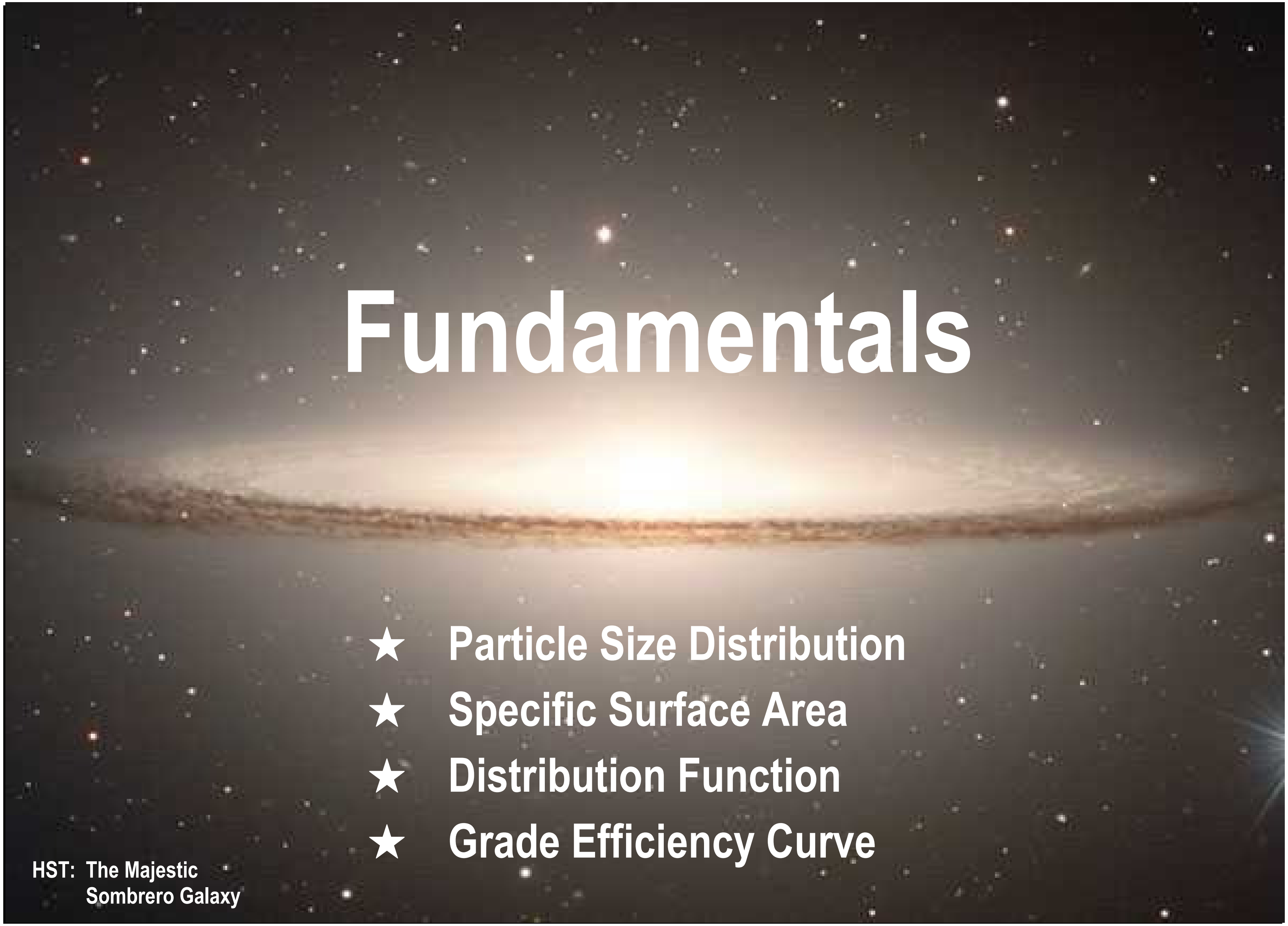

Fundamentals
★ Particle Size Distribution
★ Specific Surface Area
★ Distribution Function
★ Grade Efficiency Curve
HST: The Majestic
Sombrero Galaxy

Fundamentals of Particle Size Analysis

- ★ Introduction
- ★ Particle size distribution
  - ☆ Physical particle properties
  - ☆ Types of quantity
  - ☆ Measures of quantity
  - ☆ Equivalent diameters
  - ☆ PSA methods
- ★ Graphic presentation of PSD
  - ☆ Cumulative distribution Qr(x)
  - ☆ Density (differential) distribution qr(x)
- ★ Specific surface area
  - ☆ Definition
  - ☆ Evaluation from PSD
  - ☆ Blaine principle
- ★ Distribution functions
  - ☆ RRSB distribution
  - ☆ RRSB distribution grid
- ★ Grade efficiency curve
  - ☆ Definition
  - ☆ Tromp curve
  - ☆ Characterisation of a separation
- ★ References

Introduction [3]

- ★ Particle size analysis comprises the measurement and the quantitative description of physical properties of particulate matter
- ★ Particulate or disperse systems consist of a finely divided particulate phase in a continuous carrier or dispersion medium
- ★ Particulate phase and dispersion medium may be solid, liquid or gaseous
- ★ Particle size analysis predominantly investigates such systems as suspensions, emulsions, aerosols (sprays) and aero-dispersions (dry powders)
- ★ In PSA every possible physical principle has been used to determine the particle size distribution
  - ☆ Only very few have reached an important position in industrial application, e.g.:
    - Sieving
    - Sedimentation
    - Laser diffraction

Particle Size Distribution [3]

Individual elements of disperse matter form a distribution. It is elements can be classified according the their size.

The distribution is characterised by a quantity, e.g. the number or the mass of particles present in individual size classes.

Physical particle properties used in PSA are:

- ★ Geometric properties
  - ☆ Linear dimension
  - ☆ Surface area, projected area
  - ☆ Volume
- ★ Mass
- ★ Settling velocity
- ★ Distortion of electrical, optical, acoustic field

The types of quantity used in PSA are defined as follows:

Quantity type	Index r
Number	0
Length	1
Area, surface	2
Volume	3
mass	3 (if ρ_s = const.)

Measures of quantity used in PSA are:

- ★ Cumulative distribution Qr
- ★ Density or differential distribution qr

Equivalent diameters are diameters of spheres that yield the same value of a certain physical property when analysed under the same conditions as the irregularly shaped particles

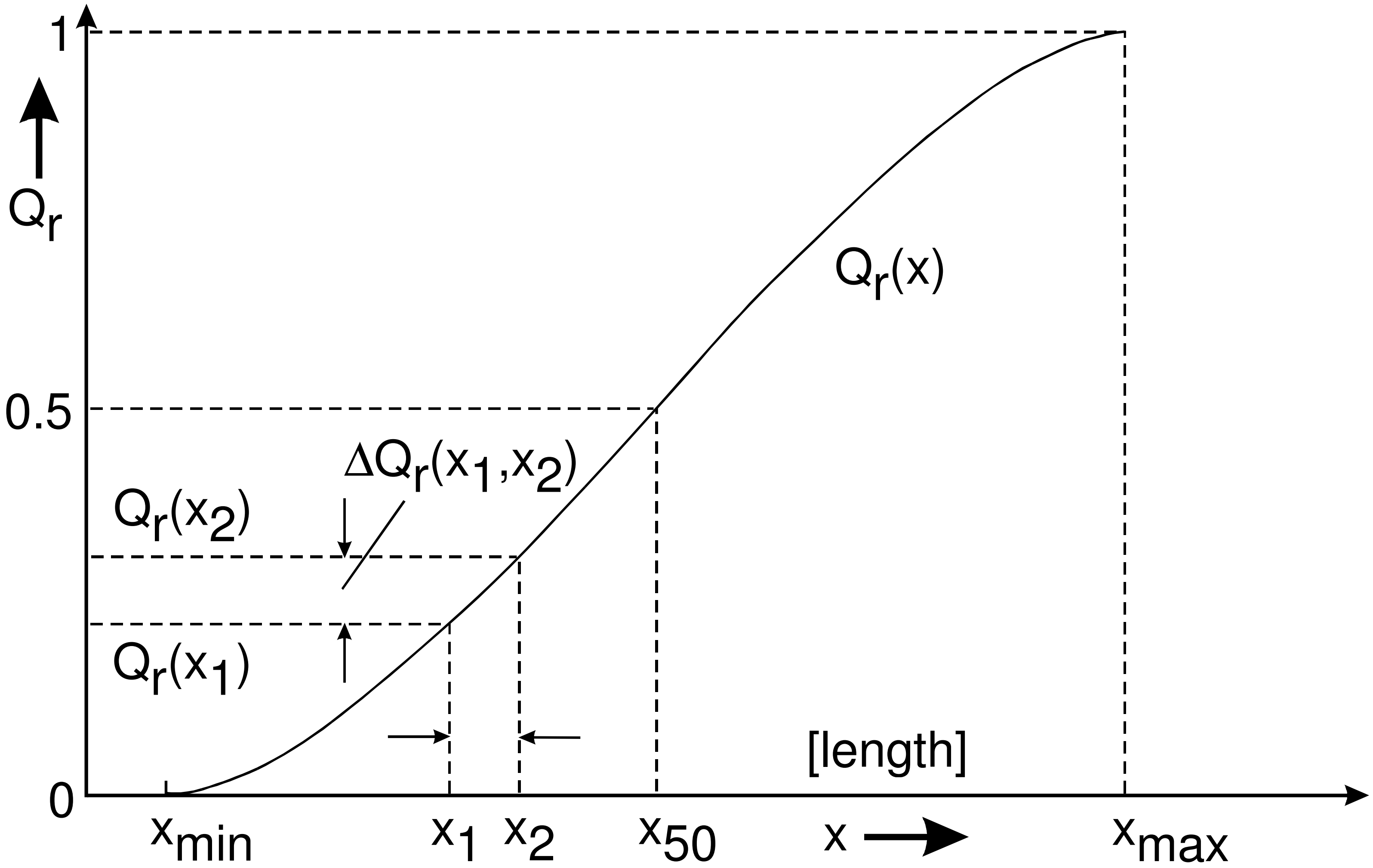
PSA methods related to physical properties and quantity types, e.g.:

Method	Particle property	Quantity type
Sieve analysis	linear dimension	mass
Sedimentation	settling velocity	mass
Coulter counter	volume	number
Laser diffraction	distortion of optical field	area

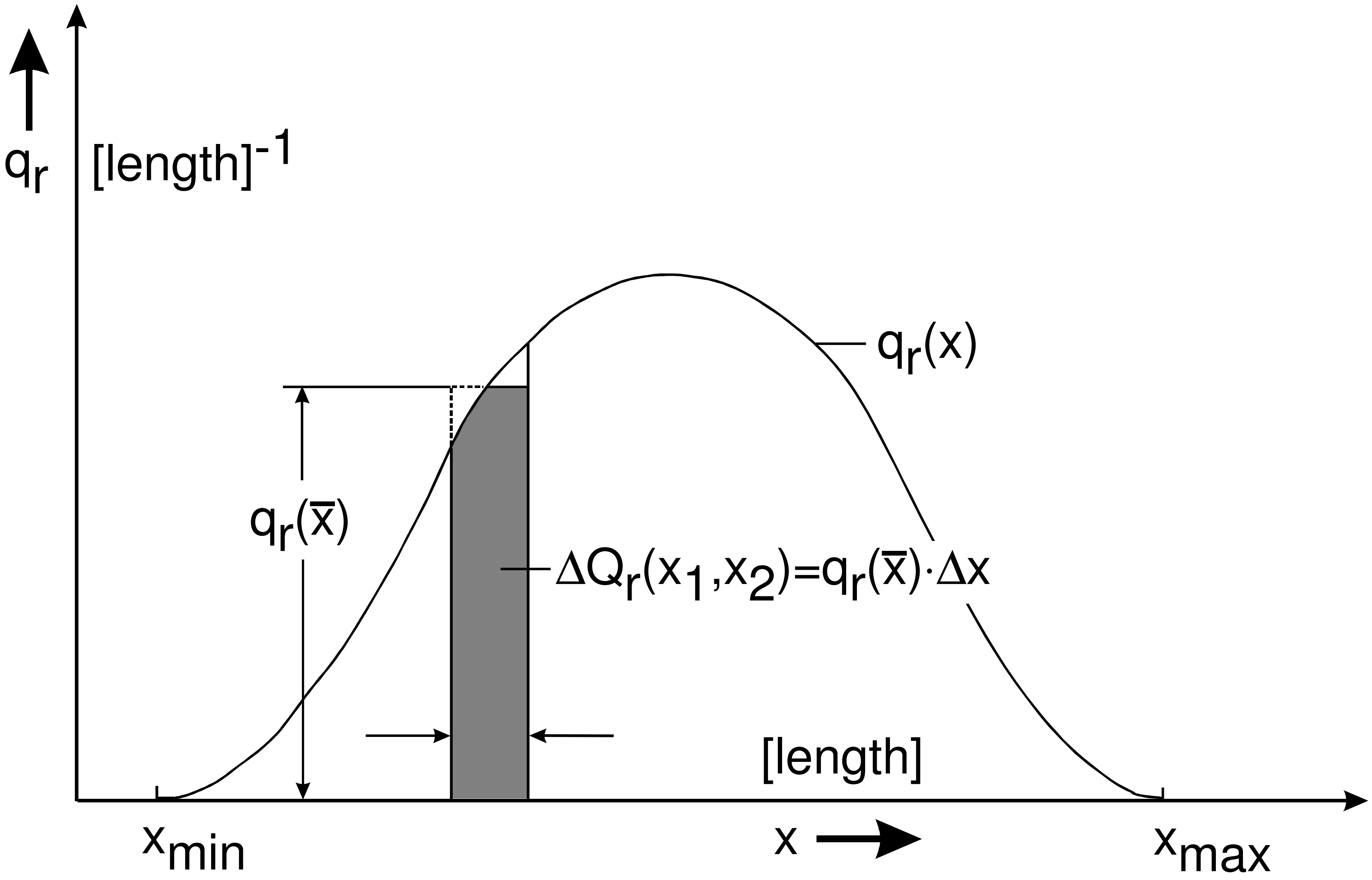
Graphic Presentation of PSD [4]

In a two dimensional graphic presentation of PSA data, the independent variable, plotted on the abscissa, describes the physical property chosen to characterise the size of the particles.

The dependent variable characterises type of quantity and measure of quantity and is plotted on the ordinate (refer to ISO 9276-1).



Cumulative distribution



Density of differential distribution

The shaded area in the density or differential distribution curve

$dQ_r (x) = q_r (x) dx$

represents the quantity of particles dQr (x) between x and x + Δx.

The area below the density distribution curve qr (x) always equals ONE (condition of normalisation) !

$$\int_{x_{min}}^{x_{max}} q_r (x) dx = Q_r (x_{max}) - Q_r (x_{min}) = 1$$

Specific Surface Area [5]

Definition:

Volume related specific surface

$S_V = S/V$ [m^2 / cm^3]

Mass related specific surface

$S_m = S/m$ [cm^2 / g]

$S_m = S_V / \rho_s$

ρ_s = density of solid

Evaluation from Particle Size Distribution

Definition of momentum:

$$M_{k,r} = \int_{x_{min}}^{x_{max}} x^k \cdot q_r(x)\,dx$$

k = exponent k of equivalent diameter x
r = quantity measure of q
k = ... -3, -2, -1, 0, 1, 2, 3 ...
r = 0, 1, 2, 3

$$S_V = 6 \cdot f \cdot \frac{M_{2.0}}{M_{3.0}} = 6 \cdot f \cdot M_{-1.3}$$

$$S_V = 6 \cdot f \cdot \int_{x_{min}}^{x_{max}} \frac{1}{x} \cdot q_3(x)dx$$

f = Heywood shape factor

Blaine Prinicple: (DIN 66127)

$$S_V 2 = K \cdot \frac{\varepsilon^3 \quad \tau}{(1-\varepsilon)^2 \, \eta}$$

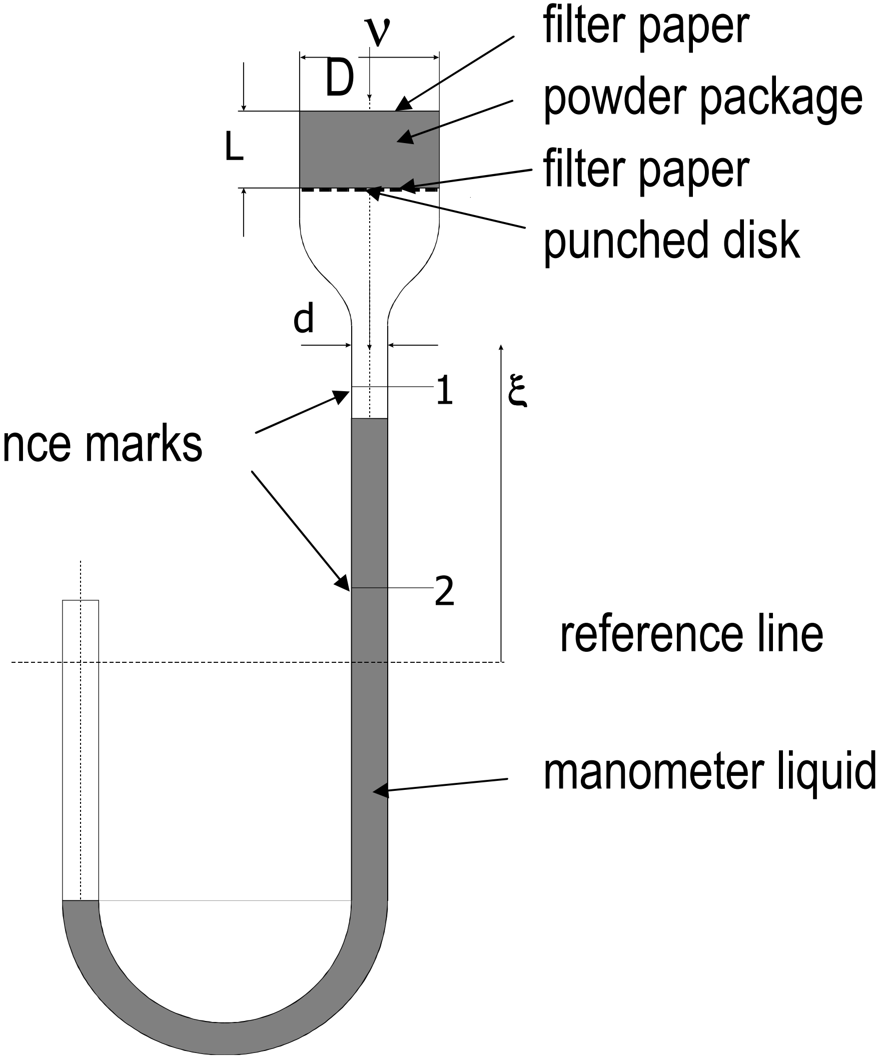
[m^2 / cm^3]

S_V = Volume related specific surface
K = Instrument constant
ε = void ratio, permeability, porosity
τ = time
η = dynamic viscosity

$$K = \frac{2}{k} \cdot \frac{g}{L} \frac{\rho_M}{\ln(\xi_1 / \xi_2)} \cdot \left(\frac{D}{d}\right)$$

k = Kozeny constant
g = Gravity constant
L = Height of bulk package
ρ_M = Density of manometer liquid
D = Diameter of package
d = Diameter of capillary
$\ln(\xi_1/\xi_2)$ = Height of manometer liquid between position 1 and 2

Principle of Blaine instrument



Distribution Functions

RRSB distribution (DIN 66145)

(Rosin, Rammler, Sperling, Bennet)

$$R(x) = 1 - Q_3(x) = \exp(-(x/x')^n)$$

Two parameter function:

x' = Position parameter

n = Scatter parameter

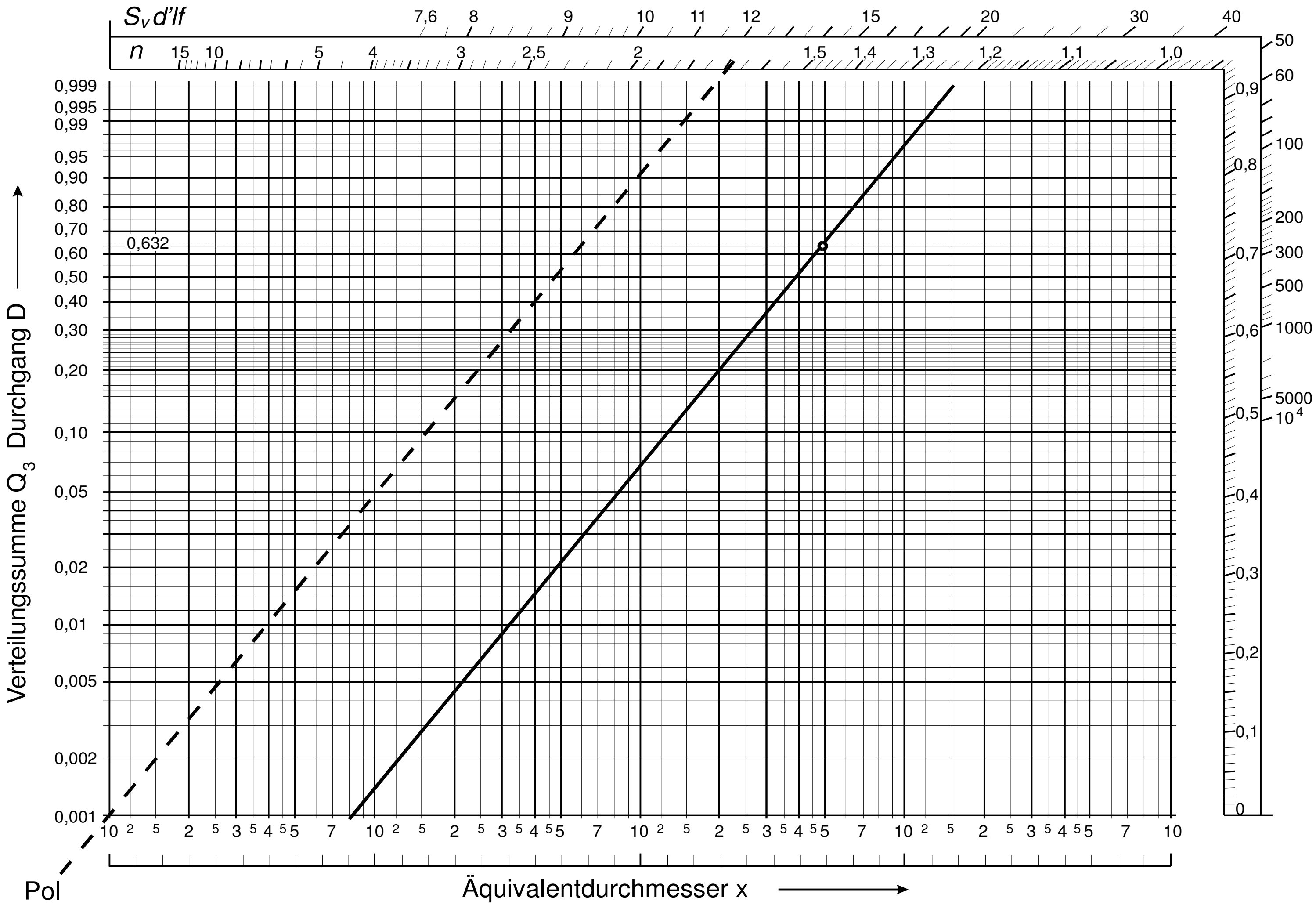
x' : $R_3(x') = e^{-1} = 0{,}368$

$Q_3(x') = 0{,}632$

n : Slope of straight line in RRSB grid

RRSB distribution grid

refer to DIN 66145



Grade Efficiency Curve T(x) [3]

Definition

The grade efficiency curve T(x) (Tromp Curve) describes the efficiency of a classification or a separation process.

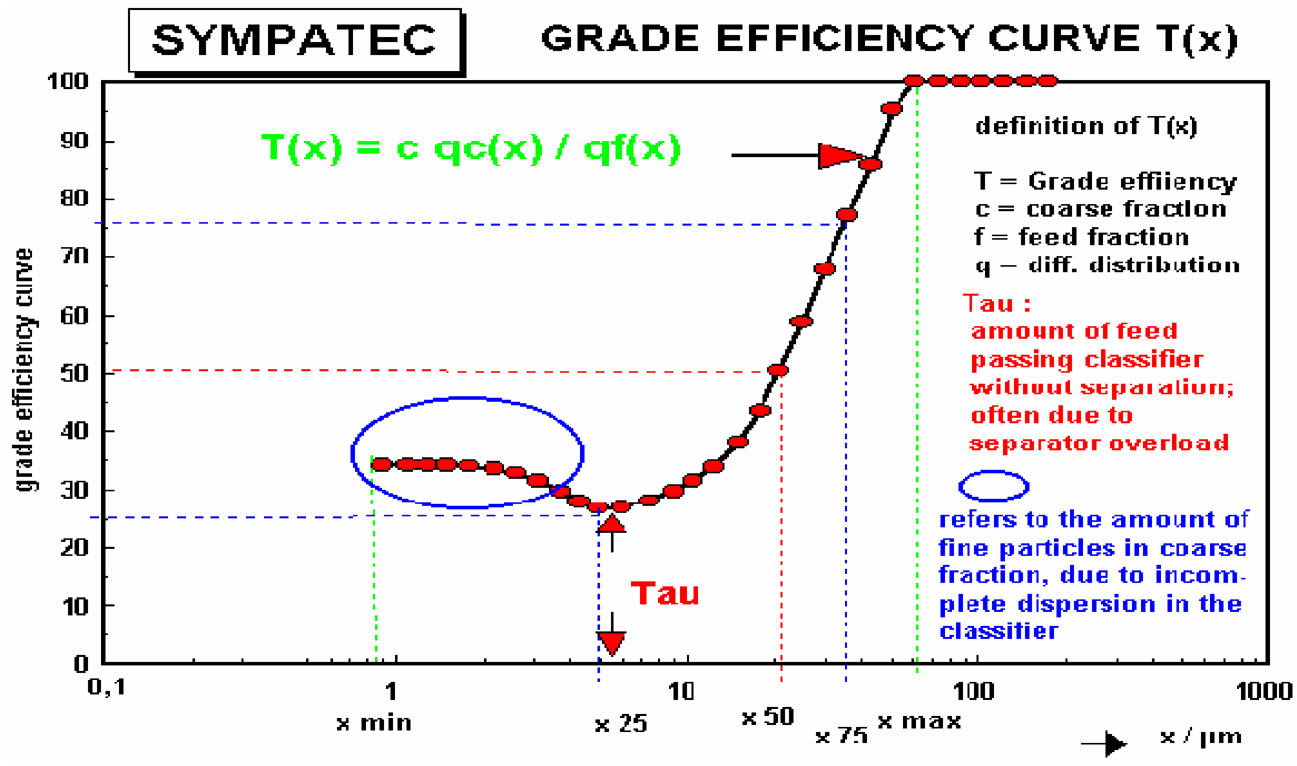
T(x) represents the ratio of the relative amount of material of certain size present in the coarse material (oversize, reject) ($C.q_c(x)dx$), to the relative amount of the same size initially present in the feed material ($q_F(x)dx$).

$$T(x) = \frac{C \cdot q_C(x)}{q_F(x)}$$

C = relative amount of coarse material

$$C = \frac{M_C}{M_F} = \frac{M'_C}{M'_F}$$

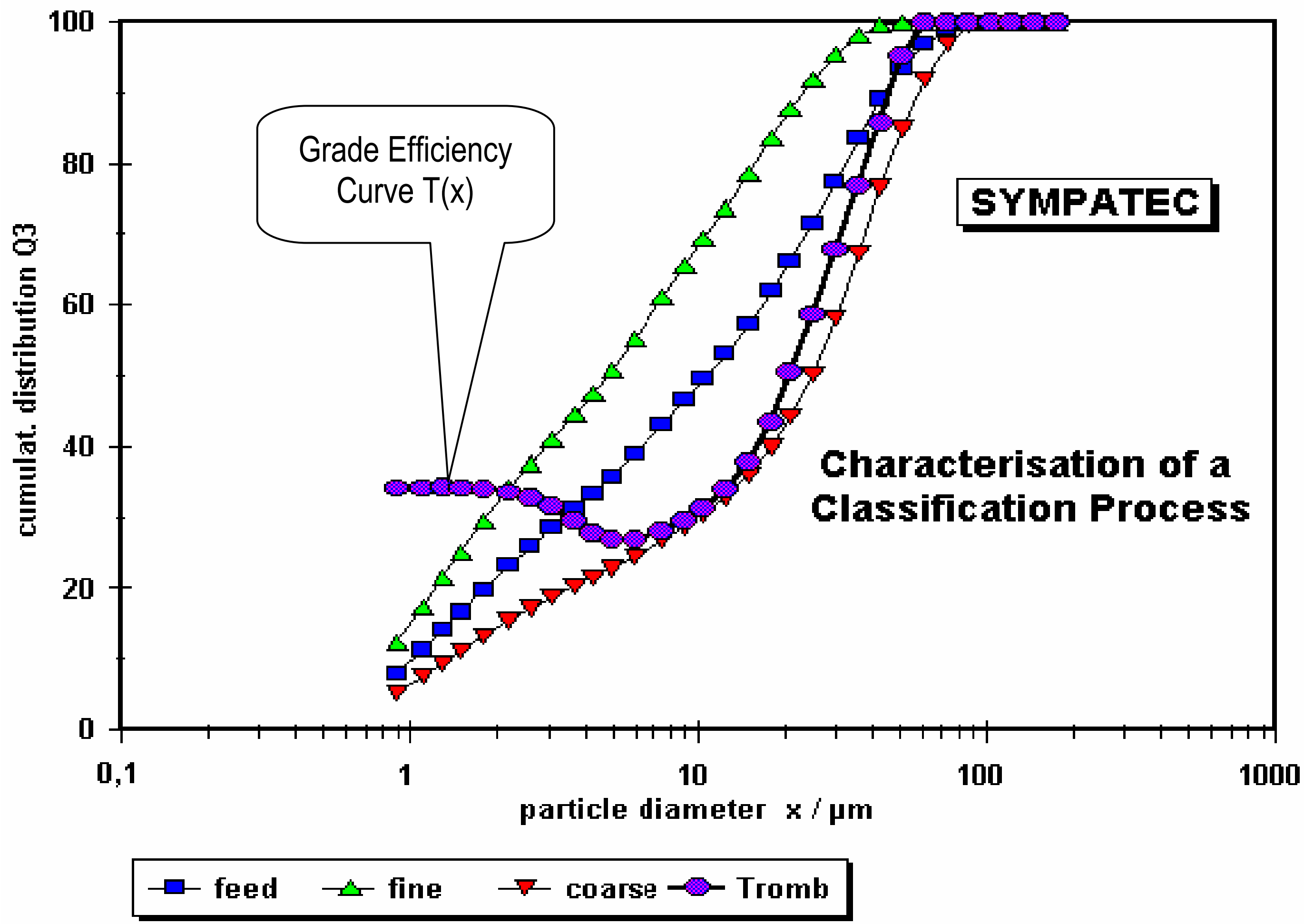
M_F, M'_F = amount mass flow rate of feed material
M_C, M'_C = amount mass flow rate of coarse material



Measures for sharpness of cut

Ecat Terra: $E_T = (x_{75} - x_{25})/2$

Imperfection: $I = (x_{75} - x_{25})/2 \cdot x_{50}$


Grade Efficiency
Curve T(x)
SYMPATEC
Characterisation of a
Classification Process
cumulat. distribution Q3
100
80
60
40
20
0
0,1
1
10
100
1000
particle diameter x / µm
feed
fine
coarse
Tromb

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ISO 9276-1: Graphical representation
ISO 9276-2: calculation of average particle size

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DIN 66141 – 66145

[6] Perry Chemical Engineer's Handbook; 8th ed.
Robert H. Perry
Chapter Particle Sizing
Dr. Wolfgang Witt