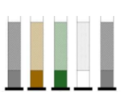
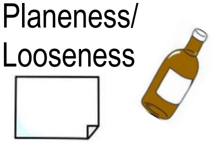
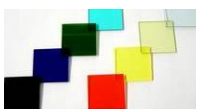
5. Processing and mechanical treatment

Survey of Processing Methods

- Waste = used products; unstructured, mixed, soiled;
- Separate collection + processing
- Waste processing methods have mainly been copied from the processing of original raw materials and, if necessary, been modified for waste processing.
  Only a few of these methods have been specifically developed for waste processing

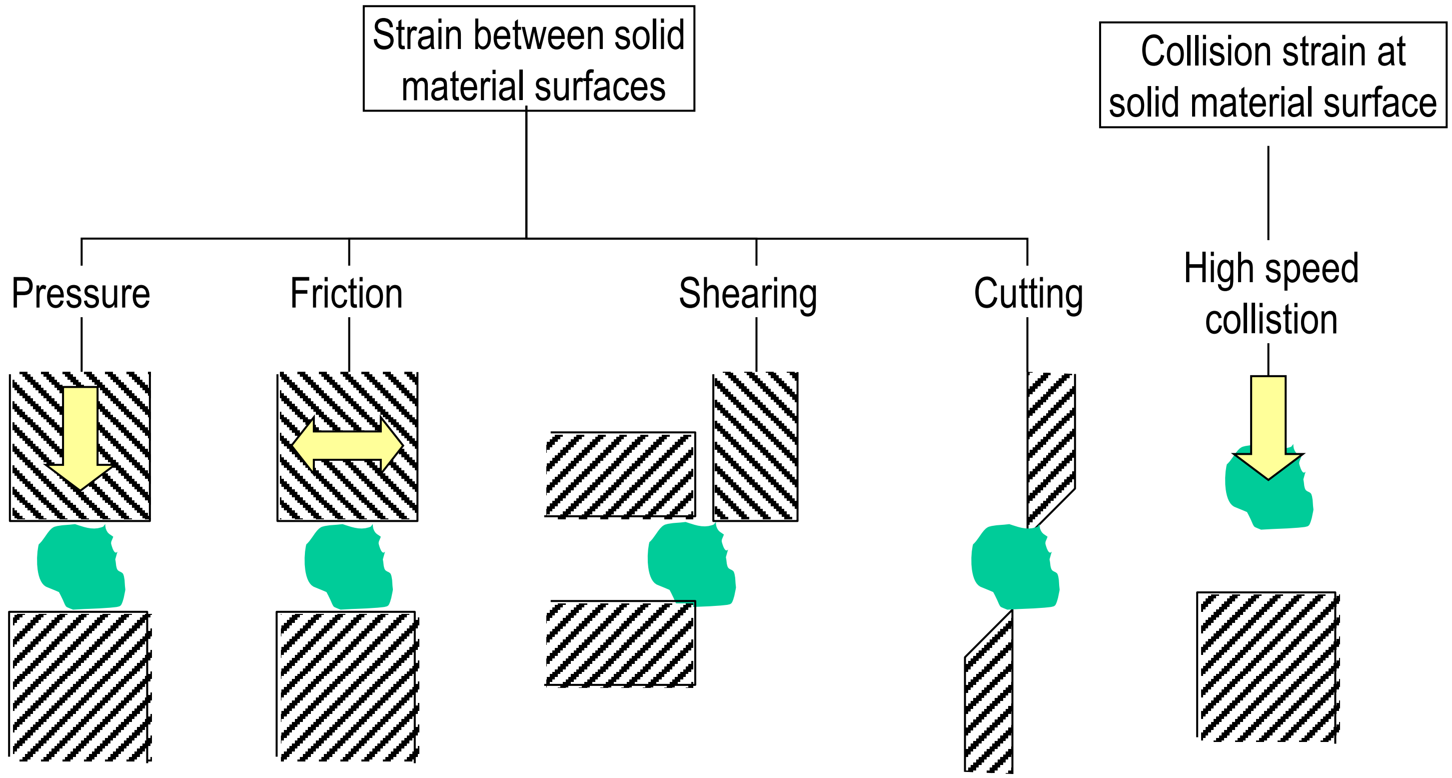
Distinguishing mark	Single methods or aggregate	Environment	Exploited material properties	Application examples for the sorting of potential recyclables
Grain size 	Comminution with mills, shears, cutting and screw rollers, crushers Pulper with tearing, grinding and suspending	dry wet	Hardness, brittleness, elasticity Loss of bonding	Separation of (elastic) metals from (brit-tle) ceramic and glass parts Suspension of cellulose fibres and sep-aration of non-fibrous materials
	Sieving	dry wet	Grain size	Vibrating screen, tension screnn, drum screen, bucket screen Rake, arc or drum sieve
Suspension velocity 	Air sorter Hydraulic sorter	dry wet	Size, density, shape, inertia, wettability	Vertical, zigzag and ballistic sifters, jig-ging machine, oscillating table; float/sink sifter, flotation, hydraulic jigging ma-chine and oscillating table
Planeness/ Looseness 	Rolling goods separator, Slanting belt sorter	Dry	Rolling movement of round parts, adhesion of flat, lighter parts	Separation of round glass and plastic containers from paper, cardboard, and of round building rubble from flat light materials

Survey of Processing Methods

Distinguishing mark	Single method or aggregate	Environment	Exploited material property	Application examples for the sorting of potential recyclables
Magnetic and electric properties 	Magnetic separator	dry	Magnetisability	conveyer belt and drum magnet for the separation of magnetisable metals
	Electro-static or	dry	Surface conductivity	Separation of plastic and paper
	electro-dynamic methods	dry	Conductivity for the production of an eddy-current	Separation of materials with different conductivity, for instance metal and glass
Optical properties 	Optical recognition and sorting	dry	Light transmission and -reflection; colour spectrum	Separation of glass/ceramics; sorting of glass according to colours, diamonds, peas
Visual/optical appearance 	Picture recording, picture evaluation for manual/mechanical picking methods	dry	Colour, size, type, shape, quality	Manual sorting of glass according to colours, wastepaper according to quality, sorting of commercial waste
Chemical or physical properties	Analysers with EDP evaluation and ensuing picking methods	dry	Material properties	Separation of plastic types; extraction of extraneous material

Comminution of Materials - Purpose and Types of Strain

- Comminution of a compound of solids for the following purposes:
  - Preparation for ensuing separation methods
  - Preparation for ensuing chemical reaction methods
  - Production of a grain size necessary for the final product quality



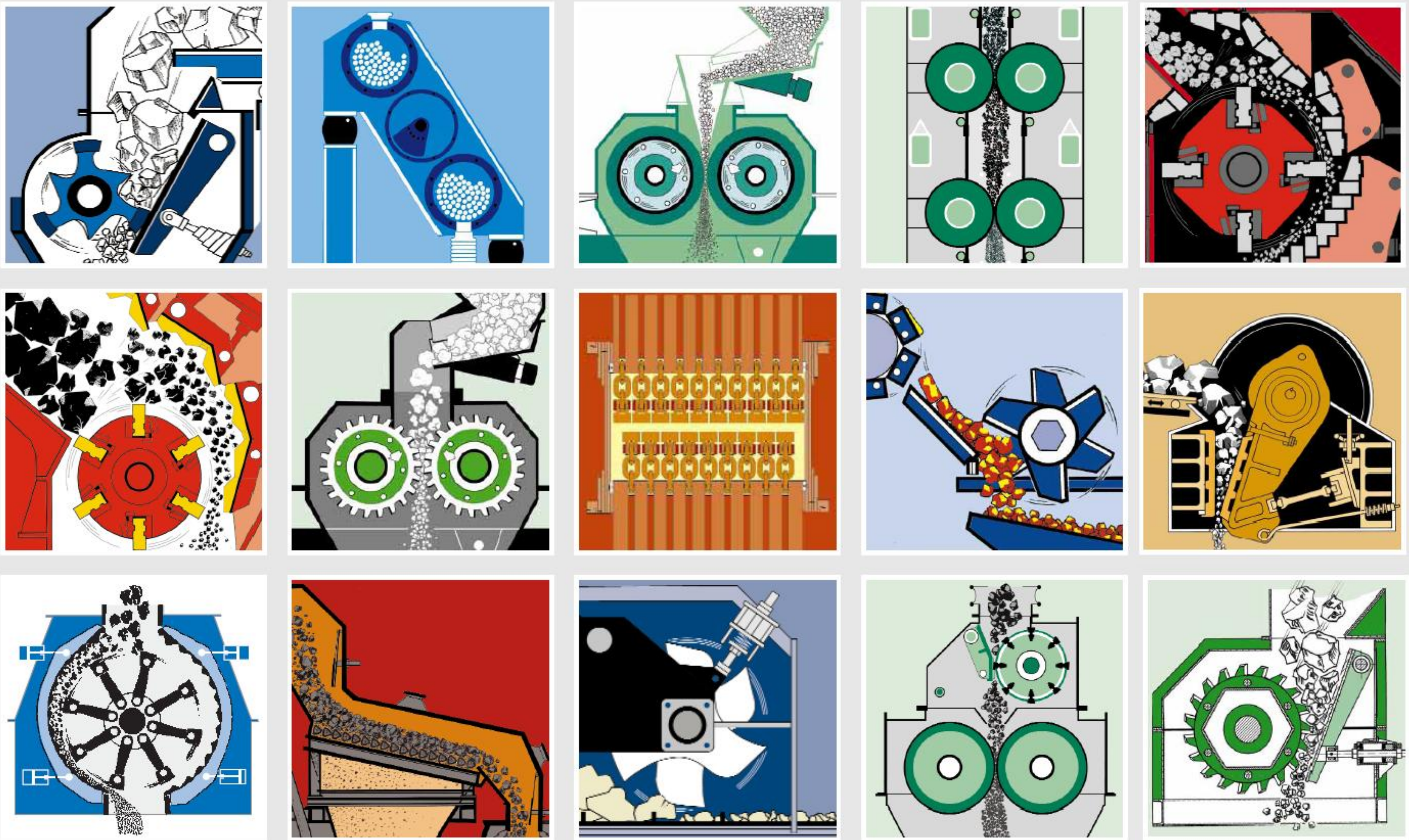
Comminution of Materials

- Typical Application Areas:

++ well applicable
\+ conditionally applicable
\- not applicable

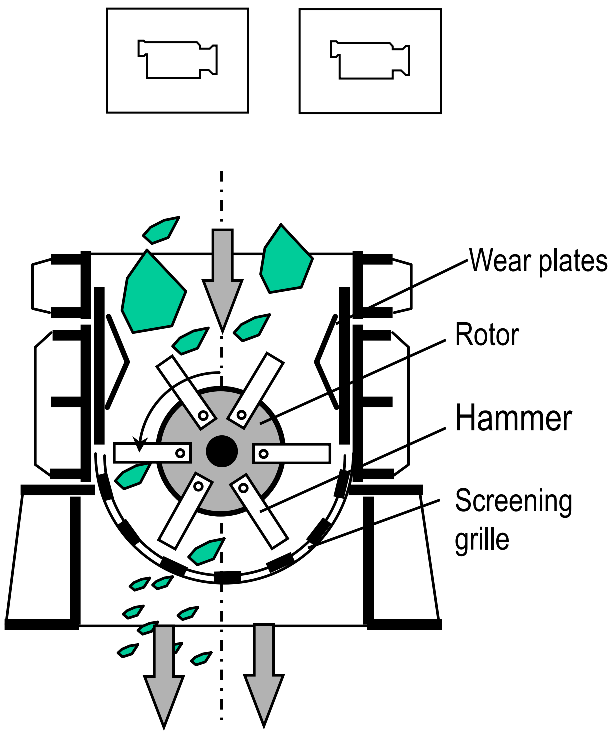
Substance properties	Hitting	Pressure	Shearing	Collision	Cutting	Grinding
hard	++	++	-	-	-	
brittle	++	++	-	++	-	
medium hard	++	++	+	++	-	+
soft	+	+	++	++	++	+
elastic	-	-	-	+	++	
tough	-	-	-	++	++	
fibrous	+	-	+	+	++	+
heat-sensitive	-	-	-	++	+	
typical aggregates	baffle or hammer mill	breaker	cutting mill	baffle or hammer mill	cutting mill	Cascade

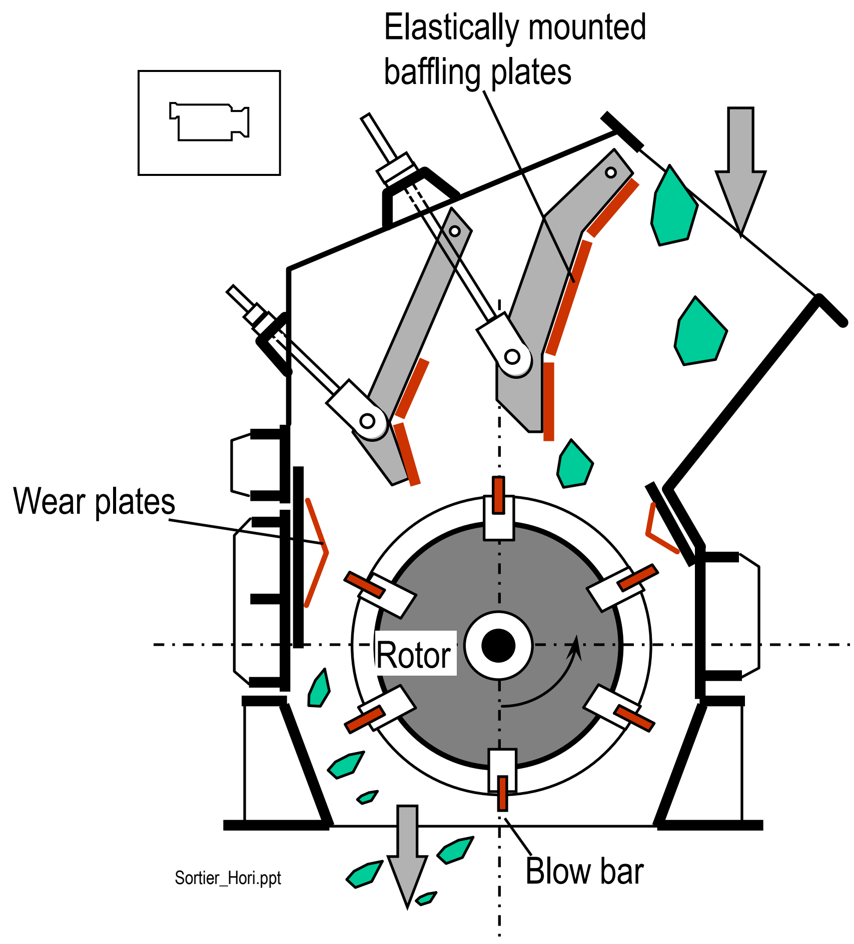
AUBEMA Crushing Technology



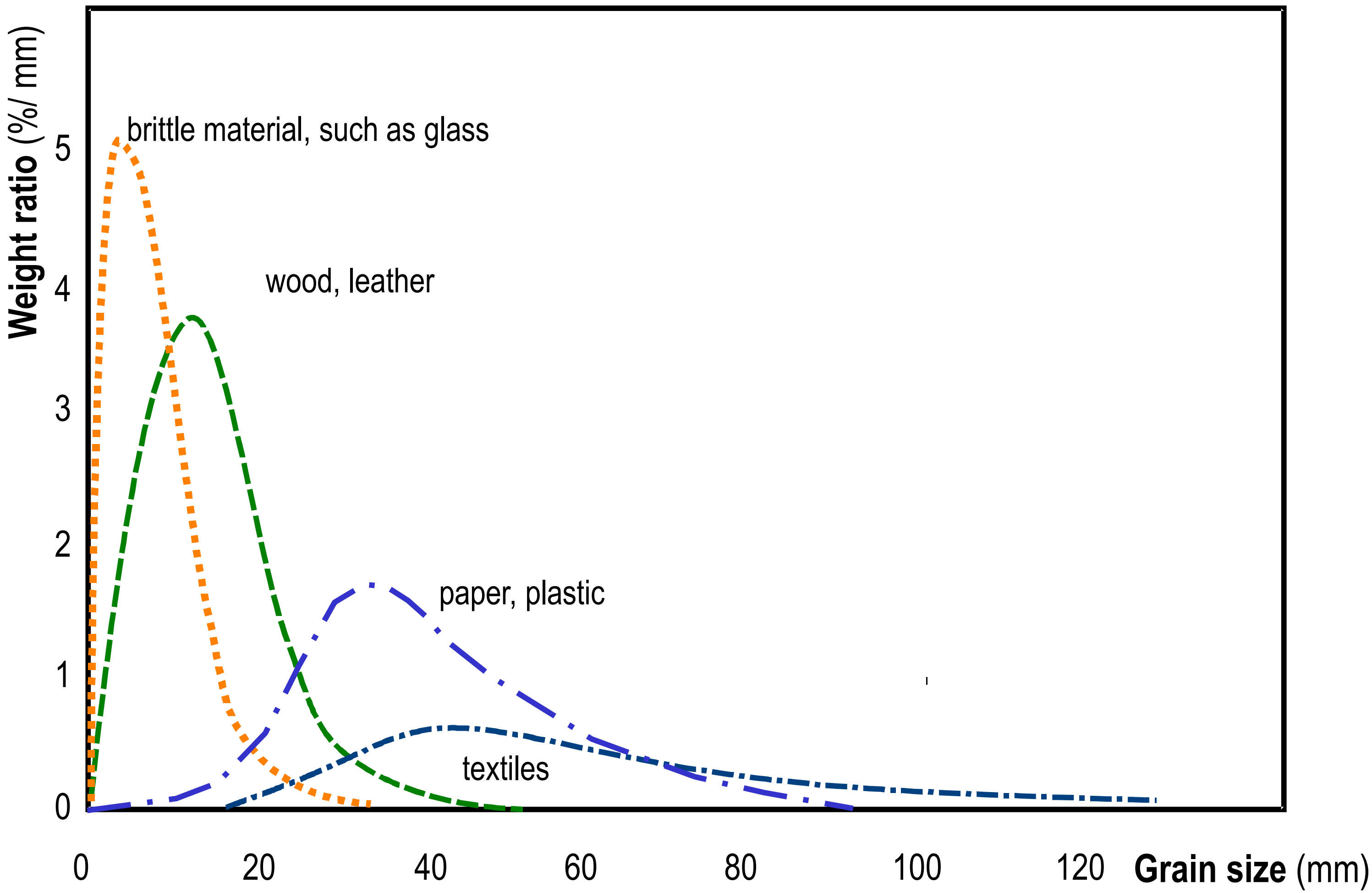
Hammer crusher/ Hammer Mill /Baffle Mill

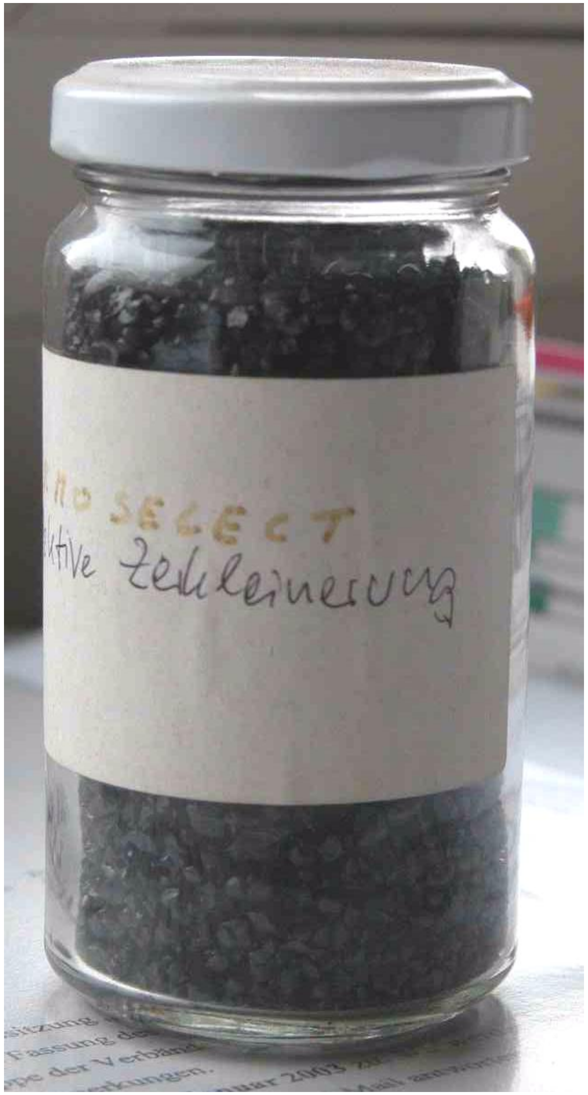
- High-speed device with v_u = 40 - 80 m/s
- Ex-Risiko





Grain Size Distribution Density after Selective Comminution with High-Speed Devices qualitative; according to Bilitewski, 1985



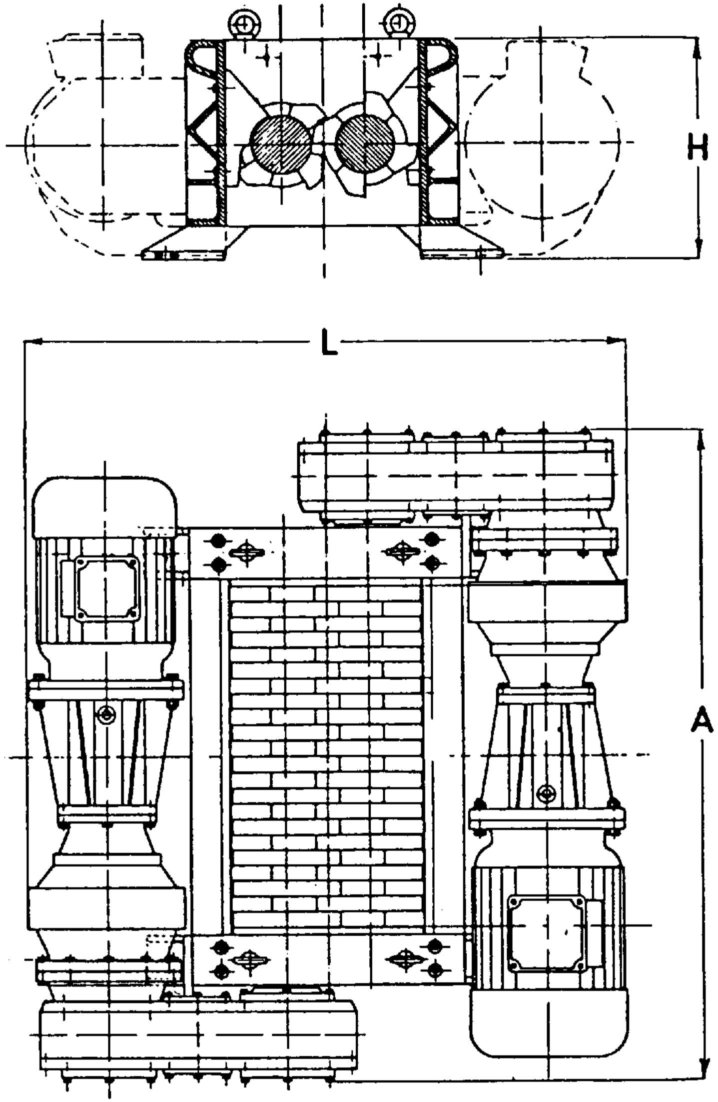


- Separation into
  - glass,
  - screwed metal cap, and
  - label

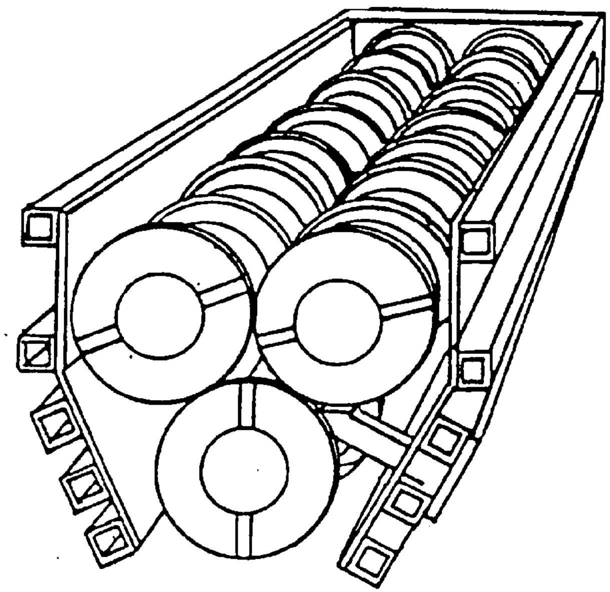
- selective comminution
- separation through sifting/air sifting

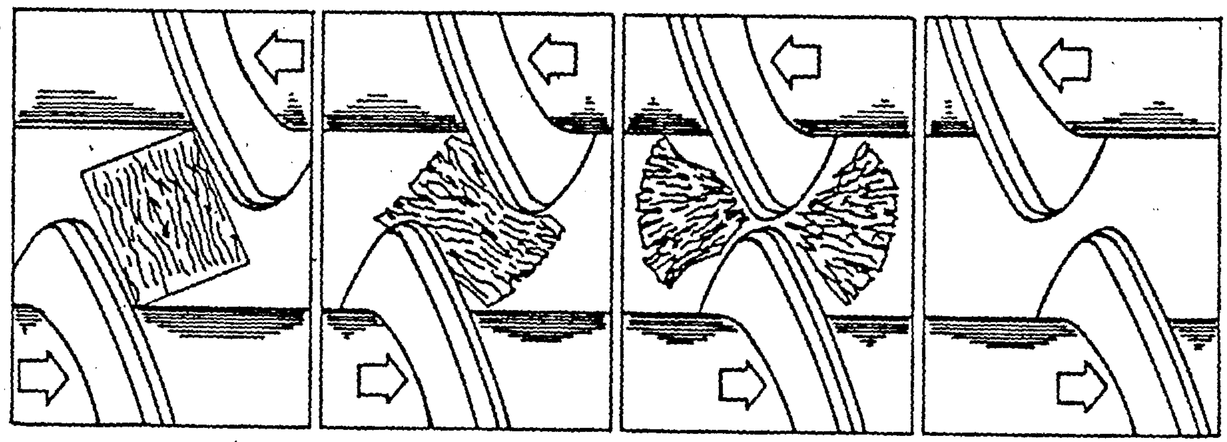
- the same effect with the separation of
  - (brittle) concrete and
  - (elastic) steel reinforcement

Cutting Roller Mill – Low-Speed Device



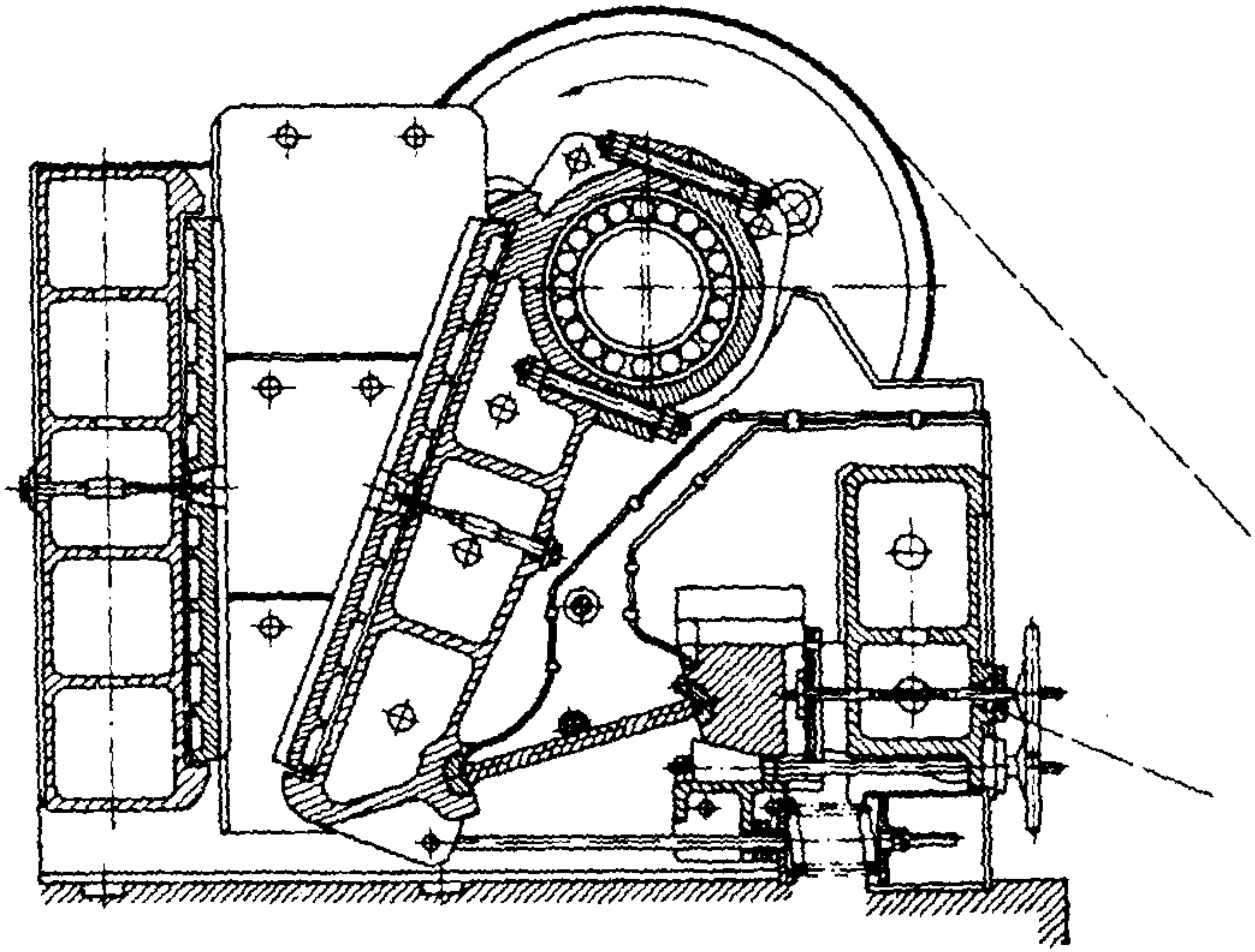
Screw Roller Mill – Low-Speed Device

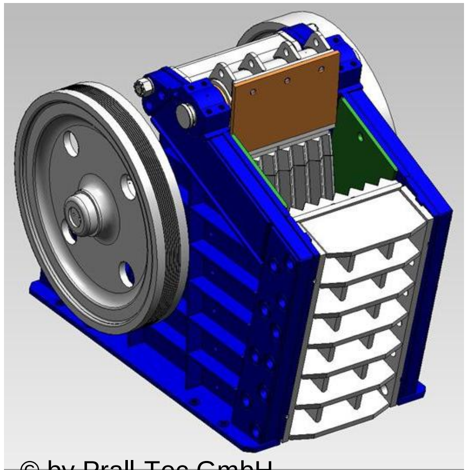




Crank Wing Breaker - SKET Design

- Comminution of brittle materials under high pressure





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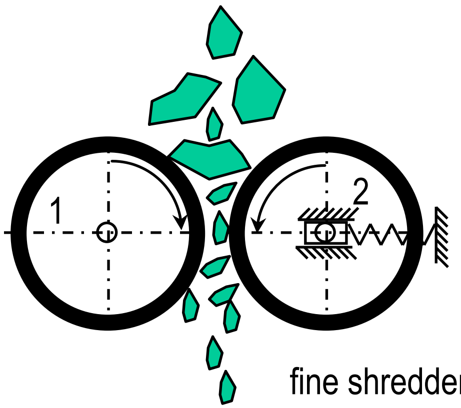
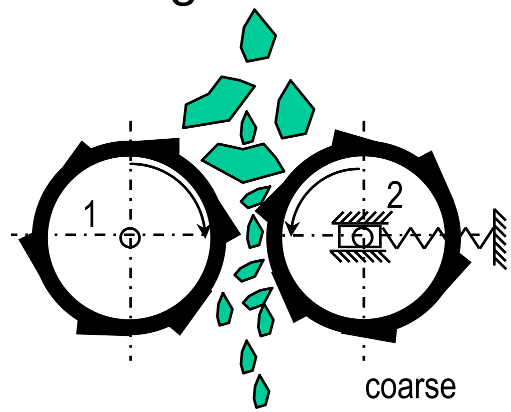
Roller shredder

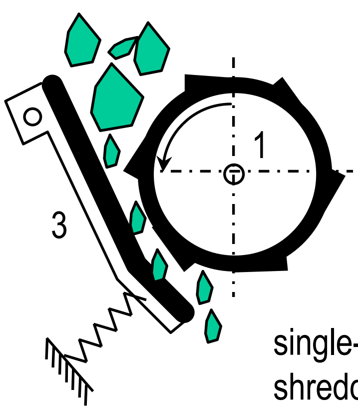
- Comminution of brittle materials
- if armoured with teeth, also suitable for coarse waste, such as bulky waste, commercial waste, building waste



fine shredder



coarse crusher



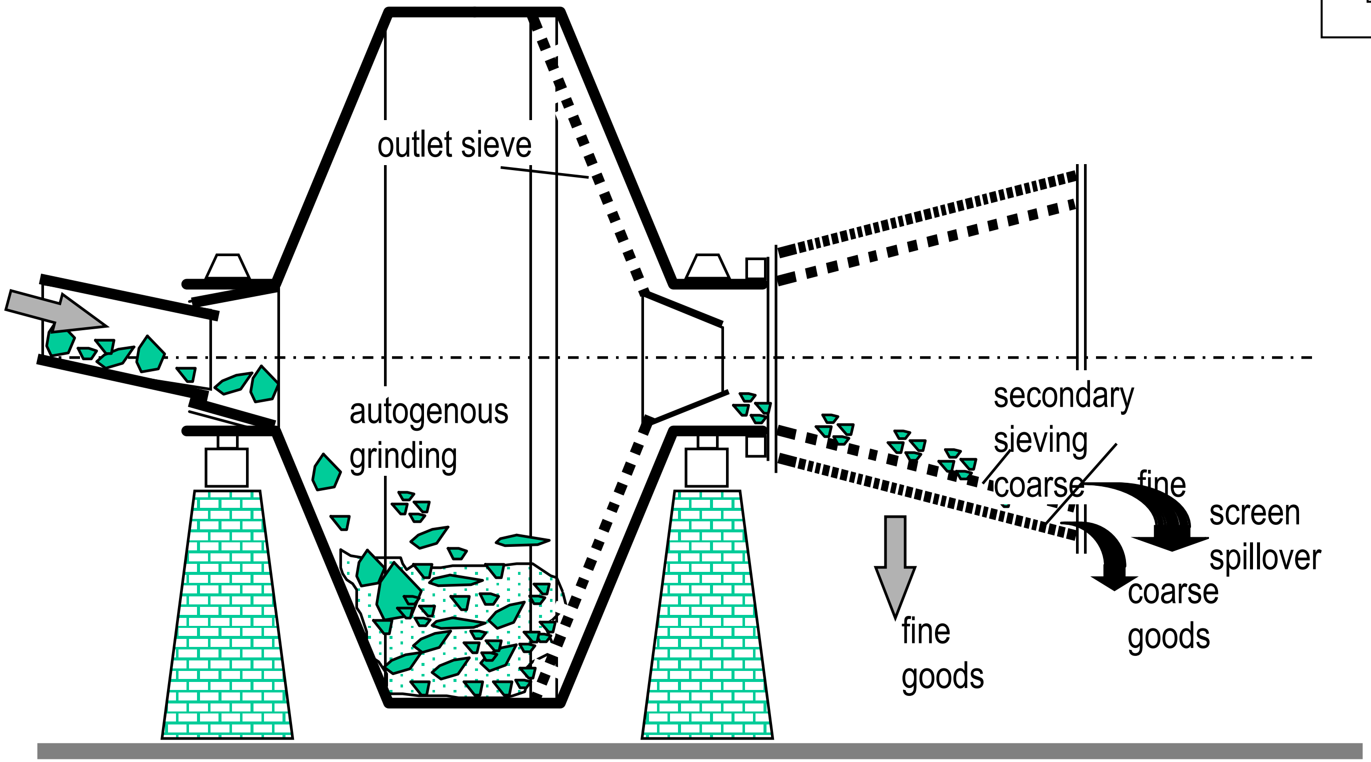
single-shaft shredder

1 firmly mounted roller
2 slidably mounted roller
3 rocker

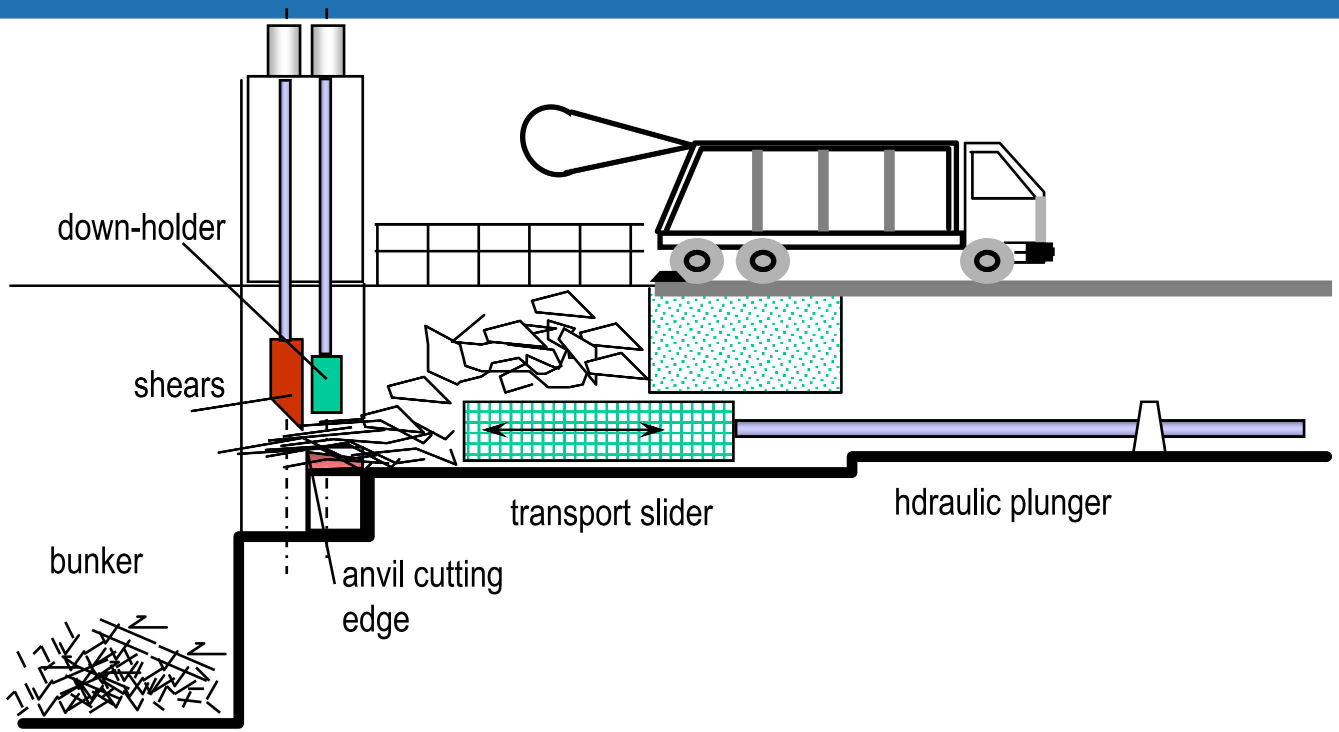
Sortier_Hori.ppt

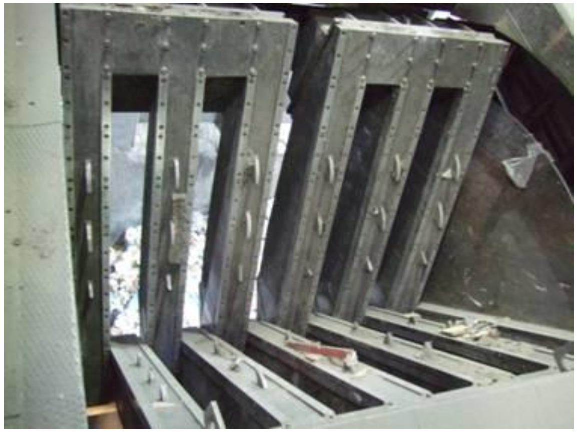
Pebble Mill Waste Cascade, Lösche Design

- Origin: rock and ore processing;
  very powerful and sturdy;
  Comminution and screening in one aggregate

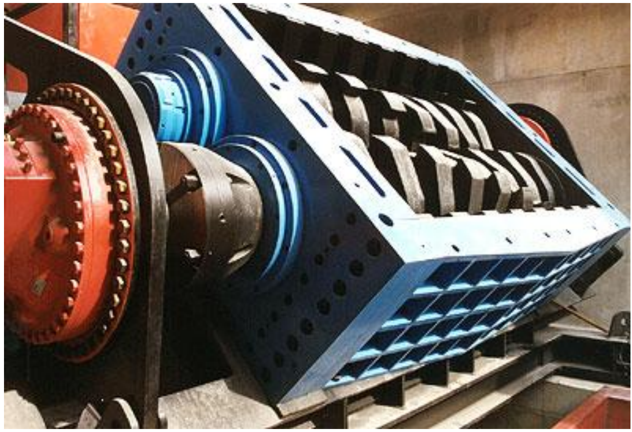


Bulky waste Shears





Bulky waste shear
(70 m³/h)
J. Stiefel, Wetzikon, ch



Bulky waste shear
(2775 t/a)
of T.A. Lauta

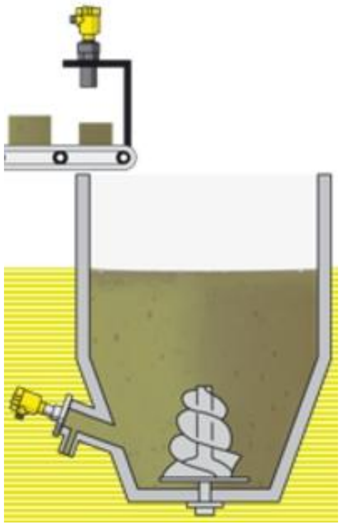
Cryogenic Comminution

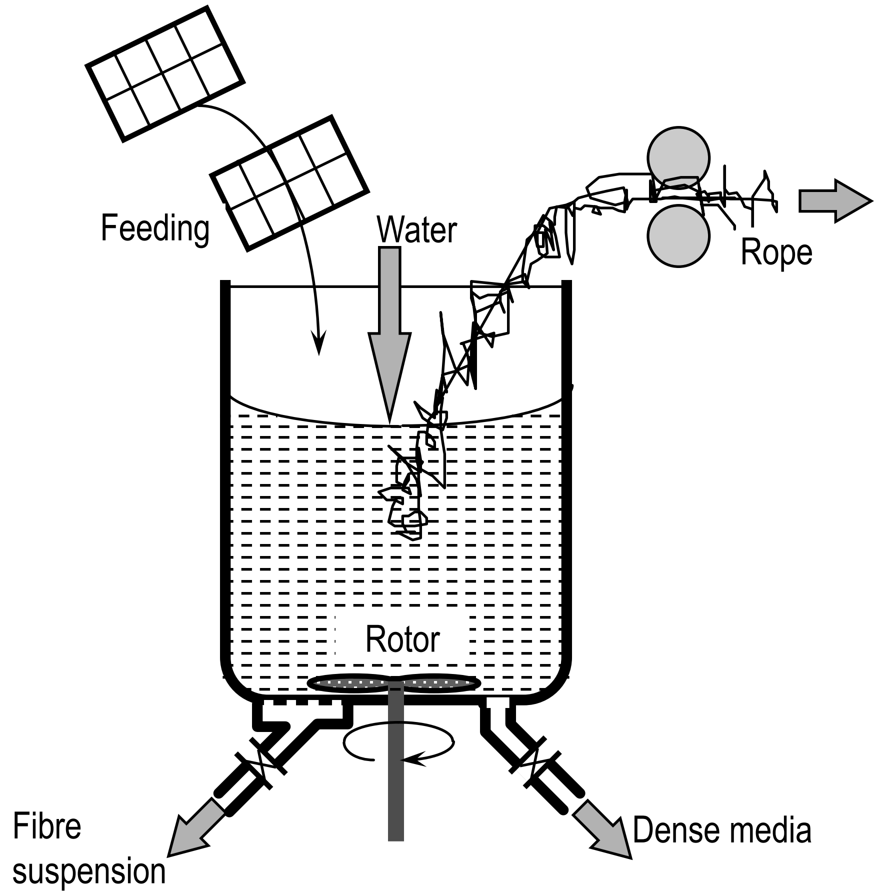
- selective comminution with the help of cooling agents (for instance liquid nitrogen), with at least 1 component embrittleable:
  - copper ≤ 200 °C
  - aluminium ≤ 200 °C
  - steel - 100 °C
  - old tyre rubber - 80 °C
  - polyethylene - 50 °C
  - PVC - 50 °C

- Applicable, for instance, for
  - old tyres into rubber and steel cords
  - electric motors/lighting dynamo into copper and steel
  - screw caps of mineral water bottles into aluminium and PVC sealing

Pulper

- Separation of paper fibres, dense media, and extraneous materials





Specific Efforts for Comminution according to BOND

$$\text{Specific efforts } W \text{ (kWh/t)} = 10 \cdot W_i \cdot \left(\frac{1}{\sqrt{x'_{80}}} - \frac{1}{\sqrt{x_{80}}} \right)$$

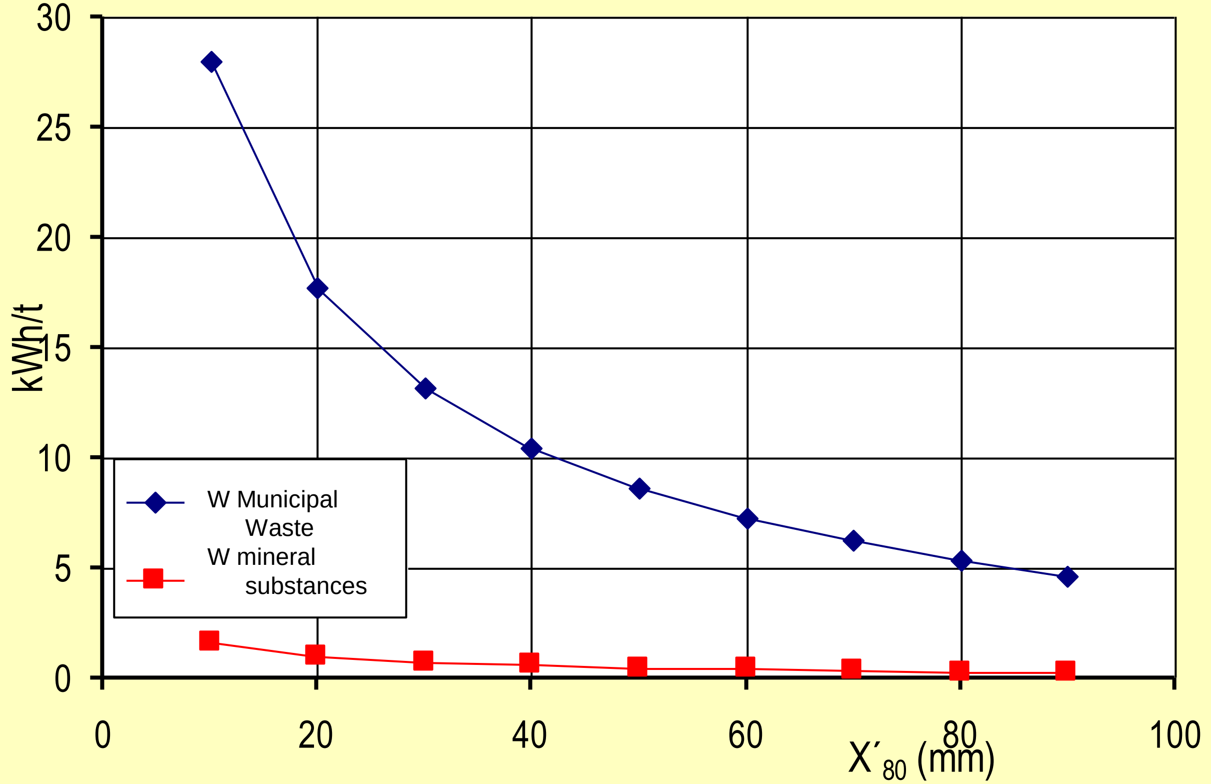
with

W_i (kWh/t) = work index at x'_{80} = 100 µm; substance specific for municipal waste, for instance, approx. 100-500 for mineral substances approx. 10- 25

x_{80} (µm) = 80 %- grain size of the fed material

x'_{80} (µm) = 80 %- grain size of the comminuted goods

bei x_{80} = 250 mm; Wi SiA = 350 und Wi min. = 20 kWh/t;



Principles of Screening

- Separation into <u>screening residue</u> R (screen spillover), and <u>screenings</u> D (screen underflow)
- in ideal cases (screening quality grade s = 100%):
  neither oversize grains in the screenings (c_c = 100 %)
  nor undersize grains in the screen overspill (c_b = 0 %).
- in non-ideal cases screening quality grade s (%) (acc. to SCHUBERT Vol. I):

$$\text{screening quality grade s (\%)} = \frac{(c_a - c_b) \cdot (c_c - c_a) \cdot 100}{(100 - c_a) \cdot (c_c - c_b) \cdot c_a} \times 100$$

with:

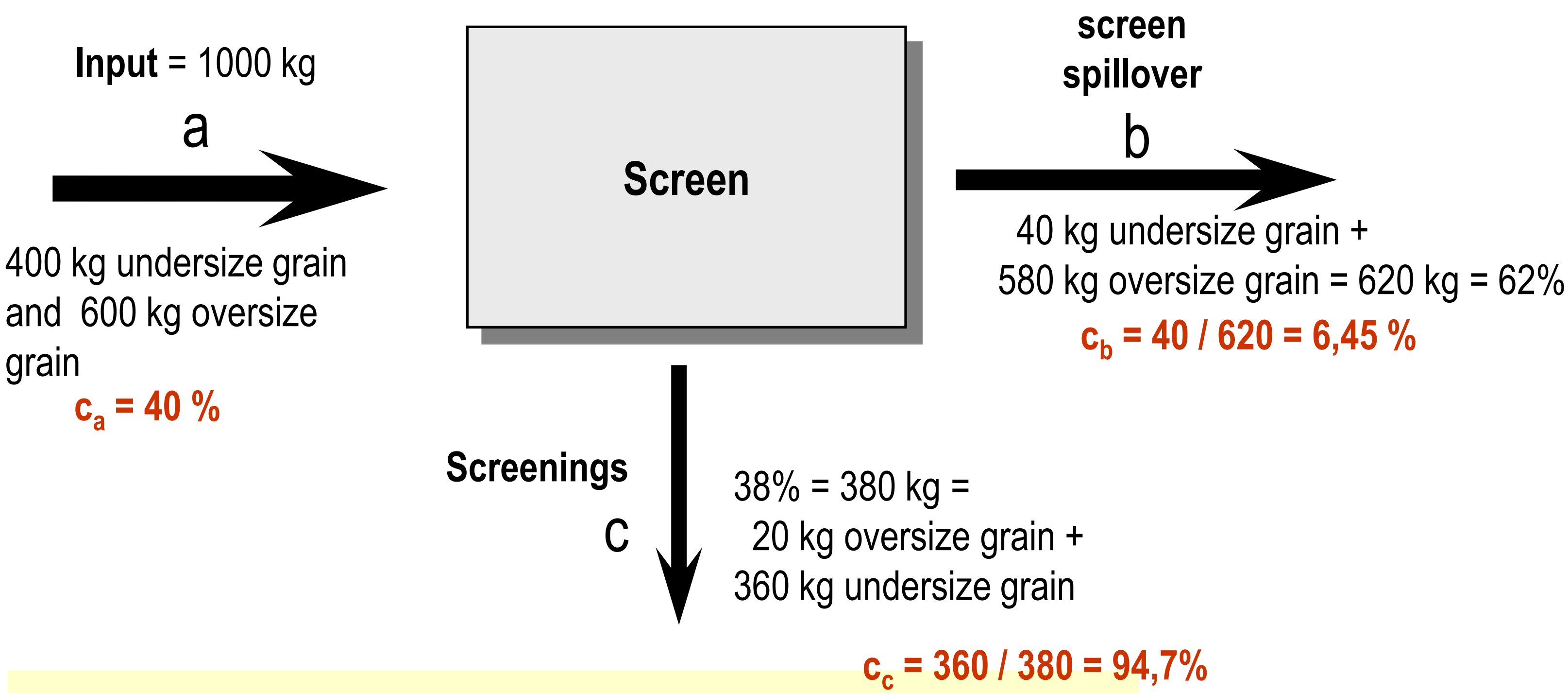
c_a = undersize grain contents (% of the charging goods)
c_b = undersize grain contents (% of the sieve spillover)
c_c = undersize grain contents (% of the screenings)

If no oversize grain appears in the screen underflow (tunner grain) (c_c = 100 %), the equation above can be reduced to:

$$\text{sieving quality grade s (\%)} = \frac{(c_a - c_b) \cdot 100}{(100 - c_b) \cdot c_a} \times 100$$

$$\text{or} = \frac{\text{fine grain in the screenings (kg)}}{\text{fine grain in the feeding goods (kg)}} \times 100$$

Example Sieving Quality Grade



Screening quality grade s (%) = $\frac{(c_a - c_b) \cdot (c_c - c_a) \cdot 100}{(100 - c_a) \cdot (c_c - c_b) \cdot c_a} \times 100$

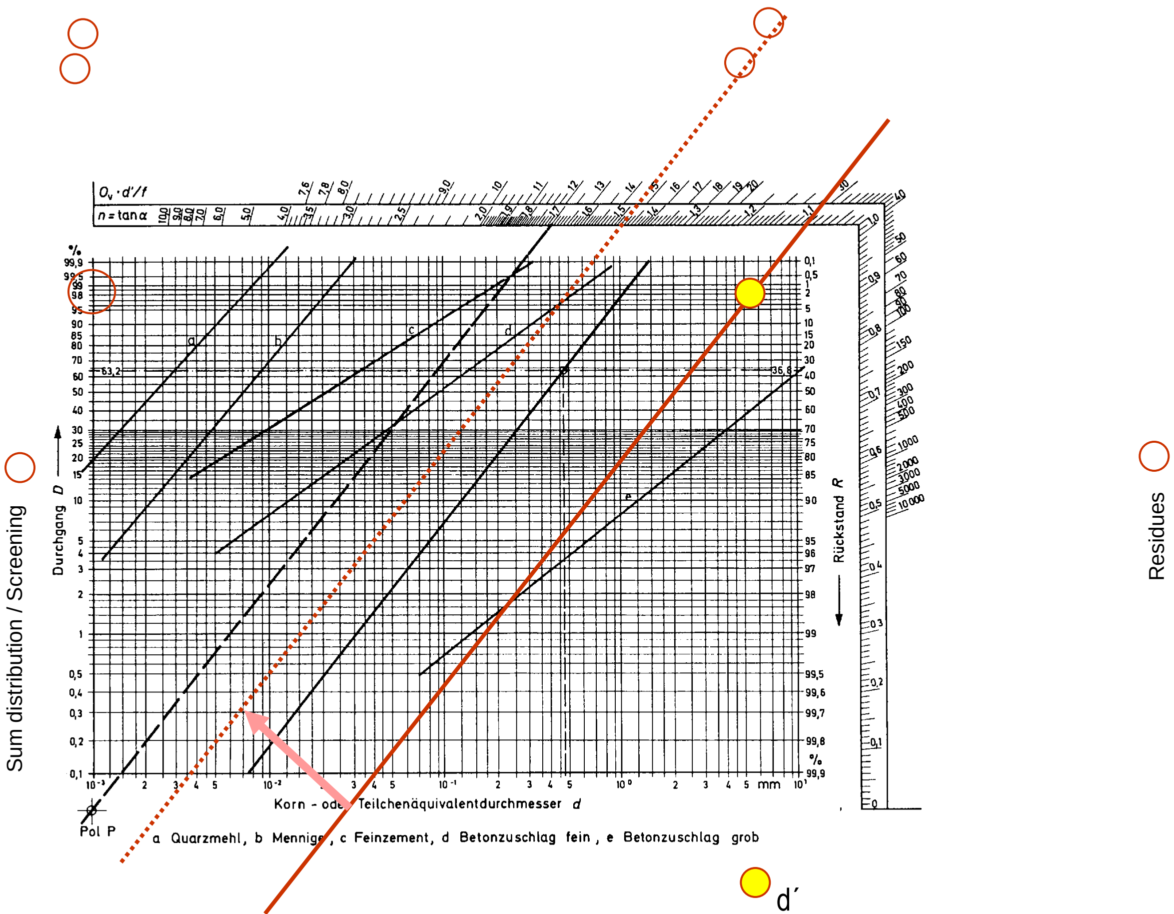
c_a = undersize grain contents (%) of the charging goods
c_b = undersize grain contents (%) of the screen spillover
c_c = undersize grain contents (%) of the screenings

s = (40 - 6,45)·(94,7 - 40) · 100 · 100% / ((100 - 40) · (94,7 - 6,45) · 40)
= 86,6 %

RRSB Graining Grid according to **R**OSIN / **R**AMMLER / **S**PERLING AND **B**ENNET

cf. DIN 66145

d´and n = particle parameter of the RRSB straight lines



Grain or particle-equivalent diameter

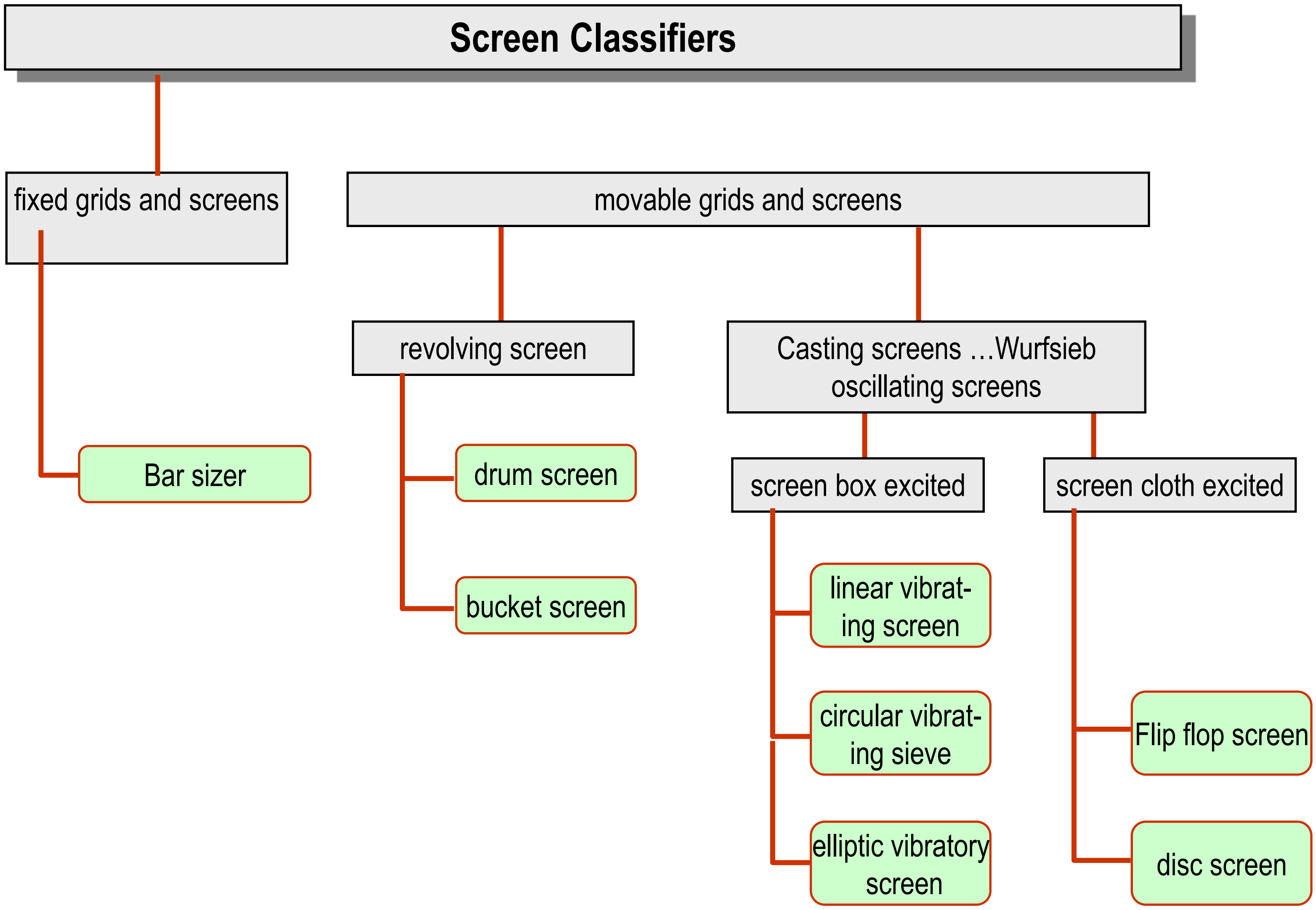
a: Quartz flour, b: red lead, c: fine cement, d: concrete aggregate fine, e: concrete aggregate coarse

$D(d) = 1- R(d) = (d/d_{max})^m$, $\lg D(d) = m \cdot \lg d + const$

- **lg lg 1/R = n lg d + constant**
- **R** = screening residues/spillover
- **n** = constancy coefficient = tan α = inclination of the straight line shifted through Pole P
- D = 1-e^{-1} = 0,632 resp. R = 0,368
- **d'** = grain size mean, read at **63,2%** of the cummulative oversize curve D or at 36,8% of the cummulative downsize curve R
- **Ov** = specific surface (cm²/cm³); to be determined of the index number O_v * d'/f (read for d' =1 and f=1 through parallel shifting of the straight line in the RRSB grid through the pole) and multiplication with actual f/d' for the respective solid (cf. HEMMING, 1975)
- **f** = form factor (= ca. 1 to 10) as relation of the surface of a body to the surface of a globe with the same volume (f=1)
- Example:
  $O_{vreal} = (O_v*d´/f_{Pol}) * f_{Sand}/d´_{Sand}$ = 12 * 1,43 / 0,48 = 37 cm² / cm³

Cork	1,98
coal dust	1,75
sand, round	1,43
glass, angular	1,9
tungsten powder	1,18

Systematics of the Grids and Sieves according to Uhlig in Thome



General Aspects for the Screen of Waste

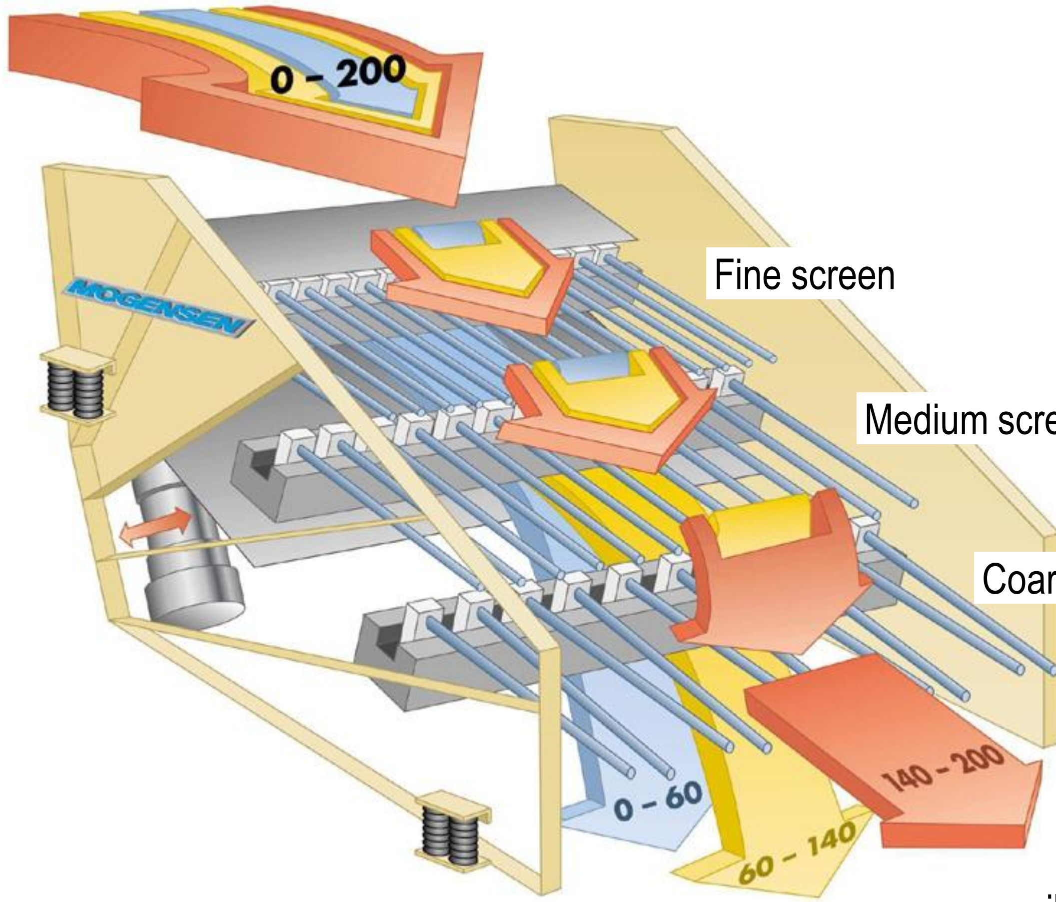
- In contrast to mineral material:
  with waste, there is bonding and clogging >>
  self-cleaning !!

- Suitable for waste are mainly:
  - drum screens
  - bucket screens
  - bar screens
  - Flip flop screen

- Separation of identical substance types according to grain size (coarse or fine compost), or

- Sorting according to grain size for the separation of different types of materials (example: bottles)

Bar Sizer



Fine screen

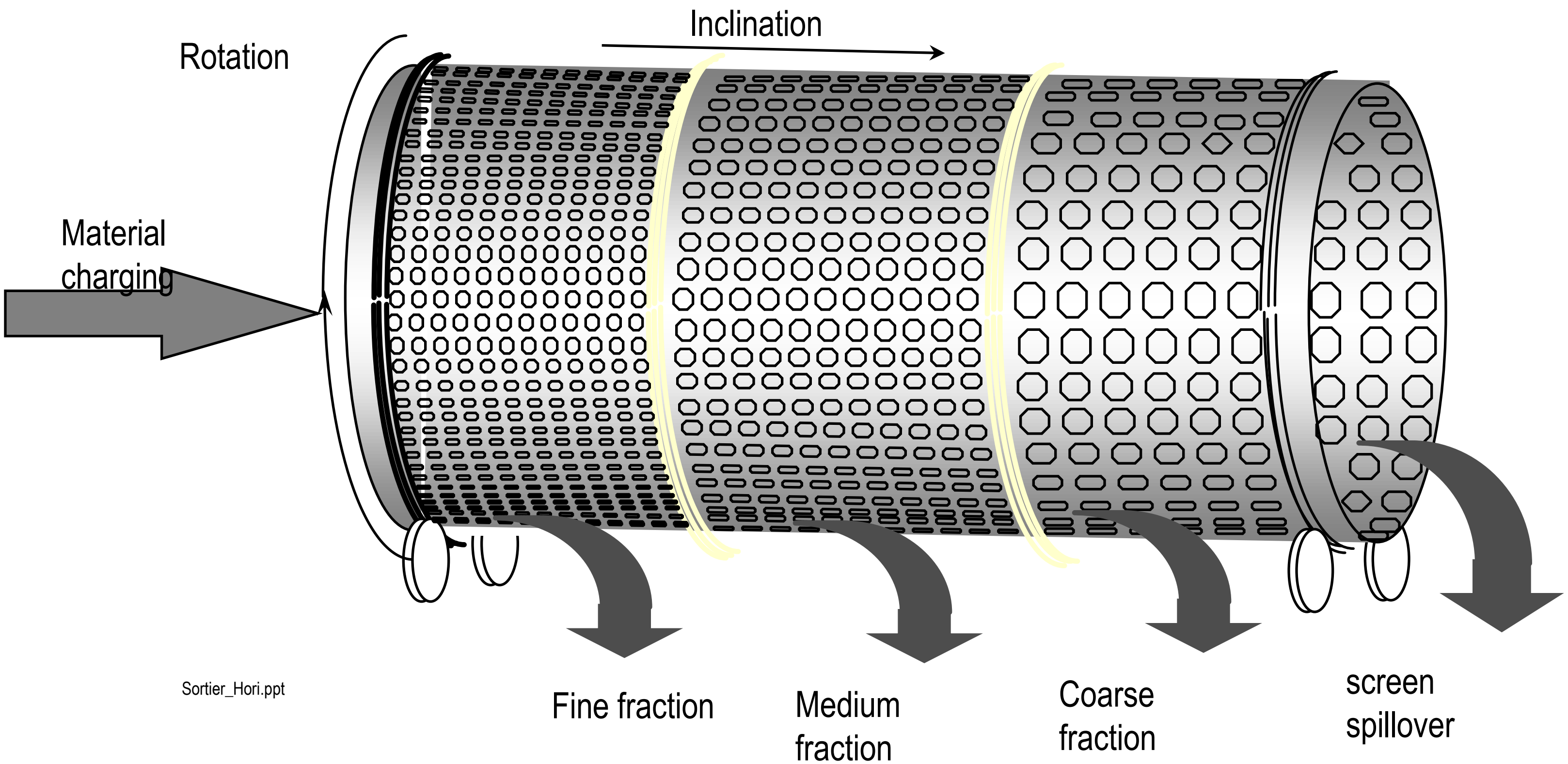
Medium screen

Coarse screen

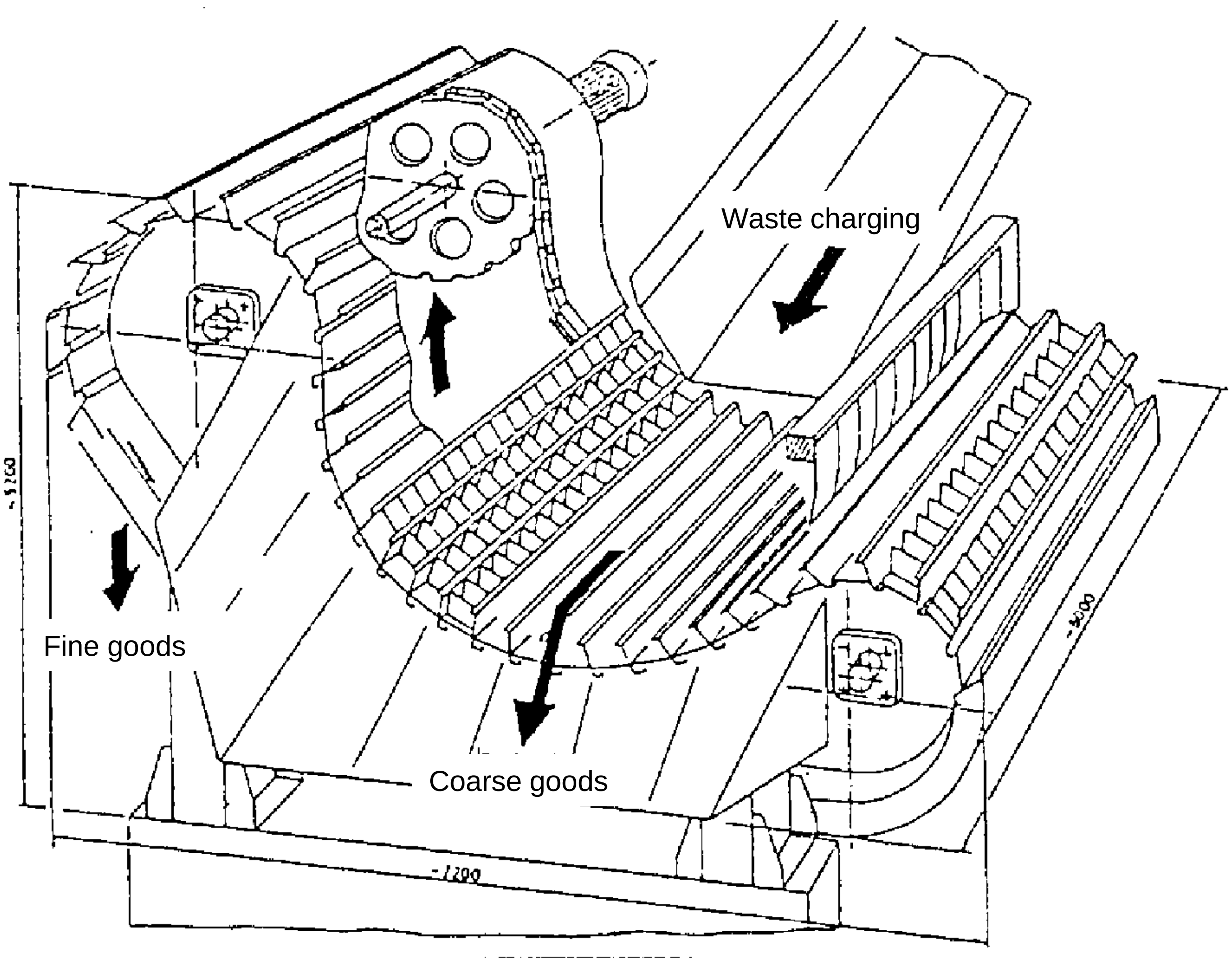
screen spillover

Drum Screen

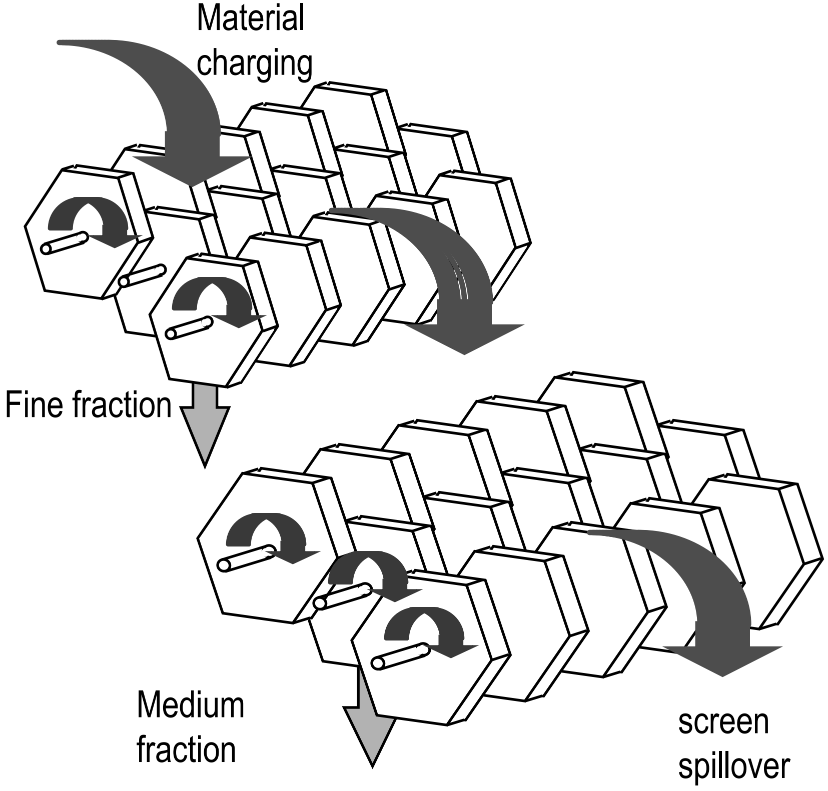
- under certain conditions self-cleaning
- several screen fractions in one aggregate



Bucket Screen



Disk Sifter



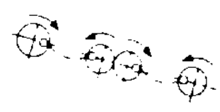
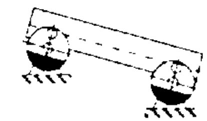
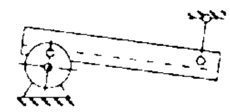
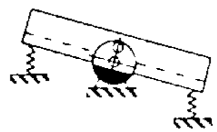
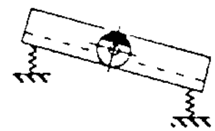
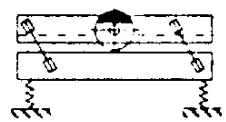
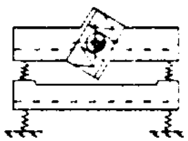
Material
charging
Fine fraction
Medium
fraction
screen
spillover

Sieving machines according to UHLIG in THOME-KOZMIENSKY, 1992, S. 292

Linear swinger sieving machine

Double imbalance sieving machine

Eccentric sieving machine

		screen cloth excited	Screening box excited		
		Lagging swinging screening machines	Circular swinging Screening machines	Elliptical swinging Screening machines	Linear swinging Screening machines
Compulsion drive (range-restricted)	subcritical				
	hypercritical				
Mass force crive (power-restricted)					
					
Spring force drives (power-restricted)	Resonance				

Basic Data of Swinging / Vibrating Screens

- The crucial factors are the vibration frequency f (sub-critical, critical (resonance) and hyper-critical) and the vertical acceleration a_v.
  With circular vibrations with the turning radius r and the frequency f, the centrifugal acceleration equals the = **vertical acceleration**

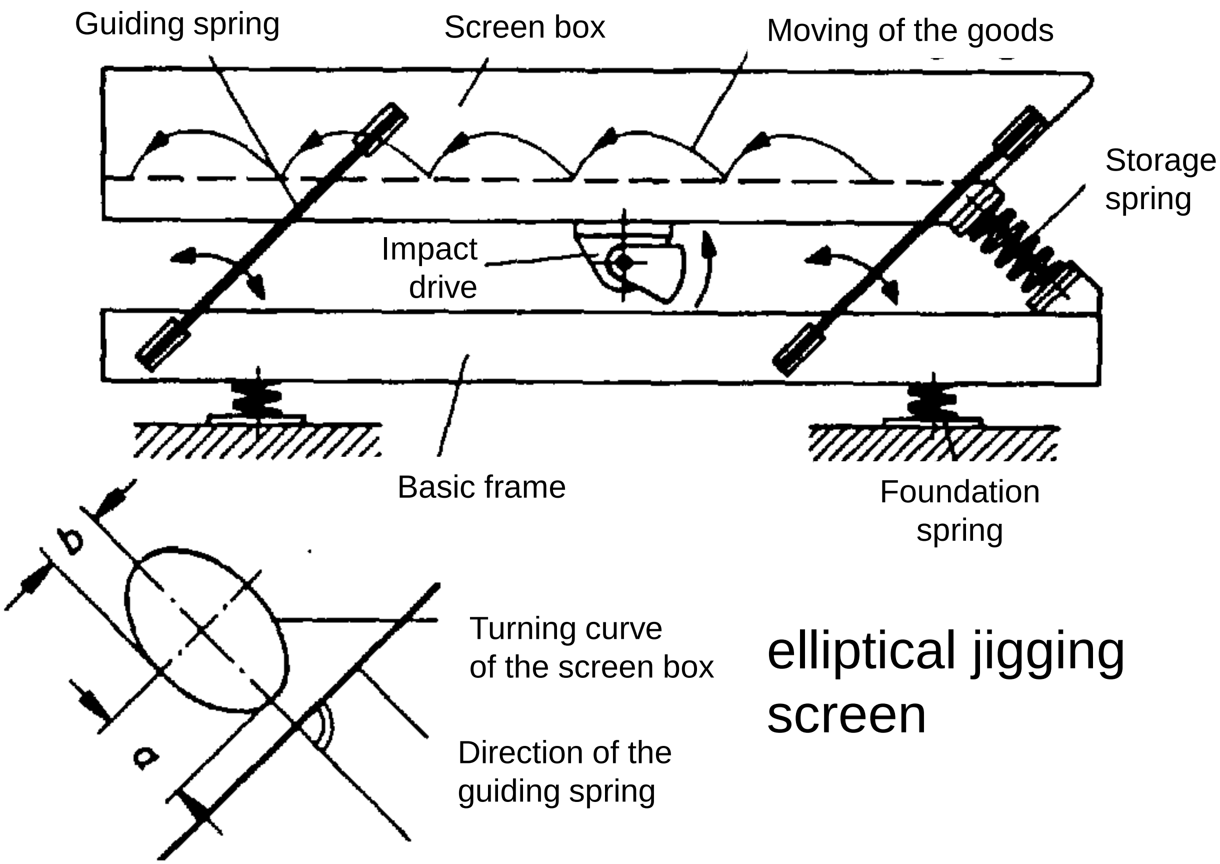
$$a_z = a_v = r \cdot \omega^2 = r \cdot (2 \cdot \pi \cdot f)^2$$

- With $a_z > g$ (acceleration due to gravity), the screening goods are lifted off the bottom of the screen.
  With $a_z/g = 3,3$ (resonance), the casting period ...Wurfdauer = equals the vibration duration

- Vibrating screens are used for medium to fine, non-sticking, hard goods, circular or elliptical vibrating screens for fine, hard goods with $a_z/g > 3,3$.
- **Throughput capacity** Q ($m^3/m^2 \cdot h$) for vibrating screens (SCHUBERT in THOME, 1992) = f (separation grain size or screen aperture width d (mm))

$$Q\ (m^3/(m^2 \cdot h)) = 2,5 \cdot d^{0,6025}$$

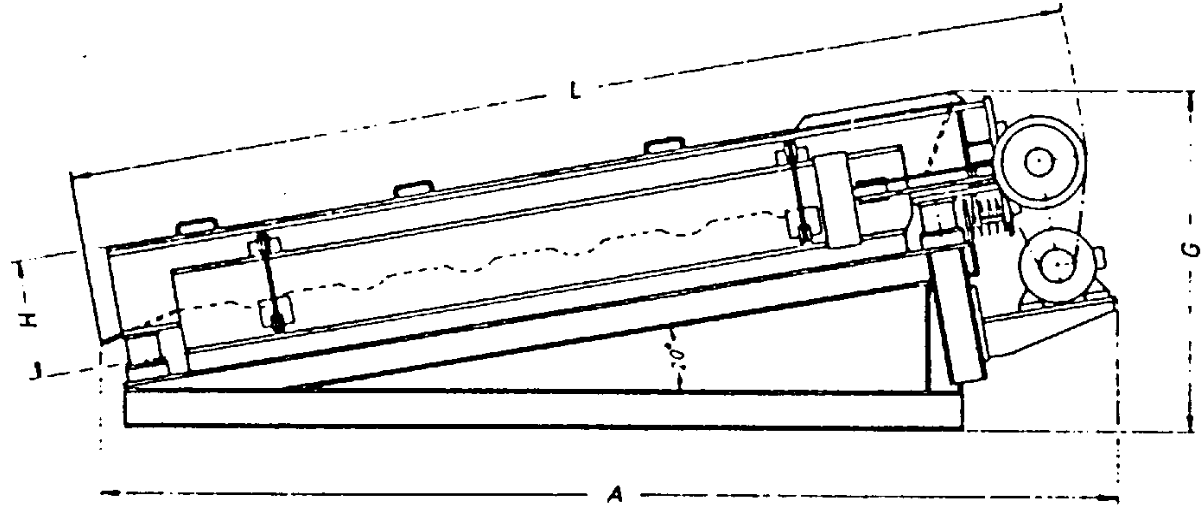
Elliptical swinging/ vibration screen

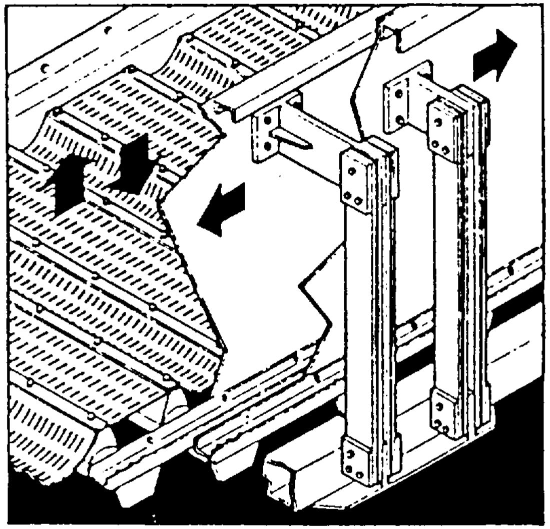


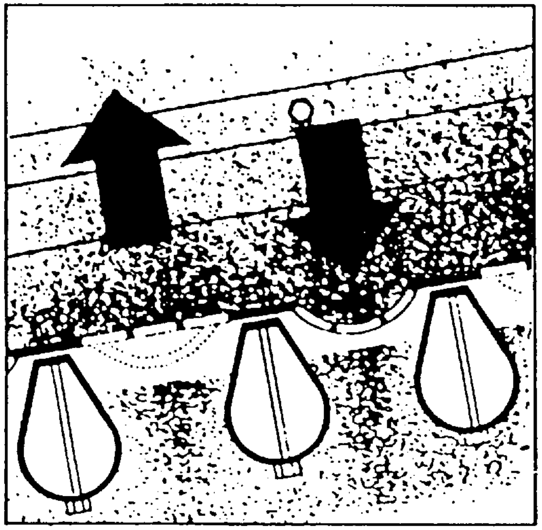
elliptical jigging screen

Shaft Axle Screen

- self-cleaning
- for moist, sticky sorting goods



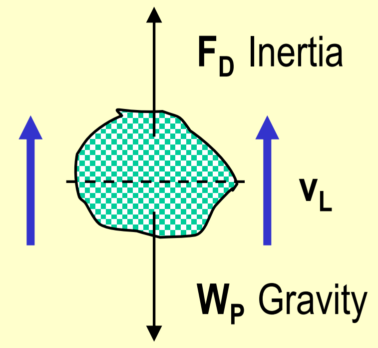




Floating Velocity

$$\frac{F_D}{W_P} = \frac{A_P \cdot \phi \cdot c_D \cdot \rho_L \cdot v_L^2 / 2g}{\tau_P \cdot V_P} \begin{matrix} < \\ = \\ > \end{matrix} 1$$

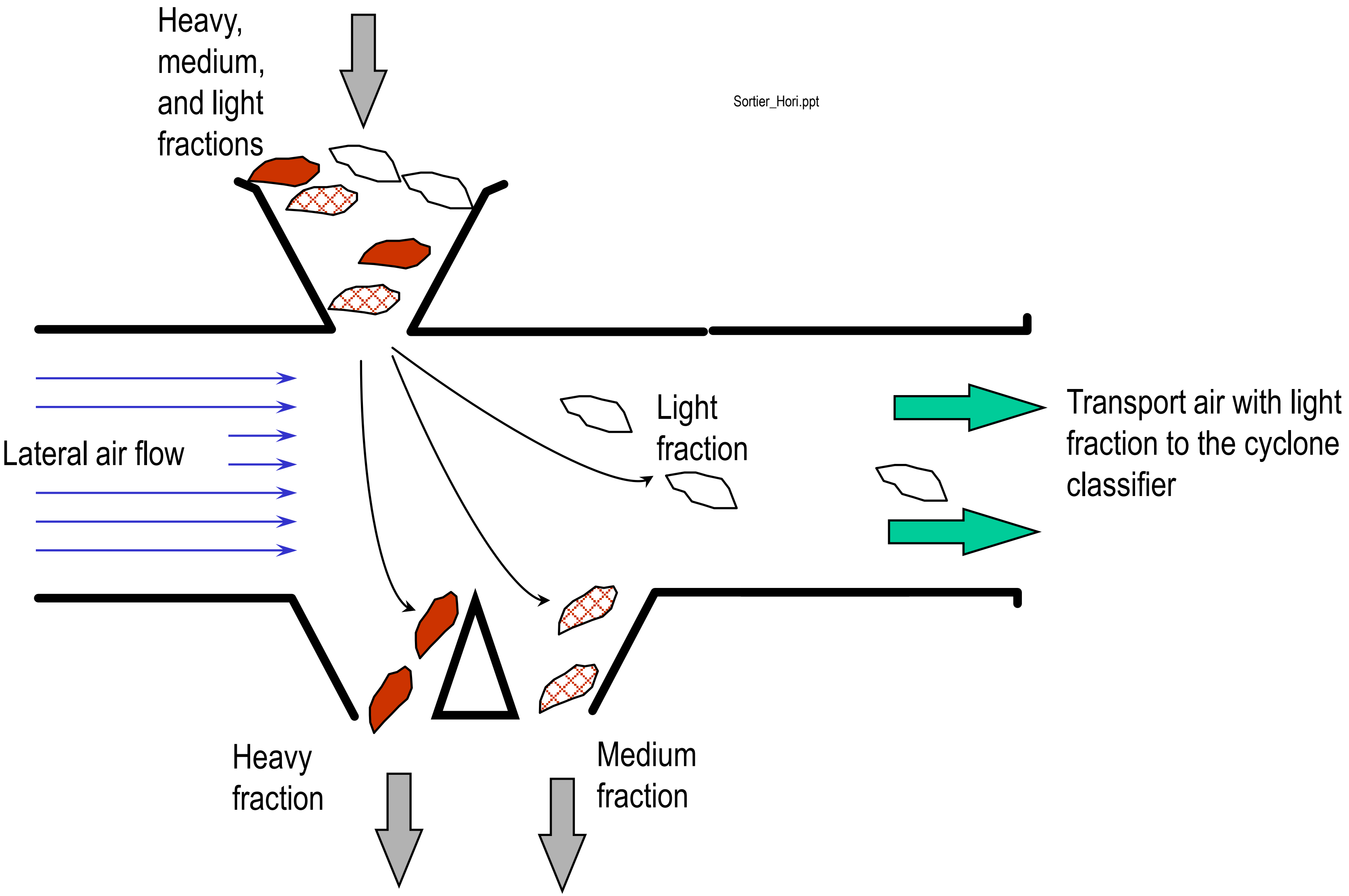
- A_P = area of the particle, vertical to the air flow
- Φ = form factor, relative to the particle form
  = 1 for globe and ca. 5 for hat shape Π
- c_D = Resistance coefficient as function of Reynolds‘ number
- ρ_L = Density of the air
- v_L = Velocity of the air flow
- τ_P = Volumetric weight of the particle
  = entire weight/entire volume
- V_p = volume of the particle



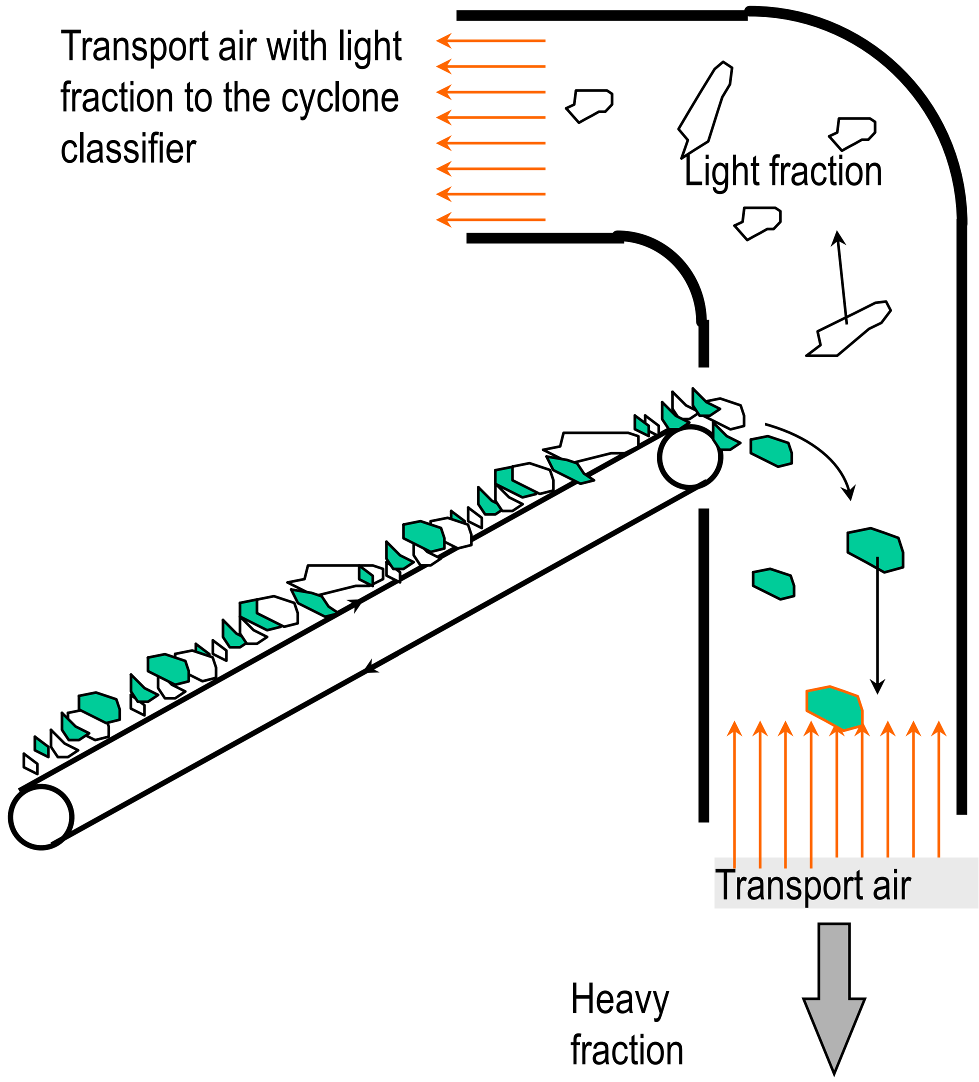
at $F_D = W_P$
the particle will float

Grain	9 m/s
Peanuts	15 m/s
Glass shard	5-10 m/s

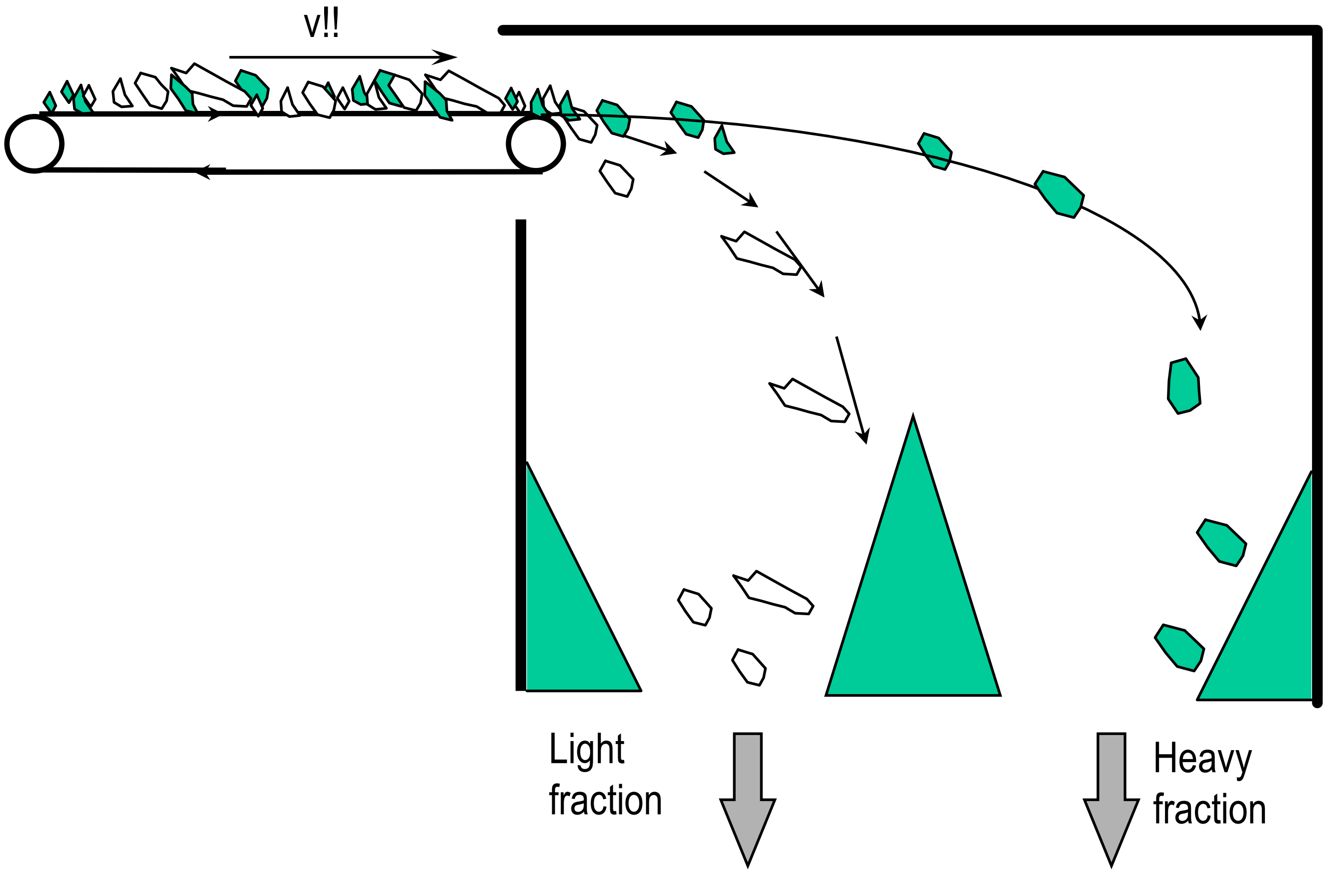
Lateral Flow Classifier



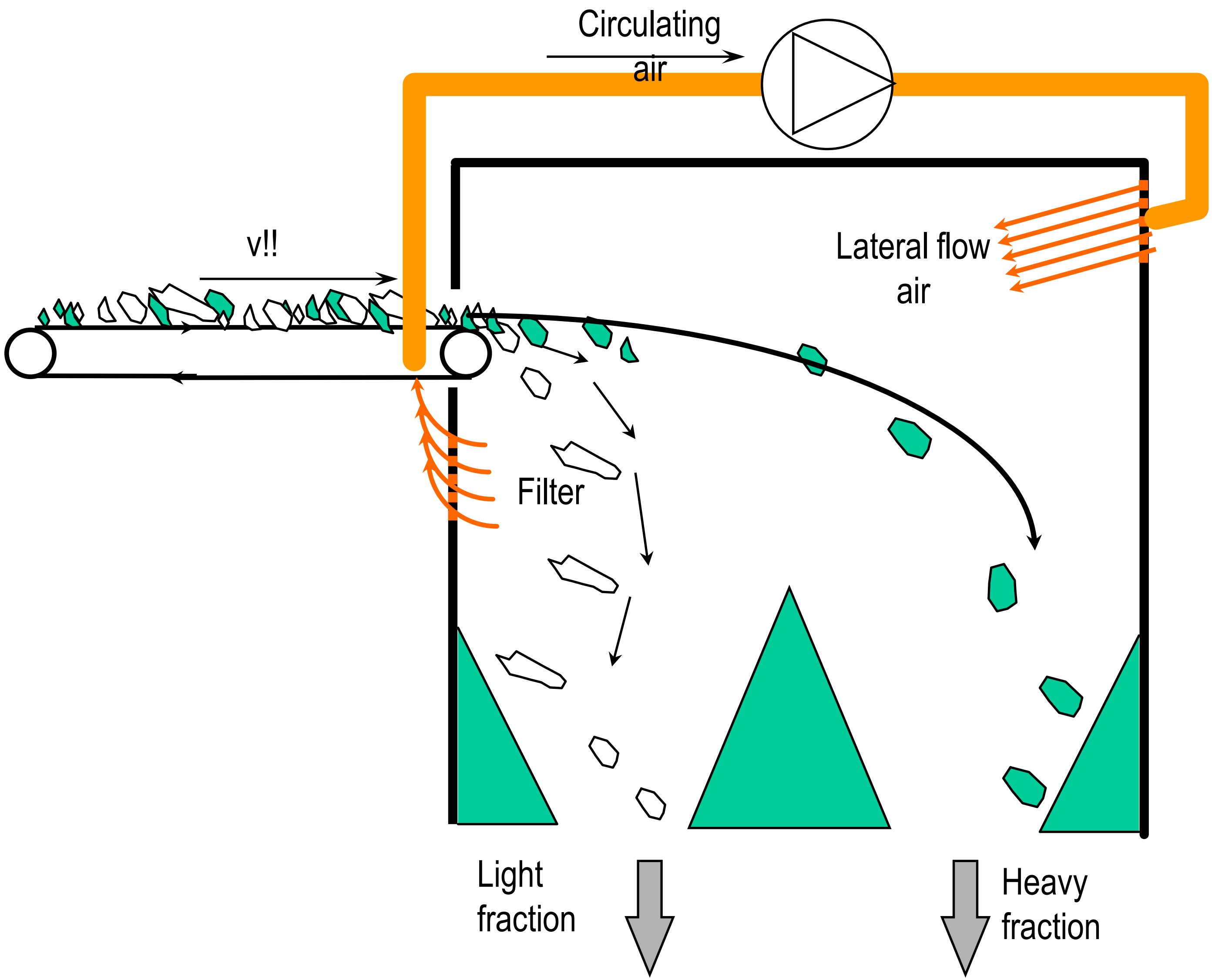
Ascending Pipe Classifier



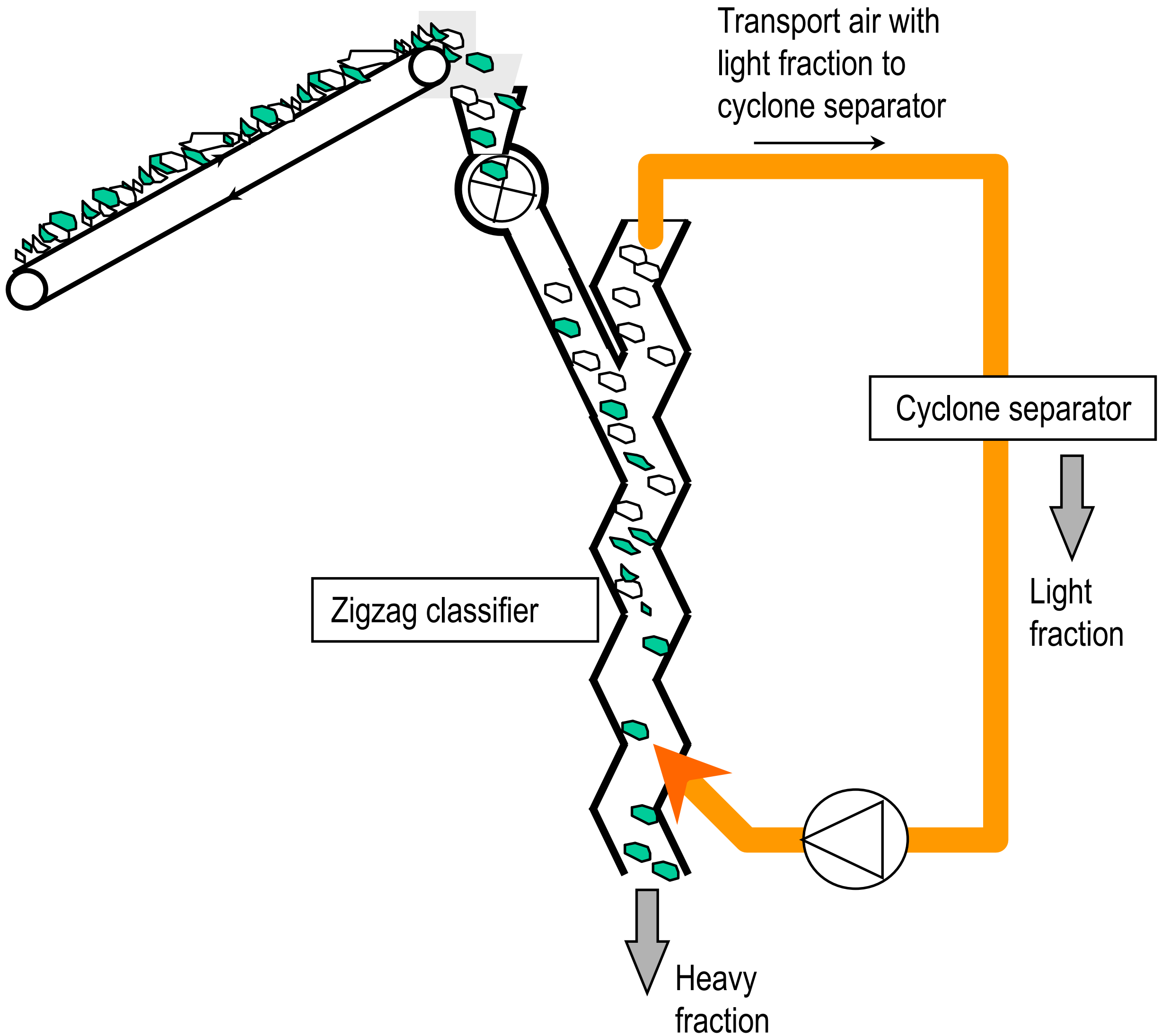
Ballistic Classifier



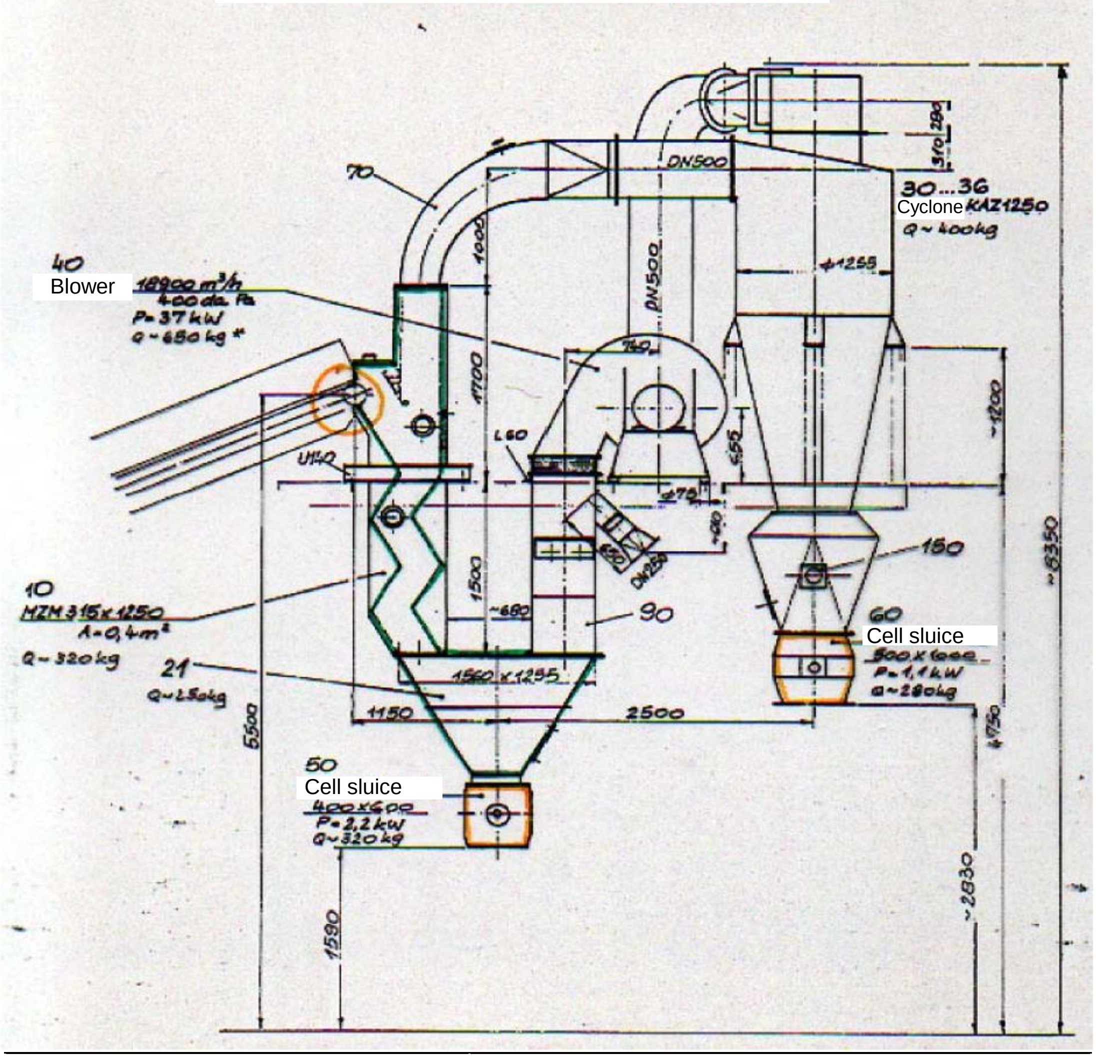
Ballistic Classifier with Lateral Flow Screening



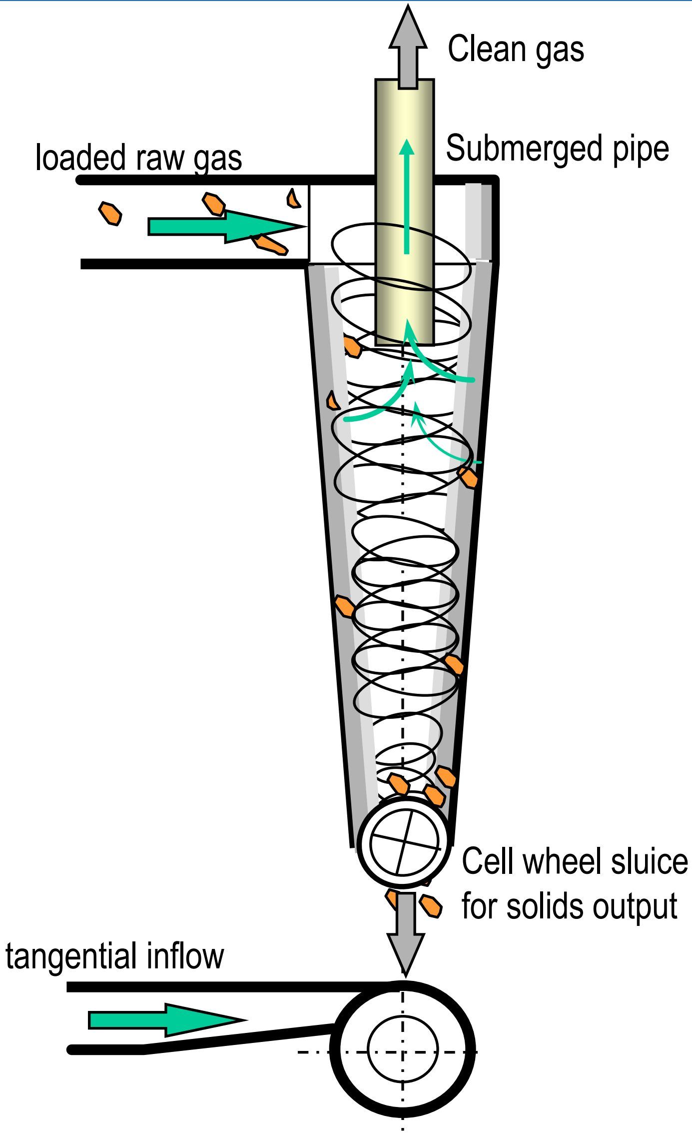
Zigzag Classifier



Zigzag air classifier



Cyclone (pneumatic or even hydraulic)



- For the separation of particles and water or air
- Examples:
  - Solids from pneumatic classifiers
  - Separation of plastic types of different density in the water

Air Classifier Data

Application areas:
- light weight packaging
- plastic processing
- refuse derived fuel processing
- processing of domestic and commercial waste

Advantages:
- only few movable parts
- separation of classifier and light fraction separator
- good separation effect
- high volume throughput

Disadvantages:
- only partial air circulation possible
- dust removal necessary
- high space demand

Classifier loading:

0,05 to max. **0,35** kg / m^3 air

Plenum chamber light fraction separation:

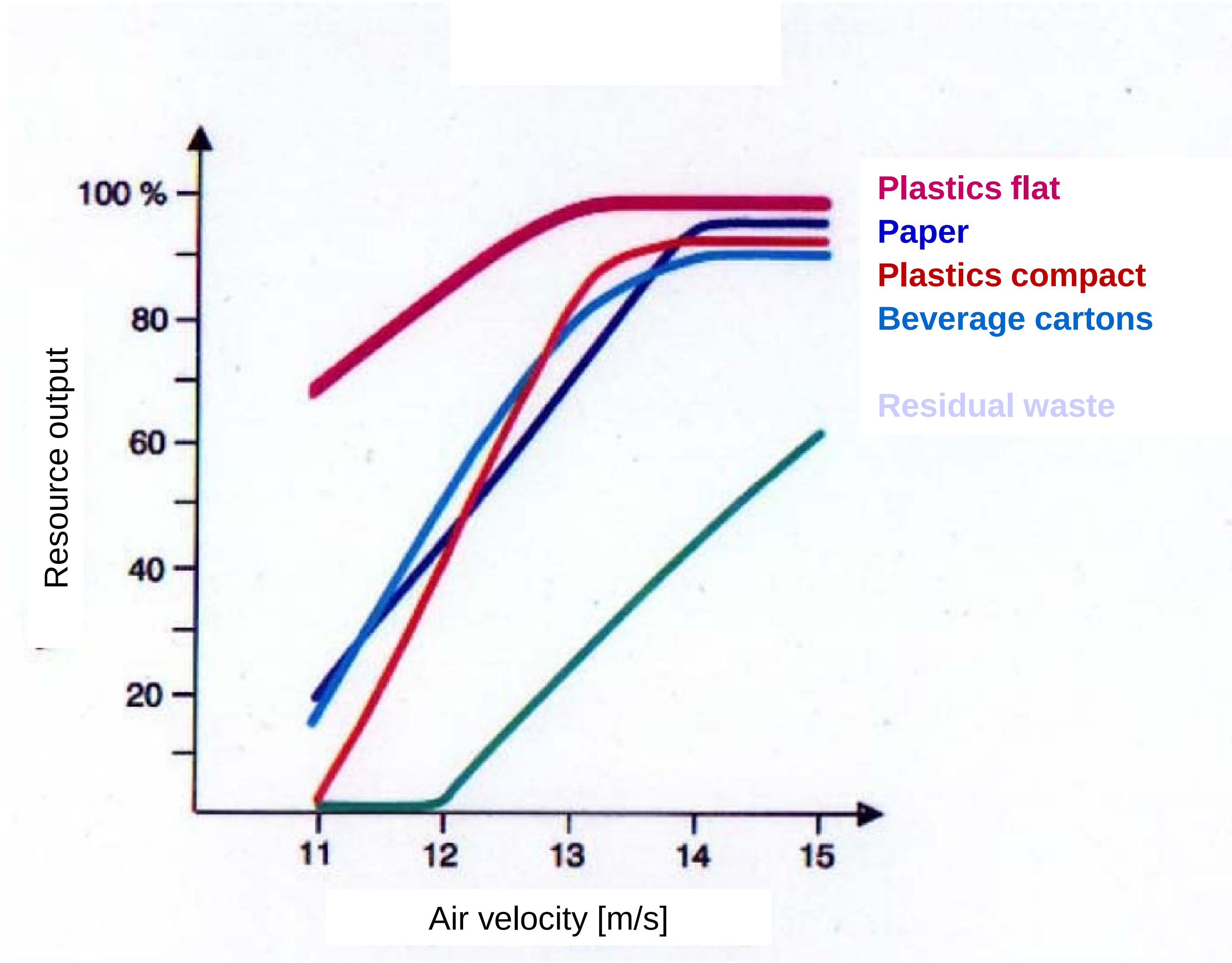
max. 2.000 m^3 / h air throughput per m^3 of the plenum chamber

Guiding radii light fraction transport:

at least 3 · D

(D = diameter of the pipeline)

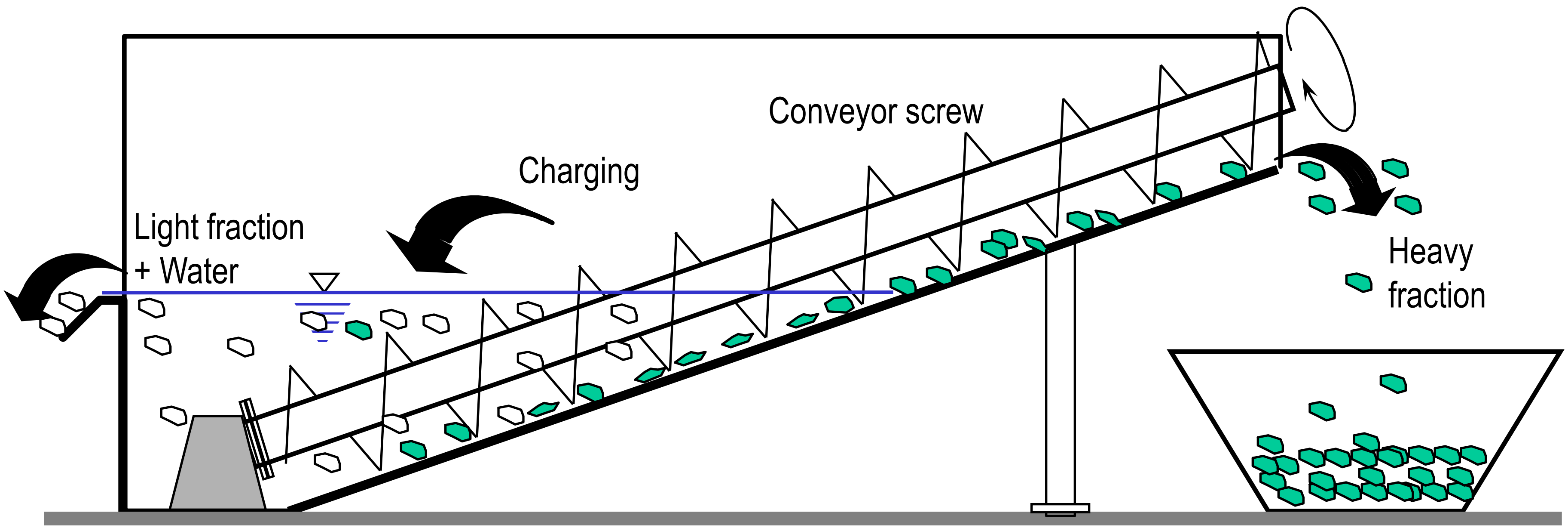
Air screening



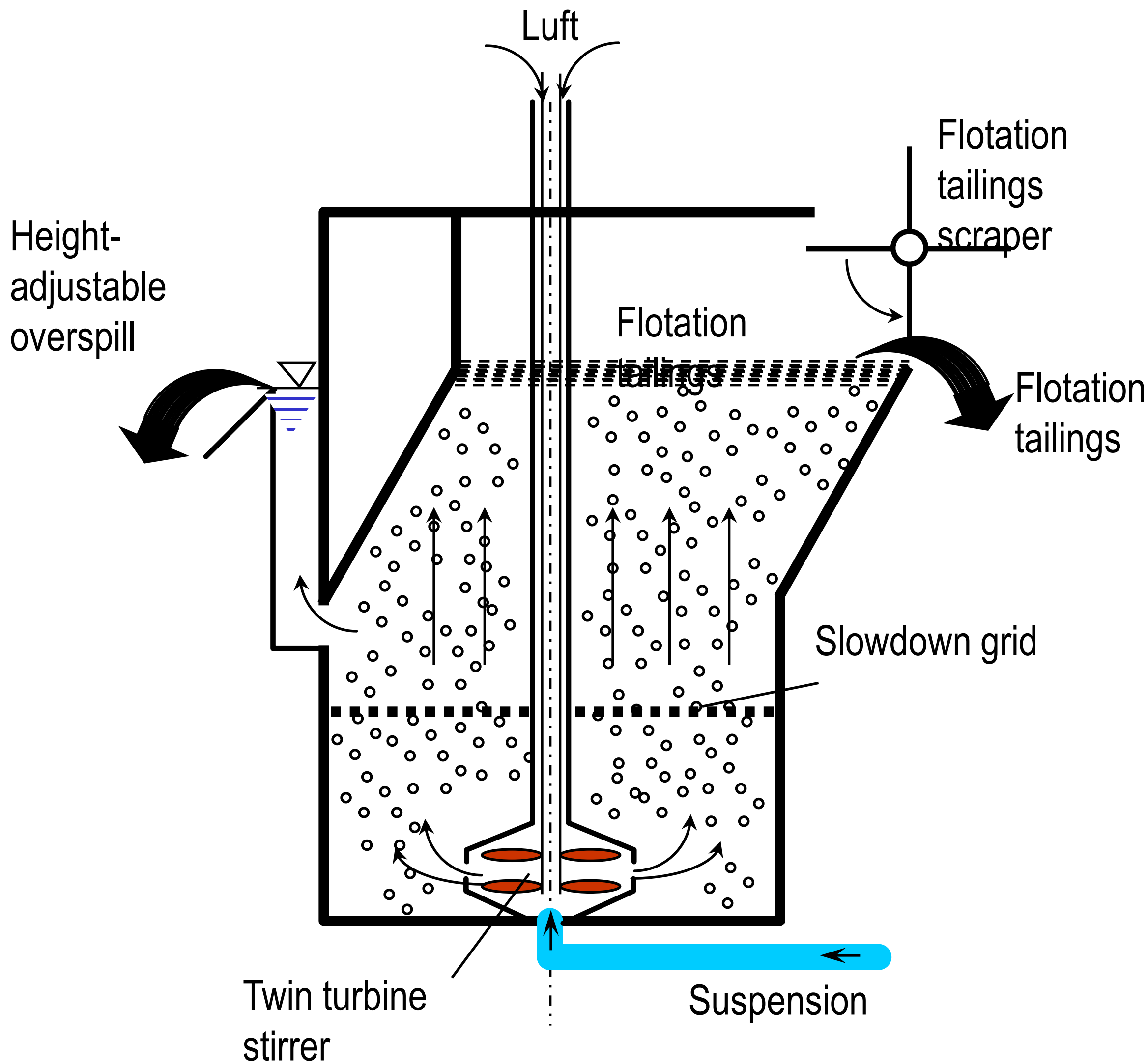
Hydraulic Spiral Classifier

Sink-or-Swim Separation:
Applicable Parting Liquids

Water	$\rho_F \approx$	1,00 kg/L
Water-Alcohol-Mixtures	$\rho_F \approx$	0,91 to 0,93 kg/L
Aqueous solutions	$\rho_F \approx$	1,05 to 1,20 kg/L
Magnetite Suspensions	$\rho_F \approx$	2 kg/L
Ferrosilicon Suspensions	$\rho_F \approx$	2 to 3 kg/L

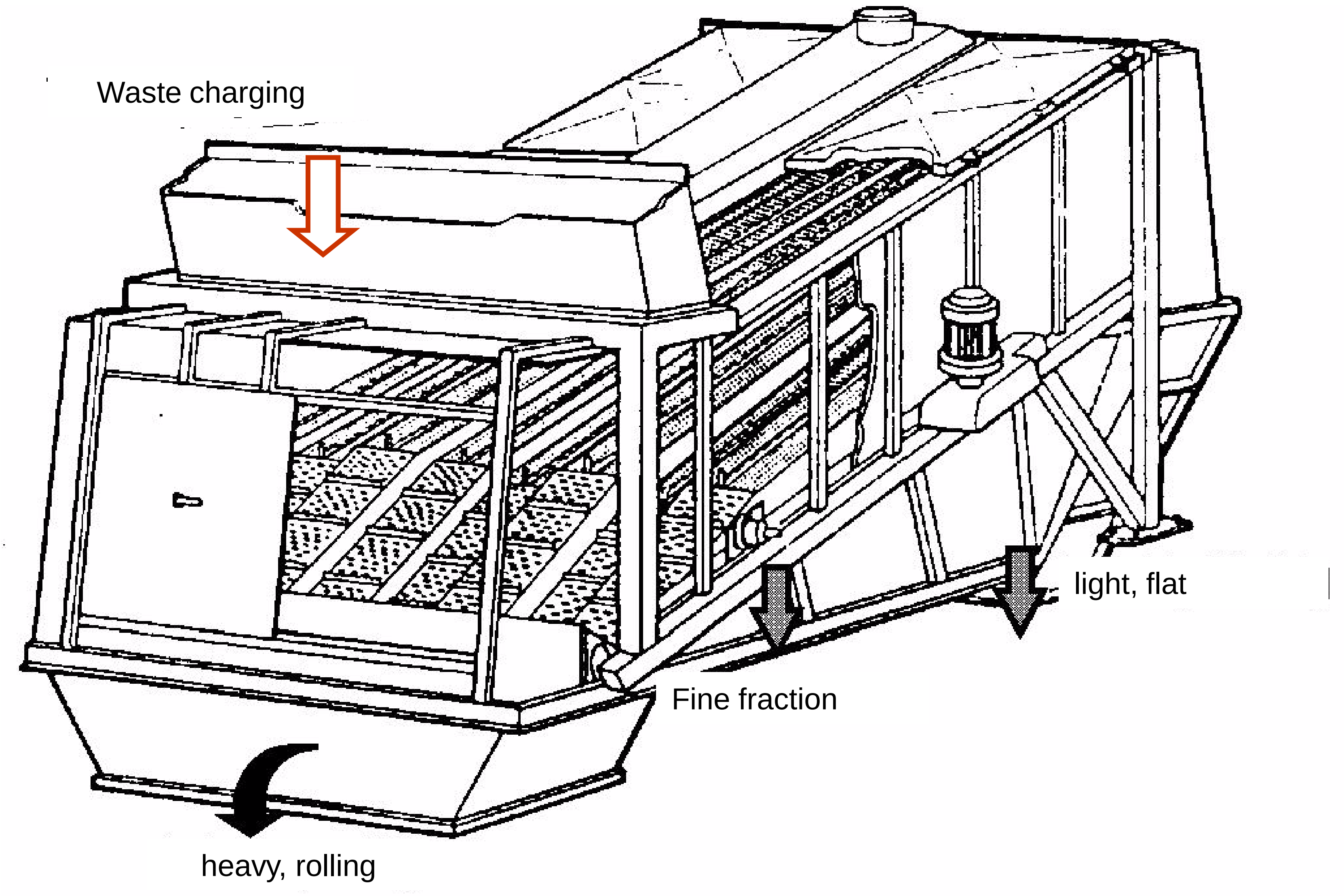


Floatation Plant

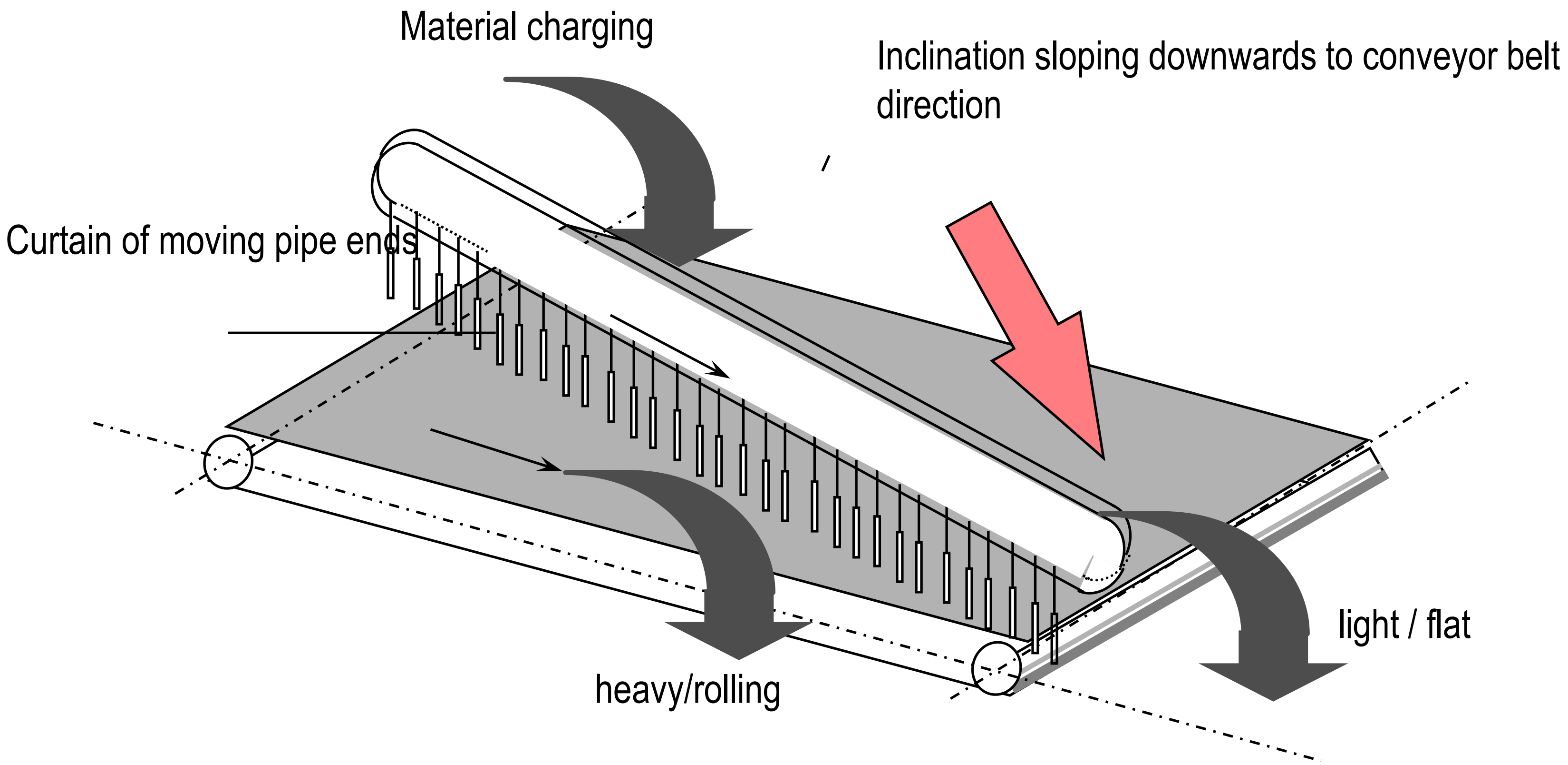


- Accumulation of air bubbles to particles which can be rendered hydrophobic
- Applicable in waste processing
  - Deinking of used paper
  - Separation of glass and ceramics

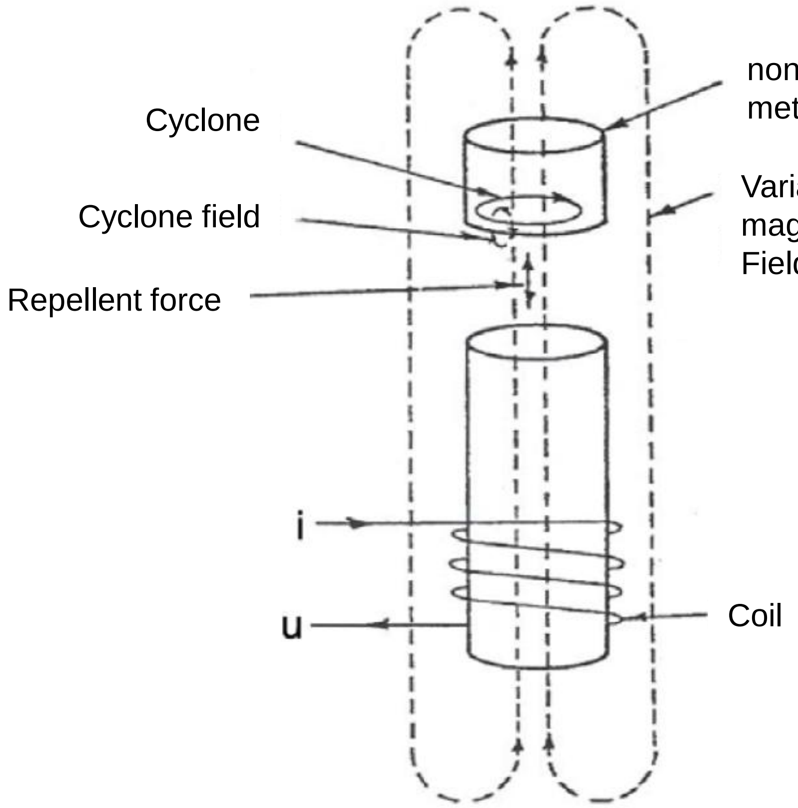
Ballistic Classifier (formerly PLM)

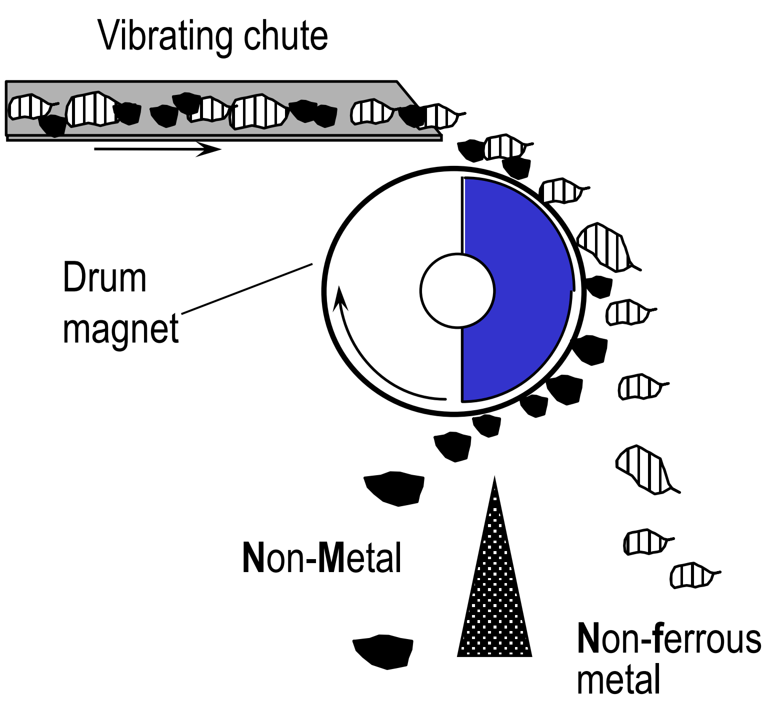


Inclined Sorting Machine



Principle of Cyclone Separation





Magnet Separation

f_m (N/kg) $\approx X \cdot \mu_0 \cdot H \cdot \text{grad } H$

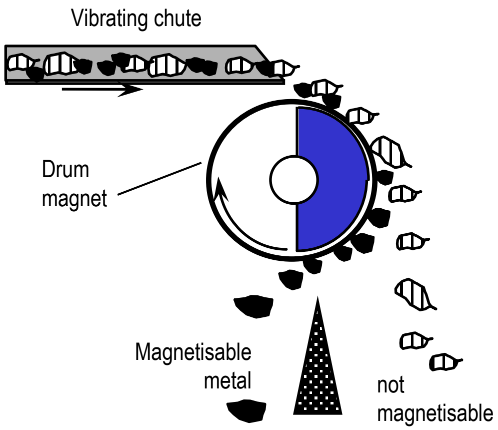
ca. 1 N/kg	Reel separator
> 10 N/kg	Overbelt separator
> 9,81 N/kg	Selection

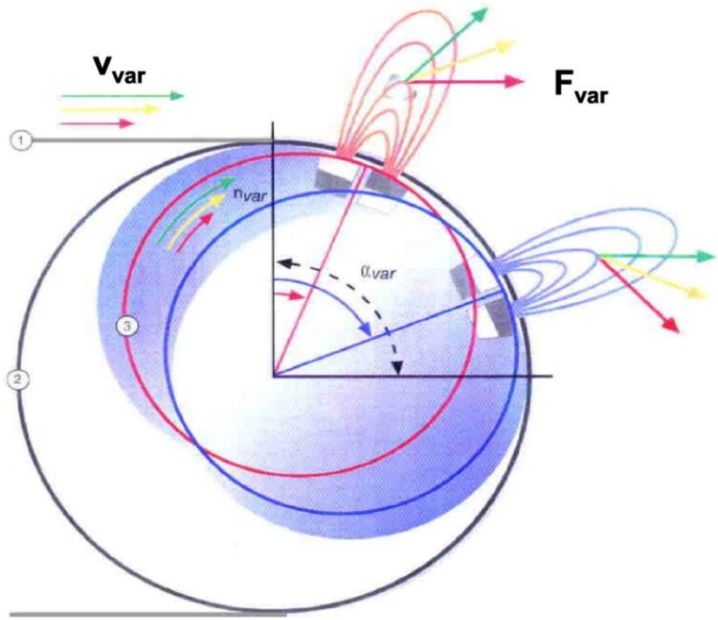
with:

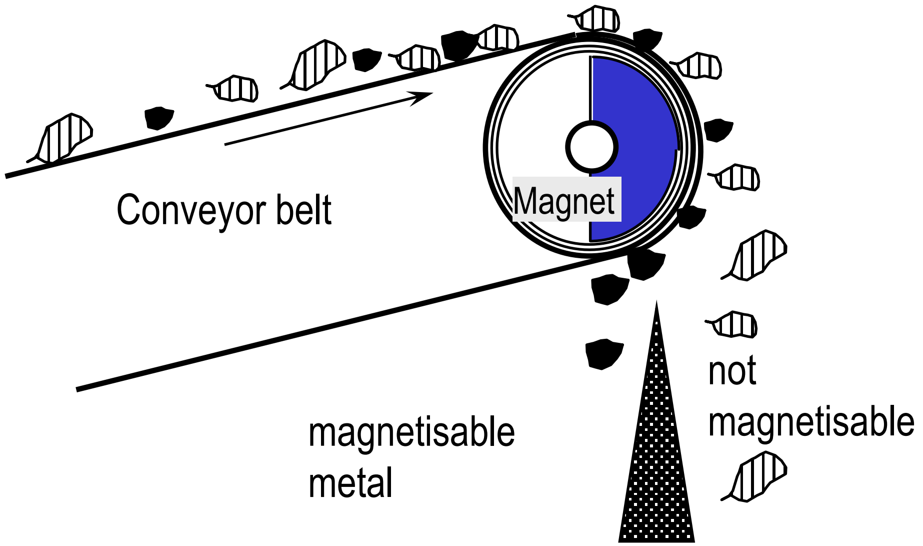
μ_0 (V·s/A·m)	$= 4 \cdot \pi \cdot 10^{-7}$ (induction constant)
H (A/m)	= Field strength
grad H (A/m²)	= Field gradient
$\mu_0 \cdot H \cdot \text{grad } H$	= Density of the magnetic force field
X (m³/kg)	= Mass susceptibility (depending on the magnetisability)

Substance Type	Mass - susceptibility X	Specific magnetic strength f_m: Weak field separator $\mu_0 \cdot H \cdot \text{grad } H = 3 \cdot 10^5 \div 1{,}5 \cdot 10^6$ N/m³	Strong field separator $\mu_0 \cdot H \cdot \text{grad } H = 1 \cdot 10^5 \div 10^6$ N/m³
	m³/kg	N/kg	N/kg
strongly magnetic (iron, magnetite)	$> 35 \cdot 10^{-6}$	$1 \cdot 10^0$	$3{,}5 \cdot 10^2$
medium magnetic	$35 \div 7{,}5 \cdot 10^{-6}$	$2 \cdot 10^{-2}$	$7{,}5 \cdot 10^1$
lightly magnetic	$7{,}5 \div 0{,}1 \cdot 10^{-6}$	$5 \cdot 10^{-3}$	$2 \cdot 10^0$

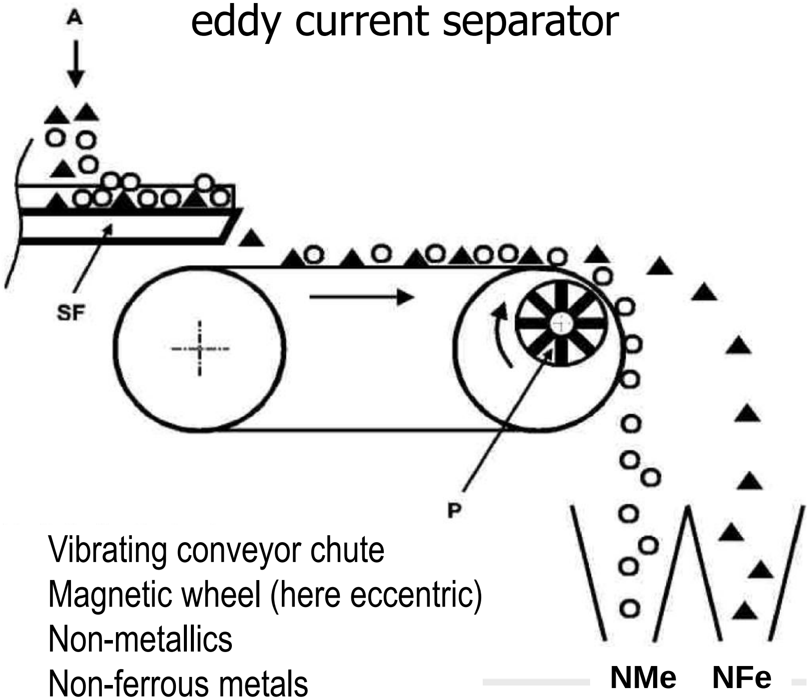
Drum Magnet Separator / Reel Magnet Separator



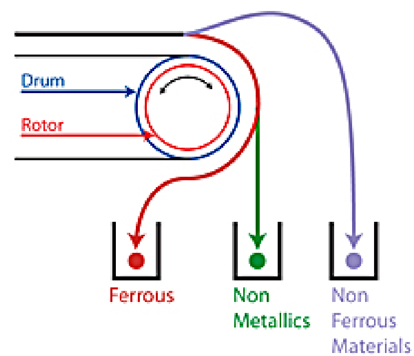


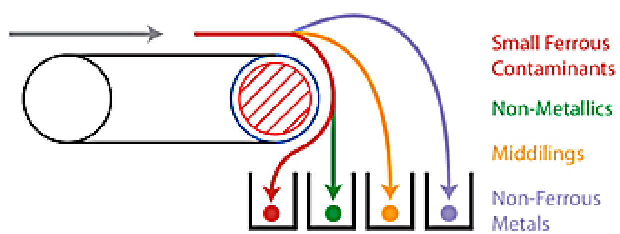


eddy current separator

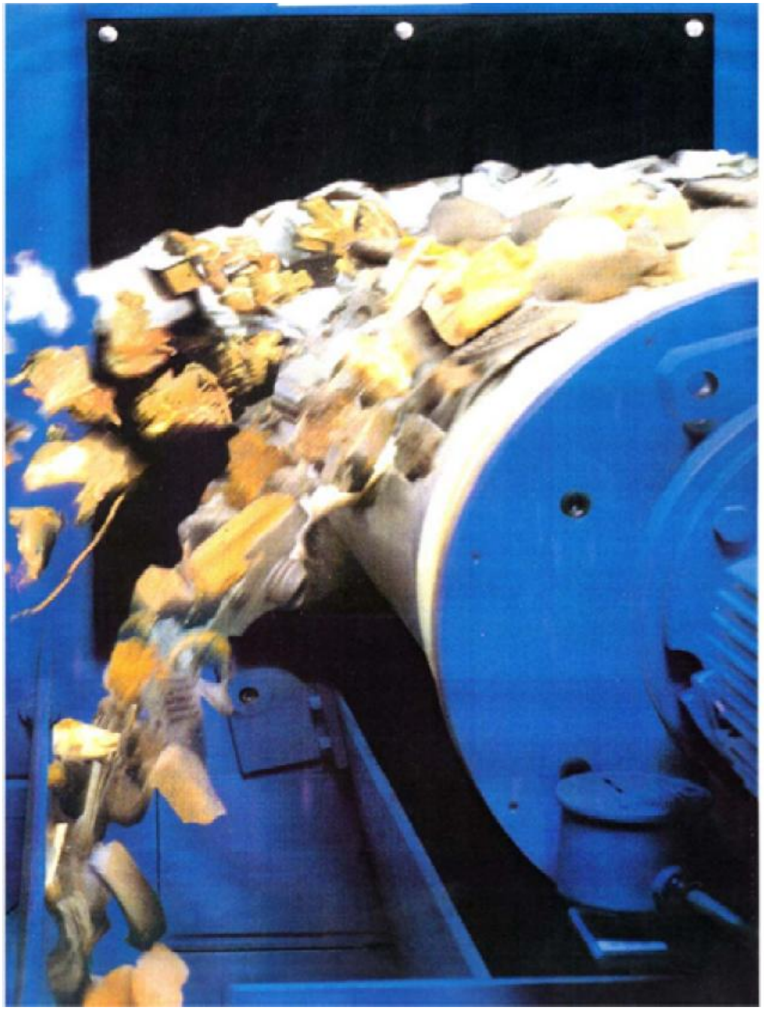


SF Vibrating conveyor chute
P Magnetic wheel (here eccentric)
NMe Non-metallics
NFe Non-ferrous metals

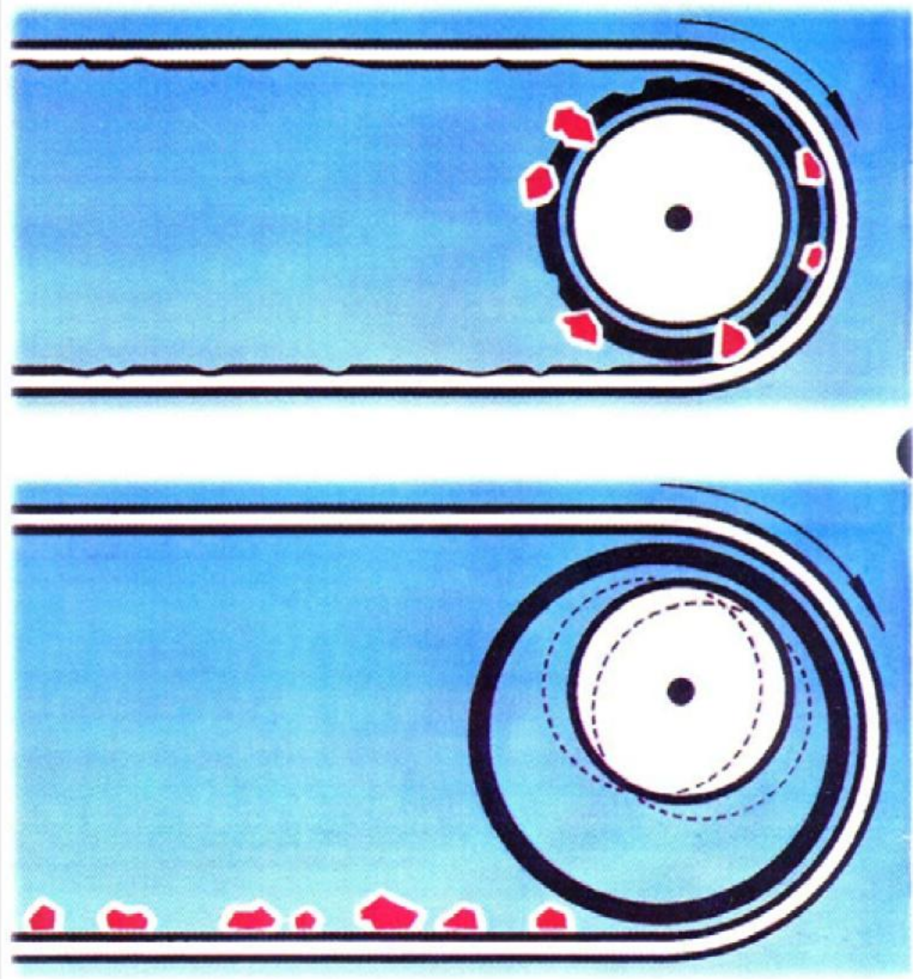




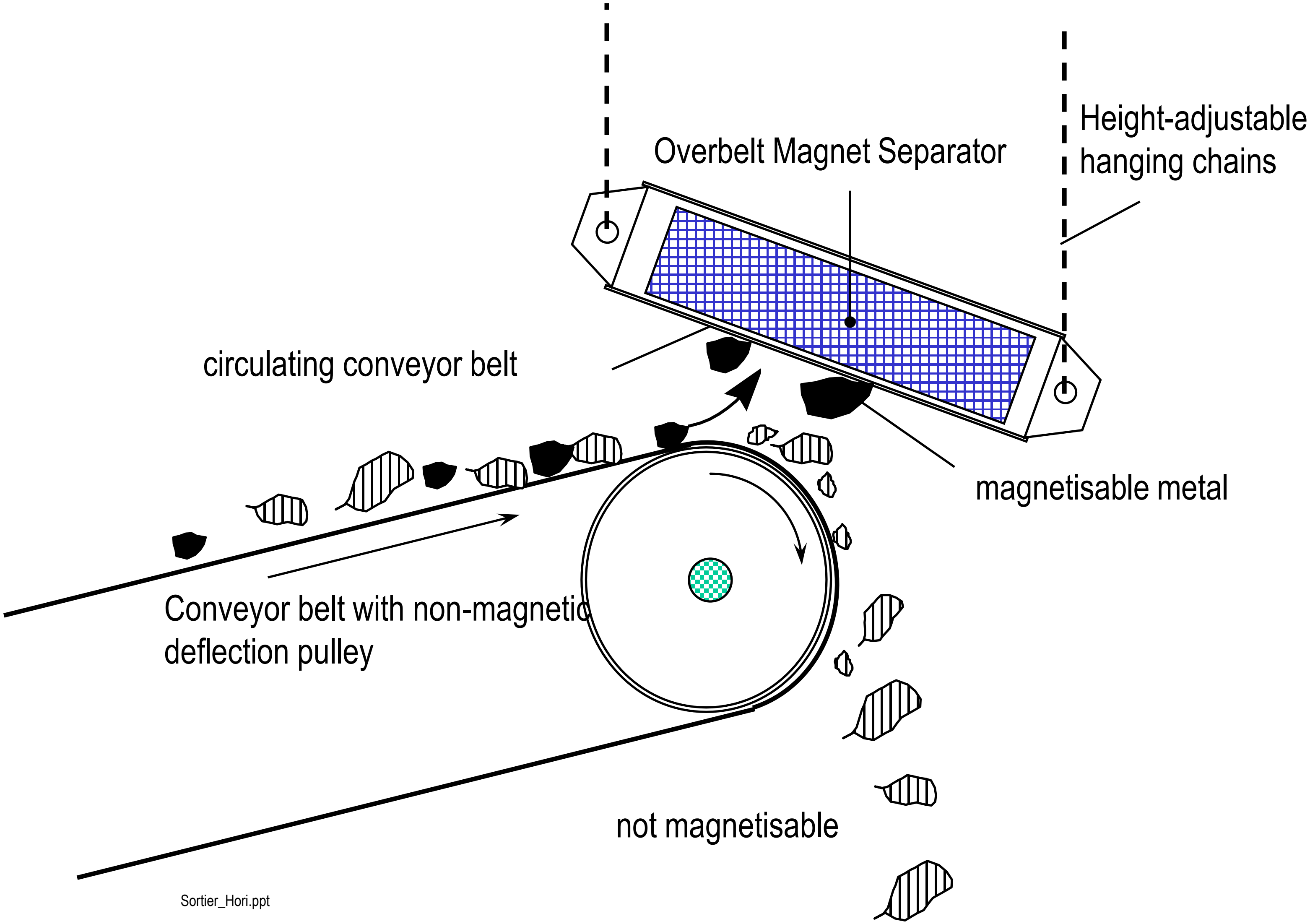
Cyclone Separation – Side view



Concentrically/excentrically mounted magnet wheel



Overband Magnet Separator

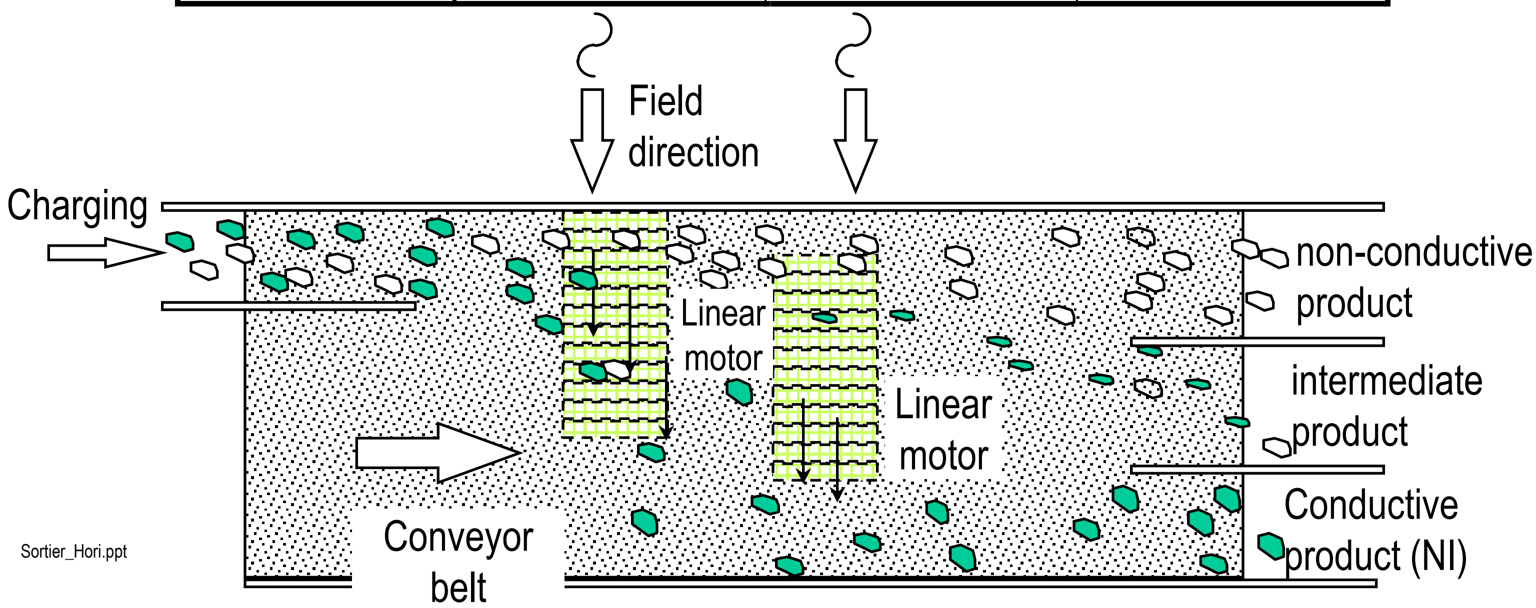


Sortier_Hori.ppt

Cyclone Separator with Linear Motor under the Conveyor Belt

- Cyclone generation through motion of conductive particles in magnetic fields

Metall	Electric conductivity σ [10^8 S/m]	Density ρ [10^3 kg/m^3]	σ/ ρ [10^3 m^2*s/kg]
Aluminium	0,35	2,7	13,0
Copper	0,59	8,9	6,6
Silver	0,63	10,5	6,0
Zinc	0,17	7,1	2,4
Brass	0,14	8,5	1,6
Tin	0,09	7,3	1,2
Lead	0,05	11,3	0,4



Sortier_Hori.ppt

Rubber

Plastic agglomerate

Aluminium

Iron

Cyclone Separator (Non-ferrous metal separator)

Output : 80 - 85 %

NF -Contents: 85 - 95 %

Special designs Exner System (Motion reversion of the conductive particles by 180 °)

Preconditions:

no light and loose components, such as foils

- Sorting of the material flow (single grain layer on the belt)
- efficient magnet separation before the NF separator

Technical Data:

- Width between 0.3 and 2.0 m
- Belt speed up to 2.6 m/s
- Grain size from 1mm to ca. 150 mm
- Frequency of the magnetic alternating field ca. 400 - 1000 Hz

Applications:

Wood processing (e.g. aluminium fittings)

DSG sorting (aluminium packaging

Glass processing (bottle caps)

Scrap processing

GI slags processing

Domestic waste processing

Recycling of other metalliferous residues

Parameters Influencing the Separation Success

- **Size and weight of the NF Metals**
  Position and separation apex must be considered!
  Better separation results if the preliminary screening is as tight as possible

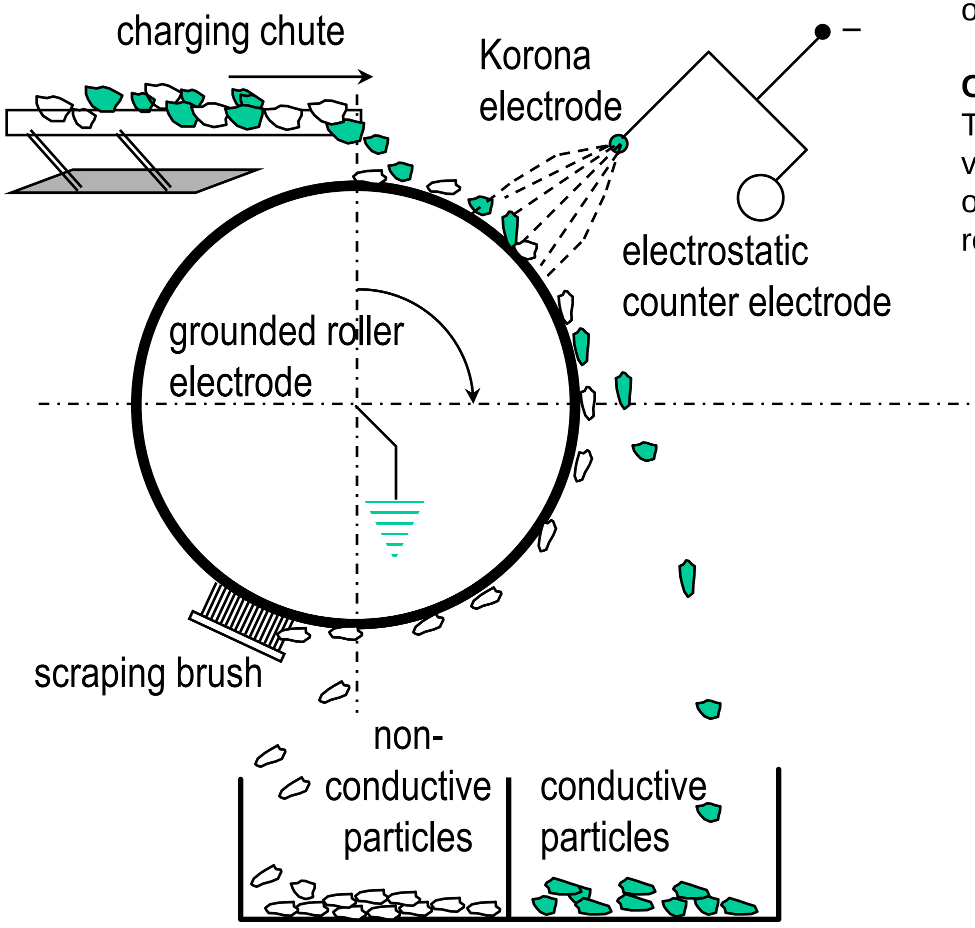
- **Shape of the NF Metals**
  Bad deflection of elongate parts such as copper wires

- **Electric resistance and density of the NF Metals**
  Quotient of conductivity and density yields a measure for the repellent force on an NF metal particle at the same shape and particle size

- **Strength and range of the magnetic alternating fields**
  the repellent force grows linearly with the square of the induction

- **Frequency of the magnetic alternating field**
  the finer the NF metal particles are, the higher the selection of the field frequency needs to be

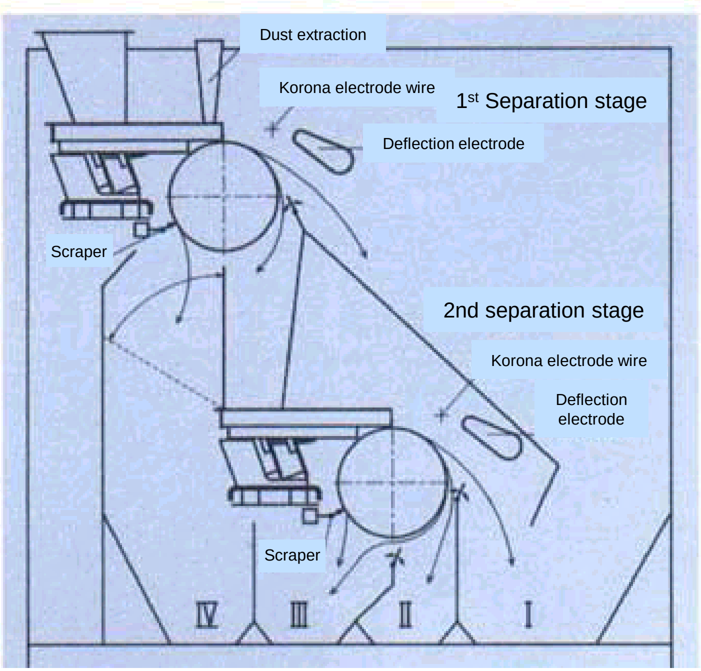
Korona Induced Roll Separator according to SCHUBERT, II, S. 224



The particles lying on the roller get into the range of the Korona electrode, where they are charged independent on their electric conductivity

Conductive particles leave the roller
The conductive particles discharge the received charge very soon, due to their electric contact with the roller. Because of the centrifugal force, the conductive particles leave the roller and are additionally deflected by the planar electrode.

Figure 3: Scheme of a two-stage Steinert Korona Roll Separator



Roller diameter:	150 - 400 mm
Rotation speed:	40 - 150 min^{-1}
Electrode potential:	5 - 20 kV
Korona separator:	20 - 40 kV
Chamber separator:	> 100 kV
Currency:	< 10^{-3} A
Field strength:	ca. 5 kV / cm

Application:

- special separation tasks with high-grade goods in small amounts
- Grain size range from 0.1 to ca. 4 mm (gravity separator up to 10 mm)
- Bulk goods, if possible only two-component mixtures
- Mass application in rock salt processing(gravity separator or chamber separator)
- Experiences in plastic processing, but there as yet no scientific basis for gravity separators
- Electronic scrap and cable scrap processing

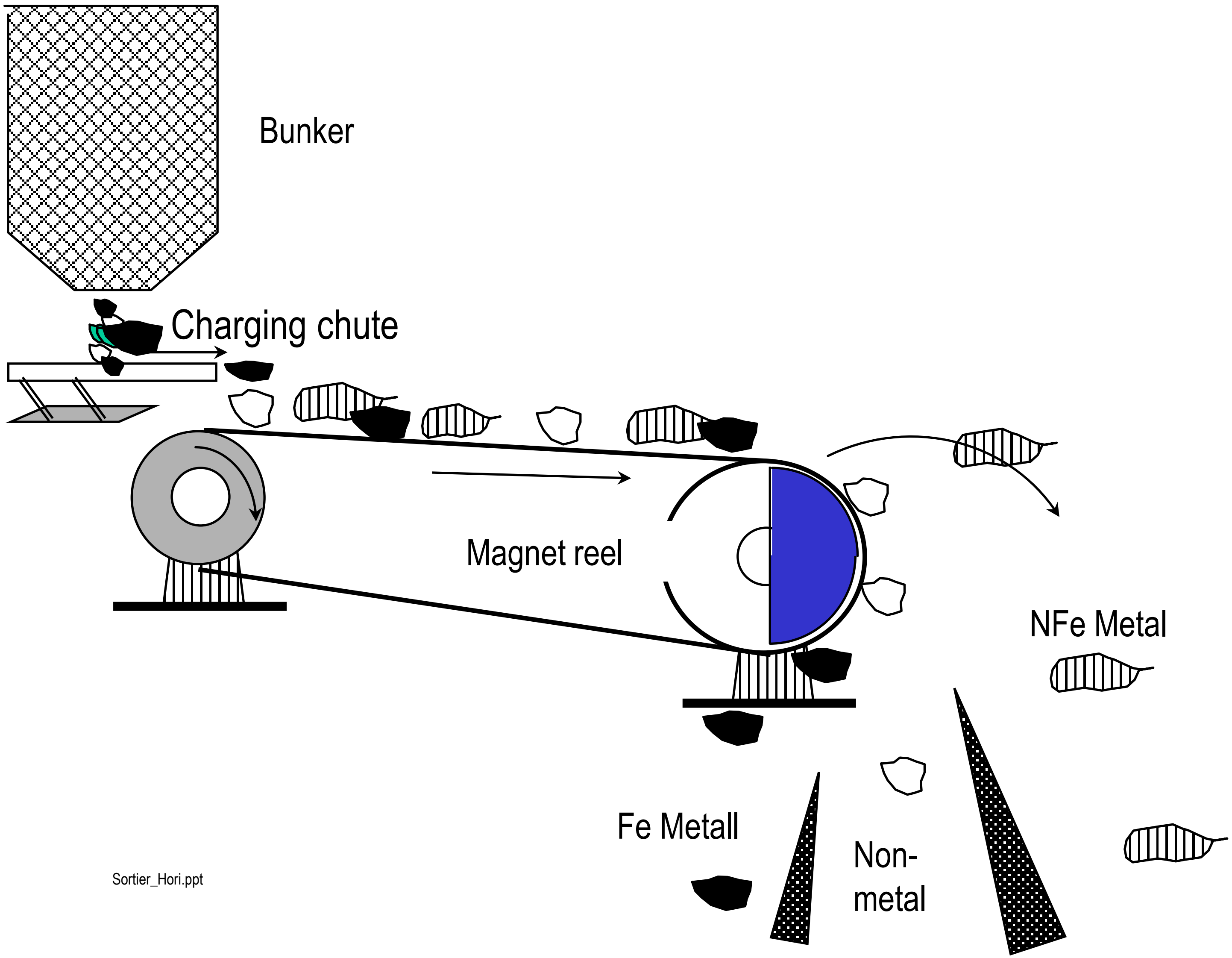
Problem: diffuse properties in material mixtures

Result: low separation effect, multi-stage procedures necessary (cascade switching), limited resources output

Plastic type	PE	PP	PA	PS	PC	PET	PVC
ε_r	2,3	2,5	3,1	2,5	3	3,5	3,5

Table: Relative di-electricity values of plastics

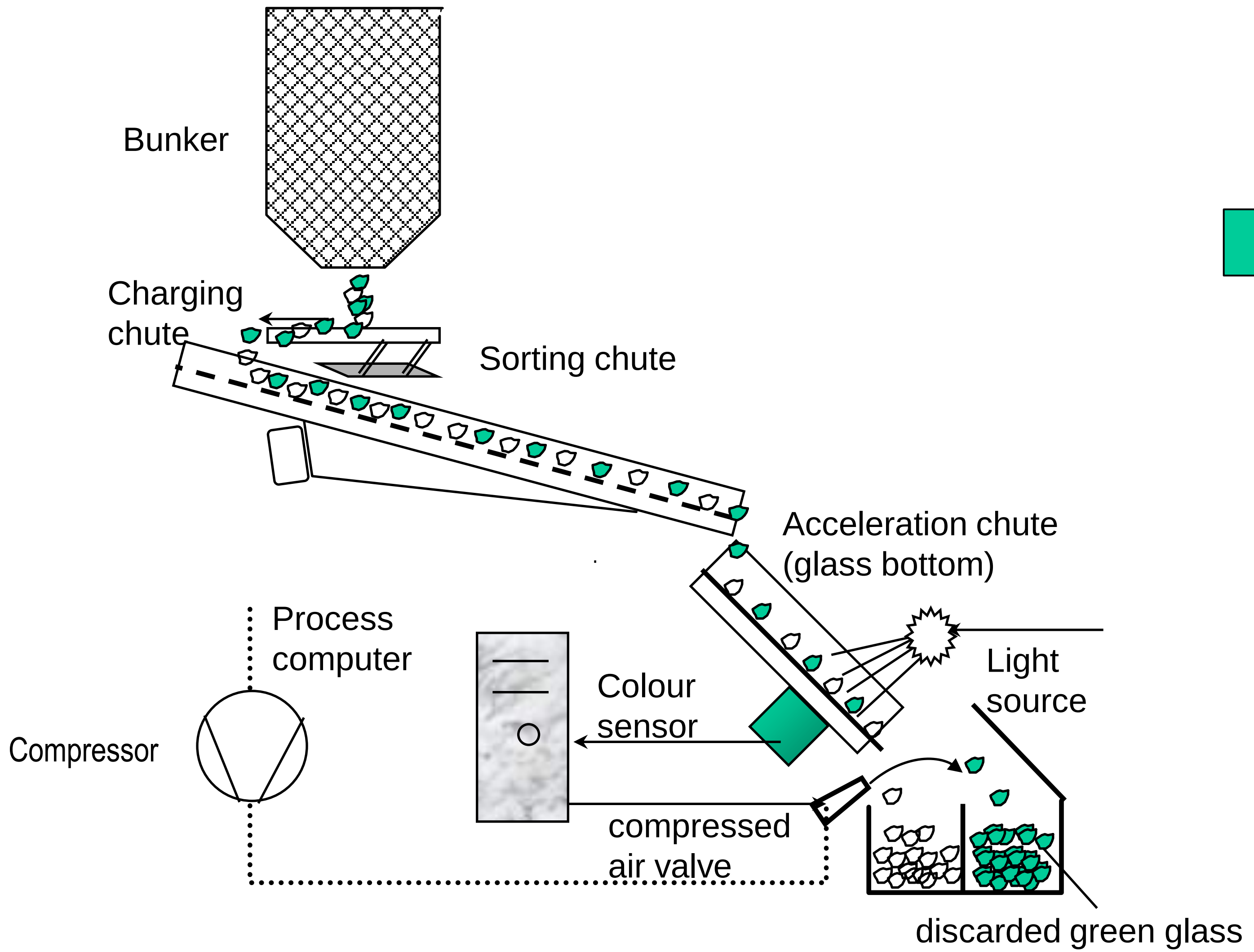
Combined Iron and NF Metal Separator



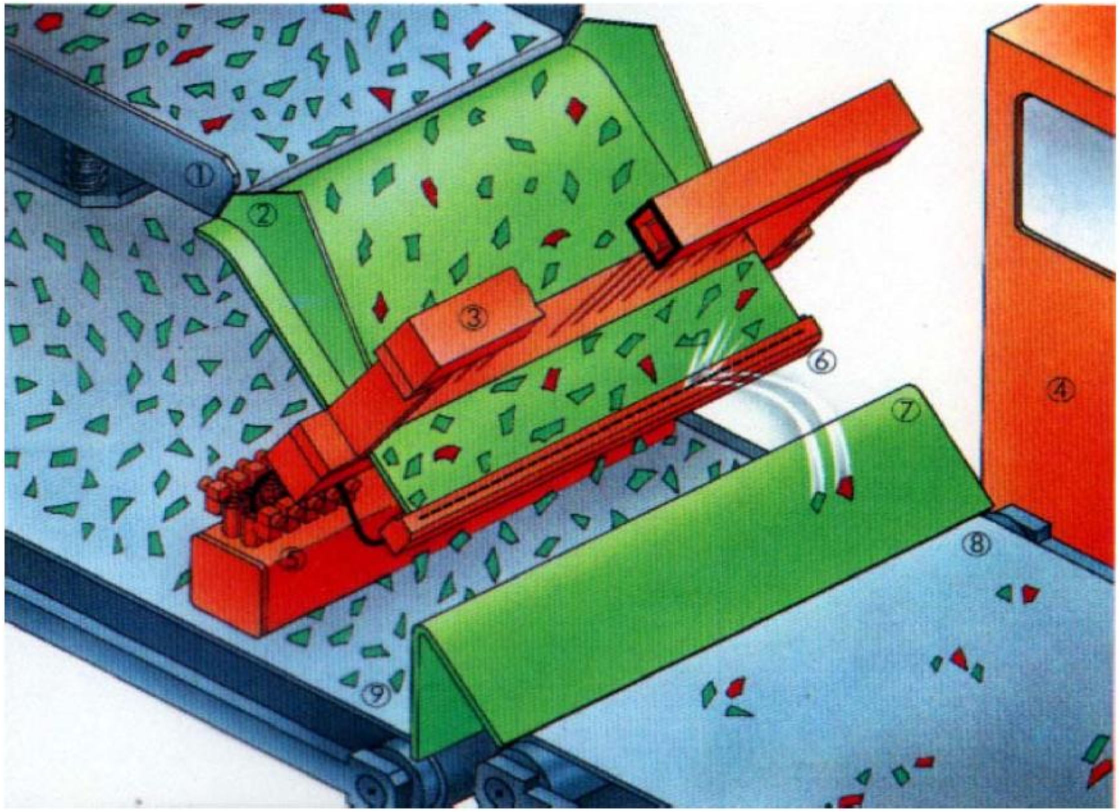
Colour Glass Sorting

Optical sorting

Optical Sorting of White and Green Glass



Colour Glass Sorting

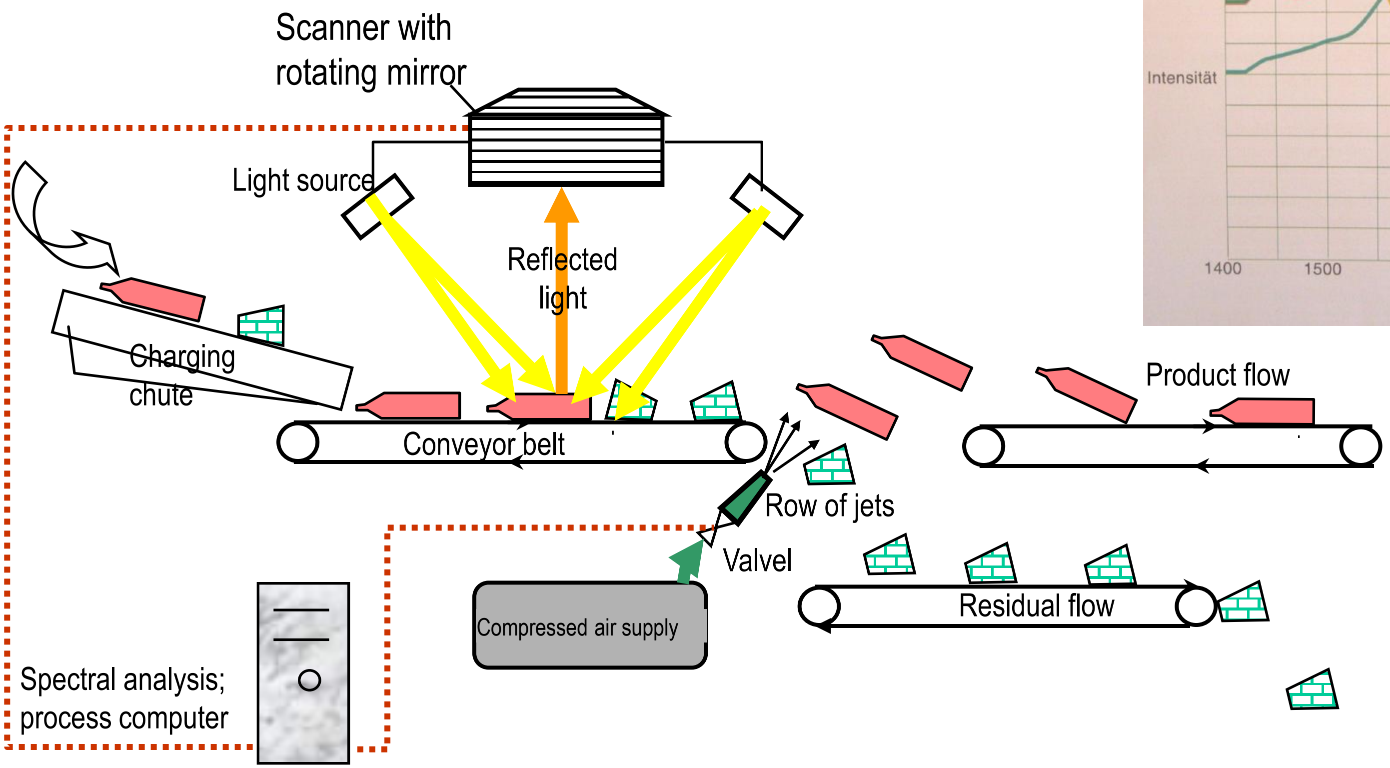


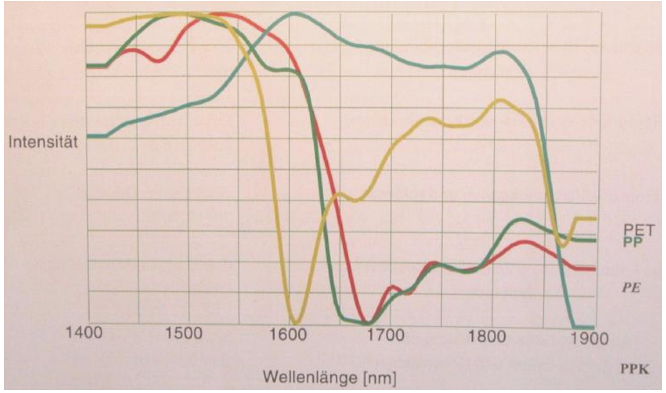
Principle

The shard stream is conveyed via the vibrating chute (1) to the charging slide (2).
The sensor (3) identifies the pollutant particle and sends a signal to the electronics (4). Micro-processors determine the exact position of the pollutant particle and control jets (6) via magnet valves (5) The purposefully aimed and dosed air jet blows the pollutant particle over the barrier (7) onto the conveyor belt for bad material (8).The clean shard stream is conveyed unhamperedly to the conveyor belt for good material (9).

Analytics + Picking Systems – e.g. (C)IR Sorting

- Via fast analytics, such as X-ray fluorescence analysis, mass spectroscopy, infrared spectroscopy (e.g. (CIR), or thermo-optical identification, mechanical picking methods can be controlled.
- Sorting examples: De-inking of recycling paper, plastics or NF metals.





RED-WAVE Video →

CIR Spectroscopy

Identification of plastic based on the specific infra-red spectrums. Wavelength detection with powerful detectors, e.g. Mercury-Cadmium-Tellurium (MCT)

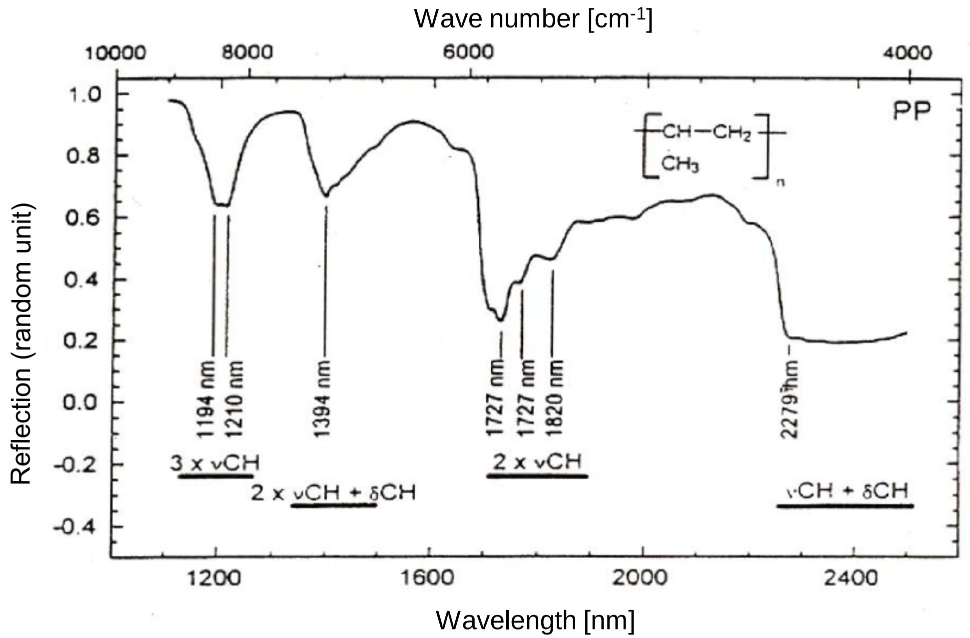
Detection

- almost all kinds of plastic, for instance.

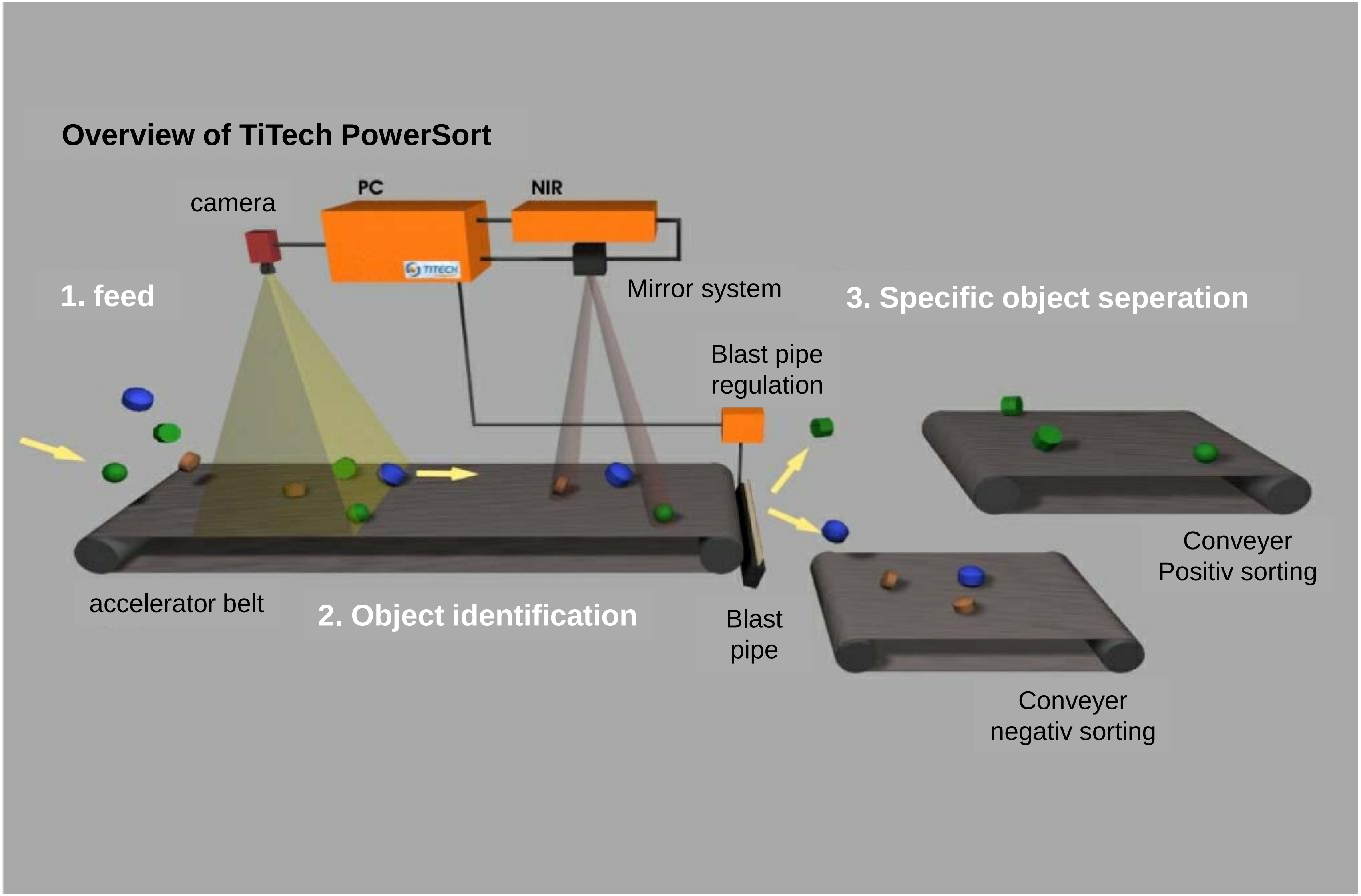
PA	Polyamide
ABS	Acrylonitrile-butadiene-styrene
PBT	Polybutylene-terephtalate
PP	Polypropylene
PE	Polyethylene
PA	Polyamide (Nylon 6/66)
PET	Polyethylene terephtalate
PVC	Poly-vinyl-chloride

- Cellulose, paper, wood

Plastic	Characteristic absorption bands in the CIR range							
	C–H in –CH_2		C–H in –CH_3		C=O		N–H	
	[cm^{-1}]	[µm]	[cm^{-1}]	[µm]	[cm^{-1}]	[µm]	[cm^{-1}]	[µm]
	5800 7200 8200	1,724 1,389 1,200	5900 8400	1,695 1,190	5250	1,905	6700 to 6800	1,493 to 1,471
Polypropylene (PP)	×		×					
Polyamide 6 (PA6)	×				×		×	



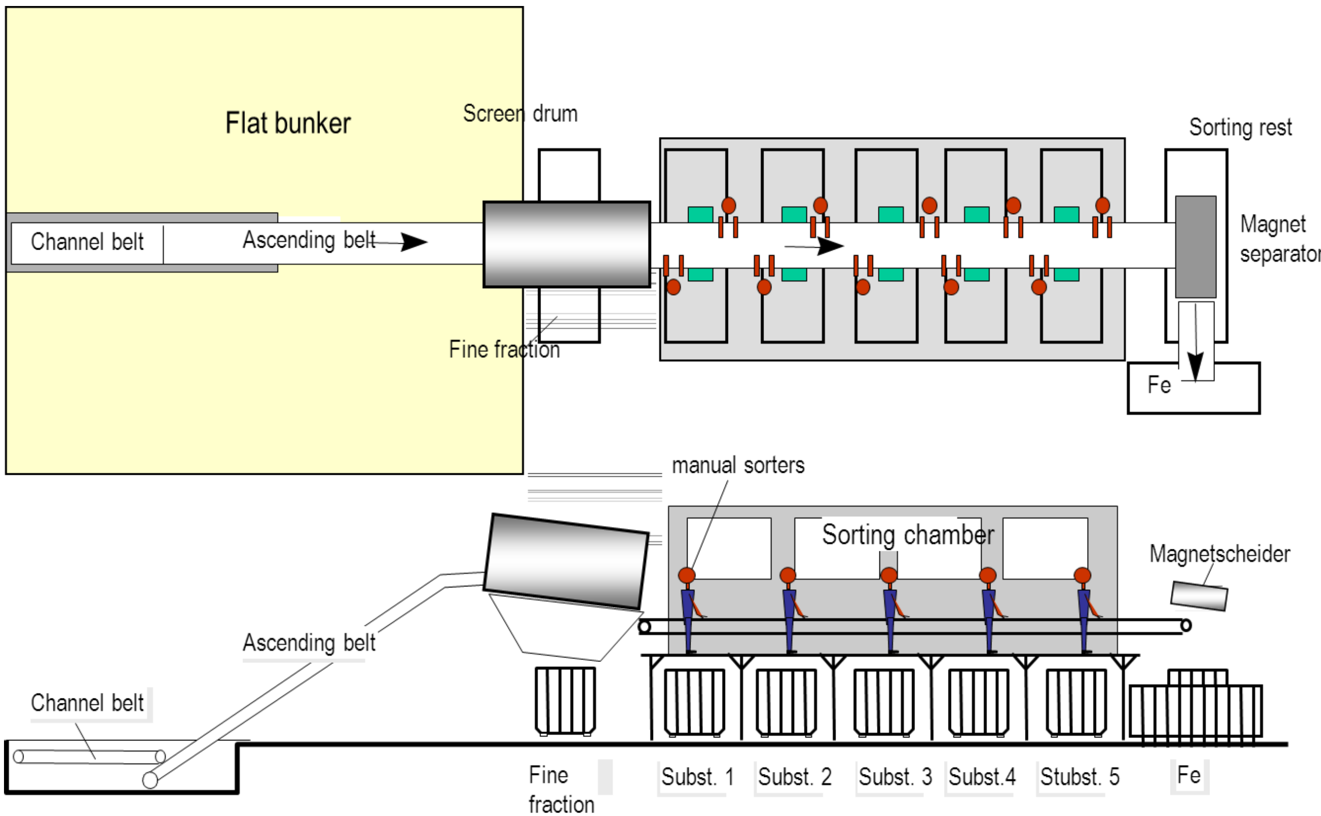
Principles of the processing of solid waste and technologies of recycling


Overview of TiTech PowerSort
camera
PC
NIR
1. feed
Mirror system
3. Specific object seperation
Blast pipe
regulation
Conveyer
Positiv sorting
accelerator belt
2. Object identification
Blast
pipe
Conveyer
negativ sorting

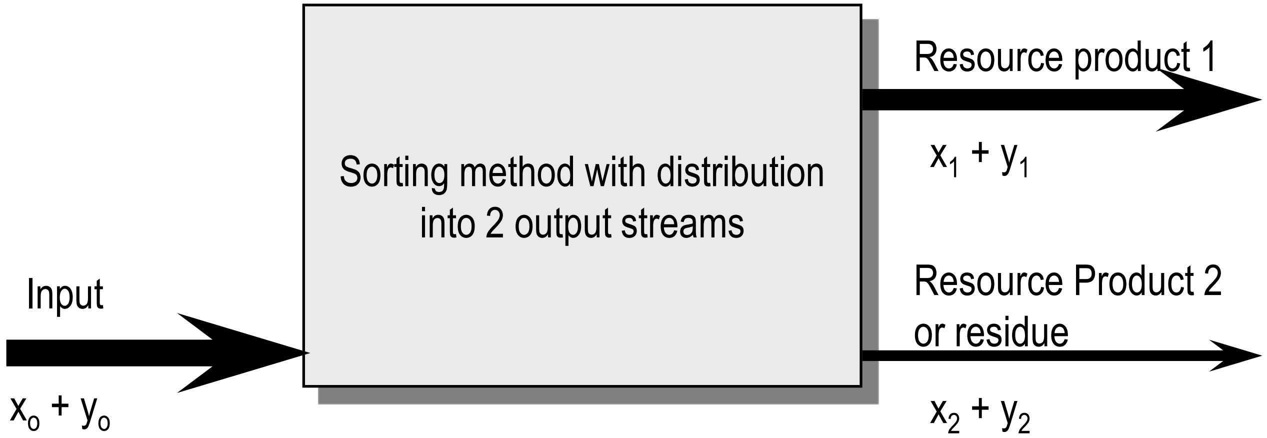
Manual Sorting

- Most universal sorting technique
- Grasp time at least 1 to 3 s per taking → wages/sorting costs
- Reasonable in case of
  - large variety of the taking
  - sufficient size of the pieces → prior to comminution
- Negative sorting = extraction of quantitatively low (negative) extraneous material
- Positive sorting = extraction of the (positive) resources
- Hygiene and work safety requirements for the sorting places and cabins, e.g. in TRBA 210 Technical Rules for Biological Working Materials
  - Air change, air control
  - Circulating air filters

Manual Sorting Plant



Evaluation of Sorting Methods – Distribution to 2 Sorting Streams



x_o = Mass flow of product x in the input = $x_1 + x_2$
y_o = Mass flow of product y in the input = $y_1 + y_2$

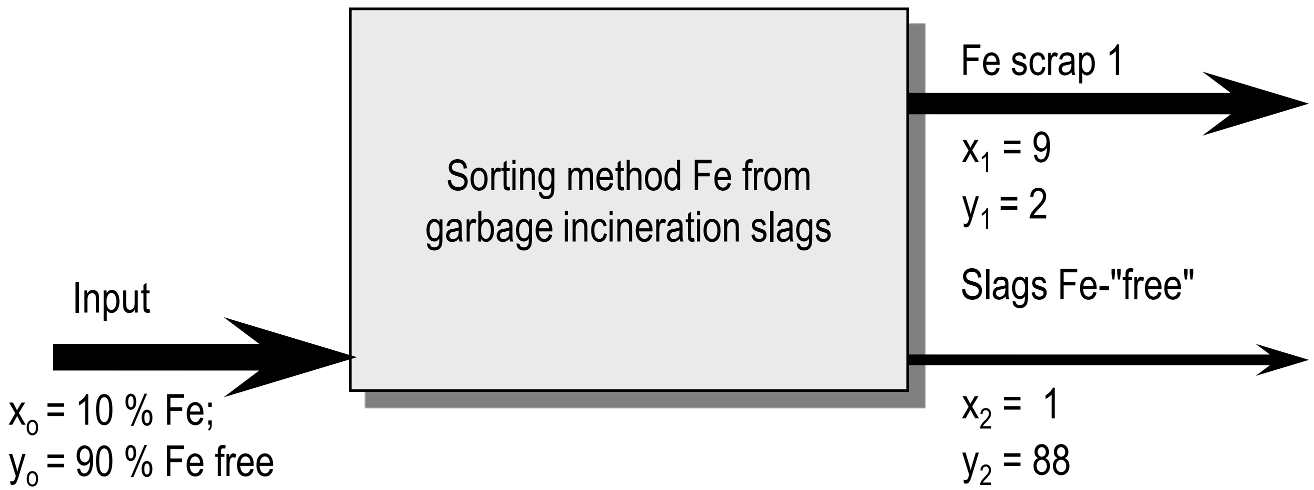
Mass output rate M_{x1} (%) = 100 · x_1/x_0; ideal $x_2 = 0$, then M_{x1} = 100%

If one calculates in concentrations $c_0 = x_0/(x_0+y_0) = x_0/m_0$ etc.,

the mass output rate amounts to $M_{x1}\,(\%) = \frac{m_1 \times c_1}{m_0 \times c_0} \cdot 100$

Purity grade P_{x1} (%) = 100 · $x_1/(x_1+y_1)$

Example: Fe Sorting of Garbage Incineration Slags



mass output rate	M_{x1} (%) = 100 · x_1/x_0	= 100 · 9 / 10	= 90 %
purity grade	P_{x1} (%) = 100 · $x_1/(x_1+y_1)$	= 100 · 9 / (9 + 2)	= 81,8 %

Combination of Single Methods to Method Chains

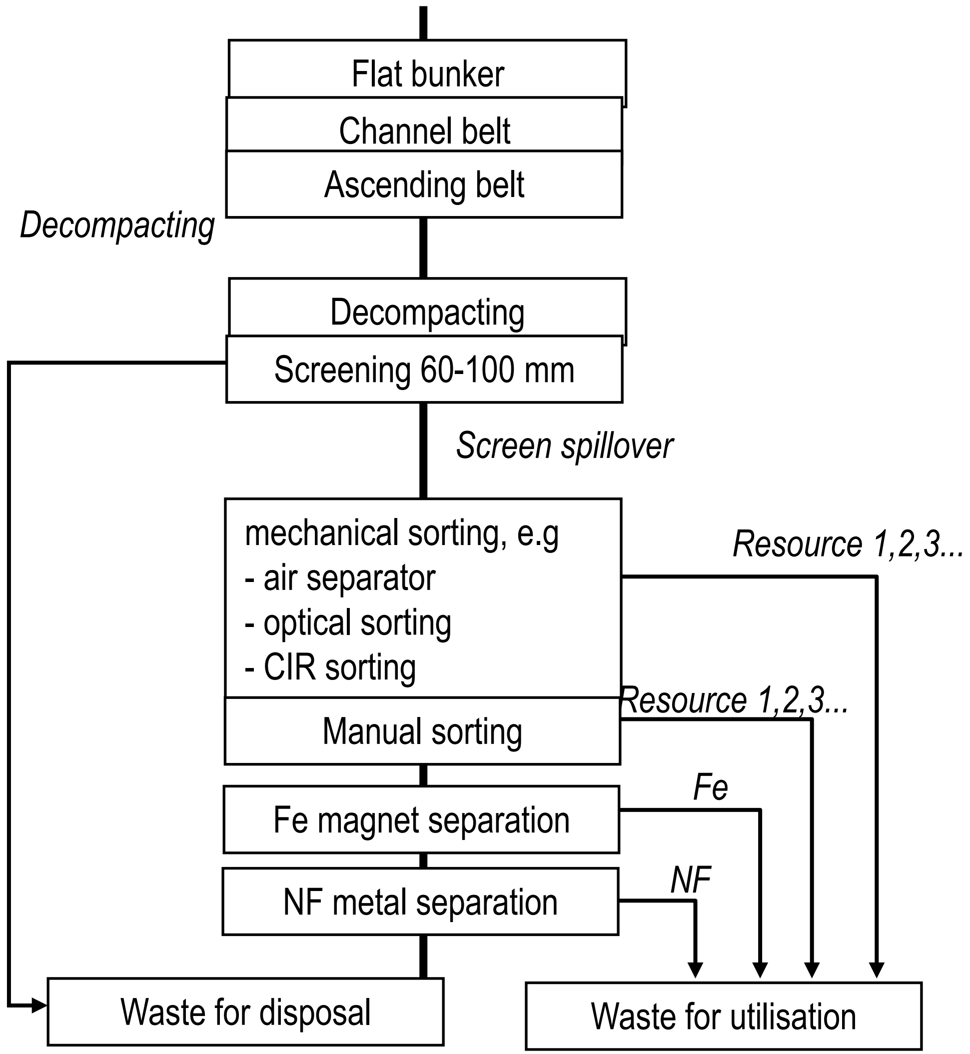
- Per sorting aggregate, distribution into 2-3 fractions.
  The more heterogeneous the waste, the more stages/aggregates.

- The sorting target depends on the application of the sorted product (quality requirements), possibly several sorting levels:
  - place of production
  - (pre-) sorting plant at the salvage material trader
  - sorting prior to/during production

- Consideration of changing input quality (seasonal, origin, etc.)
  - throughput capacity of the complete plant limited b the capacity of every single stage
  - reserves? intermediate storage?

- Modification or conversion should be made easy through a low number of trussless halls with a sufficient working height (clearance height > 8-10m)

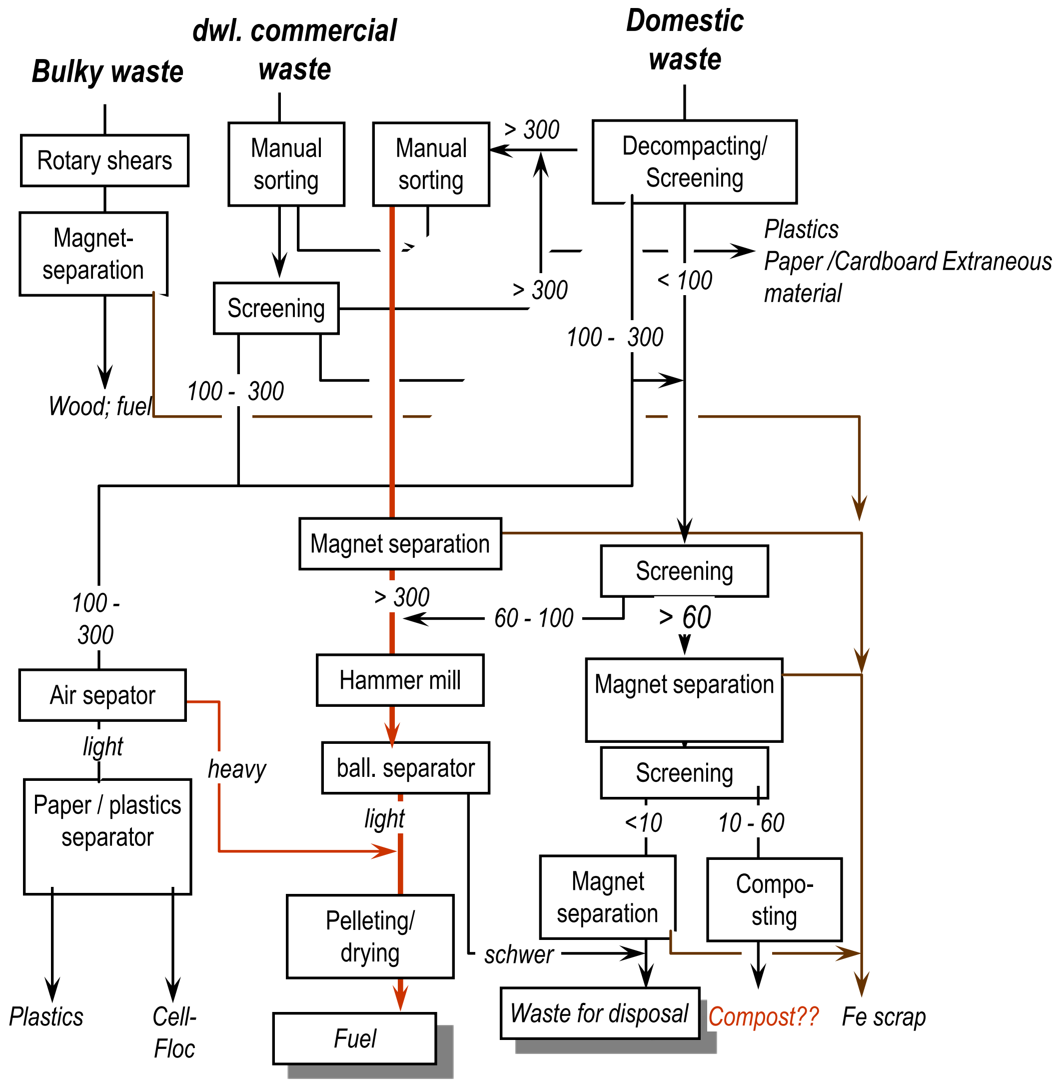
Typical Components of a Resources Sorting Plant



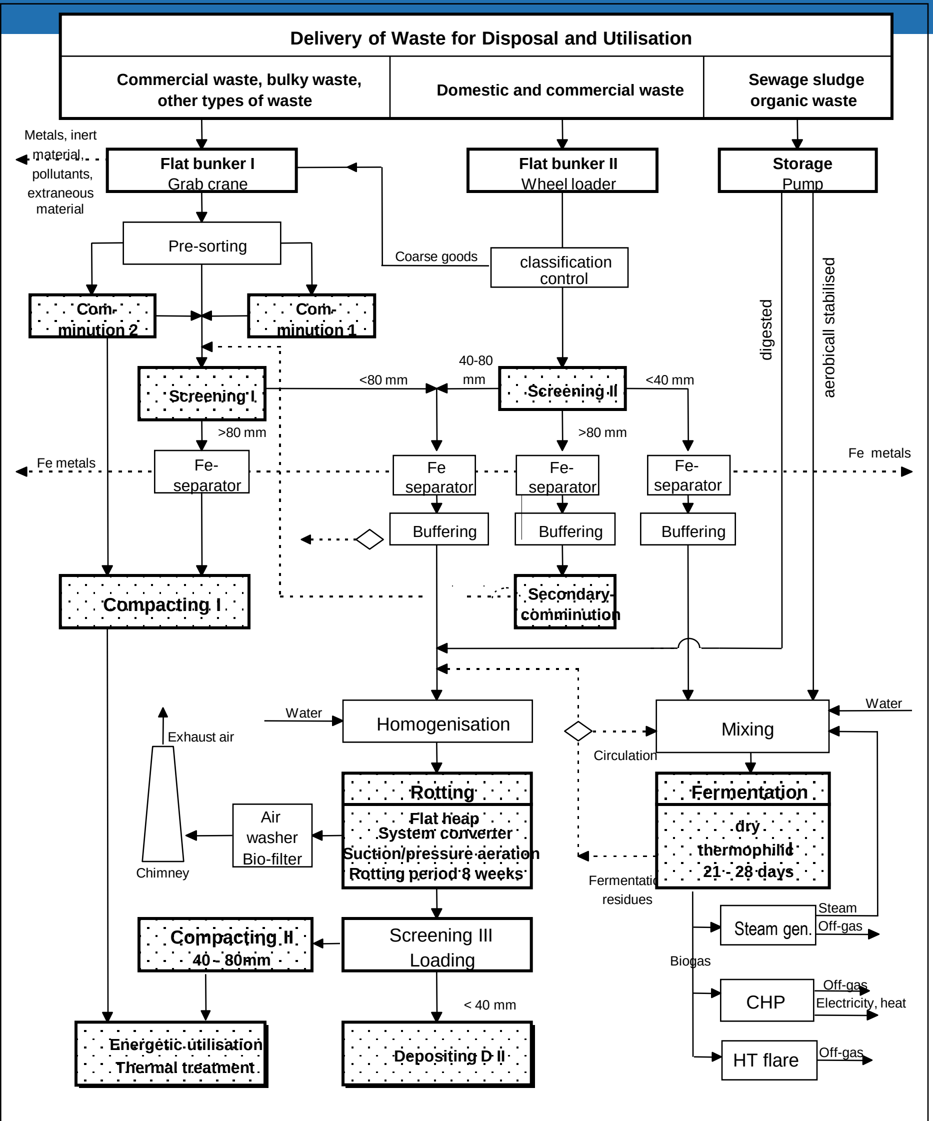
Weight and Caloric Value Ratios in DW/CW for RDF Production

Waste type group in the domestic waste	Weight ratio	Water contents	Ash contents	Caloric value Hu,raw	Caloric value contribution	
	%	%	% of DM	kJ/kg raw	kJ/kg waste	% of the energy contents
Paper, cardboard	22	20	13	11.000	2.420	29,0
Plastic, textiles	8	15	10	32.000	2.560	30,7
Wood, leather, rubber, bones	9	20	20	16.000	1.440	17,2
Intermediate sum high caloric value	**39**			**16.462**		**76,9**
Garden and kitchen waste	32	55	15	4.000	1.280	15,3
Fine fraction < 8mm and unsorted residues	13	20	60	5.000	650	7,8
inorganic (glass, metal, stones, ceramics)	16	1	99	0	0	0
total, average domestic waste	100	27,8	33,9		8.350	100

Process Design of the Sorting Plant at Dusslingen (BW) (State Mid-80s)



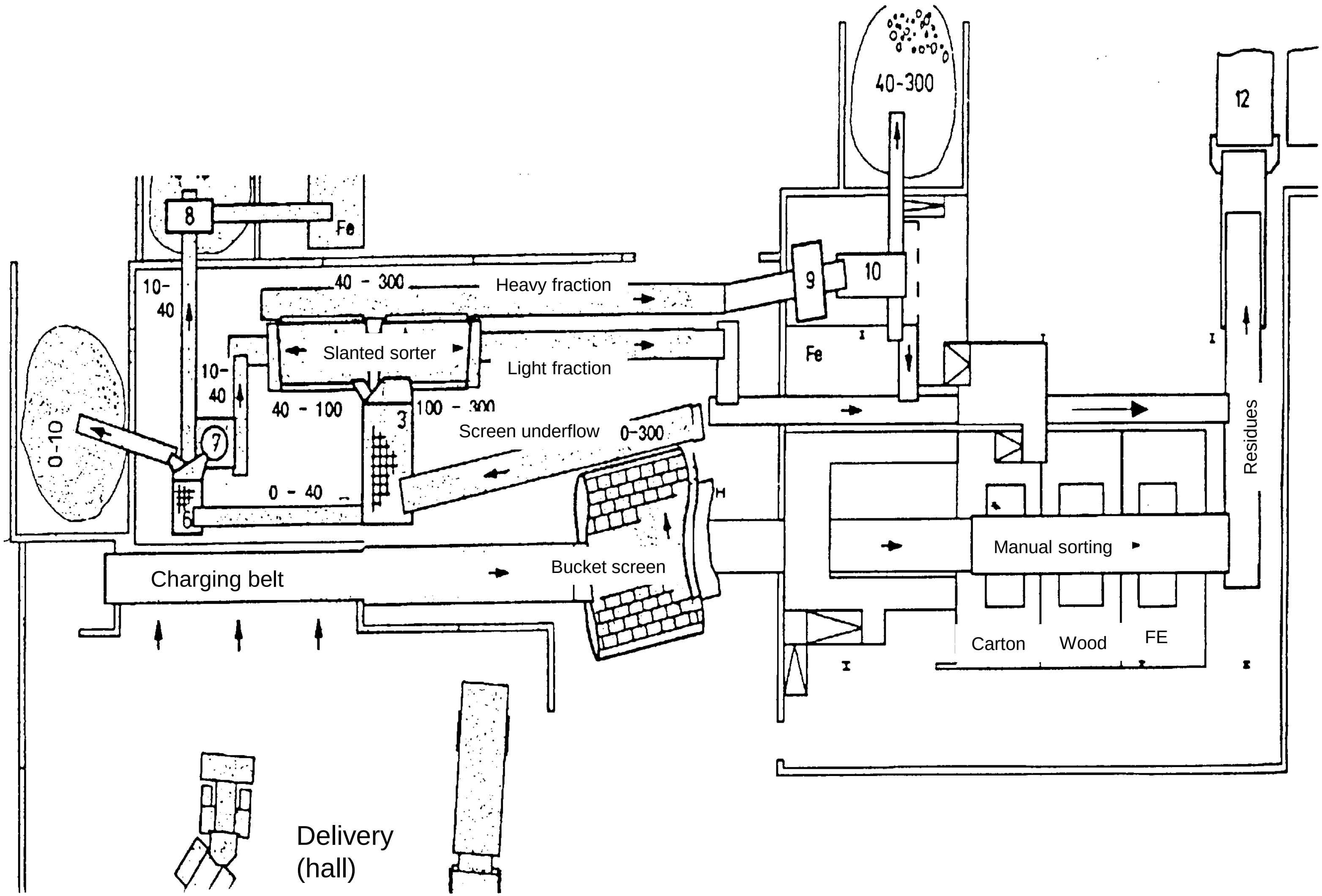
Municipal Waste Treatment Plant at Bassum



Flow diagram of the Raw Waste Treatment Plant (RABA) at Bassum/District of Diepholz

IBA

Process Diagram Processing Plant for Commercial and Building Waste at Ravensburg



Building Waste Sorting Plant Remex Compan in Stuttgart according to Bilitewski, 1995