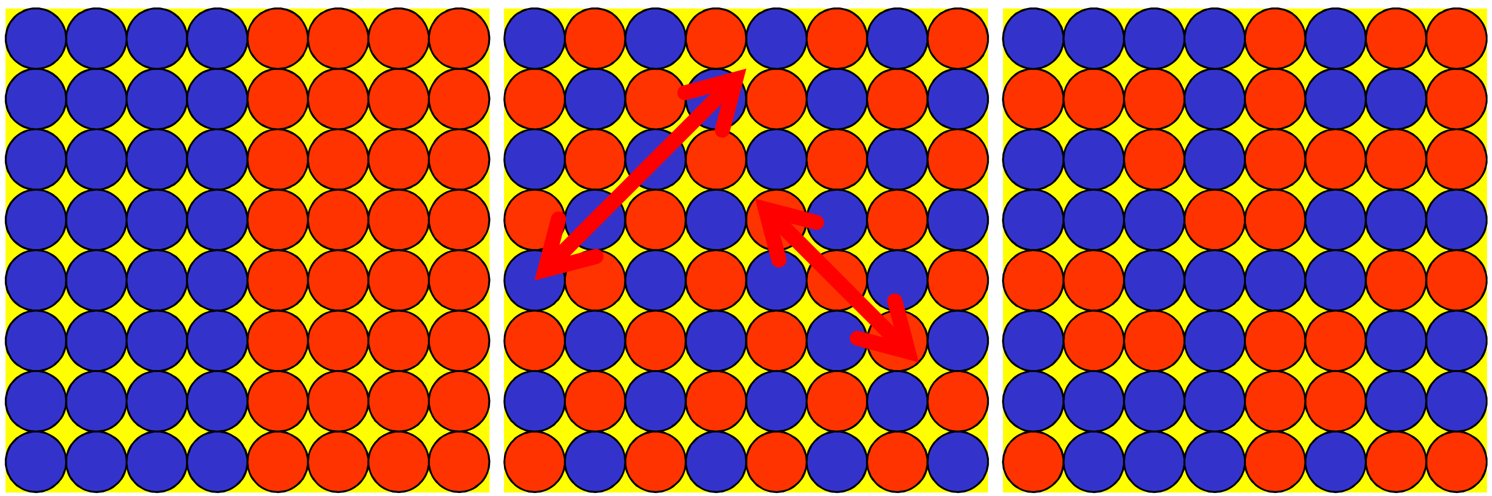


Totally demixed

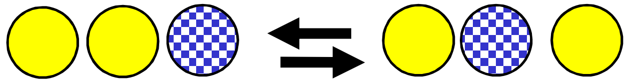
Ideally homogenized mix

Stochastically homogenized mix



Mixing Technology

- **Distributive Mixing**



no input of shearing energy

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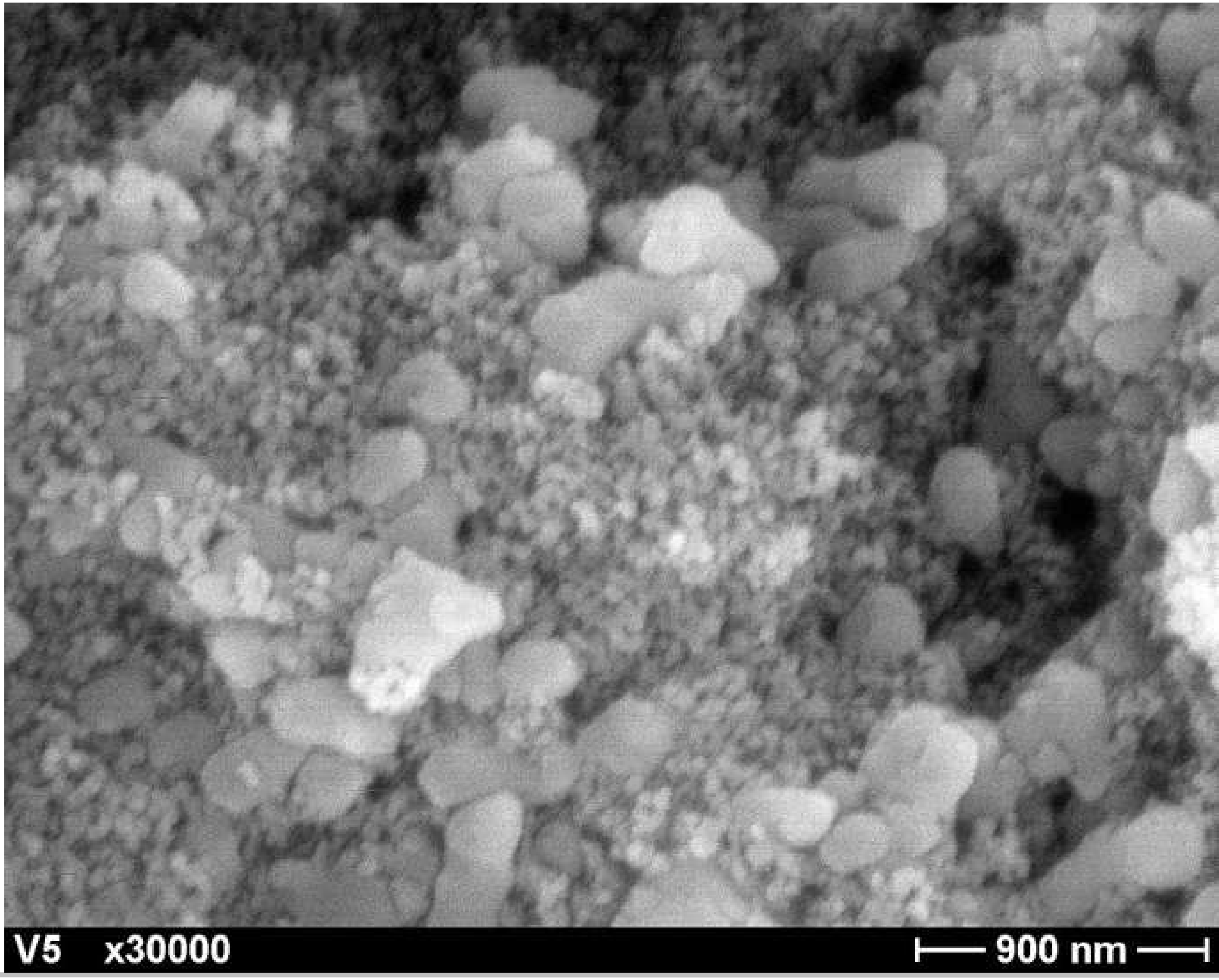

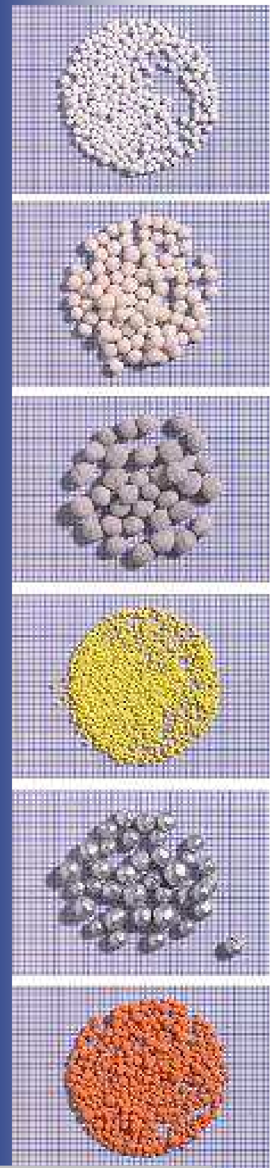

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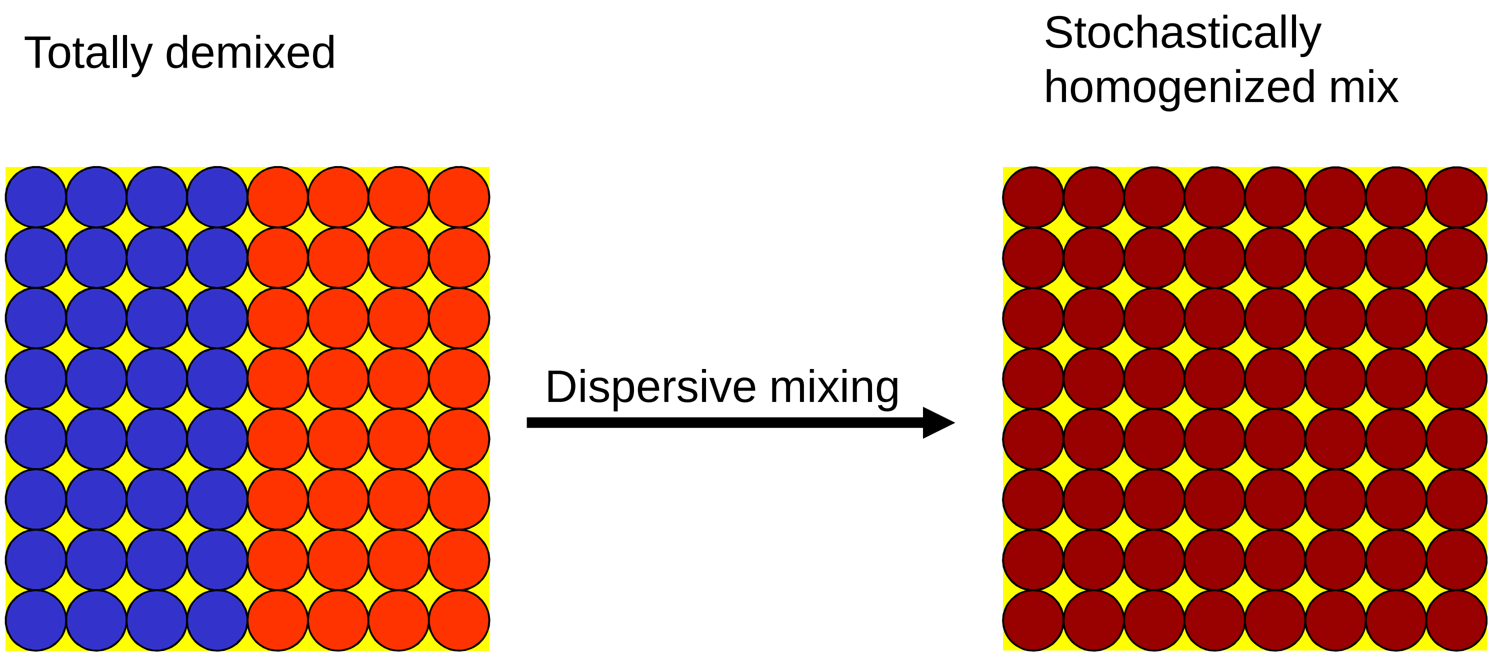
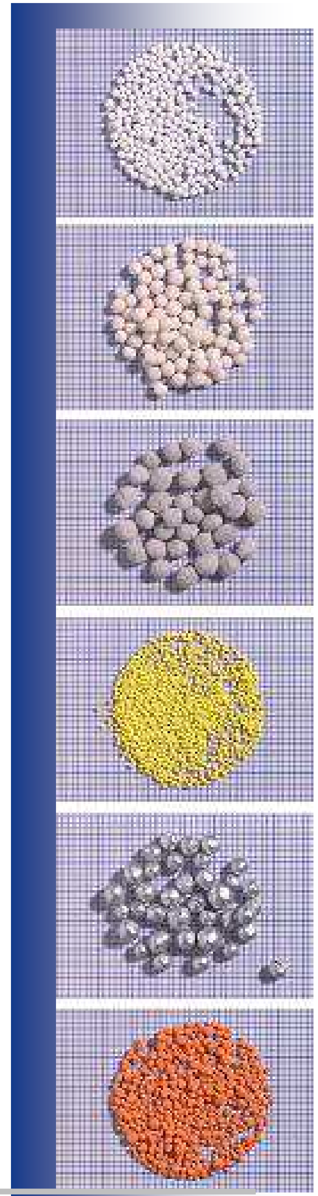
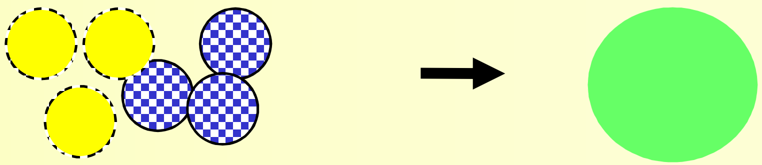




- **Dispersive Mixing**

  high input of shearing energy



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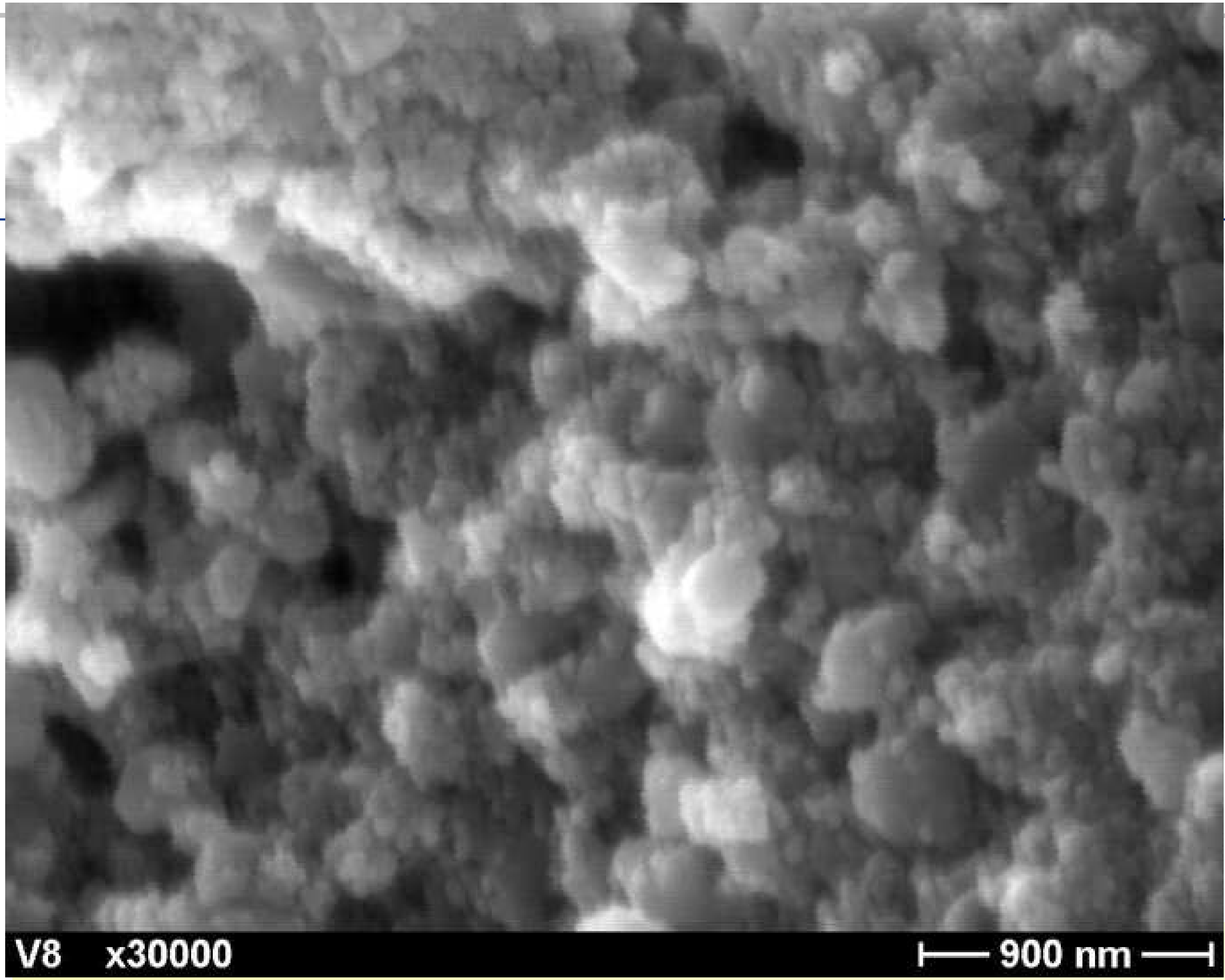
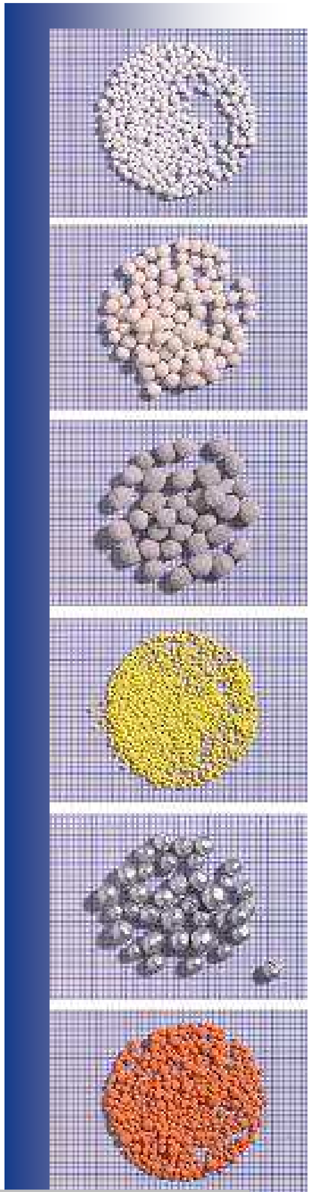
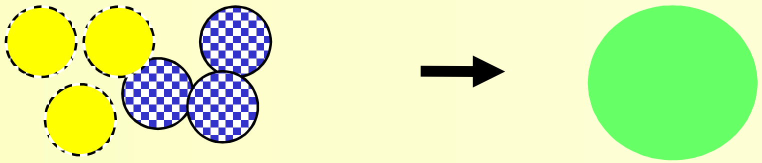




- **Dispersive Mixing**

high input of shearing energy



Eirich Intensive Mixer: R-Type

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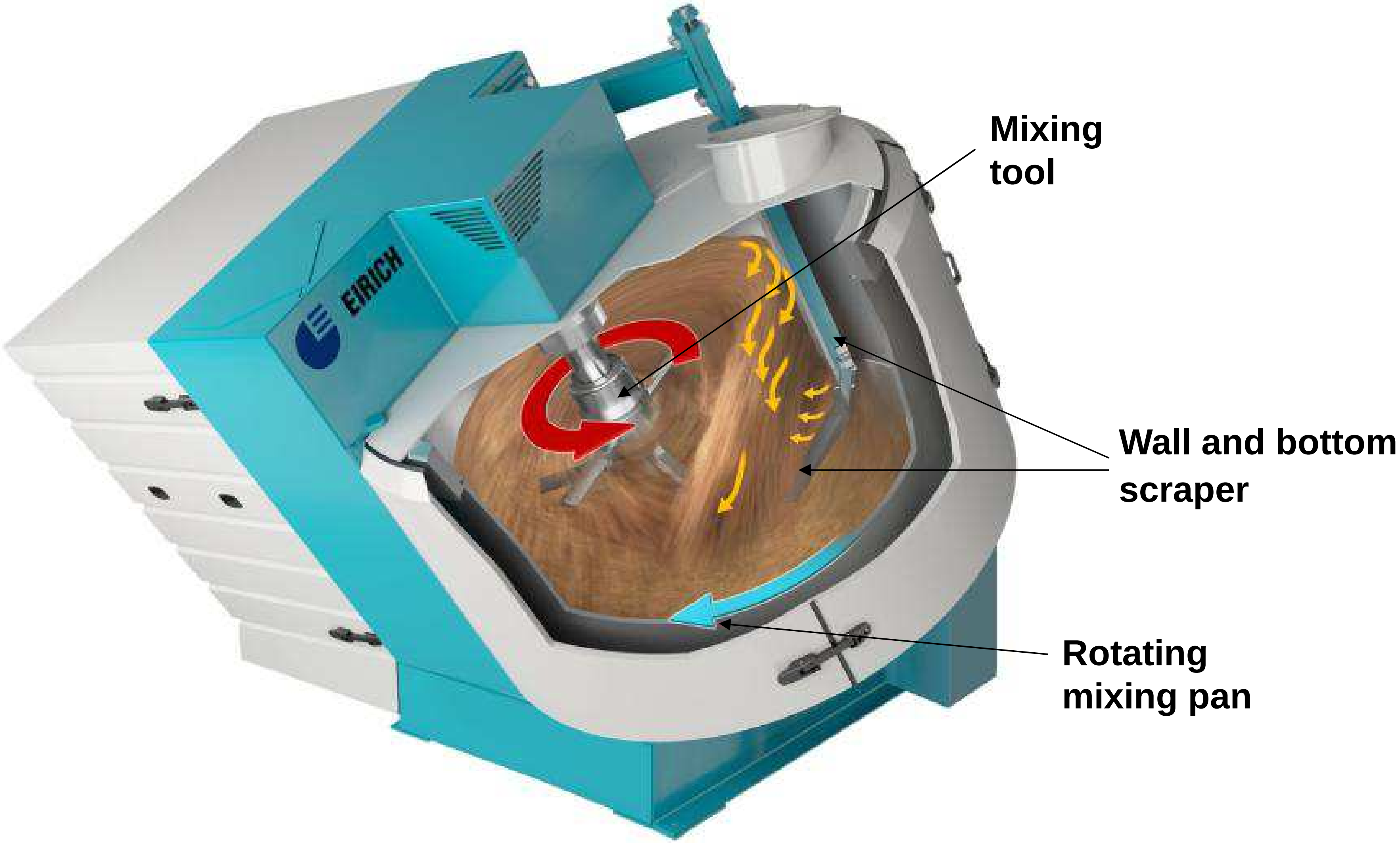

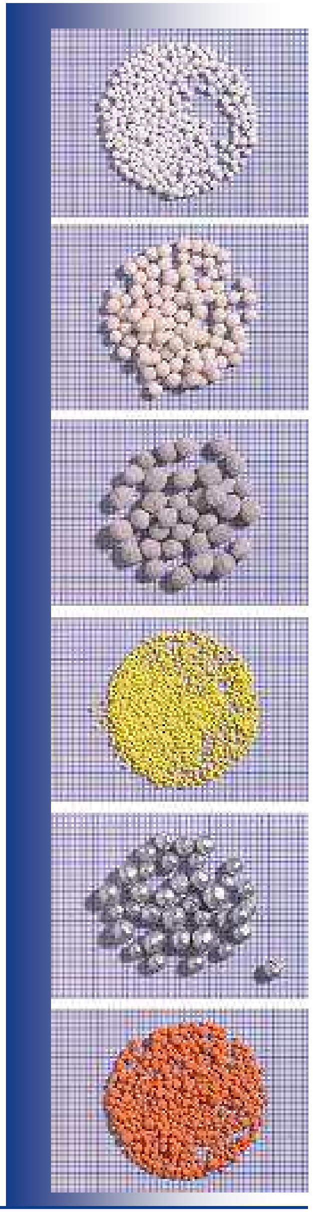

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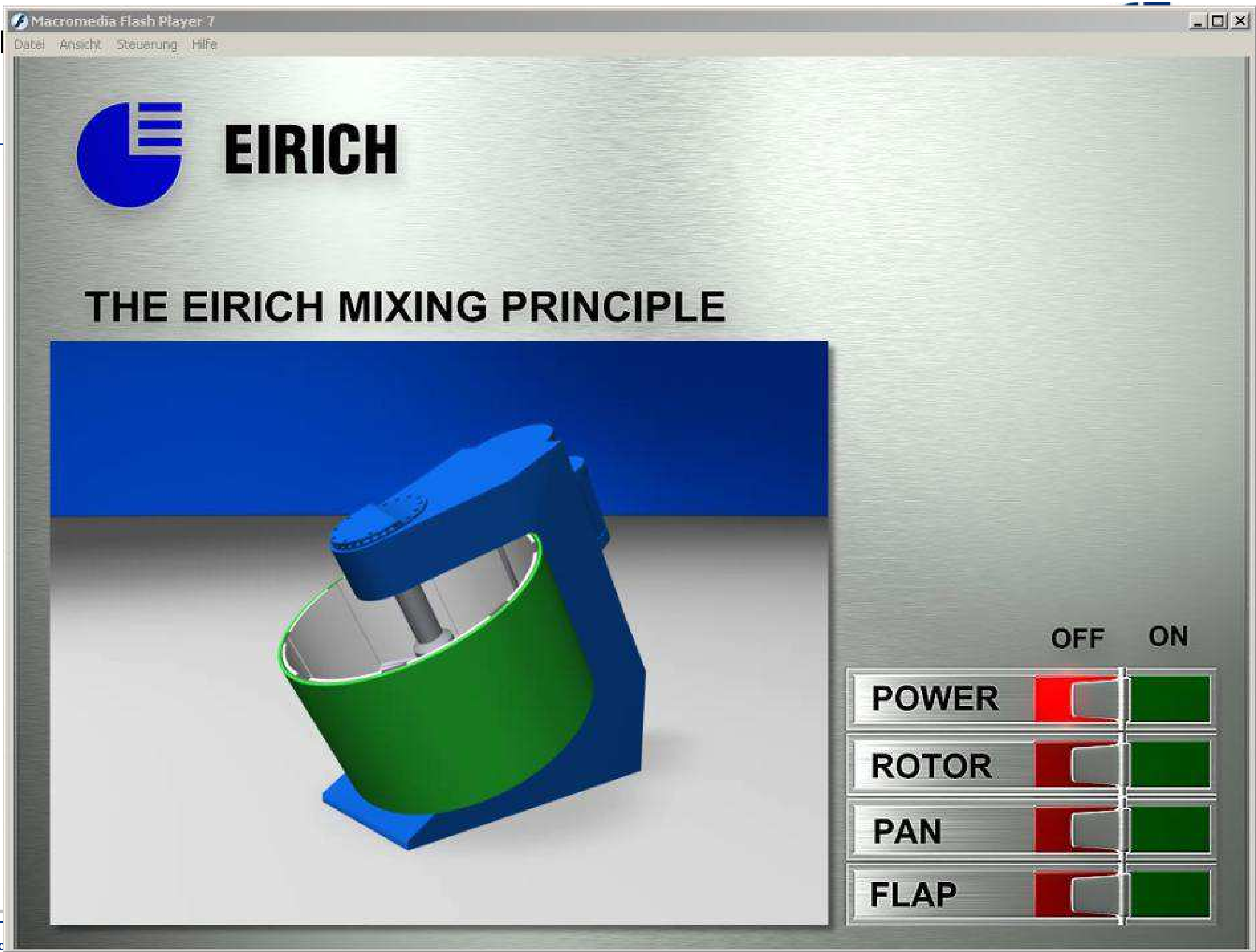

Homgeneity - mixing time

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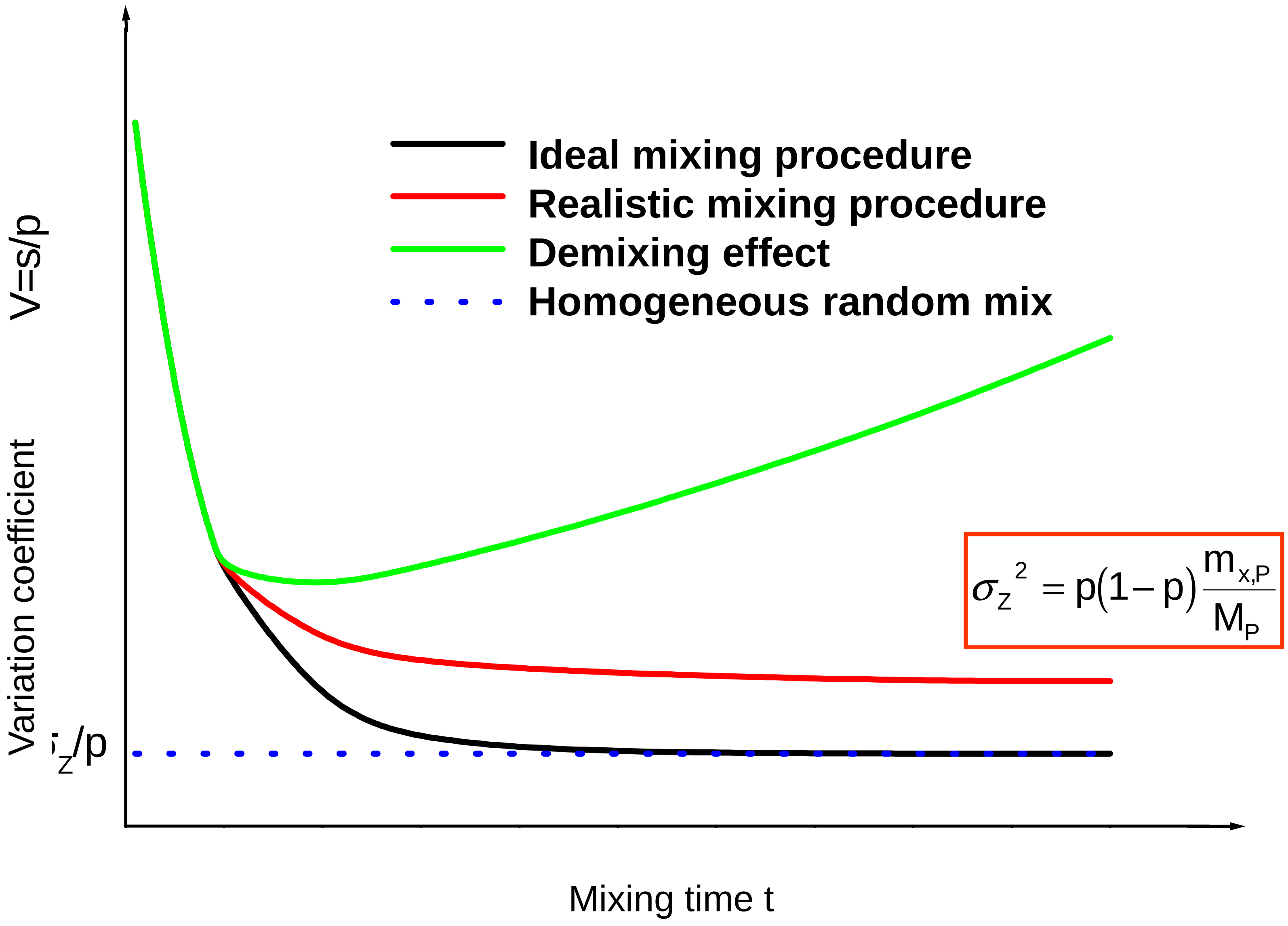
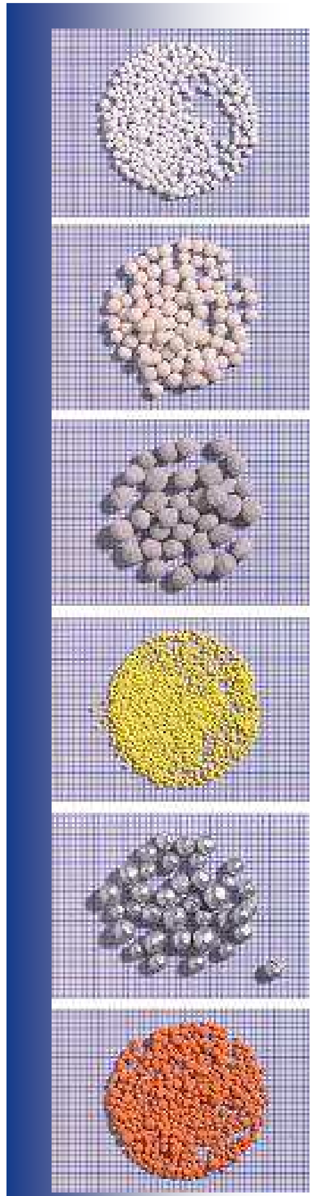


$$\sigma_Z{}^2 = p(1-p)\frac{m_{x,P}}{M_P}$$



Variations because of vol.-spec. energy densities

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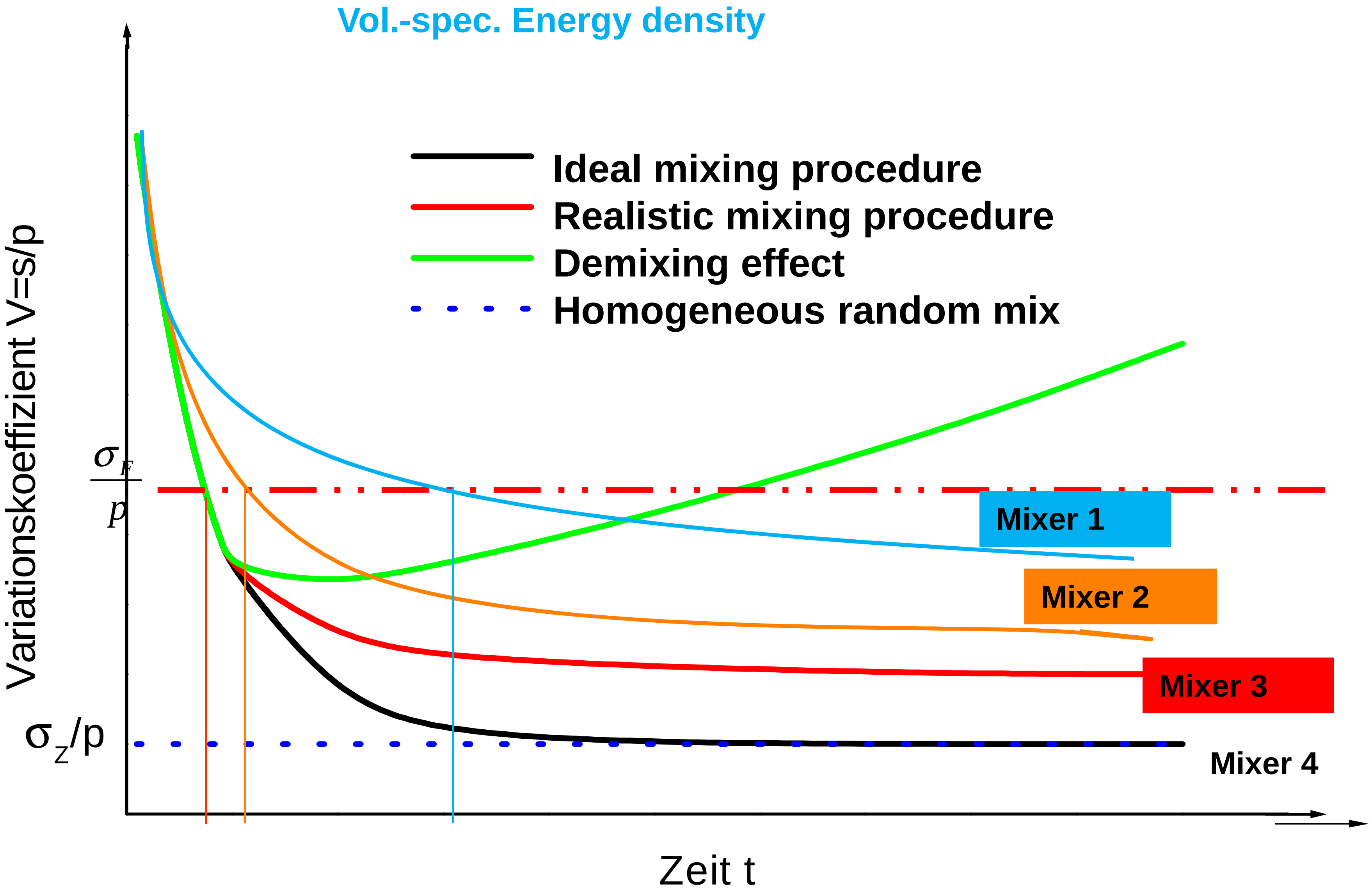

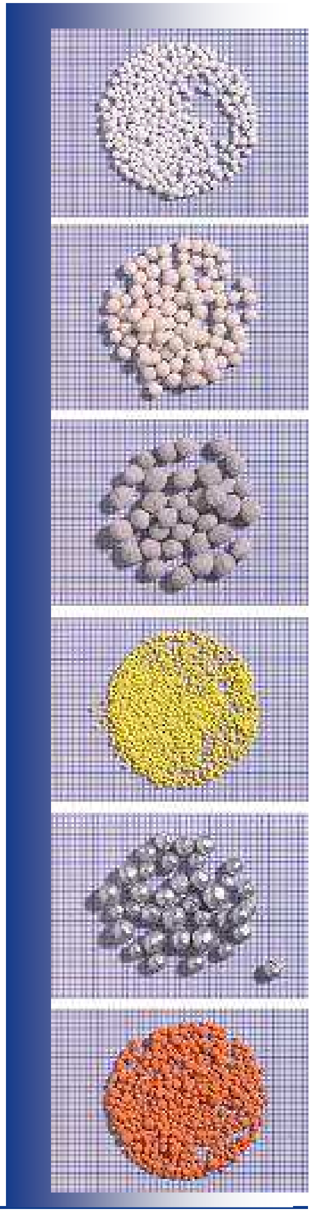

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Homgeneity - mixing time

Mixing time

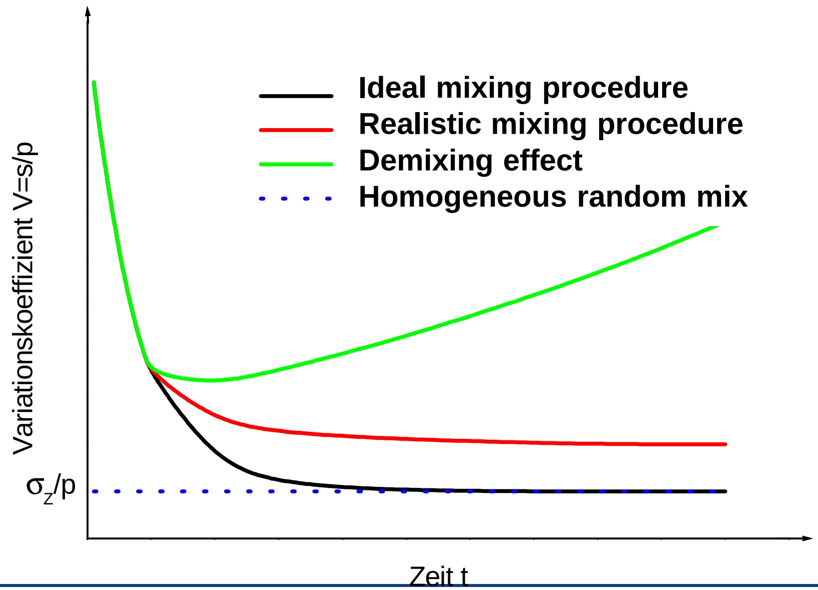
pregiven mixing time t_M

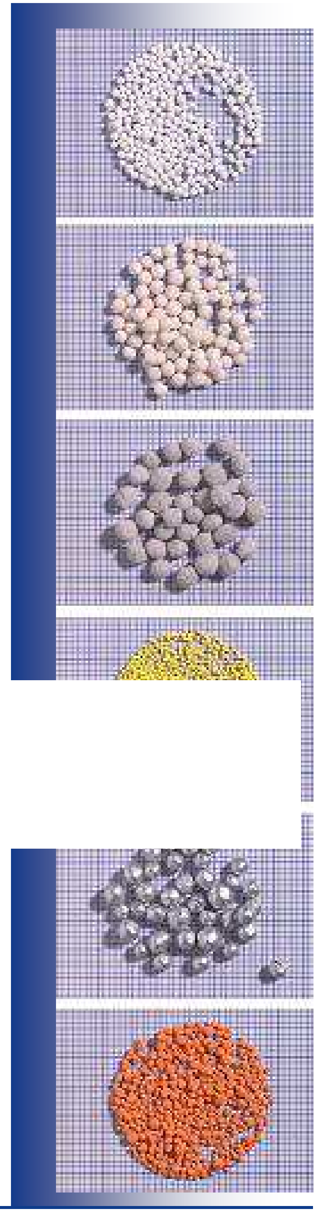
Normally t_M= 0,5 - 5 minutes, special tasks longer: swelling, de-gasing, reacting; total batchtime mostly much more longer: $t_{Ges} = t_{Füll} + t_{Misch} + t_{Ent} + t_{Rein}$

Mixing time and Mix quality

- **Mixing time and mixing quality are directly connected (bad quality → short mixing time).**
- **Different quality-parameters (sample sizes) might cause different mixing times (Macromixing, Desagglomerating).**
- **quality-development is a function of time.**

$$\sigma_Z{}^2 = p(1-p)\frac{m_{x,P}}{M_P}$$





Improvement of the homogeneity

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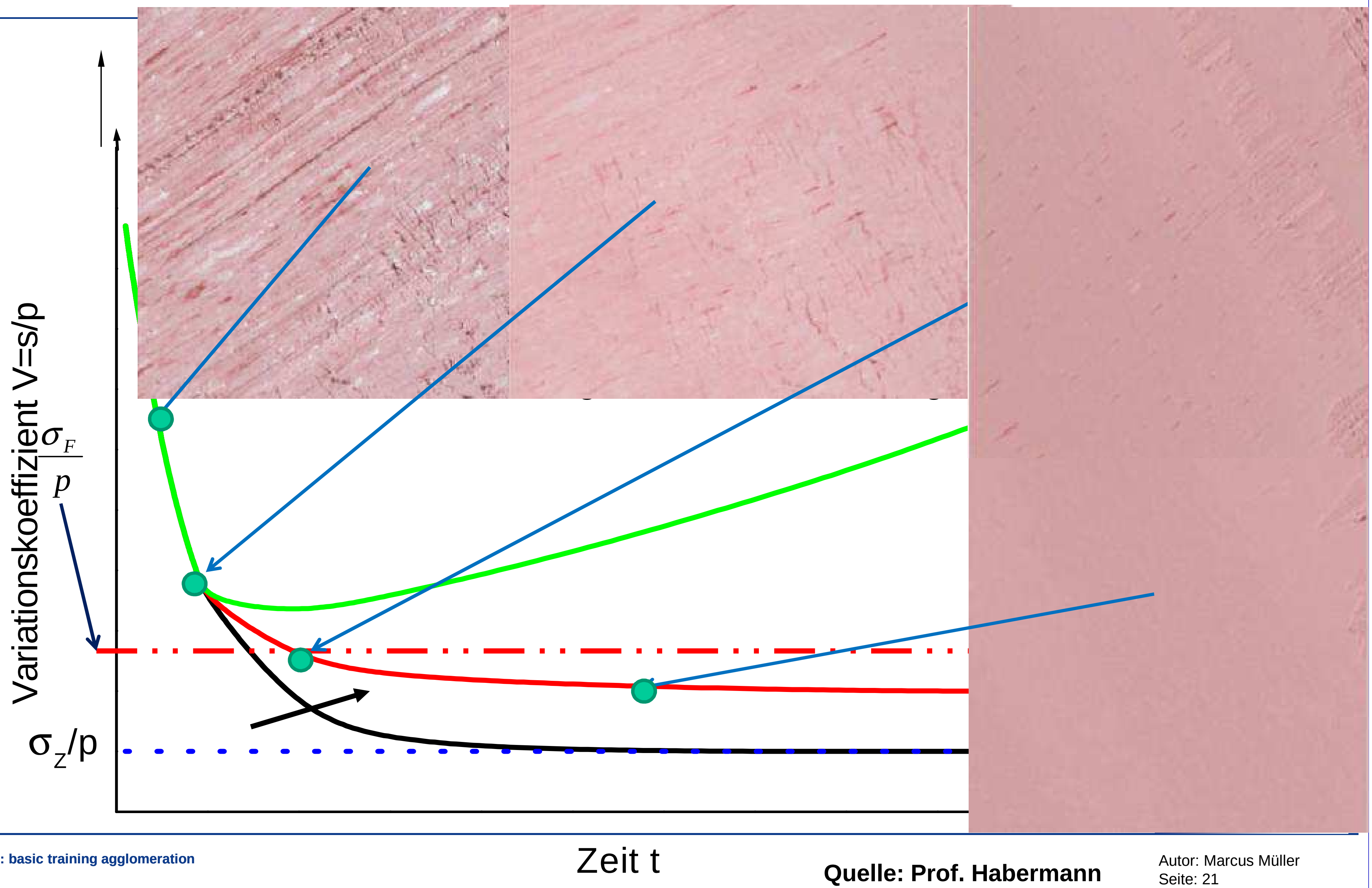

Quelle: Prof. Habermann

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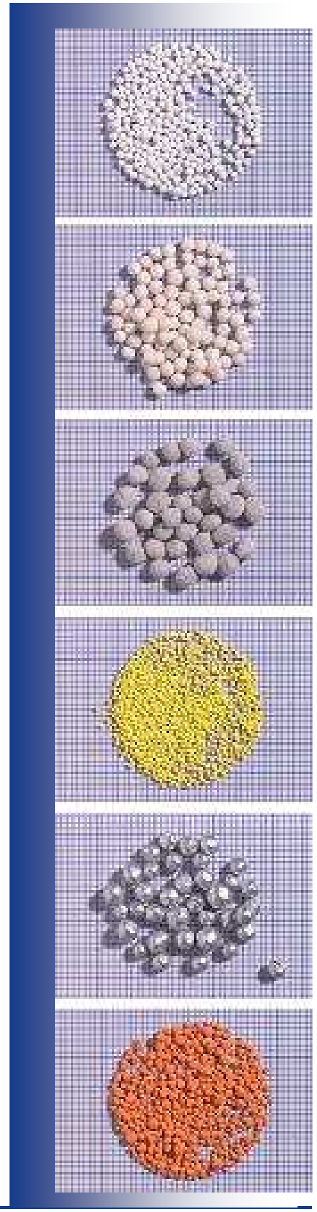
Build-up agglomeration



Granulating process

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Ceram. raw materials
Sinter additives

Binder
Softener
Pressing agent

Dispersing liquid
Dispersing agent

Granulating process

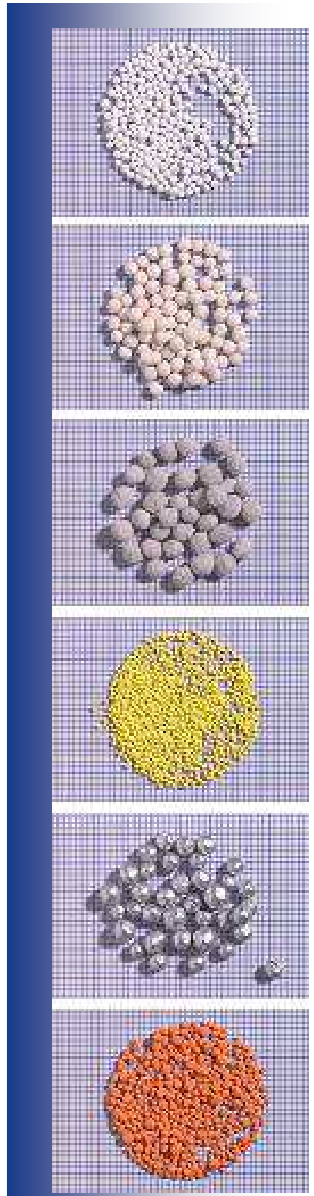
Mechanical granulation
Powder mix

Fluid bed agglomeration
Build-up agglomeration
(rolling method, disk granulator, intensive mixer)
Press agglomeration
EVACHTERM®

Thermal granulation
Suspension

Fluid bed agglomeration
(fluid bed, tumbling bed, spouted bed)
Fluid-bed coating
Spray-freeze granulation
EVACHTERM®

Dr. Nebelung, IKTS Dresden



Process technology: Build-up agglomeration

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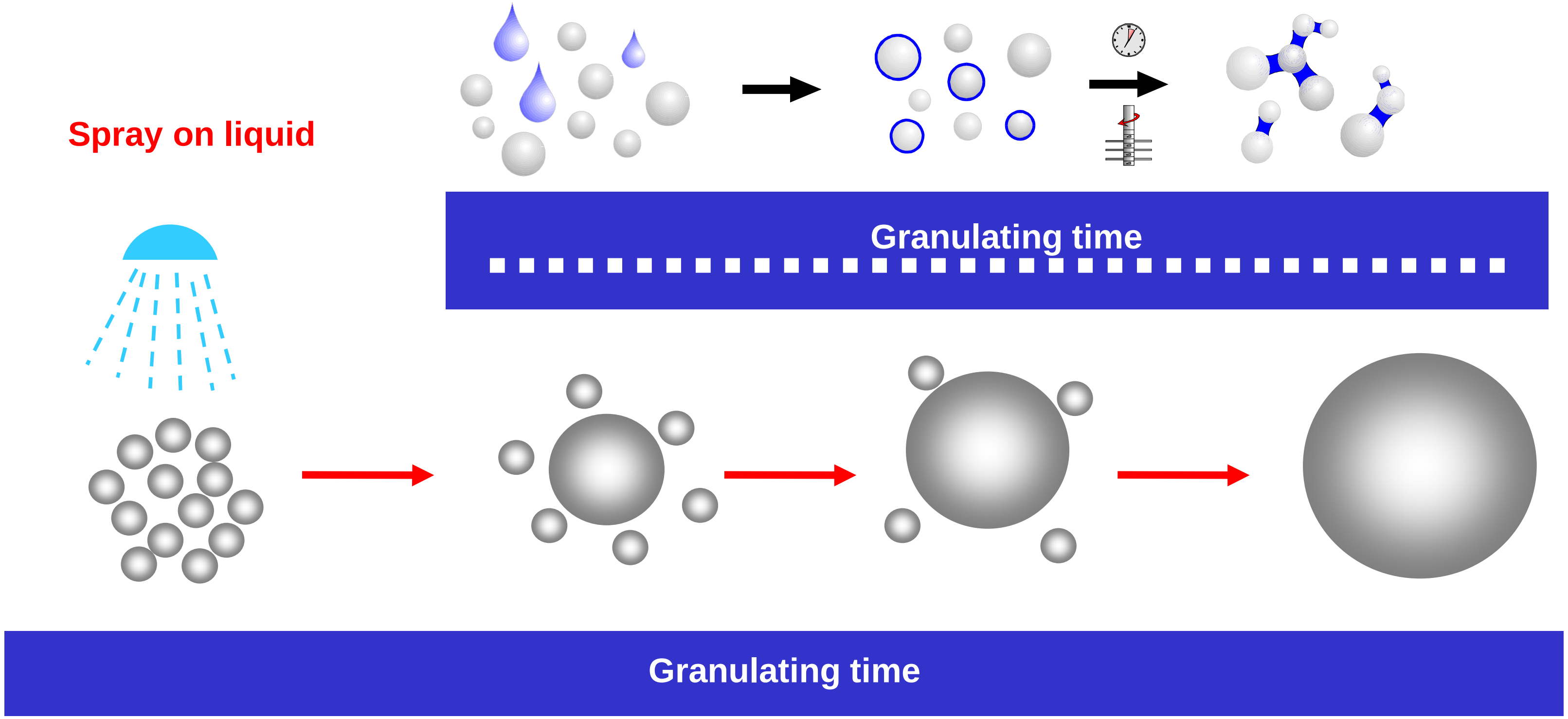

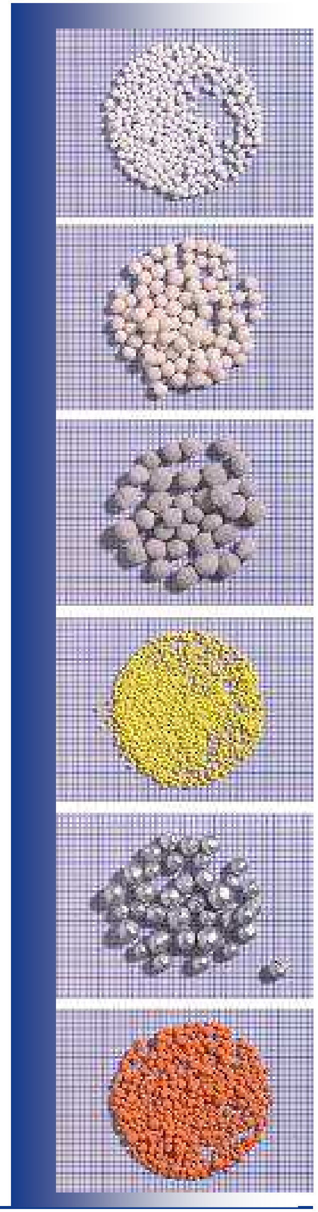

Granulate design: porosity

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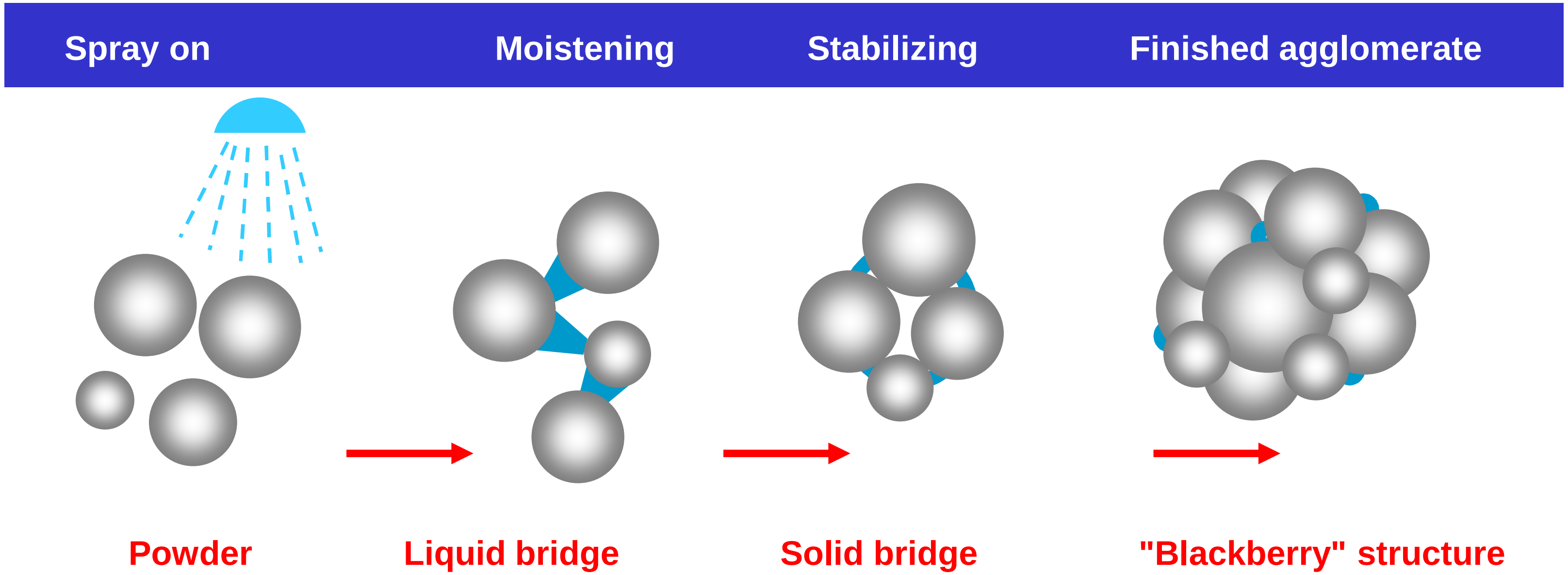
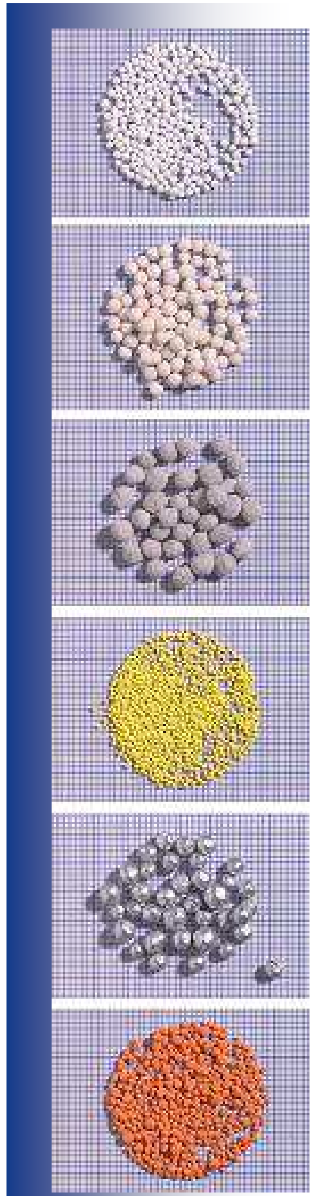
Narrow particle size distributions, monodisperse distributions, are to be agglomerated with binder, especially if a high porosity is requested





Process technology: Build-up agglomeration

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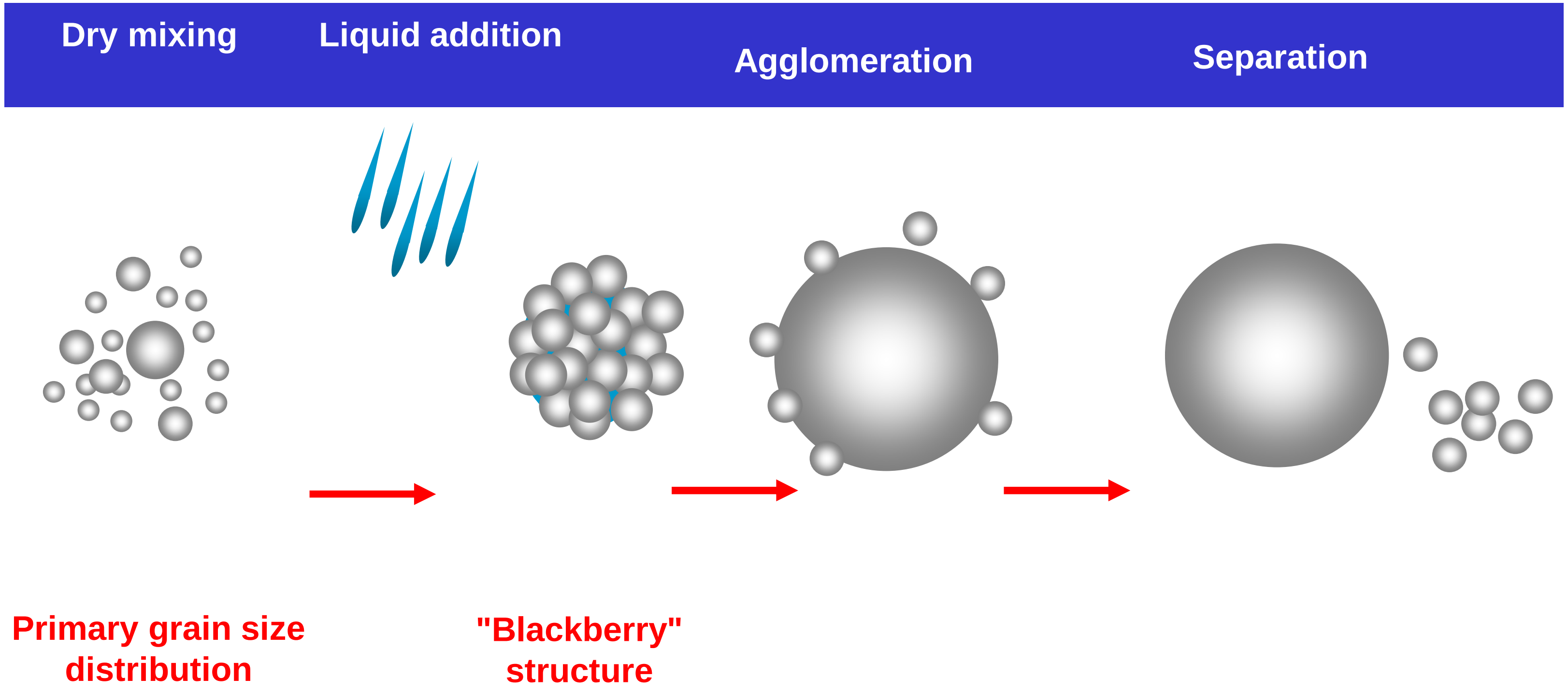
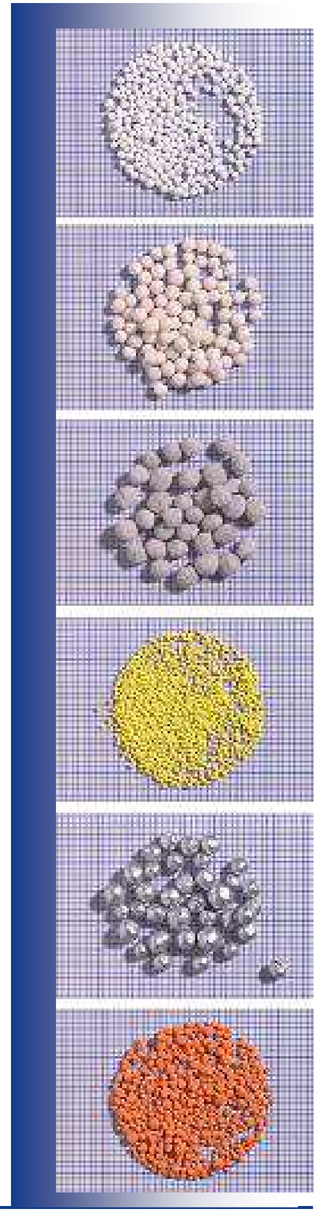
Primary grain size distribution is too coarse !!!

Created micro pellets are moistend in a wrong way





Process technology: Build-up agglomeration

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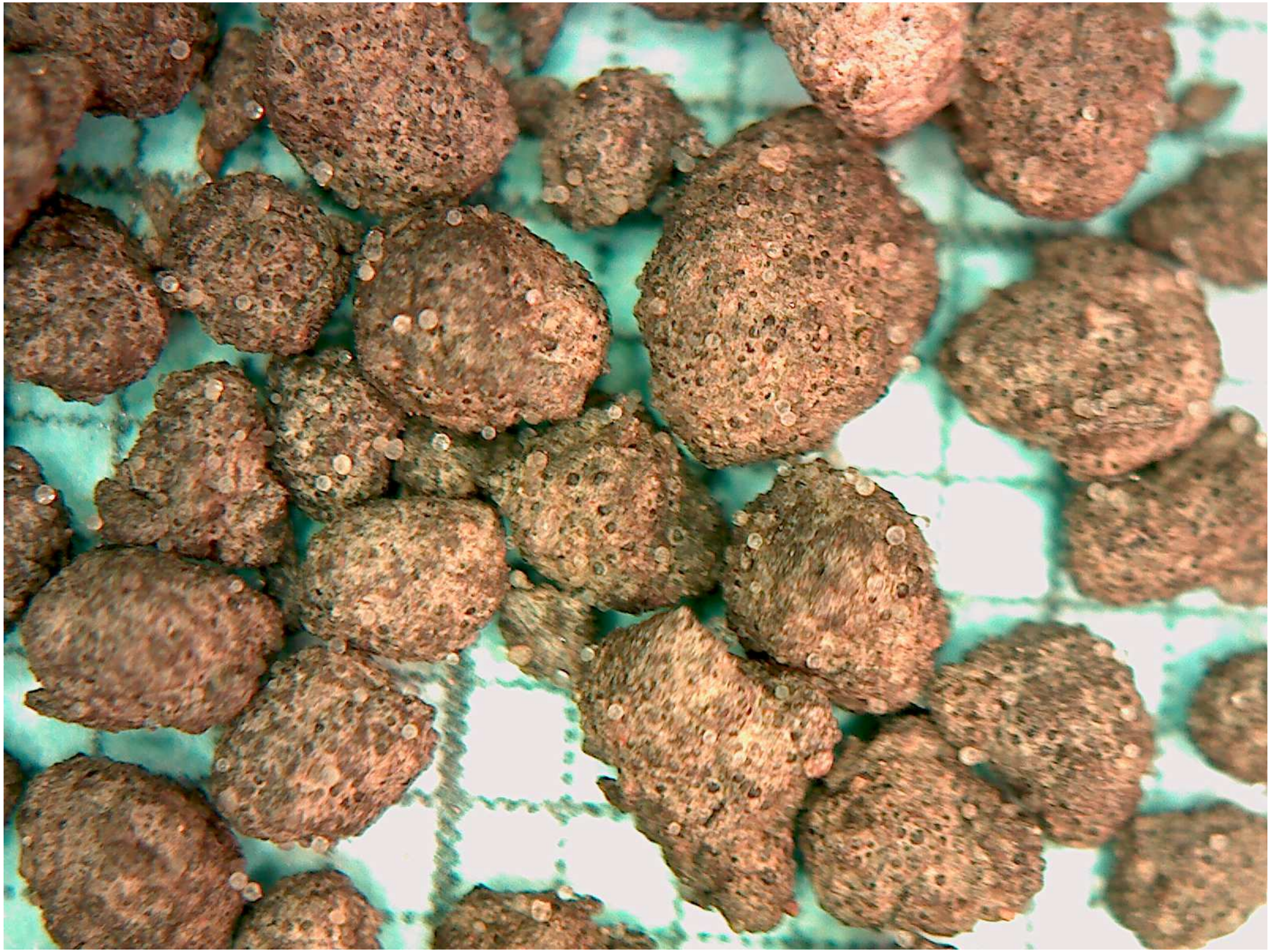

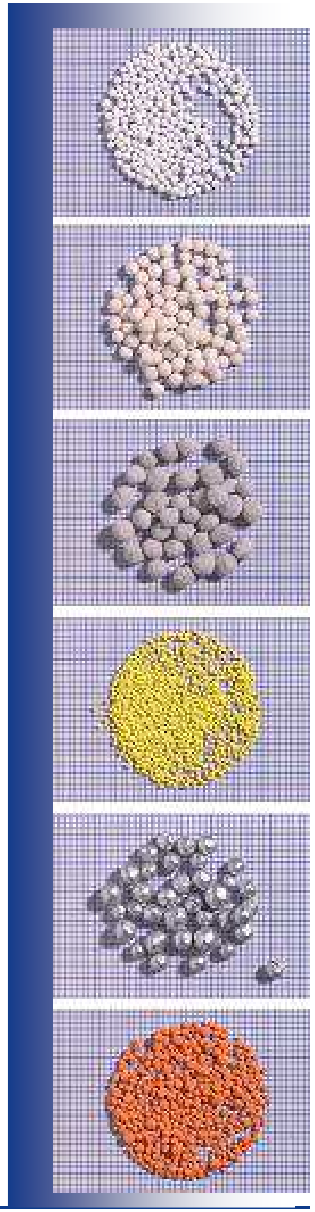

Granulation in the Eirich mixer
Examples

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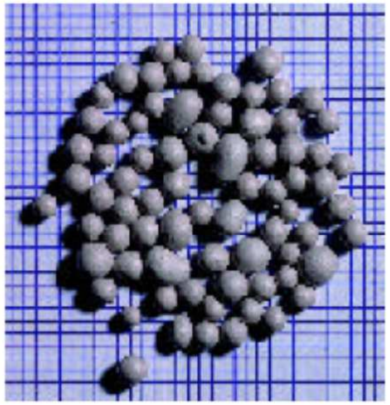
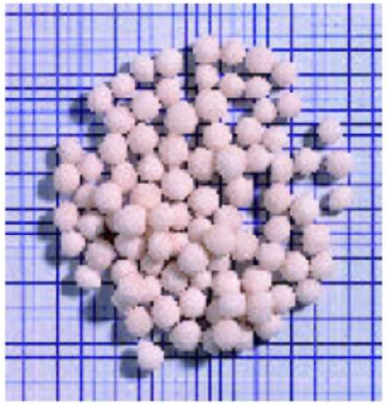
Alumina
Grinding balls

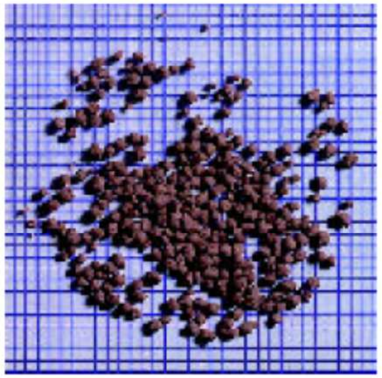


Steatite
Grinding balls

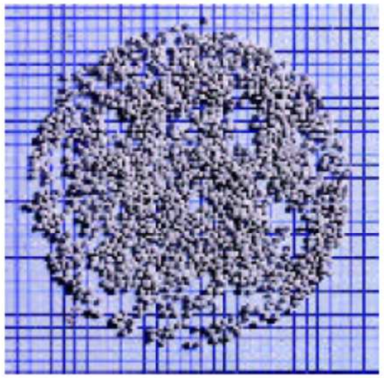


Zeolite
Molecular sieves

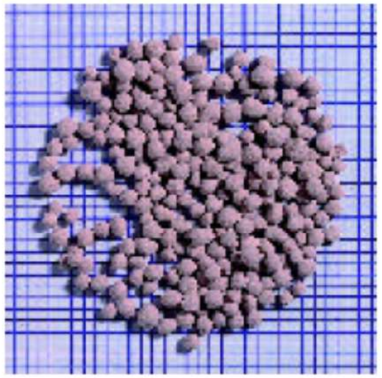
Zeolite
Molecular sieves



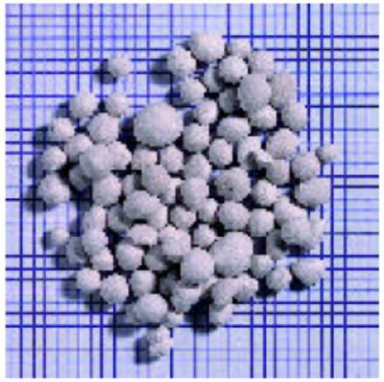
Bauxite
Proppants



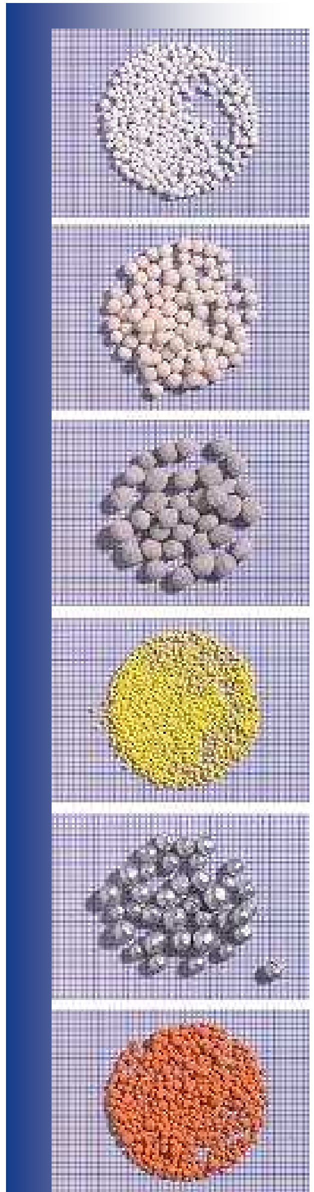
Kaoline
Proppants



Bauxite
Molding compound



Perlite
Lightweight aggregate



Granulation in the Eirich mixer
Examples

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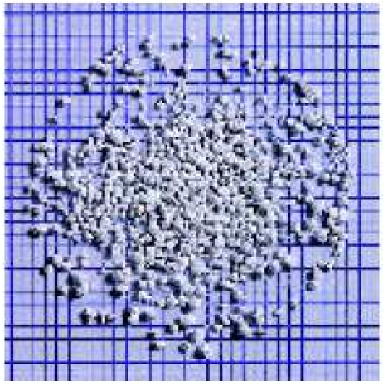
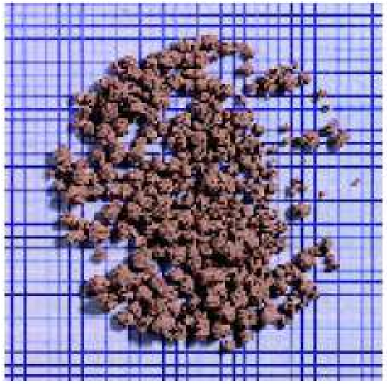
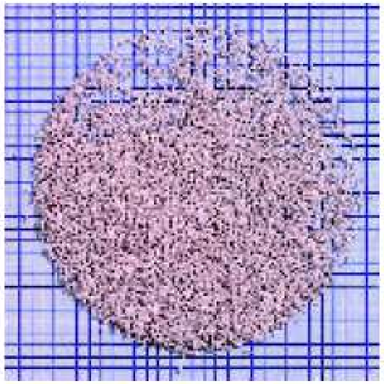


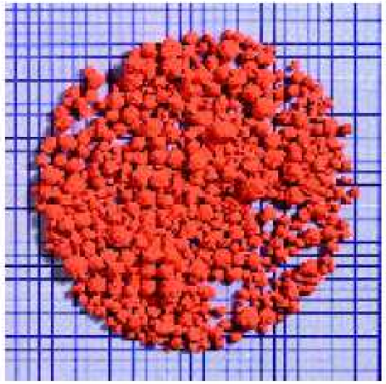
Corundum
Catalyst carrier



Clay powder
Animal food additive

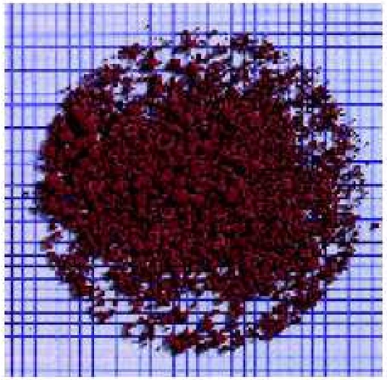


Tile press compound

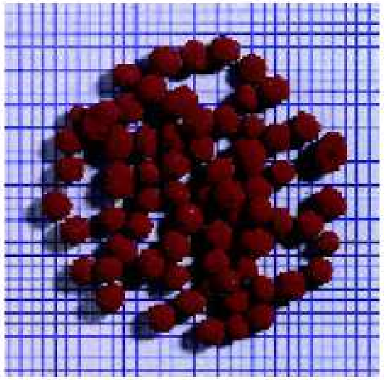


Lead glass batch

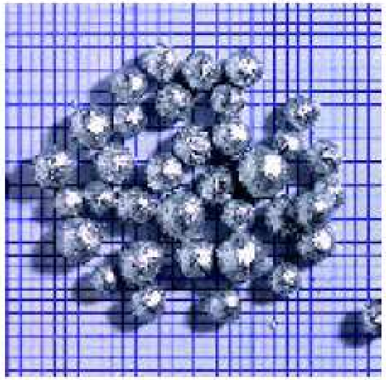
Glass powder, carbon
Foam glass



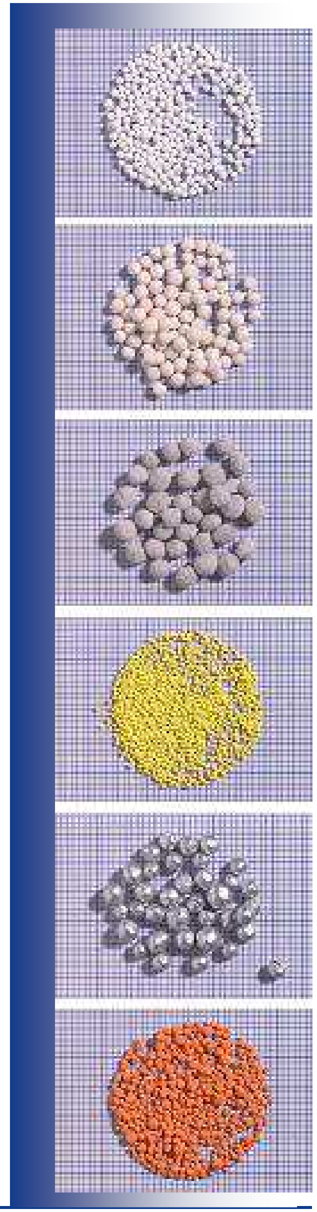
Ferrite



Ferrite



Aluminum



Granulation in the Eirich mixer

Examples

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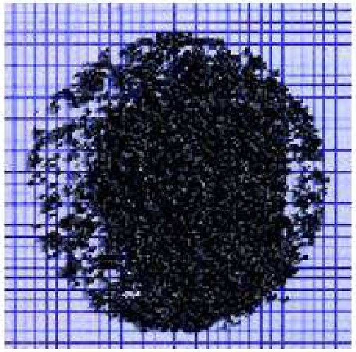
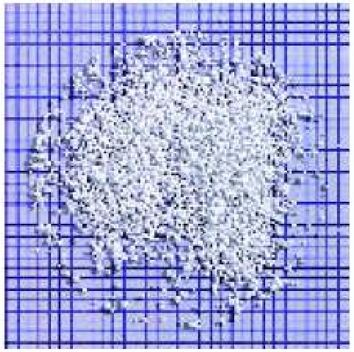
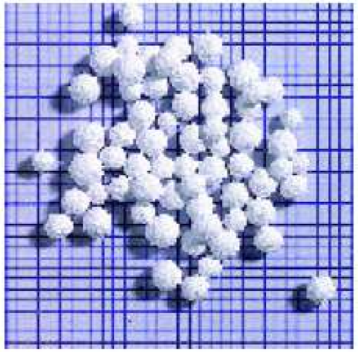


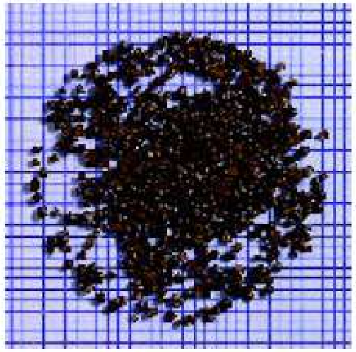
Welding powder



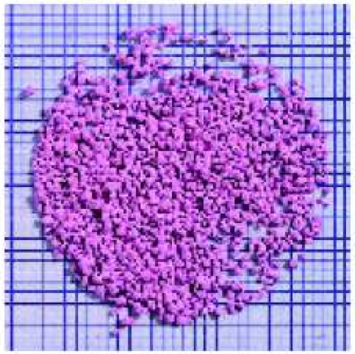
Zinc oxide
Varistors



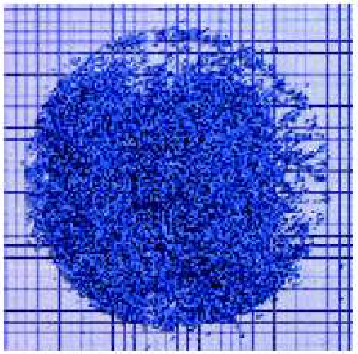
Zinc oxide
Pigment



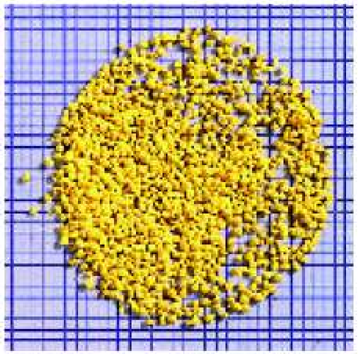
Iron oxide
Pigment



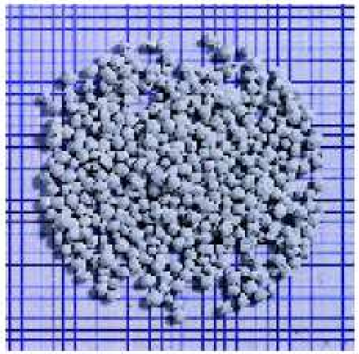
Steatite, colored
Press compound



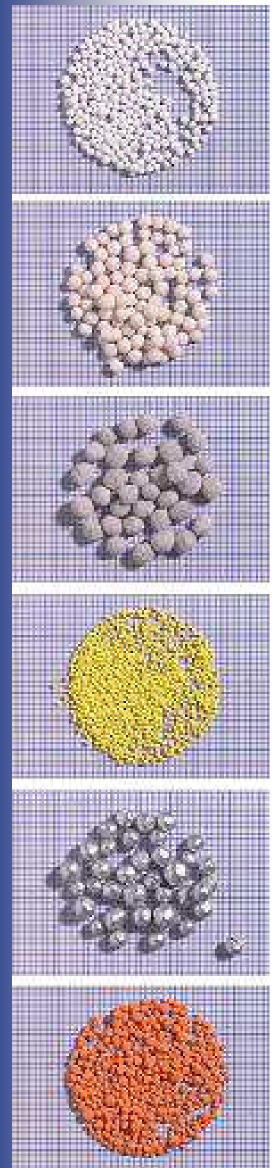
Pigment mix, blue



Pigment mix, yellow



Oxide powders
Varistors



Granulation in the Eirich mixer

Examples

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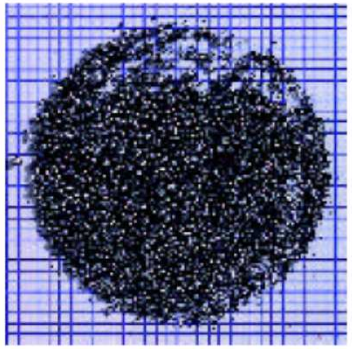
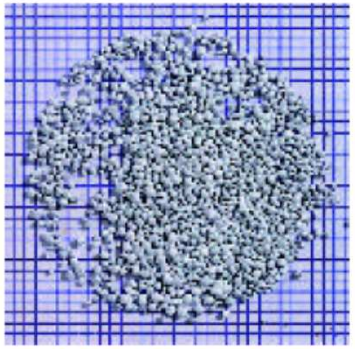
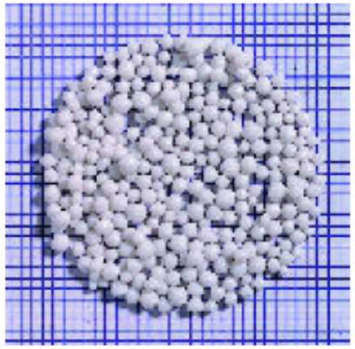


Al_2O_3-C
Iso-press compound

Oxide powders
Catalysts

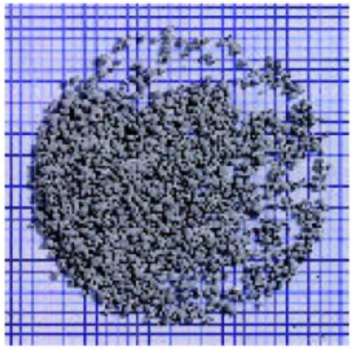


Steatite
Press compound

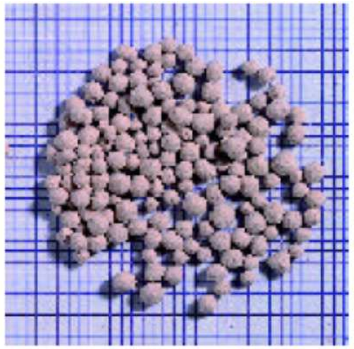


Porcelain
Contact compound

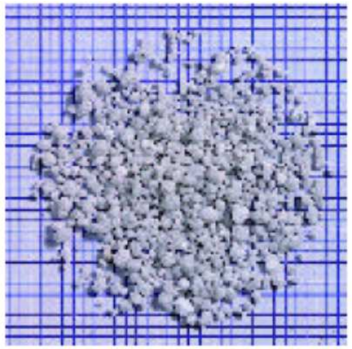
Cyclon dust



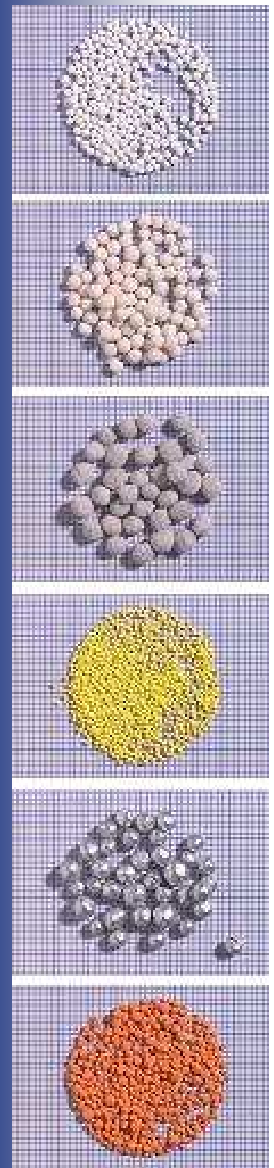
Cement
(granulated without water)



Diatom earth
Filter media



Gypsum
Building materials



Granulation in the Eirich mixer

Examples

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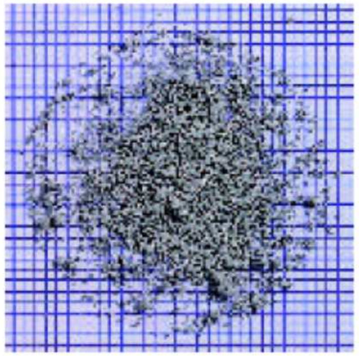
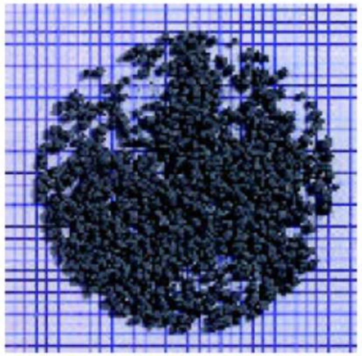
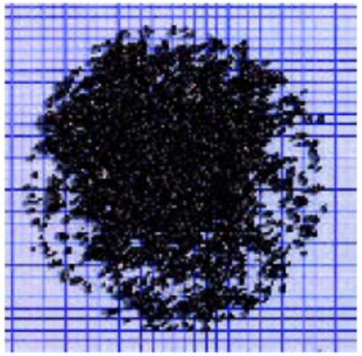


Silicon carbide
Abrasives

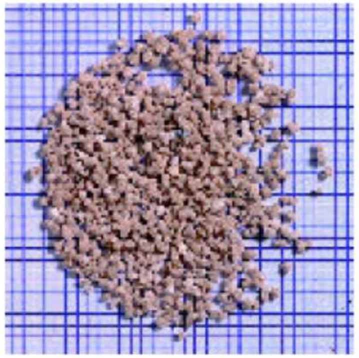


Tungsten carbide
Hard metal

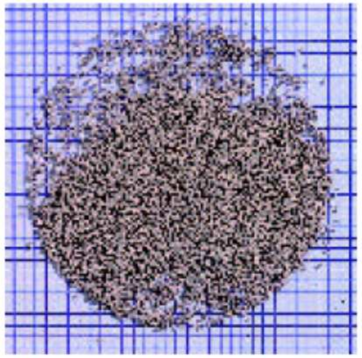


Peat fertilizer

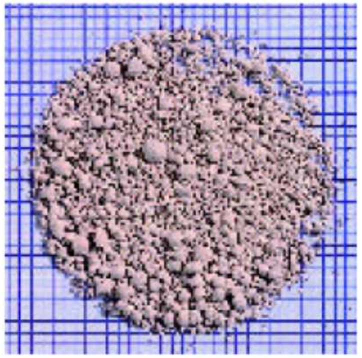
Sugar-beet seed



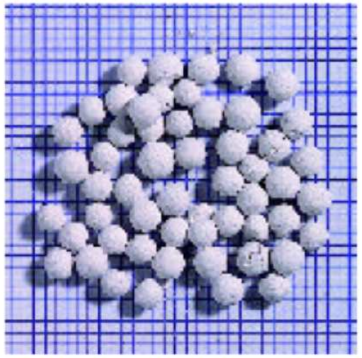
Mineral powders
Animal food additive



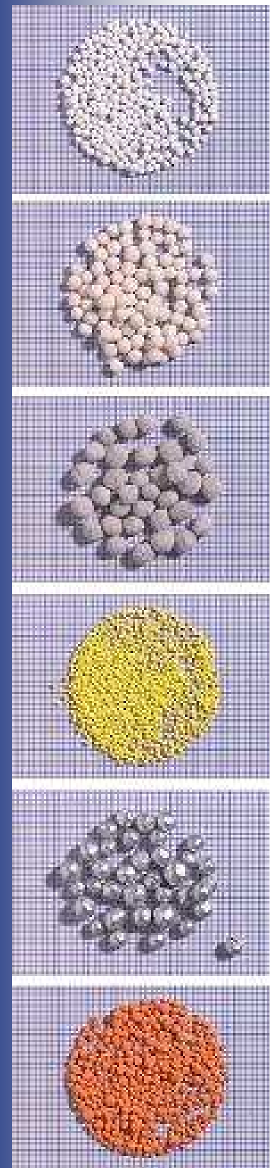
Phosphate fertilizer



Dolomite
Fertilizer



Lime
Fertilizer



Granulating mixer

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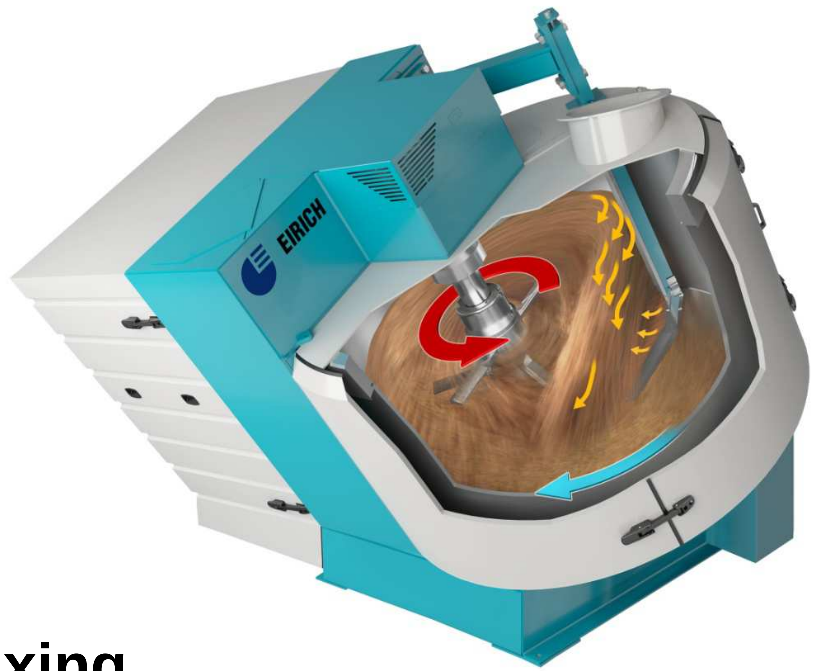
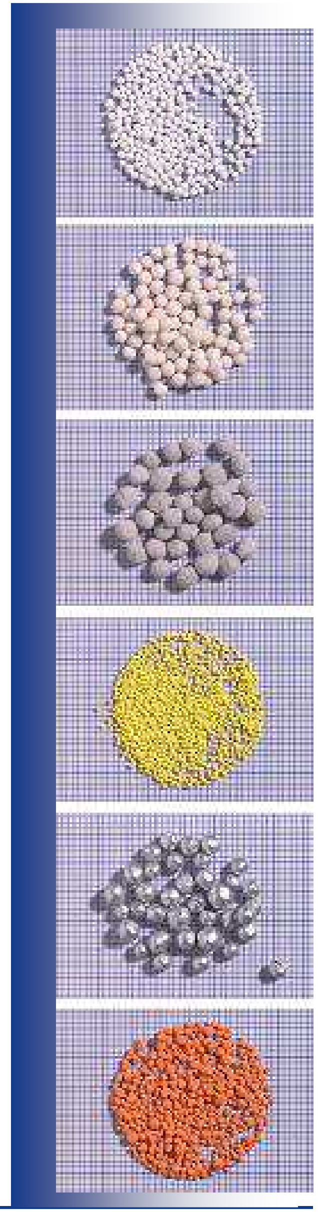
Basic material:
lumpy material
dry, fine dispersed matter

Granulating liquid:
filter cake, suspension,
solution, plastic bodies

Process technologies:
dispersive + distributive mixing
build-up agglomeration





Process technology: Build-up agglomeration Granulating mixer

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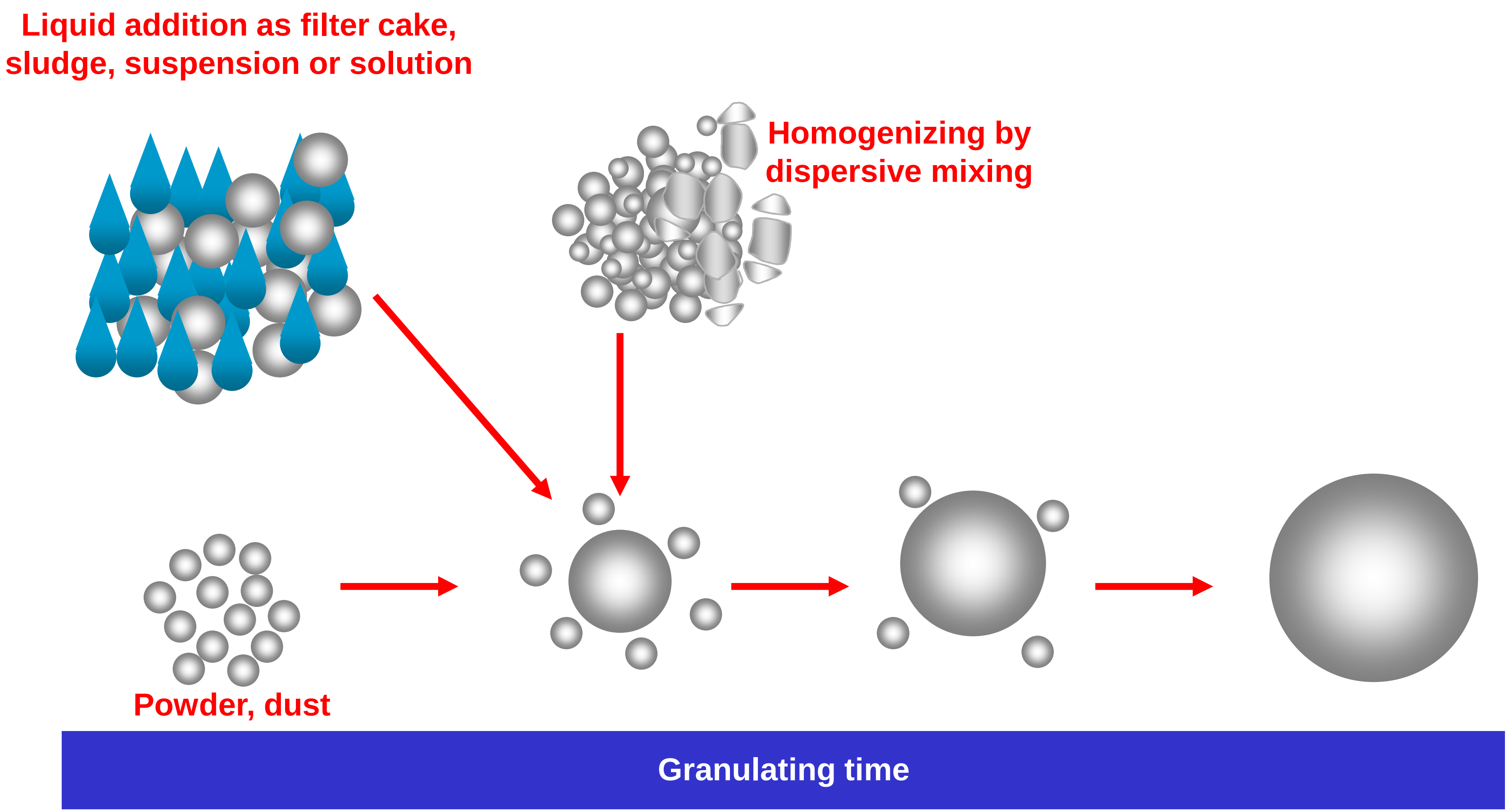

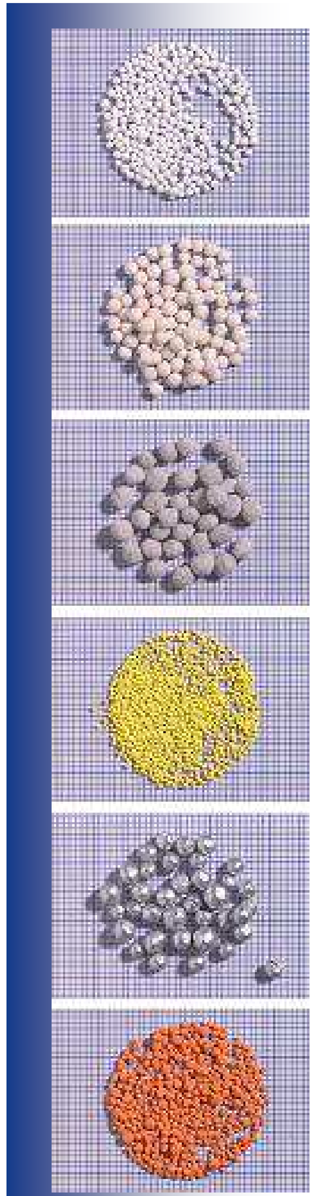

Standard plant design

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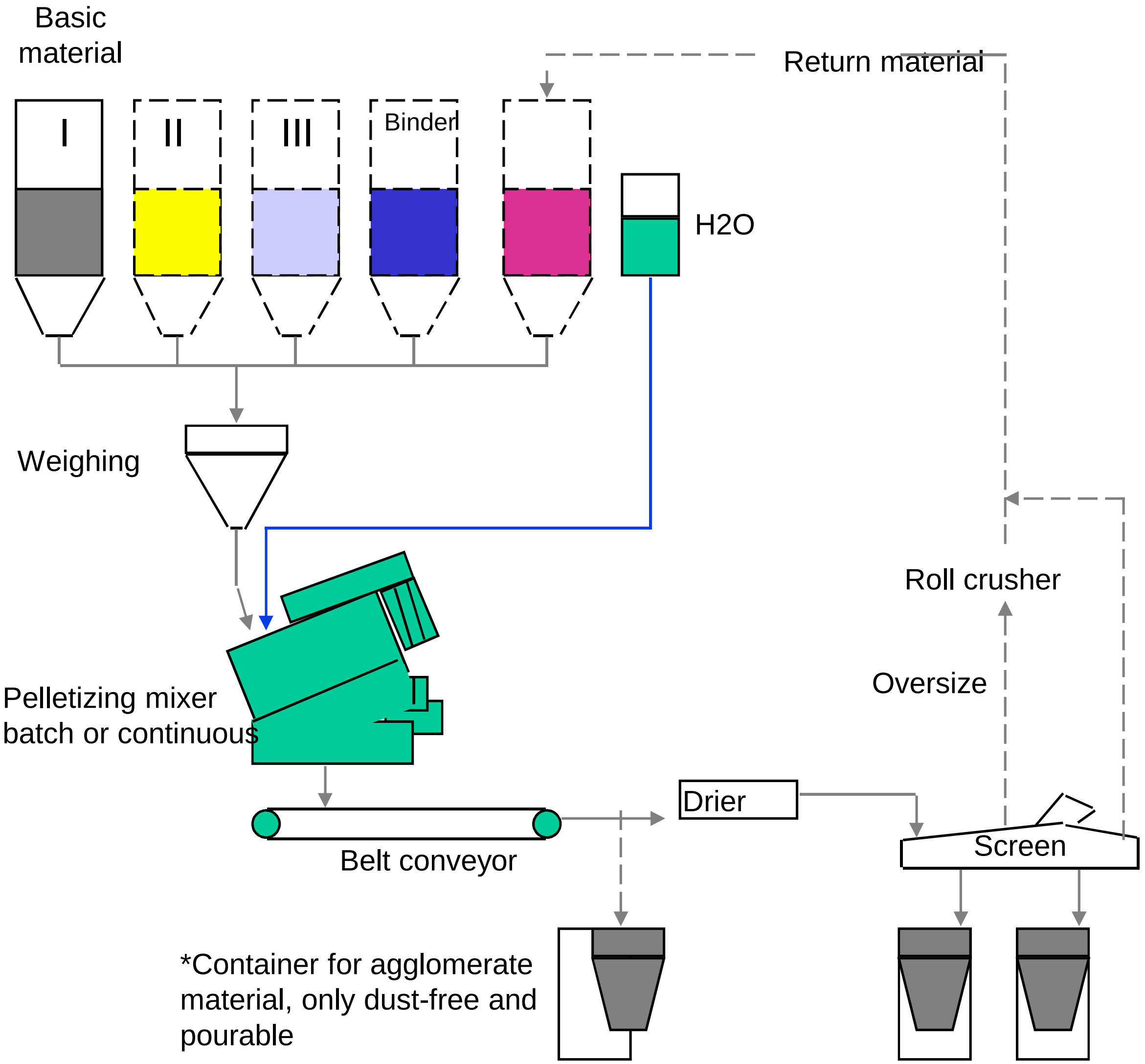


*Container for agglomerate material, only dust-free and pourable

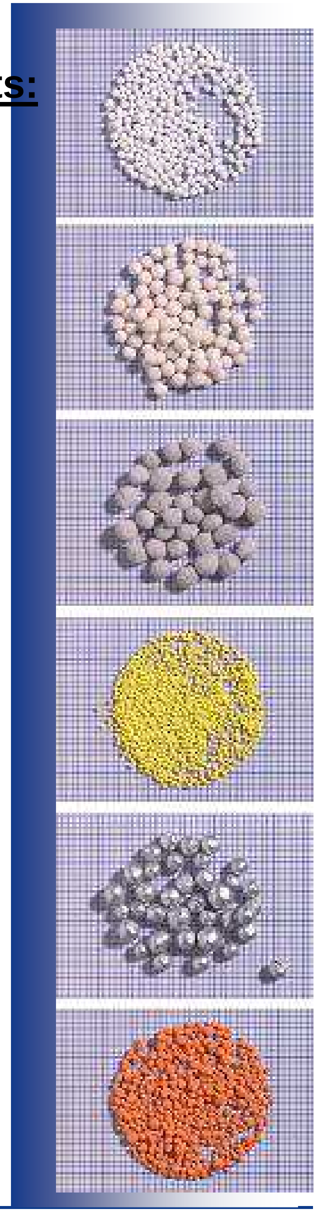
Standard system for dusts:

* dust-free agglomeration
** pelletizing

Pellet size: approx. 0.2 - 5 mm

Throughput: up to150 t/h/unit

**Container for granulate material



Particle size distribution

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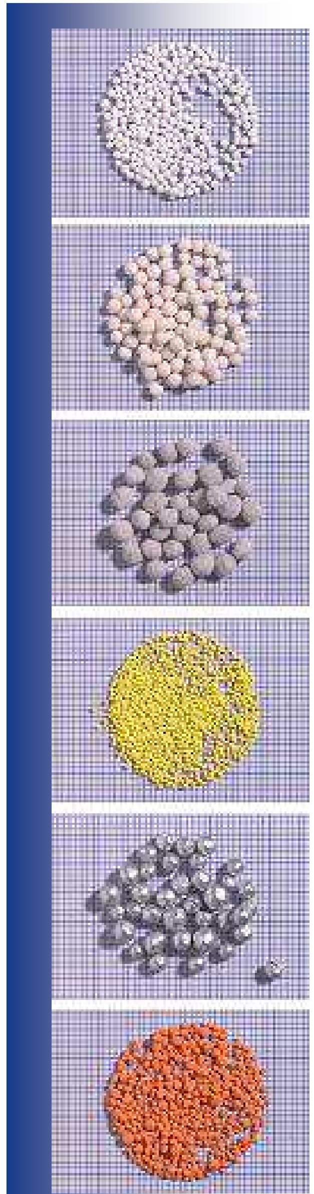
1. **Particle size distribution**
   1. **Determines the result of agglomeration (structural distribution)**
   2. **Determines the granulation moisture**
2. **Granulate size distribution**
   1. **A given value and the primary target to be achieved**
   2. **Parameter determination**



Particle size distribution ranges:

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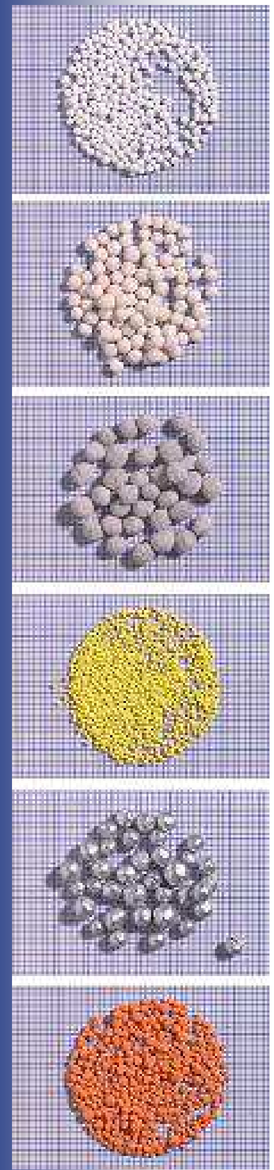

1. Essential parameter to be measured primarily
2. 100 µm is the natural limit for this process to be applicable
3. Coarse particles (return material, agglomerated nuclei, recycled material) are only incorporated if sufficient fine material is contained
4. Crushing in preparation for agglomeration
5. Fine material can determine the stability of agglomerates
6. Narrow particle size distributions, monodisperse distributions, are hard to agglomerate
7. Agglomerate coarse particles with binder, especially if a high porosity is requested

Criteria of pelletizing ability:

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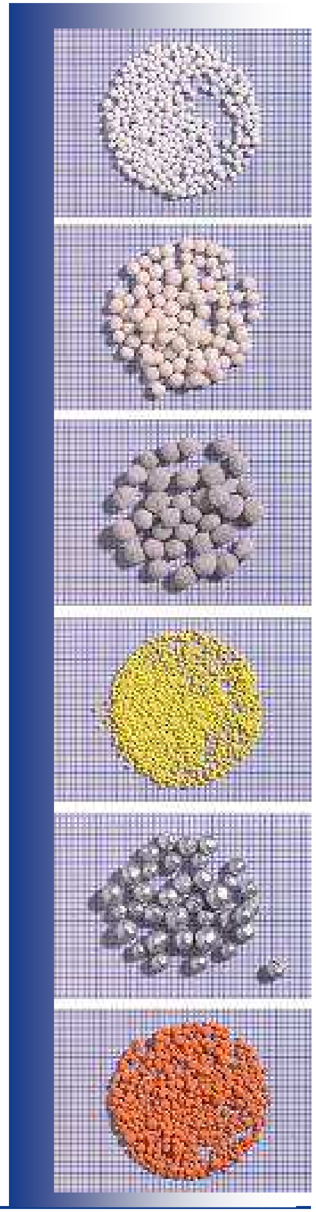

1. **Grain size and grain size distribution range**
2. **Specific surface**
3. **Shape of the individual particles**
4. **The RRSB grain grid allows assessing a known grain size distribution as to its pelletizing ability**
   Steep curve + medium to coarse grain boundary = critical
   Flat curve + medium to coarse grain boundary = satisfactory
5. **Ultrafine material → flatter grain boundary curve**
   → increases the specific surface

Particle size distributions

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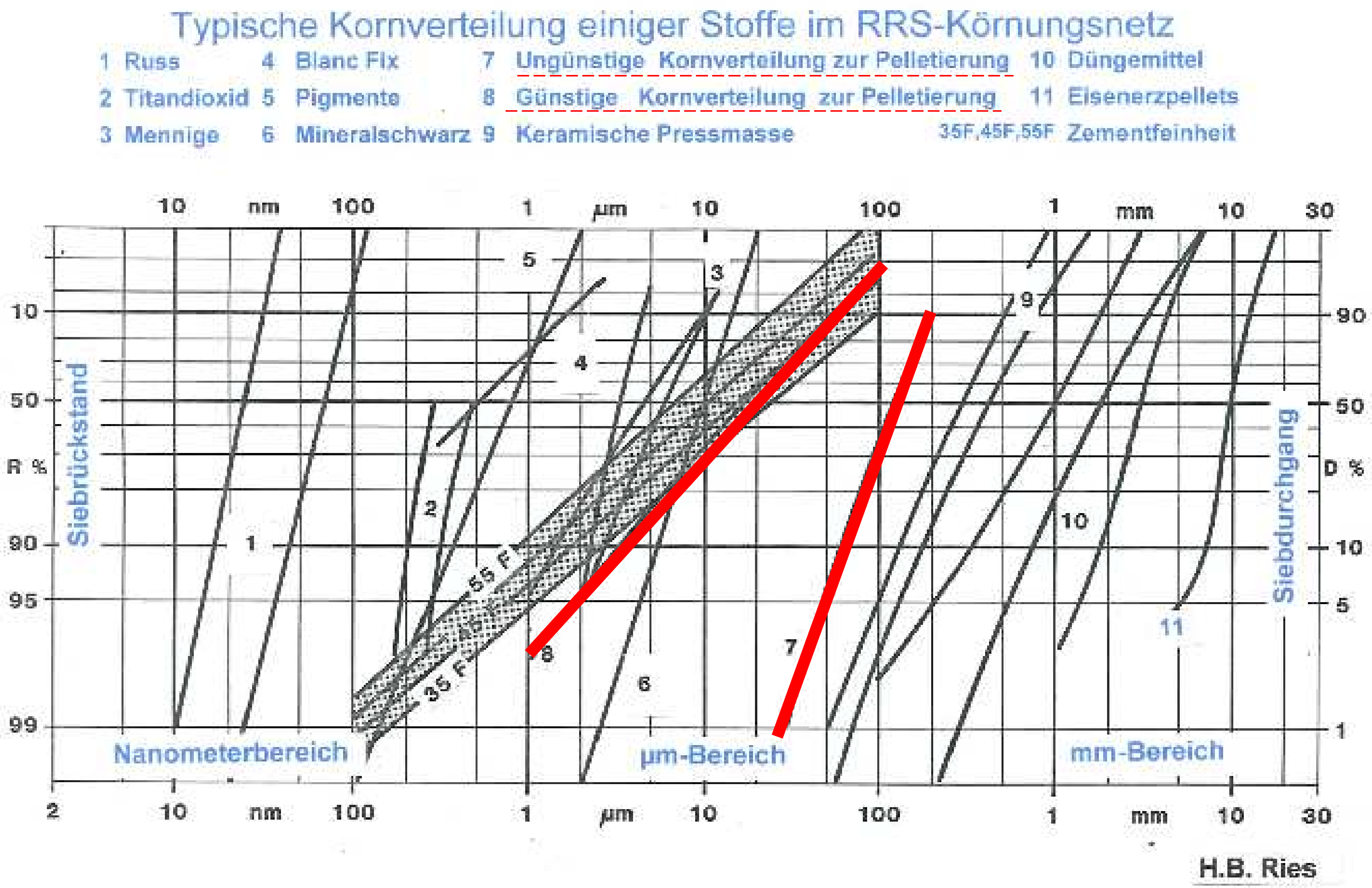

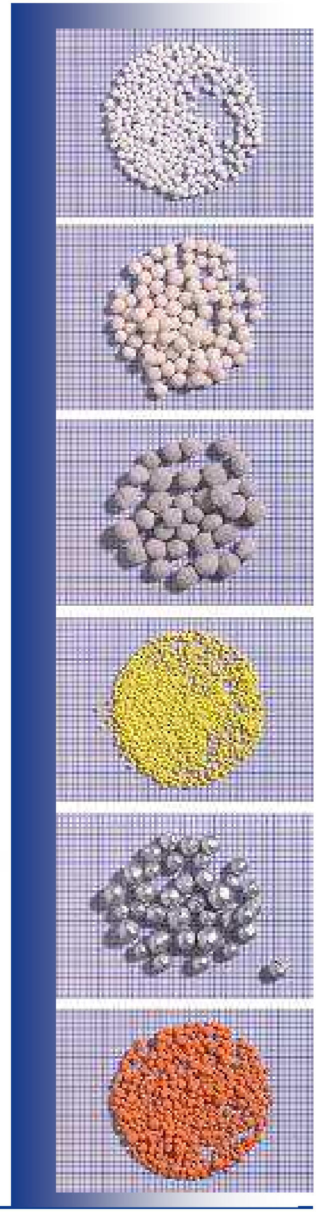

Granules particle size distributions

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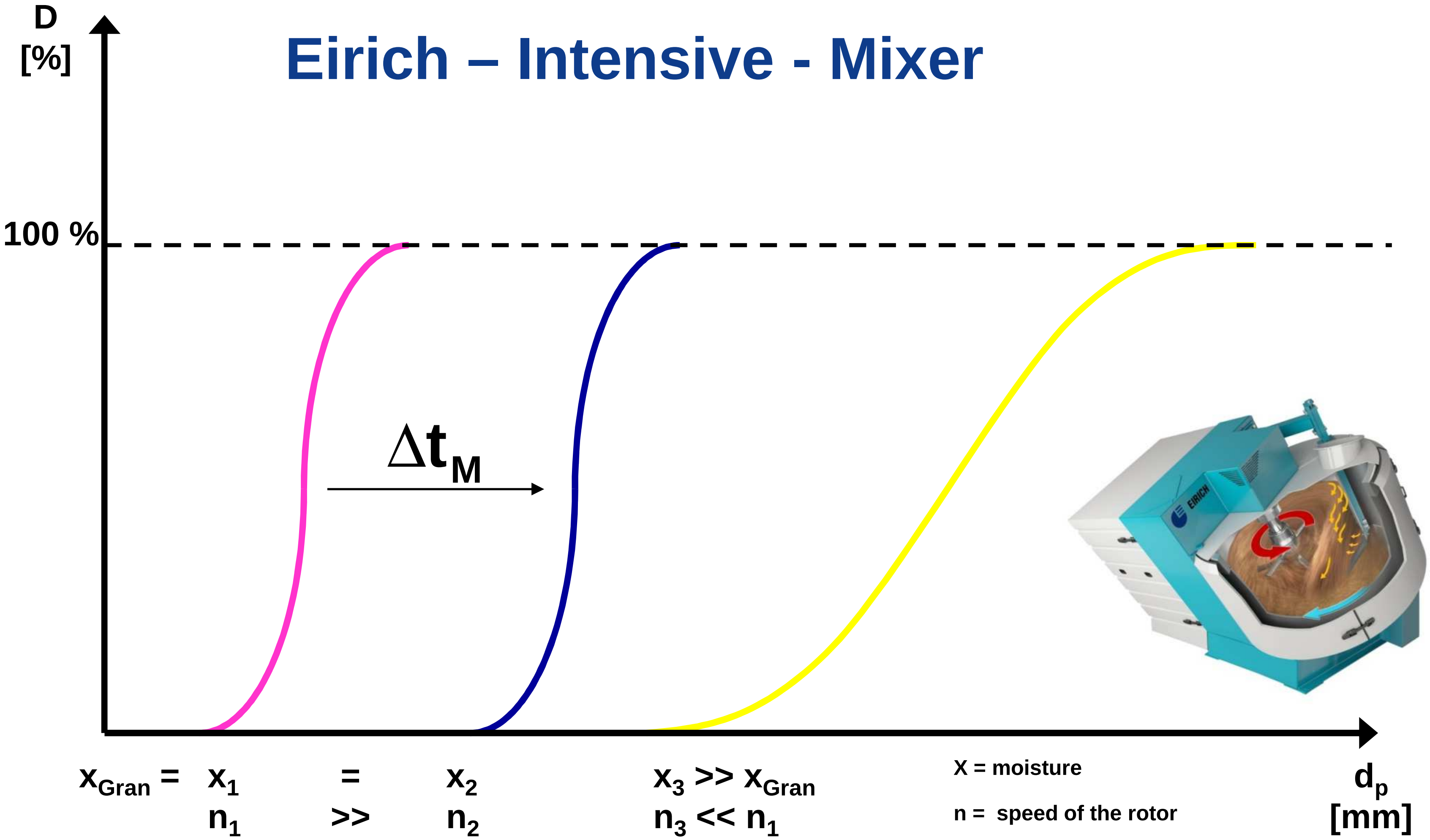
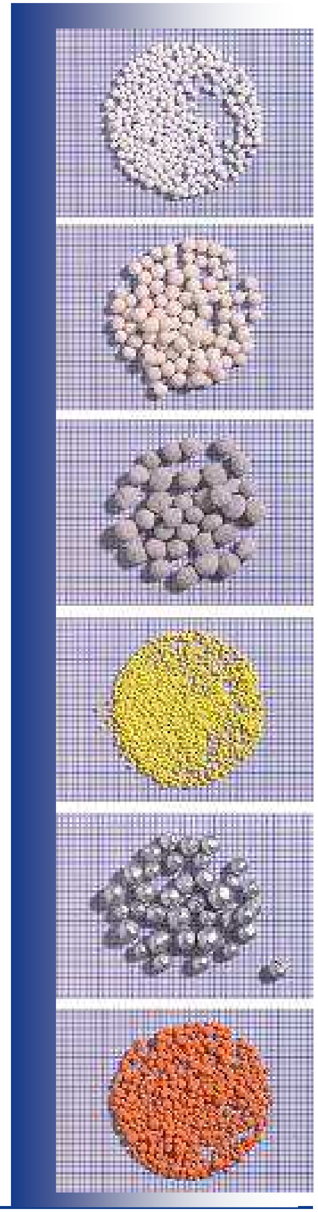
Process of granulating in the Eirich – Intensive - Mixer





Example: Granulating pigments in the 250 L mixer

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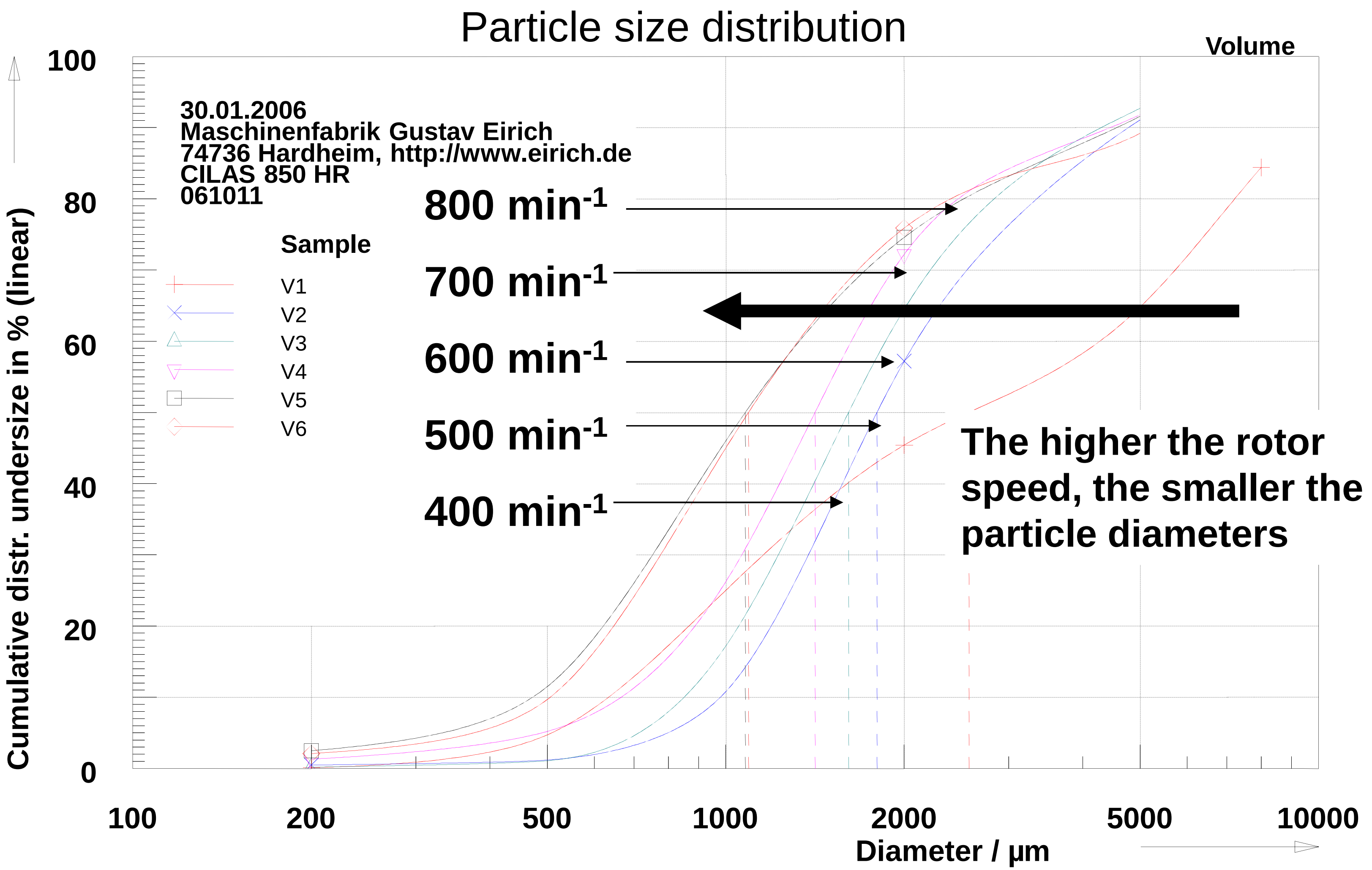

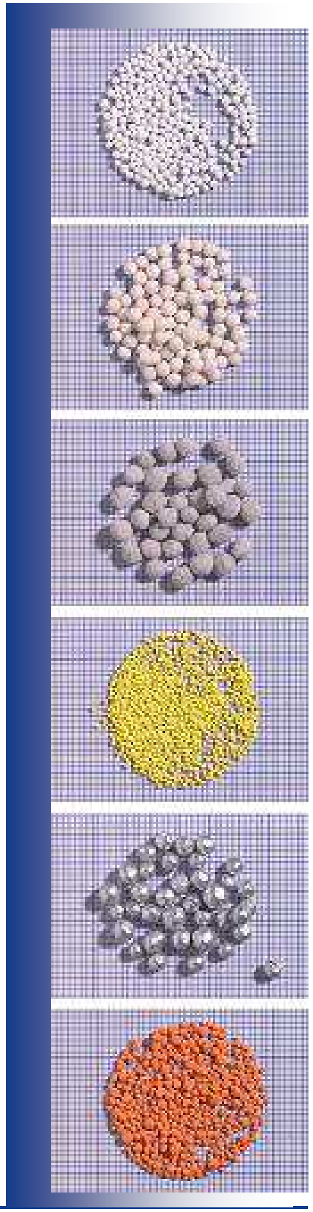

Example: Granulating fertilizers in the 10 L mixer

Influence of granulating time

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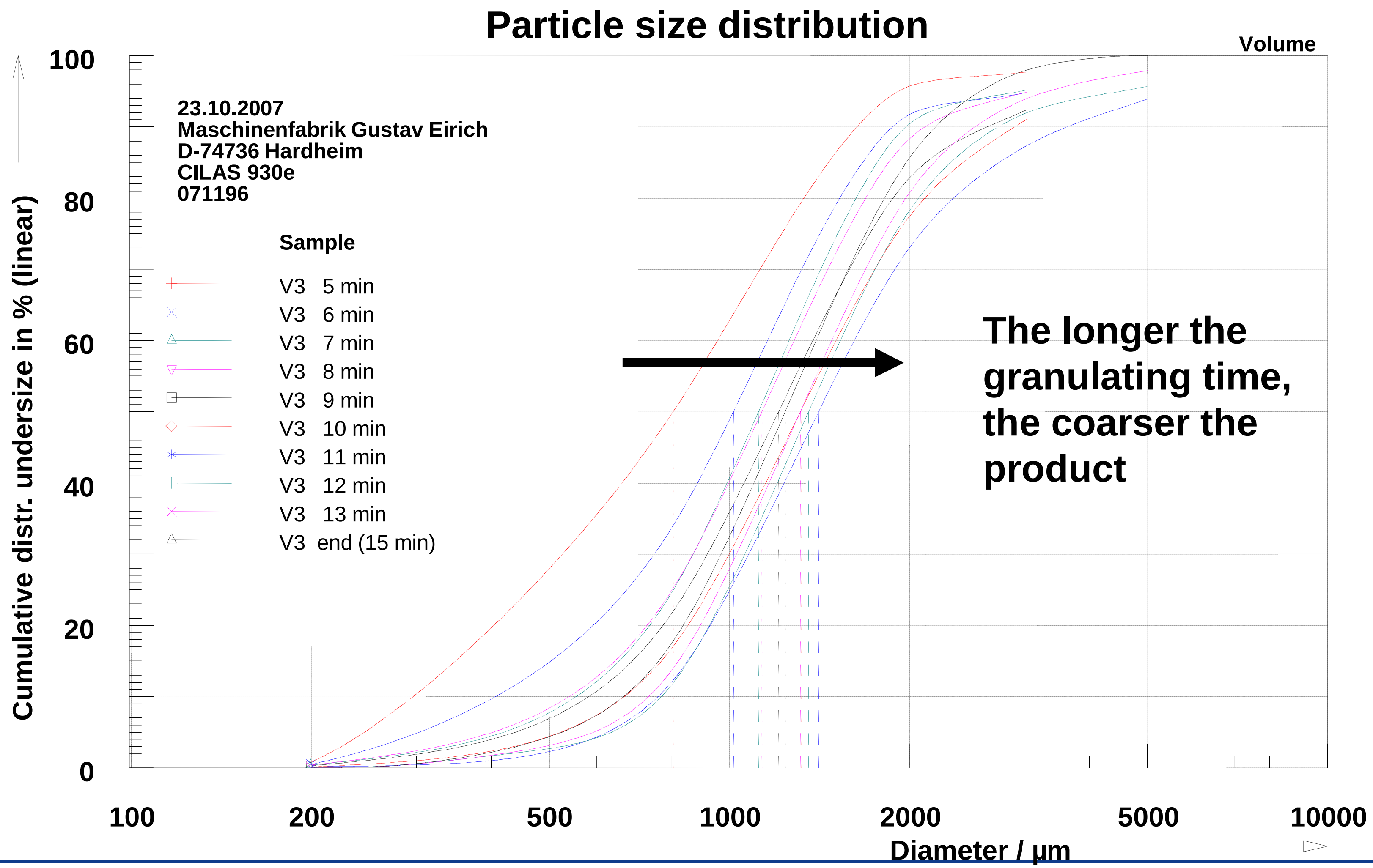

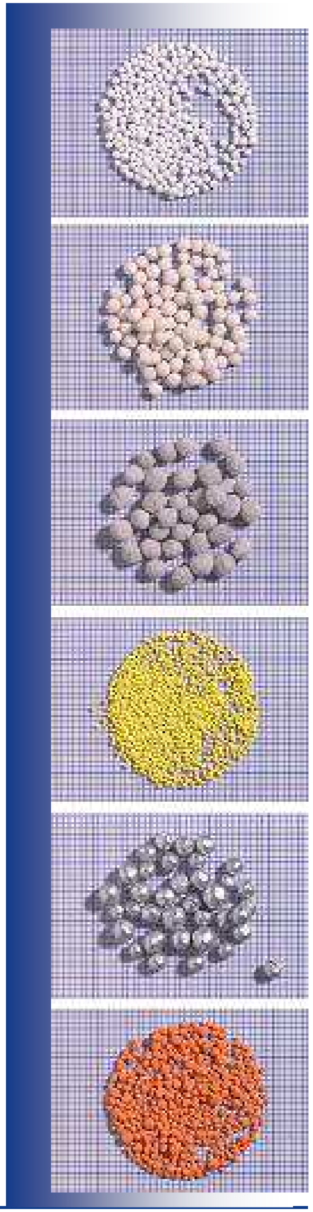

Example: Granulating proppants in the 750 L mixer

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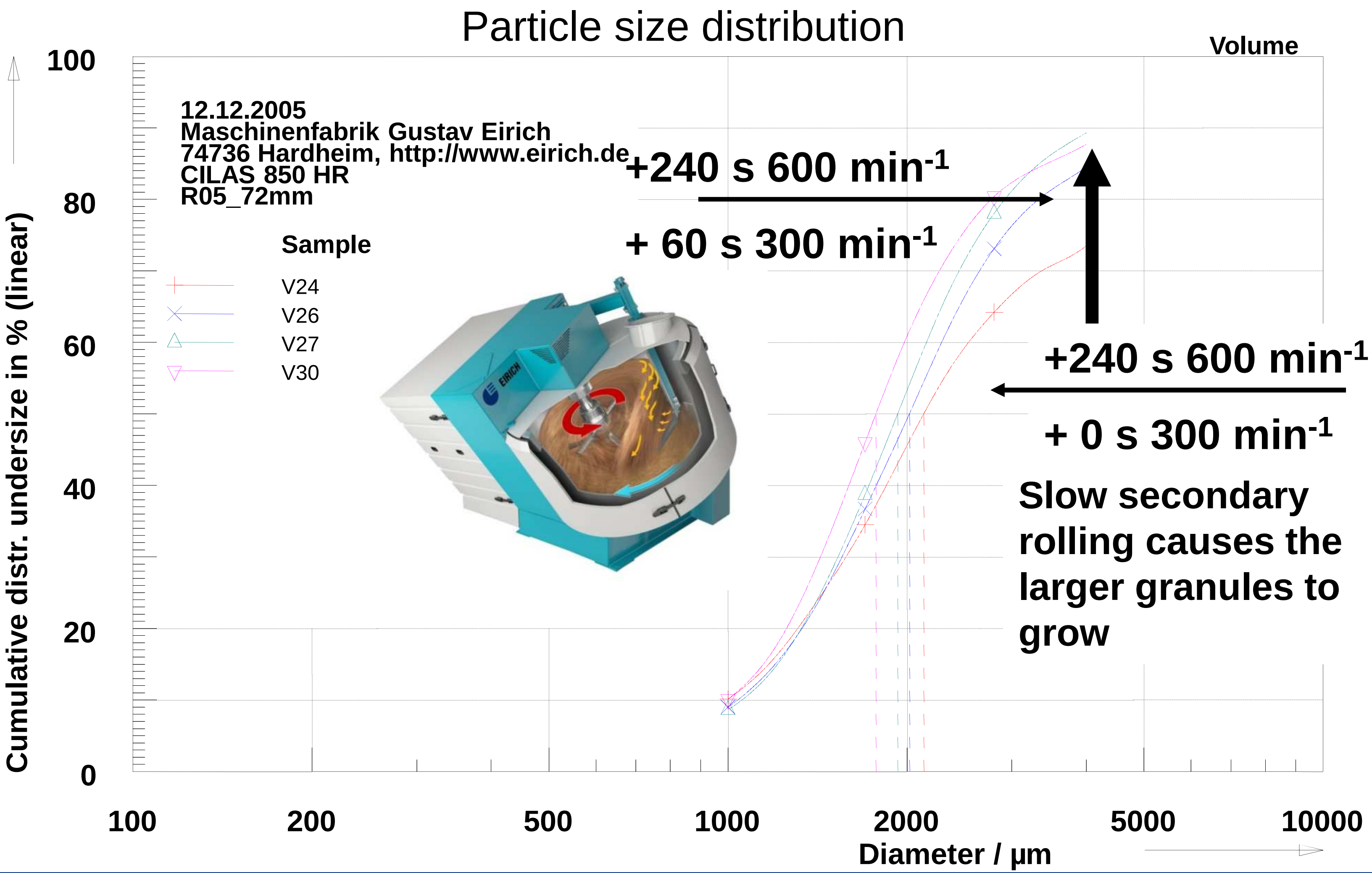

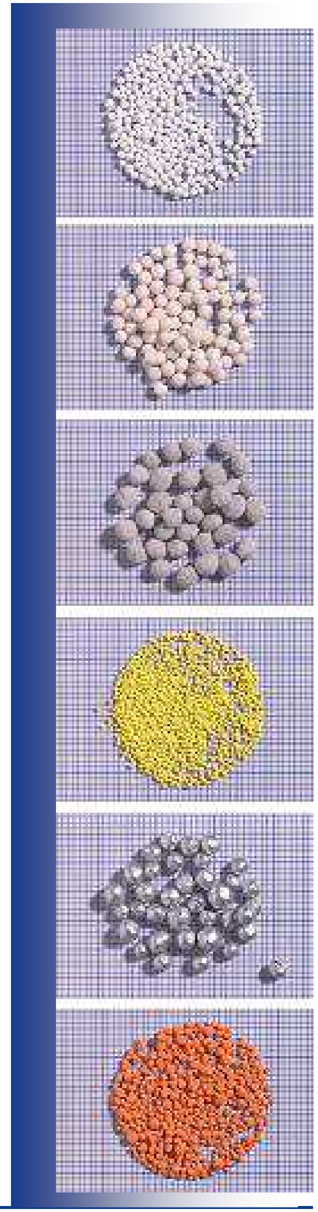

Example: Granulating proppants in the 750 L mixer

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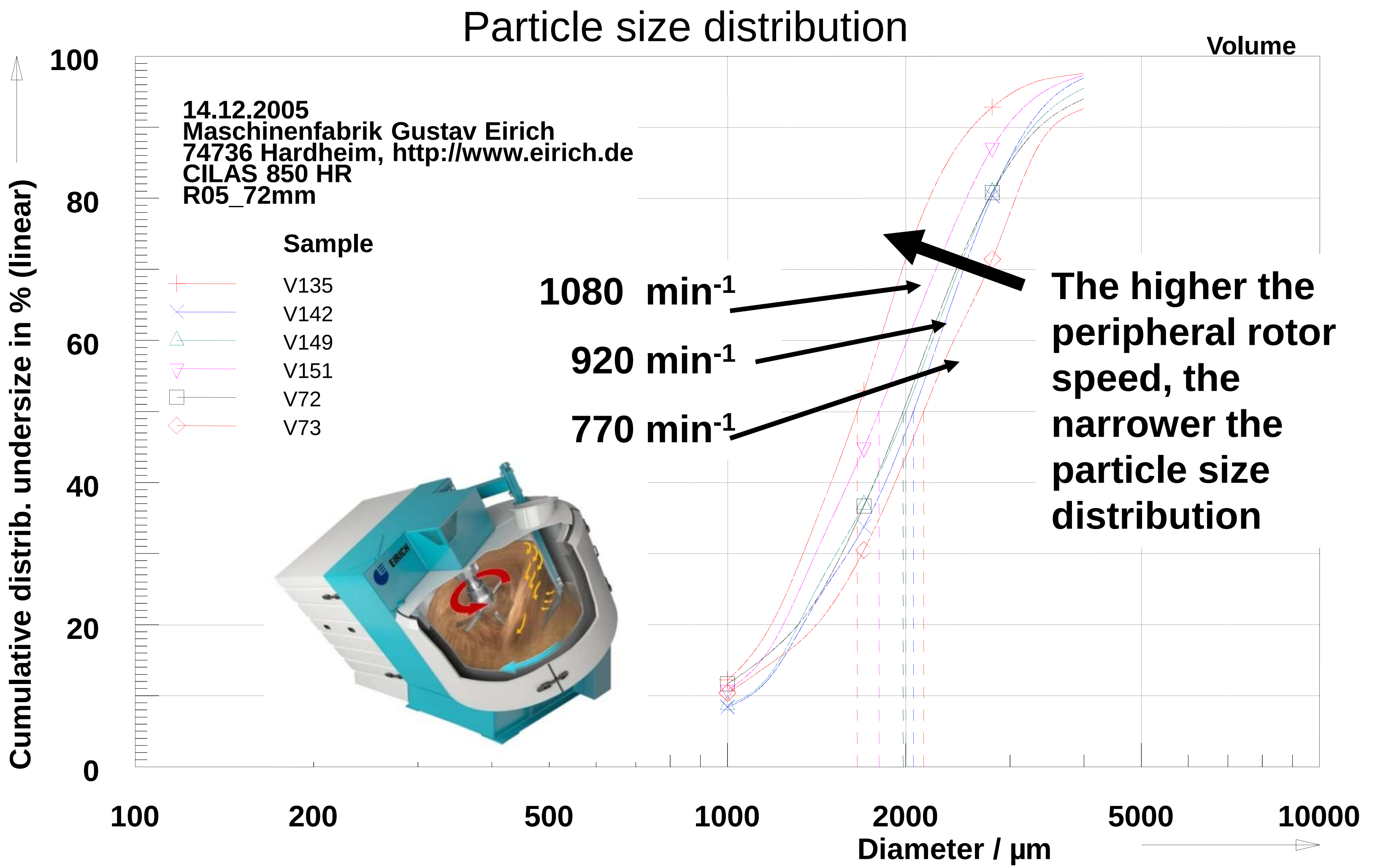

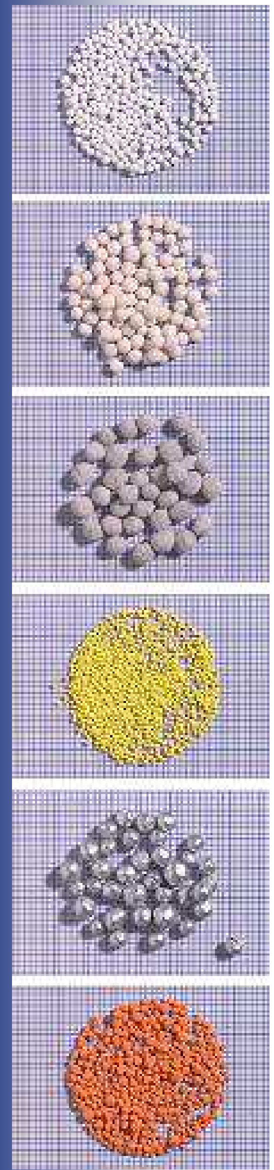

Granulation moisture

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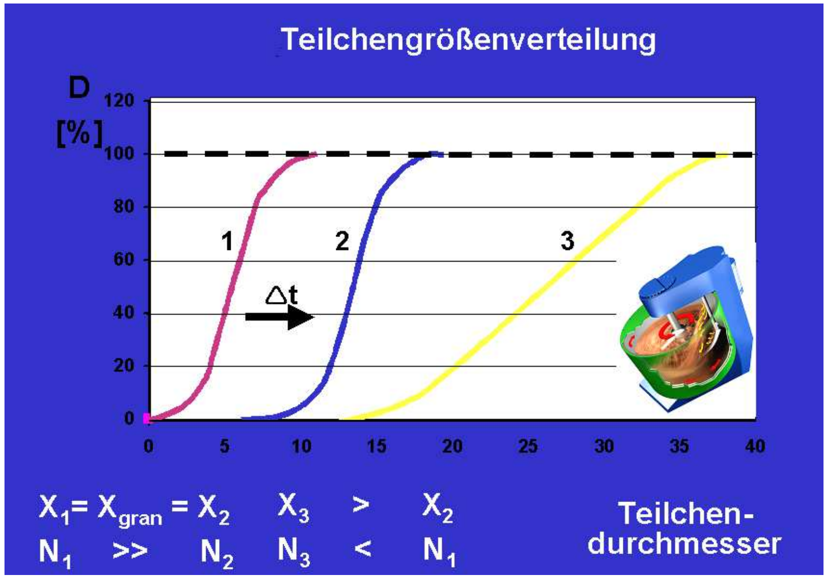
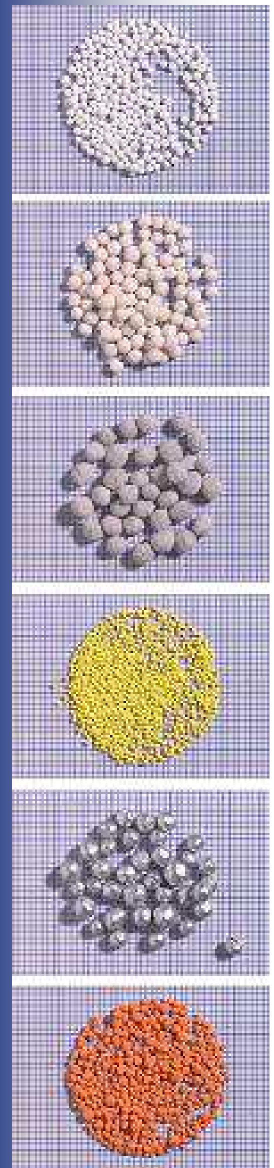
Granulation moisture = f (Grain size distribution)

$X < X_{Gran}$	**Particle size distribution shifted toward smaller particle diameters, impeded growth of particles**
$X > X_{Gran}$	**Particle size distribution shifted toward larger particle diameters, risk of plastification**





Example: Granulating proppants in the 750 l mixer

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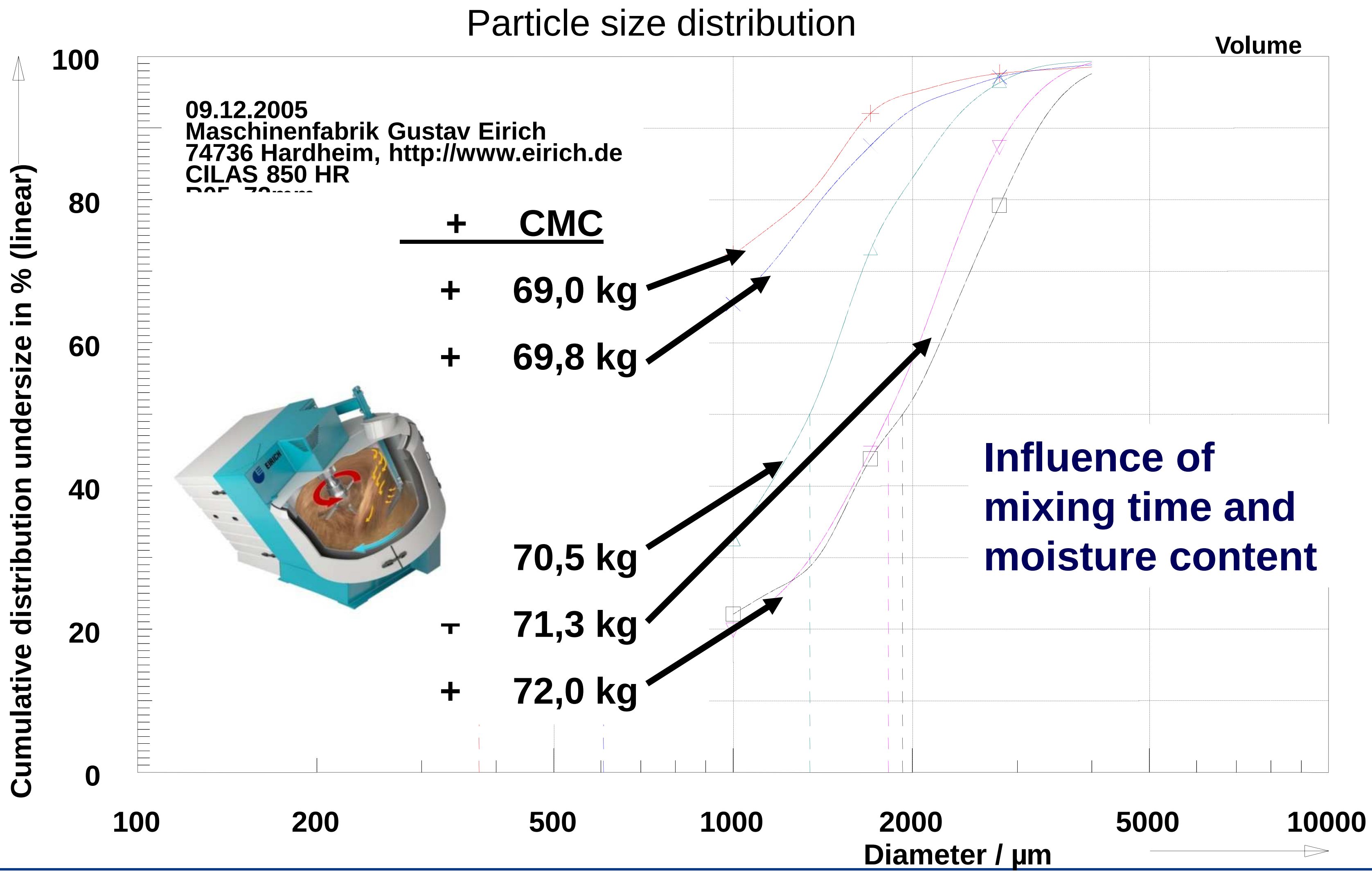

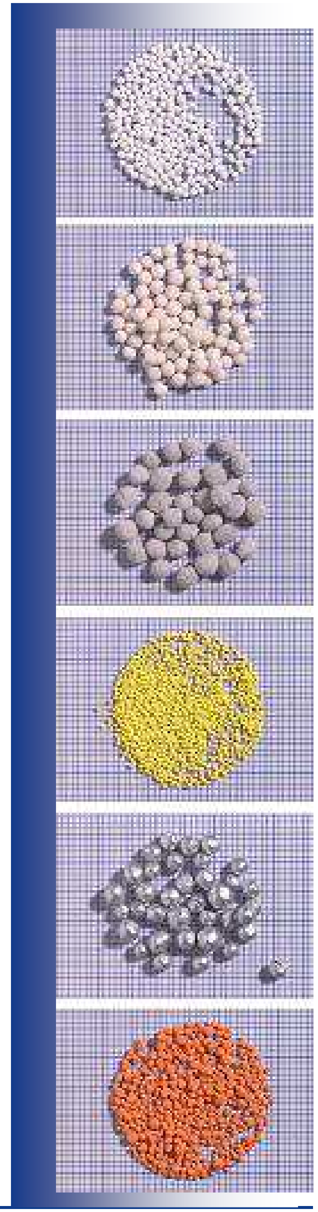

Granulation moisture

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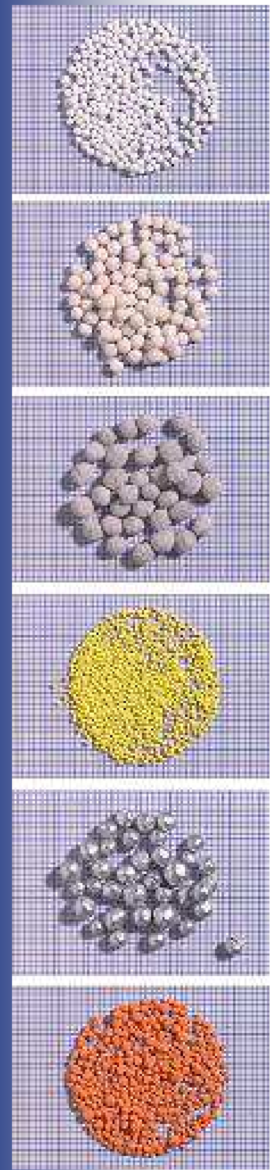

1. **The free moisture content is important for the binding mechanism**
2. **Max. moisture content = 90 – 95 % of the pore volume**
3. **Exceeding this value just slightly may result in sludge (degree of saturation)**
4. **The feeding mode is decisive for growth and quality**
   ⇒ The moisture content has to be lower
5. **The wettability is the most important property because the green strength is determined by surface tension forces or capillary forces**

Granulation moisture

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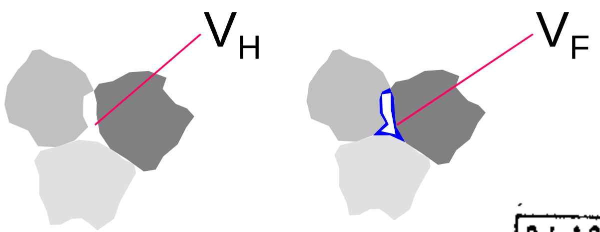
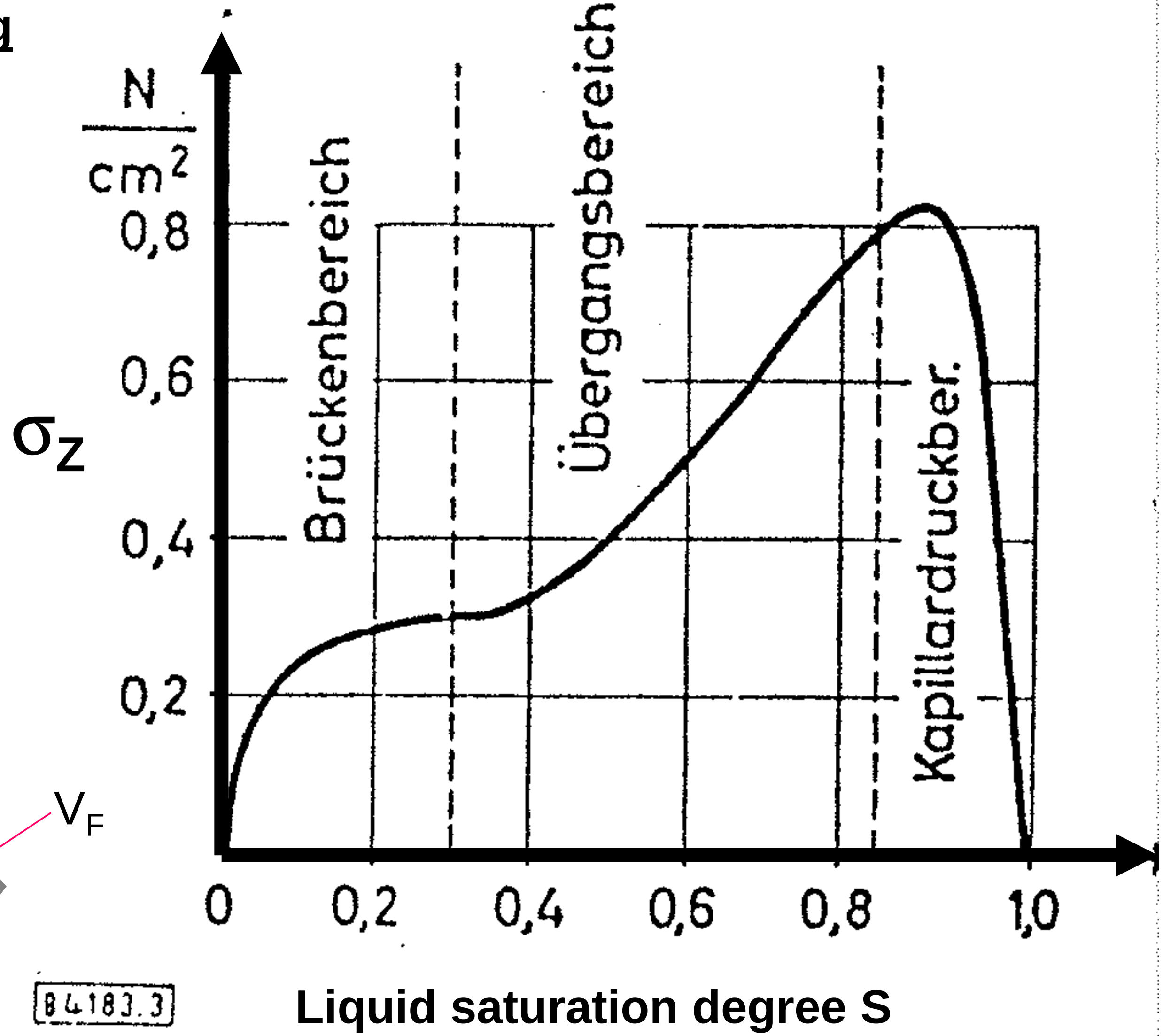
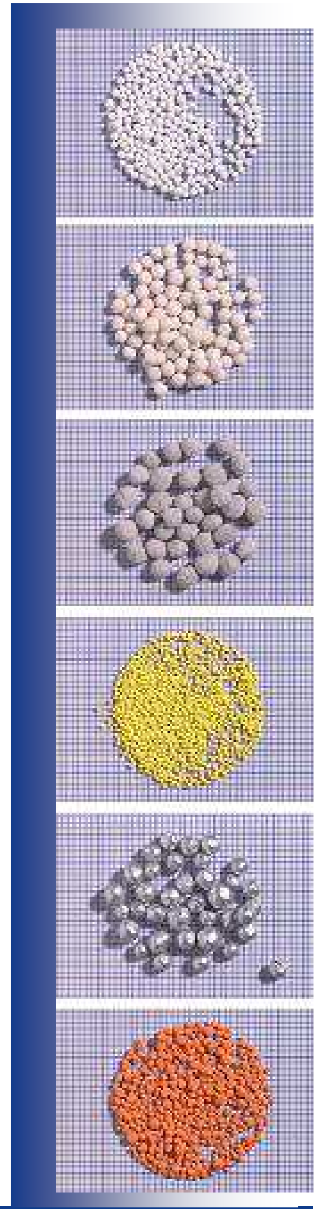
- **Moistening / wetting**
  Distributing small amounts of liquid in the bulk material.

  Liquid volume
  V_F << cavity V_H.
  degree of saturation

$S = V_F / V_H < 1$







Example: Granulating pigments in the 250 L mixer

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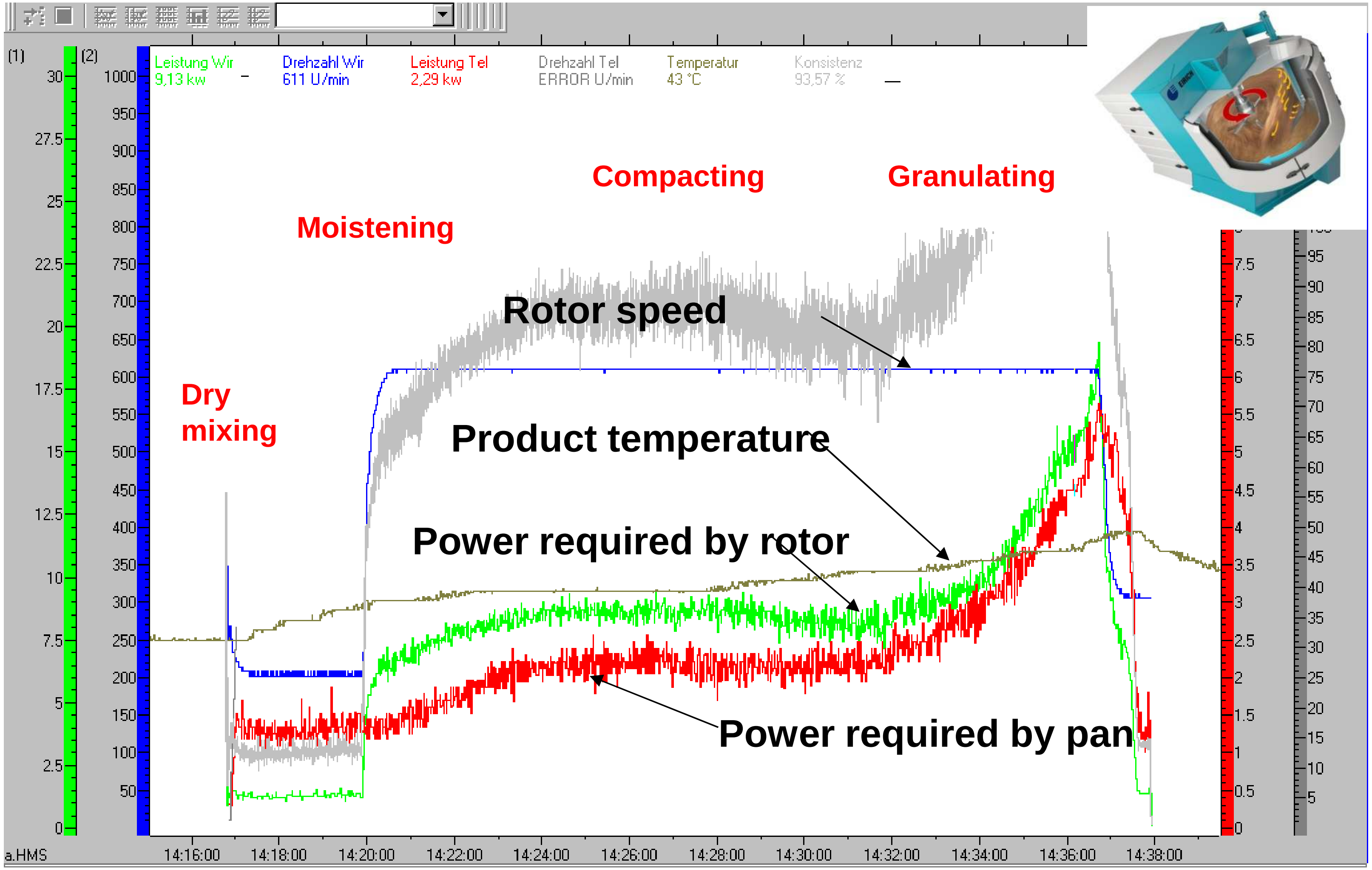

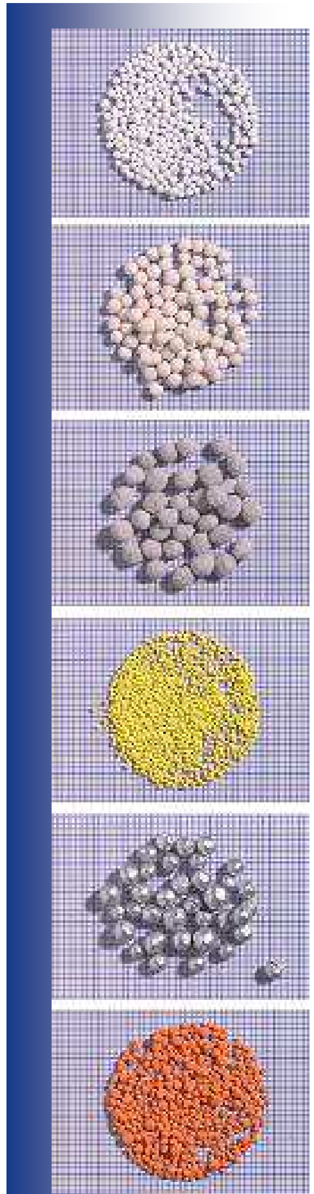

Process technology:
Improving the pourability/ flowability

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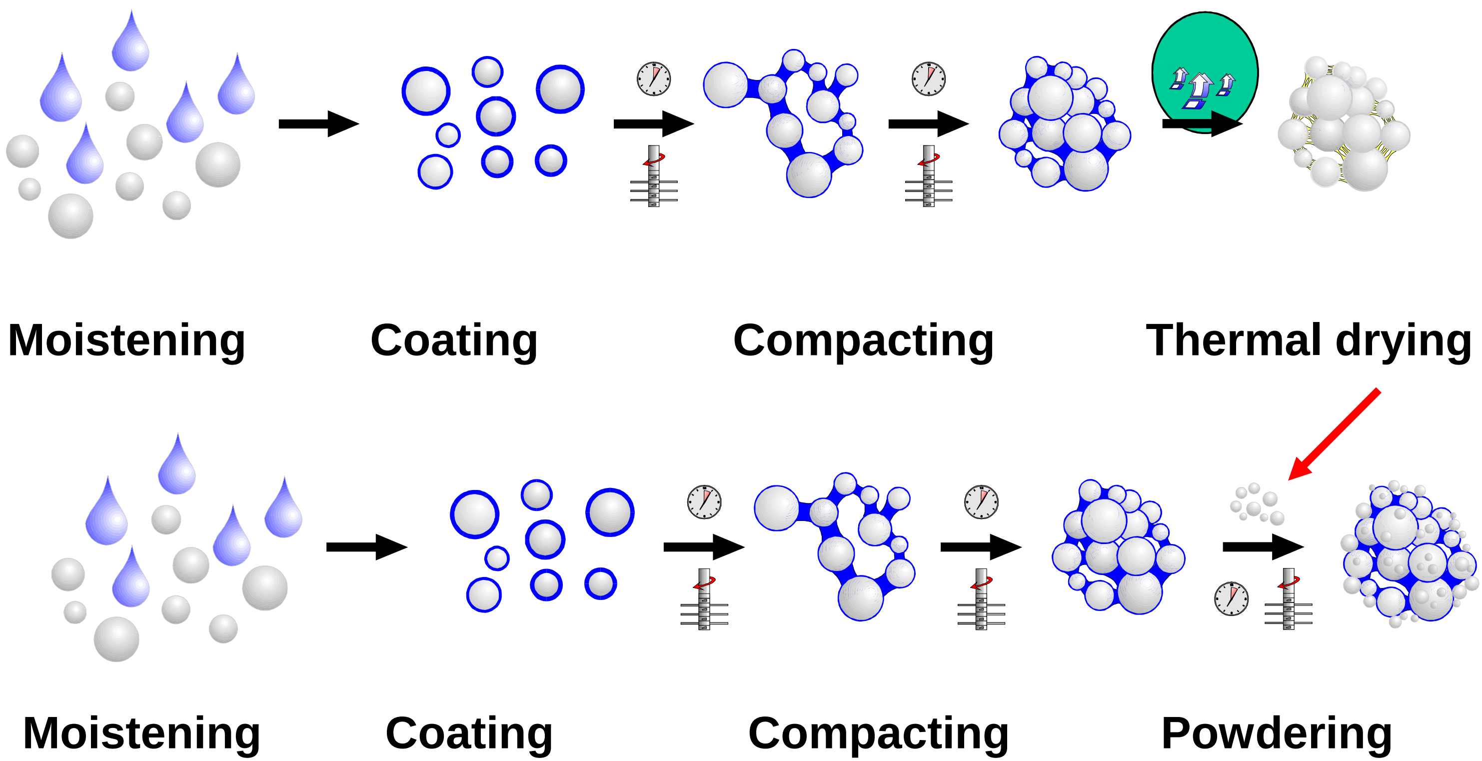

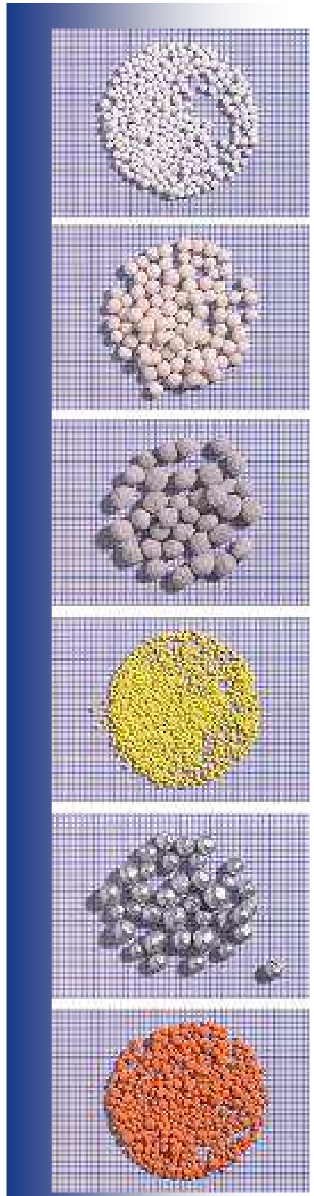

Granulation Iron Ore Concentrate

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Granulation of fine iron ore concentrate

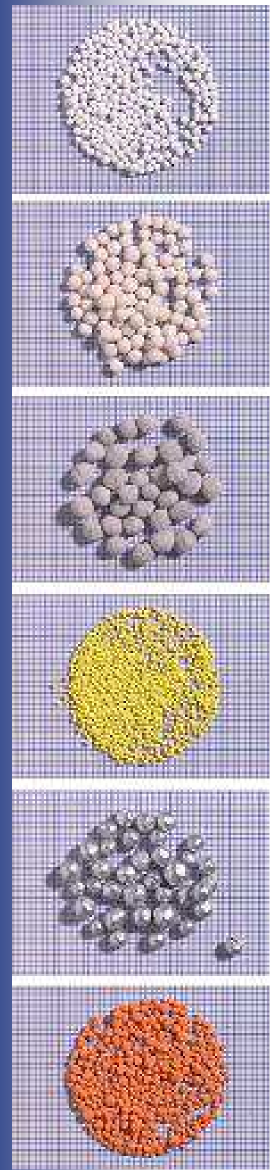
1. Trials in the Test Center 100 kg/batch scale
2. 3 days production tests with 50 t/h

Test Center :

Moisture	7,8-8,1 %
Batch time:	5 min
1 min	dispersive mixing 22 m/s
4 min	build up agglomeration 7 m/s
Binder:	calcium hydroxide

Production Test :

capacity :	4800 kg/batch
Batch time:	5 min
1 min	dispersive mixing 20 m/s
2 min	build up agglomeration 7 m/s
Binder:	calcium oxide+hydroxide



Granulation Iron Ore Concentrate

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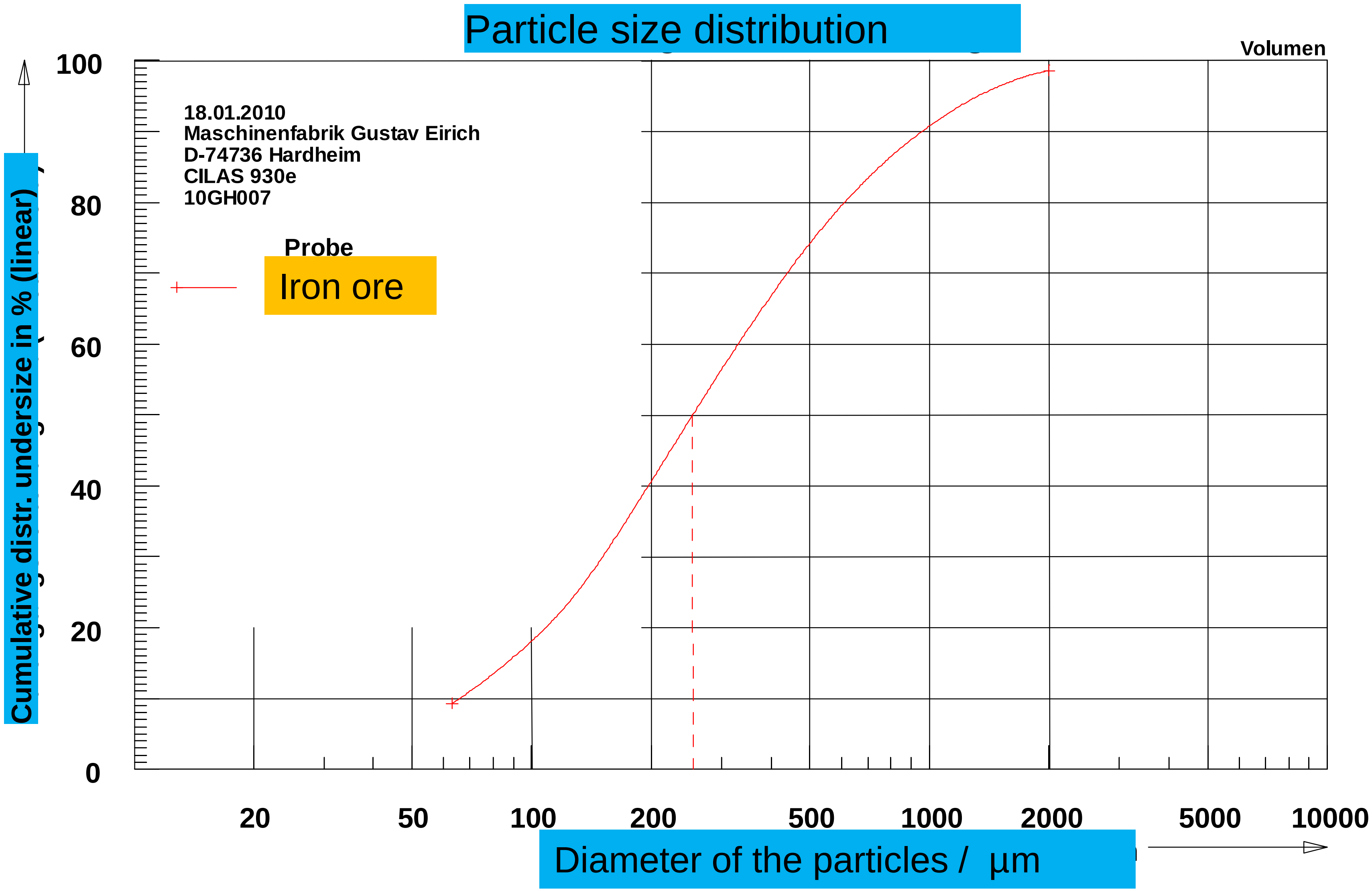

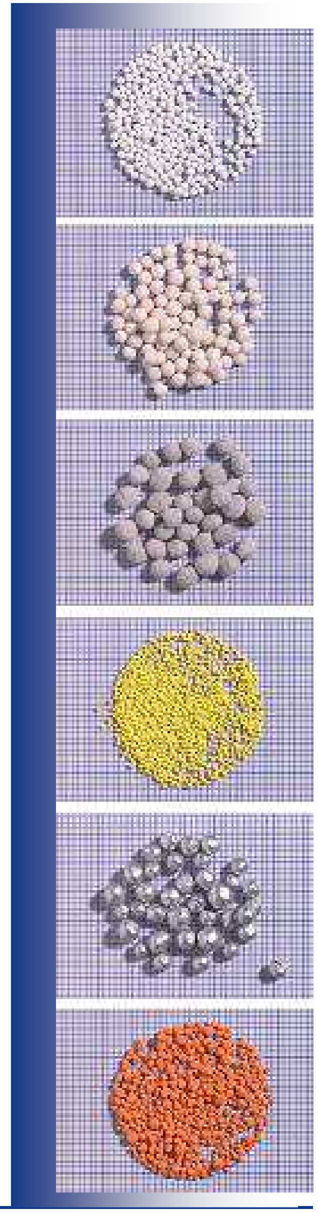

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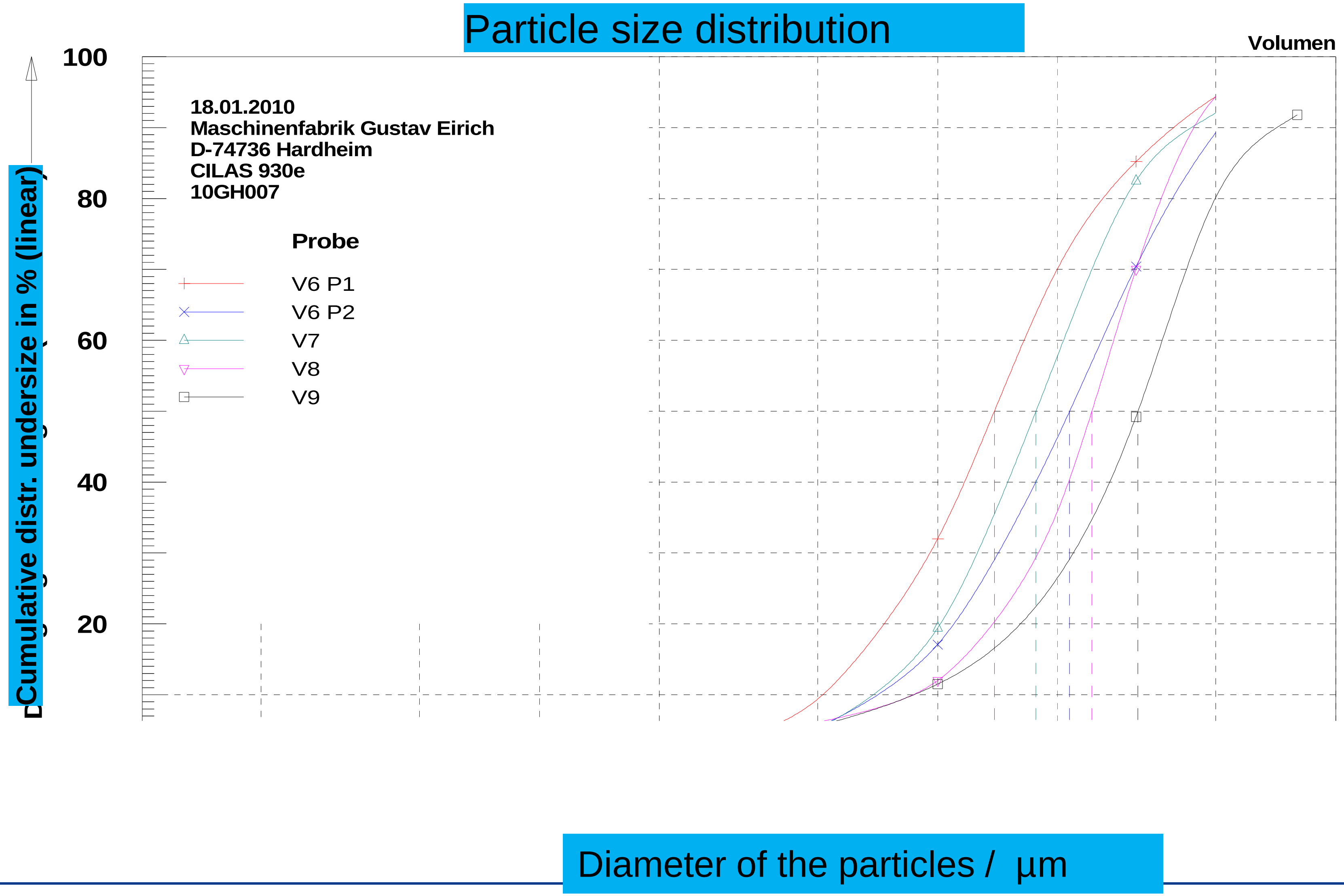

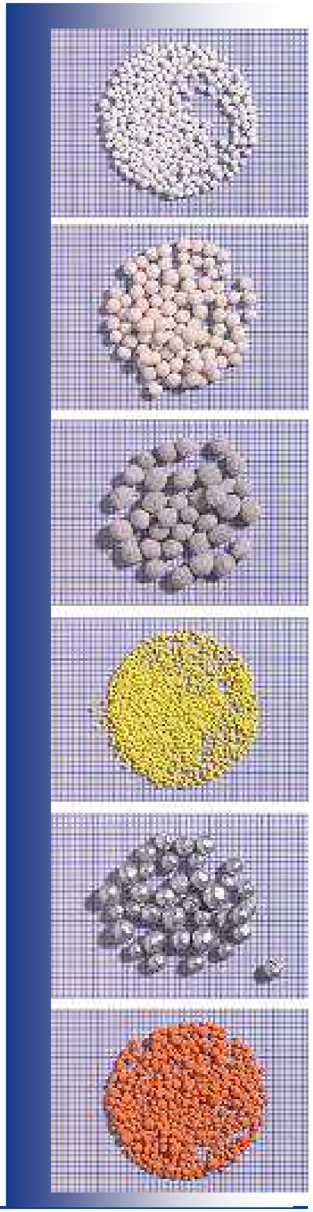


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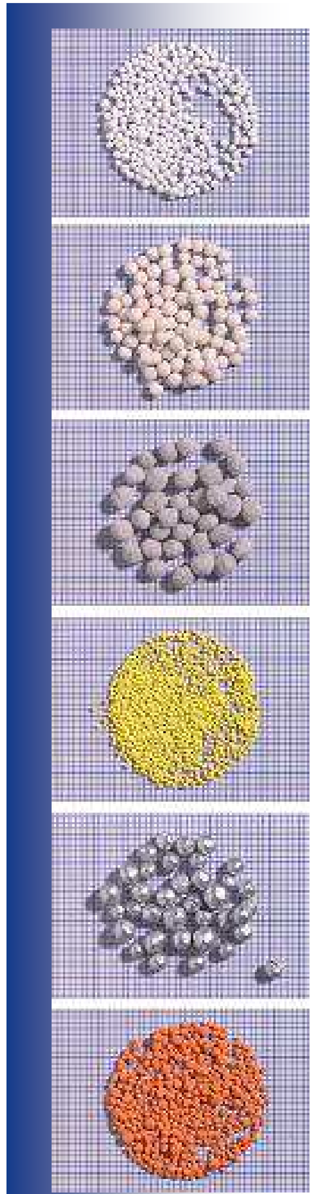

Results :

1. The productivity of the sintering can be higher than 40 t/m² h
2. Even when there is more than 10 % fines
3. If the fine iron ore is agglomerated

Granulation of Iron Ore Concentrate

+ 60 - 80 % Pelletfeed

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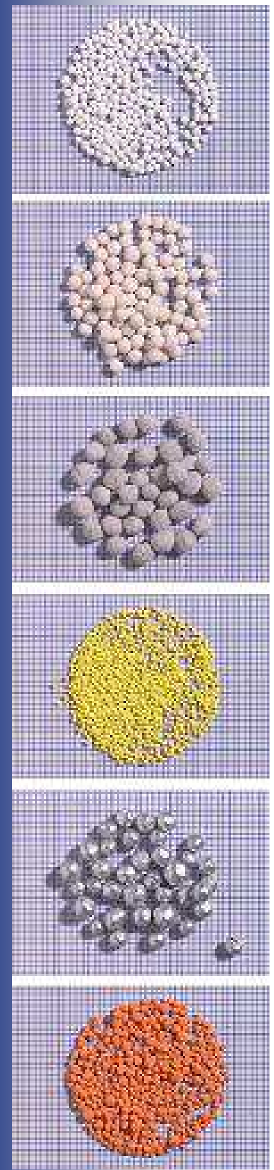


Granulation of fine iron ore + 60+80 % Pelletfeed

Trials in the Test Center 240 kg/batch scale
Mixing + agglomerating in the granulating mixer

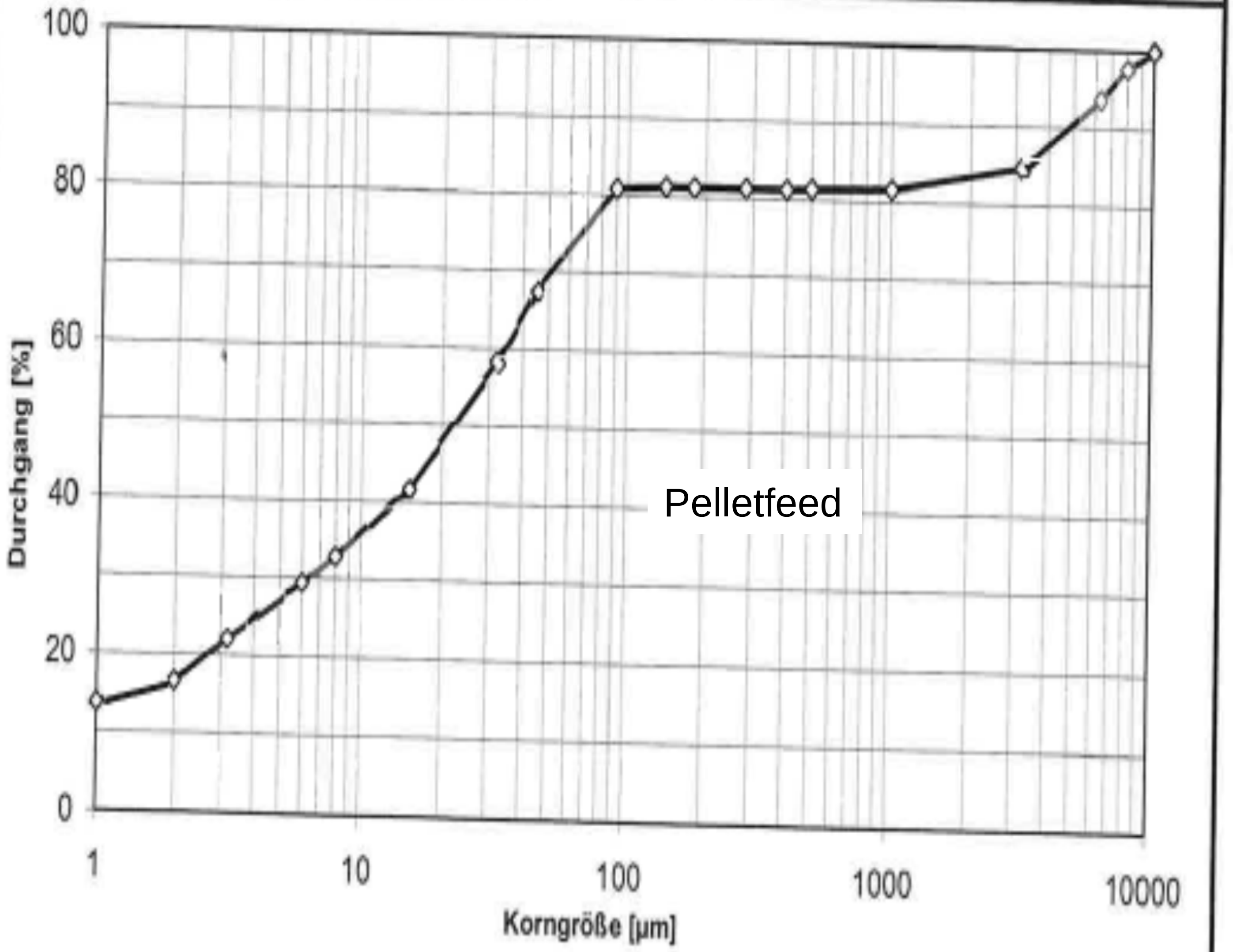
Test Center :

Moisture		5,5 %
1 min	dispersive mixing	7 m/s
1-3 min	agglomeration	2 m/s
binder:	calciumoxide	4 %

Parameter study: adding water in the mixer/ granulator
time difference between mixing and agglomerating

Korngröße	µm	32	45	90	140	180	280	400	500
Fraktion	%	9,39	13,05	0,38	0,00	0,00	0,00	0,16	0,21
Durchgang	%	58,35	67,74	80,79	81,17	81,17	81,17	81,17	81,33

Korngröße	µm	1000	3150	6300	8000	10000	12500	16000	20000
Fraktion	%	3,00	9,10	3,99	2,37	0,00	0,00	0,00	0,00
Durchgang	%	81,54	84,54	93,64	97,63	100,00	100,00	100,00	100,00



Pelletfeed E1411_11_Sieb+Cilas.xls

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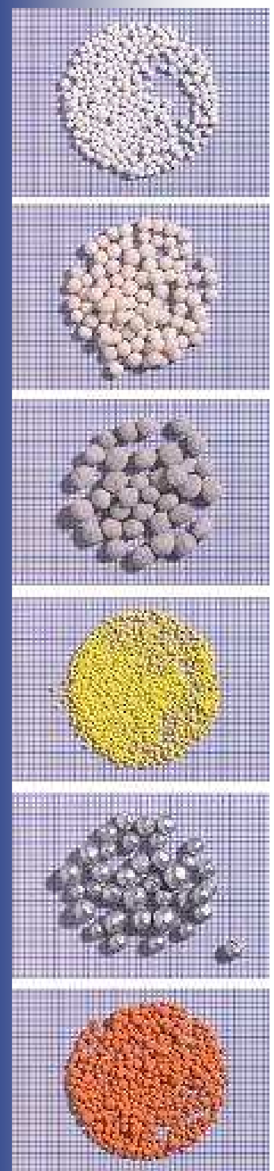

Durchgang	%	6,02	7,24	9,09	11,42	13,92	20,82	27,19	30,25
Korngröße	**µm**	**1000**	**2000**	**3150**	**4000**	**6300**	**8000**	**10000**	**12500**
Fraktion	%	10,76	12,25	6,69	17,56	10,20	2,53	0,00	0,00
Durchgang	%	40,01	50,77	63,02	69,71	87,27	97,47	100,00	100,00

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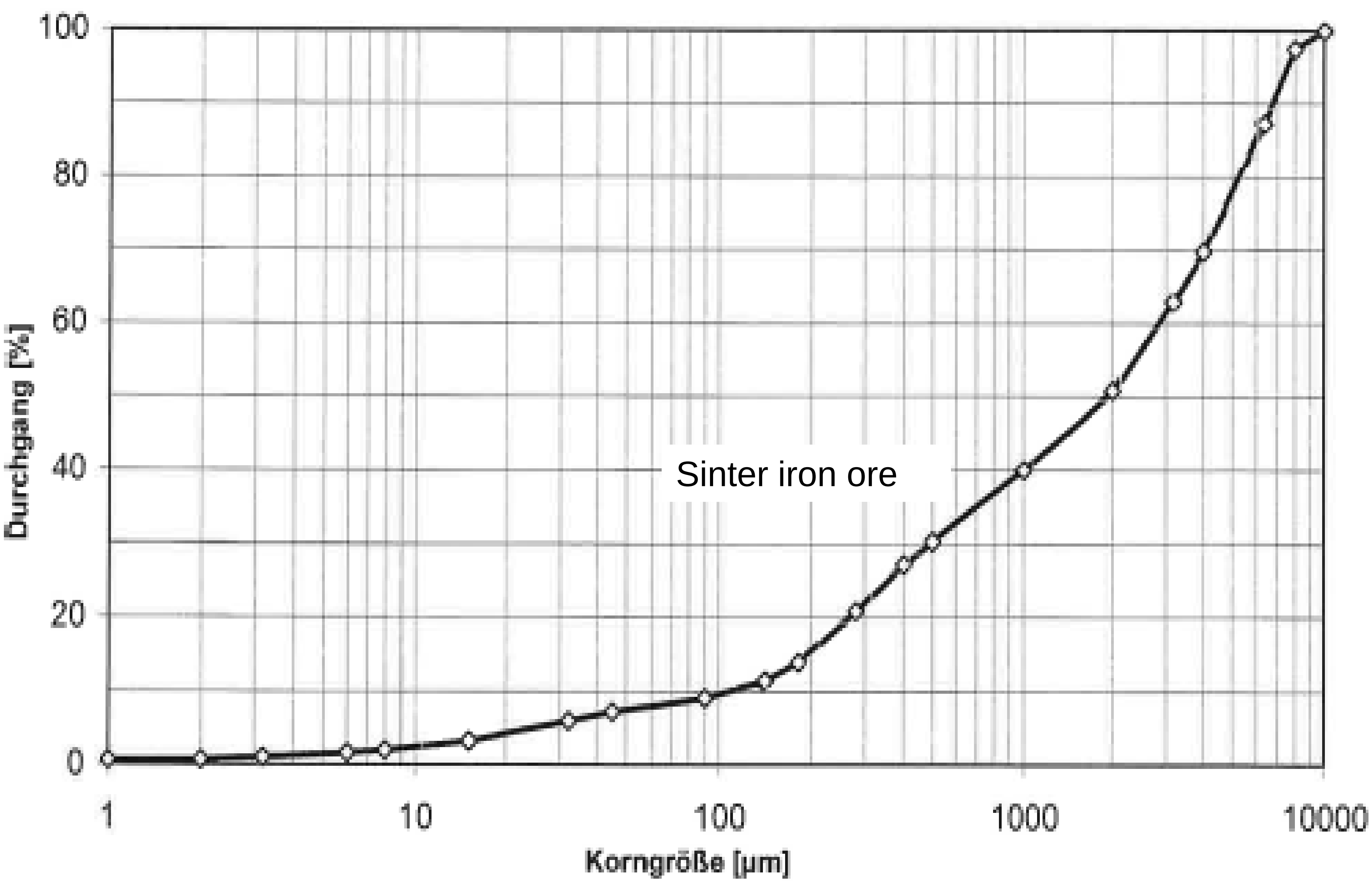

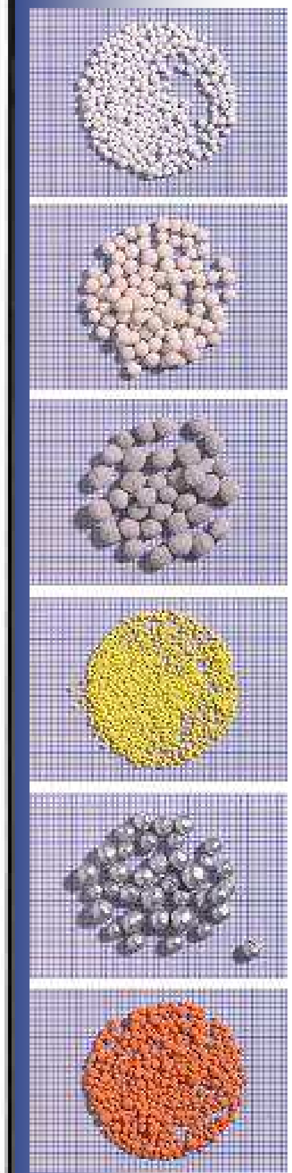

Granulation of Iron Ore Concentrate

+ 60 - 80 % Pelletfeed

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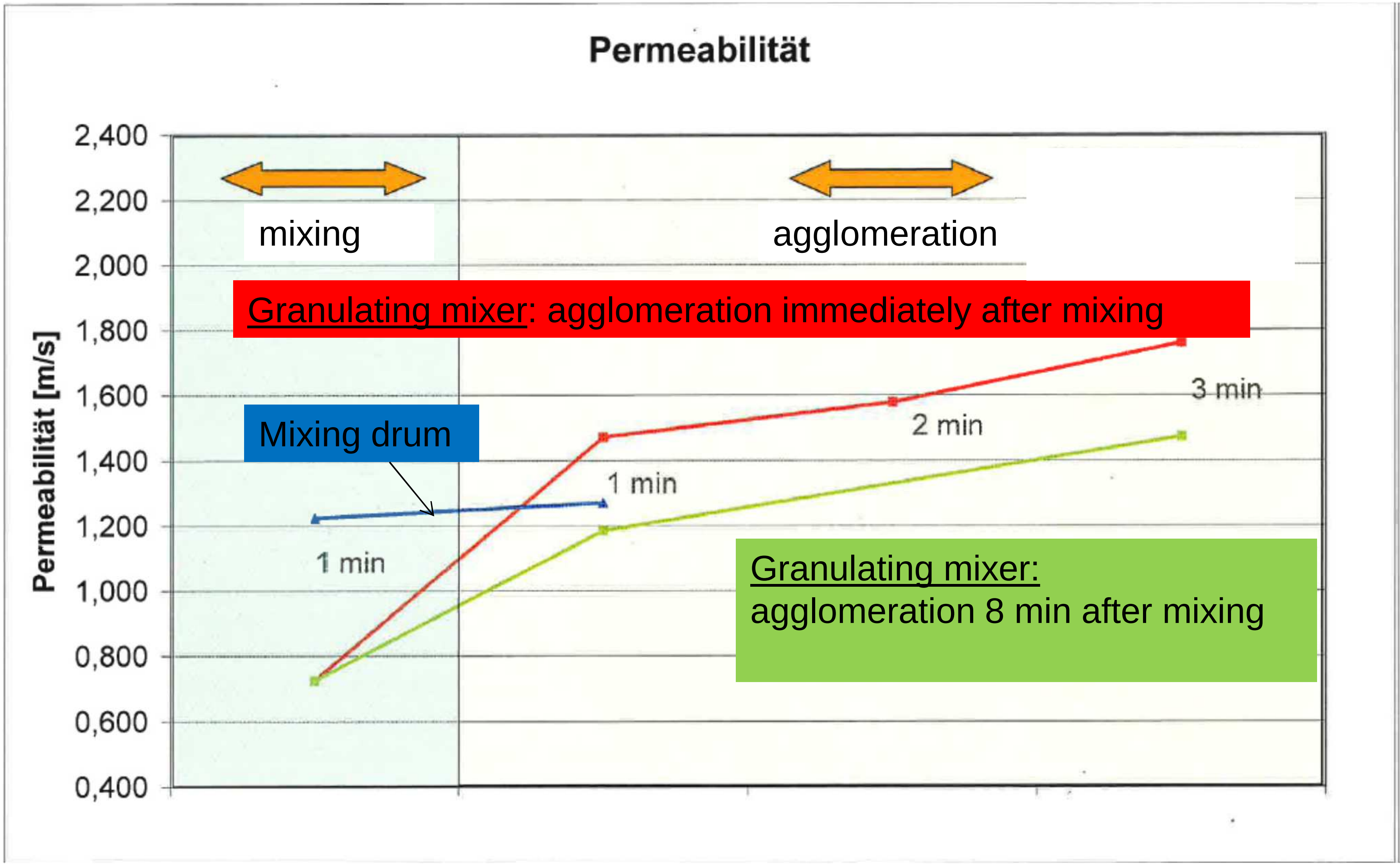

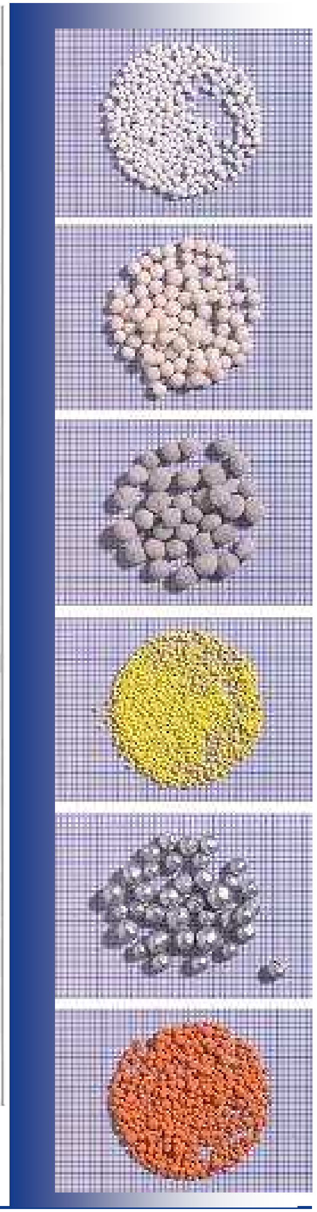

Granulation of Iron Ore Concentrate

+ 60 - 80 % Pelletfeed

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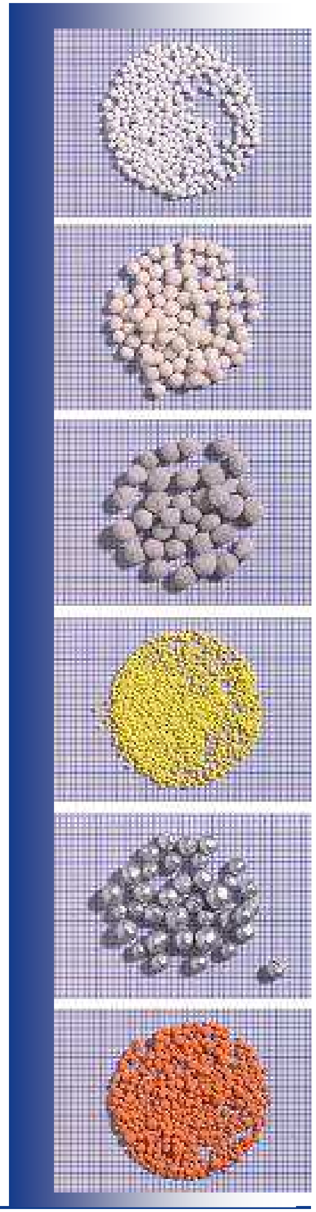
Results



1. After 60 s mixing and 60 s granulating the permeability is very high
2. After 180 s agglomerating in the mixer the permeability is higher than after 240 s in the drum
3. Adding 90 % of the water during mixing and 10 % during agglomerating brings the highest permeability
4. The agglomeration should be done immediately after the mixing
5. 2 m/s tip speed of the rotor is ideal for agglomeration, 7 m/s for the mixing

EIRICH Test Center

Center for process technology

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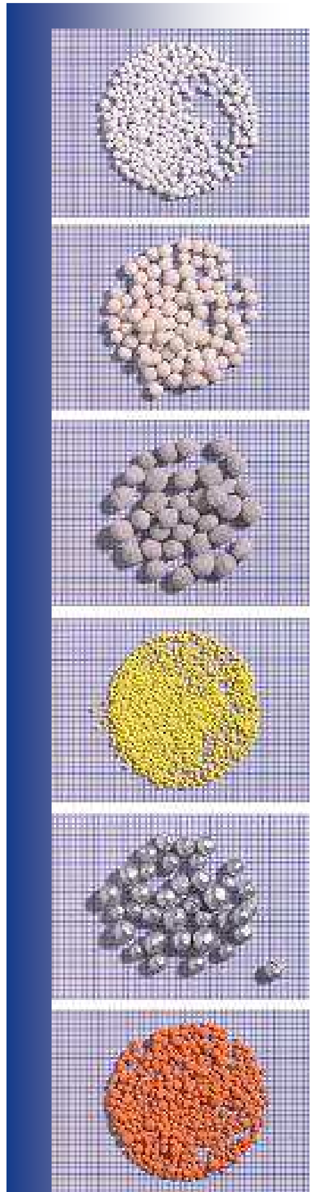
testing - developing - optimizing



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Thank you

for your

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