Today, we will:

- Continue to discuss **particle collection efficiency** in **Section 8.3**
- Do an example – the sample data from our class handout going though an air cleaner
- Discuss **air cleaners in series and parallel** in **Section 8.3**
- Do some example problems – air cleaners in series and parallel
- If time, begin to discuss **equations of particle motion** in **Section 8.4**

Grade efficiency (also called fractional efficiency) of various air cleaners:

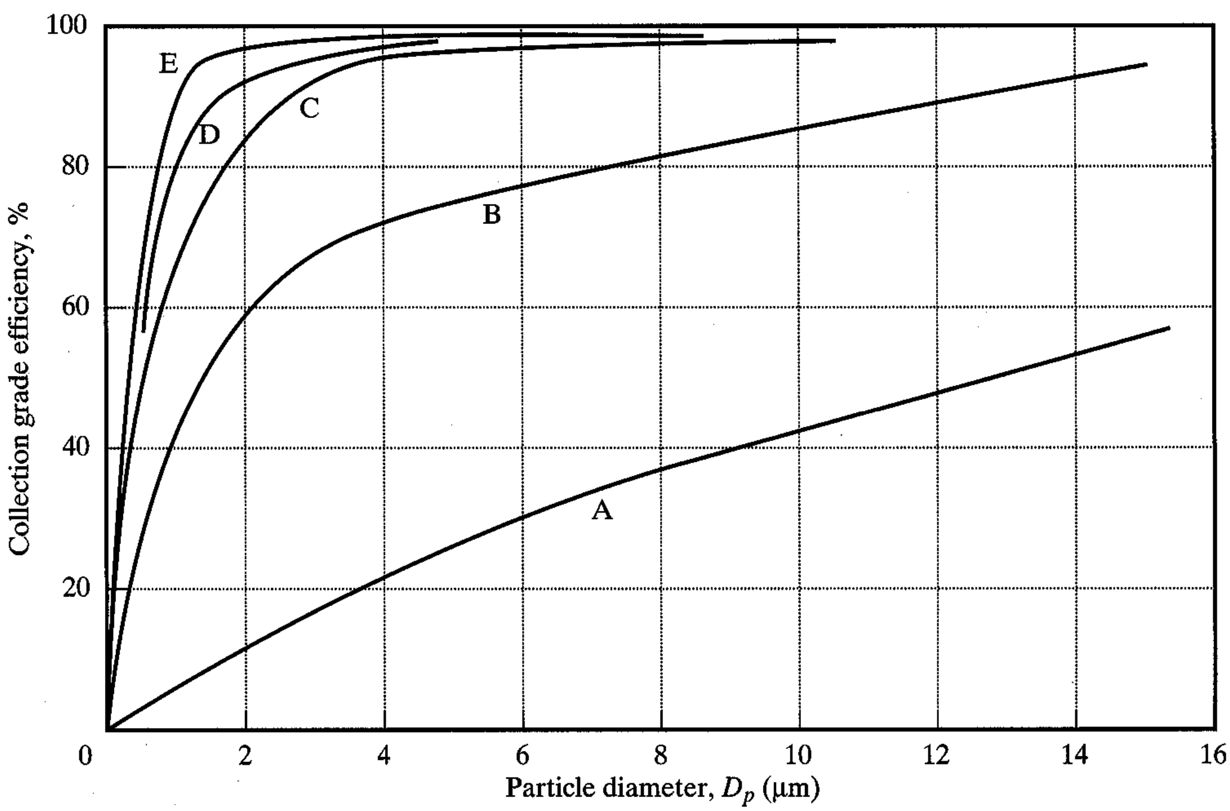
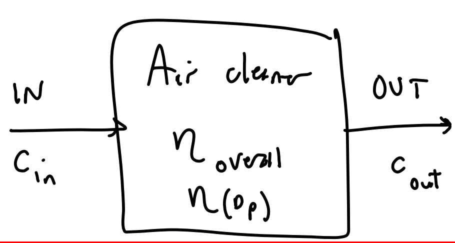


Figure 8.7 Typical collection grade efficiencies of different dust collectors; A: low-efficiency high-flow rate cyclones, B: high-efficiency low-flow rate cyclones, C: spray towers, D: electrostatic precipitators, E: venturi scrubbers.

Summary of Important Equations and Concepts for Particle Collection:

For grouped data $\quad j = 1$ to J bins or classes

$D_{p,j}$ = middle value of diameter in class j



C_{in} = overall mass concentration in

$$\boxed{C_{in} = \sum_{j=1}^{J} c(D_{p,j})_{in}}$$

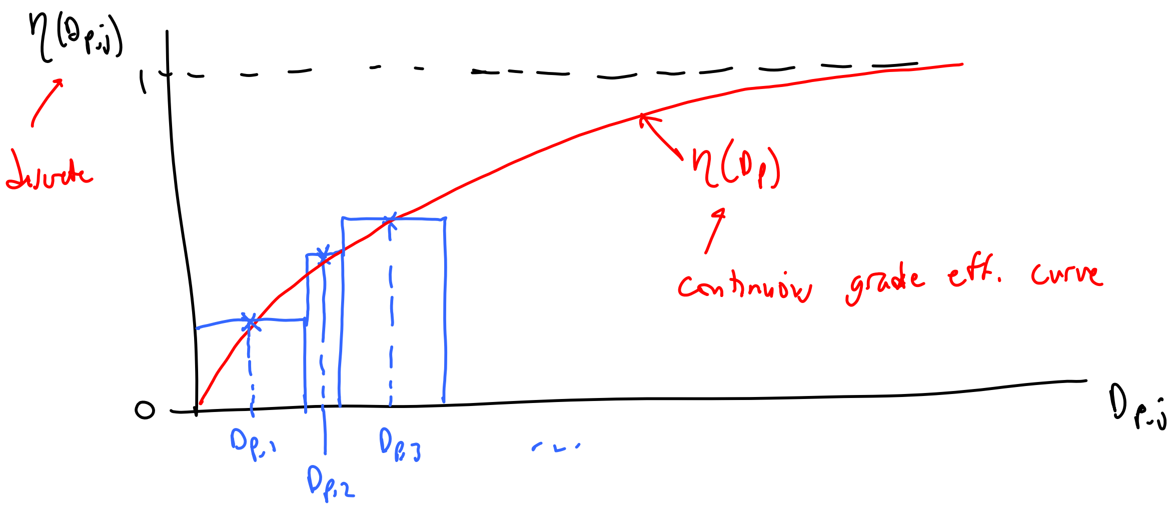
C_{out} = overall " " " out

$$\boxed{C_{out} = \sum_{j=1}^{J} c(D_{p,j})_{out}}$$

$\eta(D_{p,j})$ = discrete grade efficiency

$$\boxed{\eta(D_{p,j}) = 1 - \frac{c(D_{p,j})_{out}}{c(D_{p,j})_{in}}}$$

To generate the continuous grade efficiency, $\eta(D_p)$, we do a smooth curve fit through $\eta(D_{p,j})$



Recall, mass fraction

$$\boxed{g(D_{p,j}) \equiv \frac{m_j}{m_t}}$$

$$\boxed{g(D_{p,j}) = \frac{m_j}{m_t} = \frac{m_j/\mathcal{V}}{m_t/\mathcal{V}} = \frac{c(D_{p,j})}{c_{overall}} = \frac{c(D_{p,j})}{c}}$$

Overall Collection Efficiency

Depends on grade efficiency And on particle distribution (in)

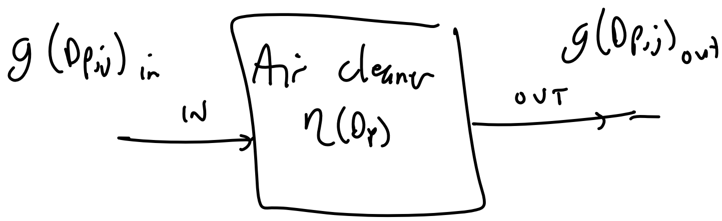
$$\boxed{\eta_{overall} = \eta = 1 - \frac{C_{out}}{C_{in}}}$$

After some algebra ...

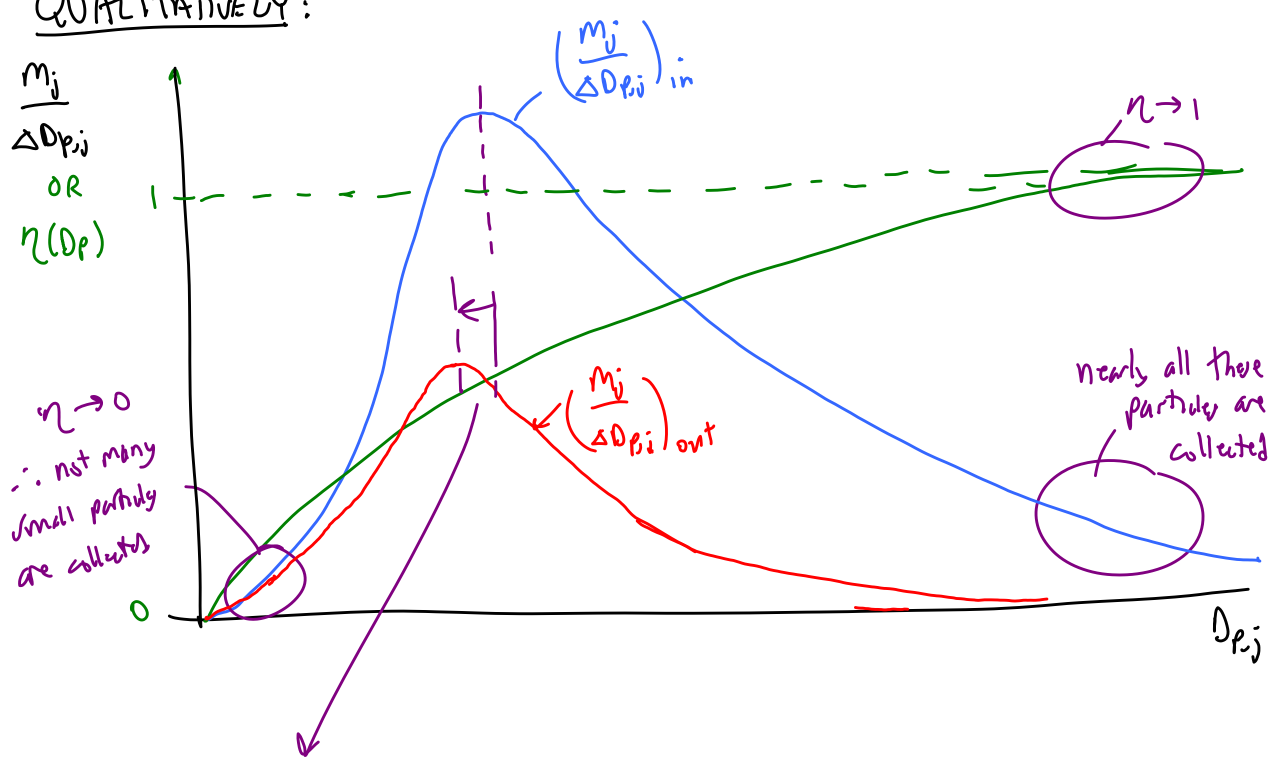
$$\boxed{\eta_{overall} = \sum_{j=1}^{J} \left[\eta(D_{p,j})\, g(D_{p,j})_{in} \right]} \qquad (8\text{-}45)$$

And, after some more algebra ...

$$☆ \quad \boxed{g(D_{p,j})_{out} = \frac{1-\eta(D_{p,j})}{1-\eta_{overall}}\, g(D_{p,j})_{in}} \qquad (8\text{-}46)$$



QUALITATIVELY:



Mass distrib. shifts to lower diameter particles

$(D_{p,50})_{out} < (D_{p,50})_{in}$ etc.

In general, the shape of the mass distrib. curve also changes

If the inlet distrib. is log normal, the outlet distribution is not necessarily log normal

Quantitative example → Let's use the particle dist. of the class handout

SEE EXCEL SPREADSHEET ON THE WEBSITE!

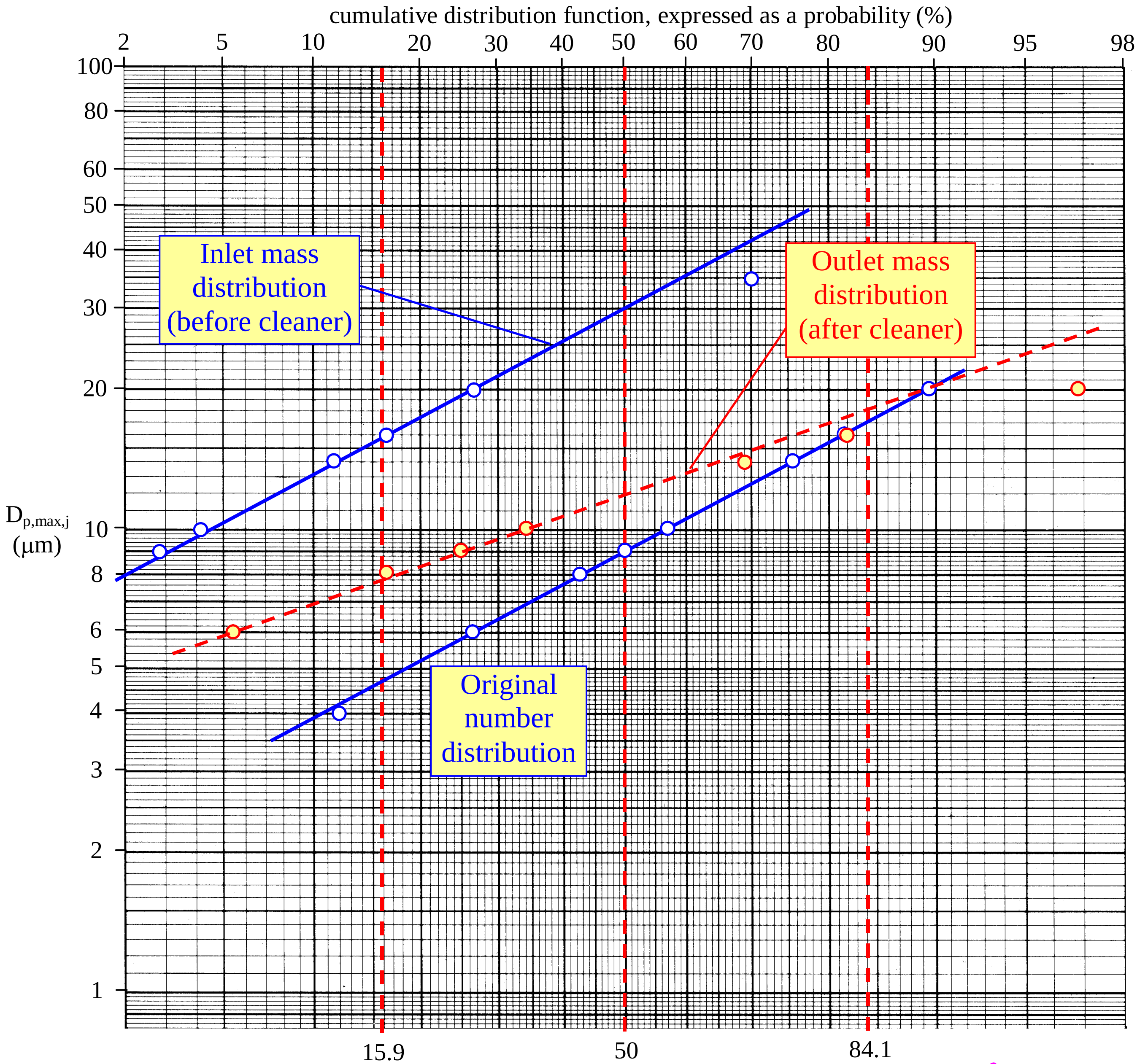
Example

Given: The particle distribution from the class handout passes through an air cleaner with grade efficiency $\eta(D_p) = 1 - \exp(-0.0068 D_p^2)$.

To do: Compare the mass distribution into and out of the air cleaner. Plot the inlet and outlet cumulative mass distributions on log probability paper and compare.

Solution: See the Excel spreadsheet on the course website.

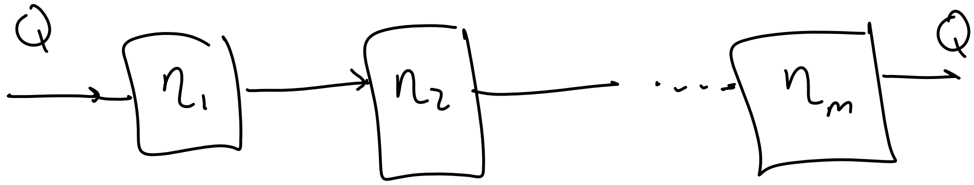
Log probability plots: sample data of the class handout (before and after air cleaner)



The outflow is sort of log normal, but not quite — it veers off of a straight line significantly at large D_p. It is not known if this is due to scatter in the data or if the cleaner leads to an outflow that is not log normal.

Air cleaners in series & parallel

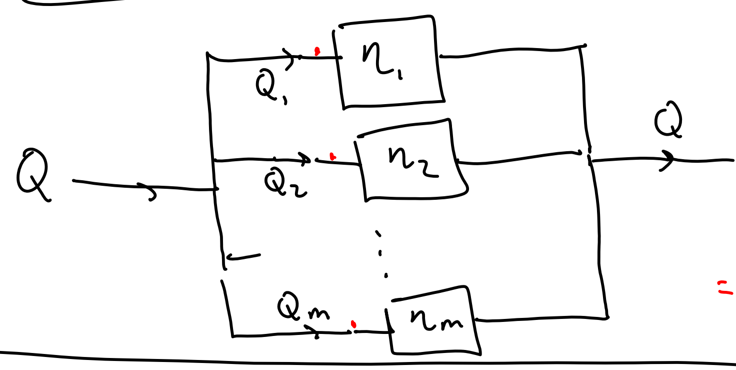
Series:



$$\eta_{overall} = 1-(1-\eta_1)(1-\eta_2)\cdots(1-\eta_m)$$

$$\boxed{\eta_{overall} = 1-\prod_{j=1}^{m}(1-\eta_j)}$$

Parallel



$f_1 = \frac{Q_1}{Q}$

$f_2 = \frac{Q_2}{Q}$

= volume flow rate fraction

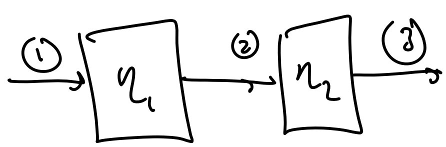
$$\boxed{\eta_{overall} = 1-\left[f_1(1-\eta_1)+f_2(1-\eta_2)+\cdots f_m(1-\eta_m)\right]}$$

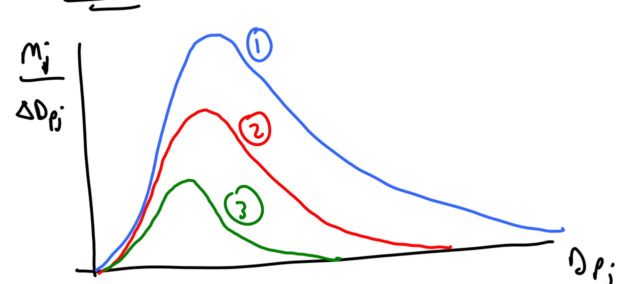
$$\boxed{\eta_{overall} = 1-\sum_{j=1}^{m}\left[f_j(1-\eta_j)\right]}$$

For parallel cleaners, Particle dist. coming into each cleaner is identical

For series cleaners, Particle dist. changes as it passes through each cleaner.

e.g.

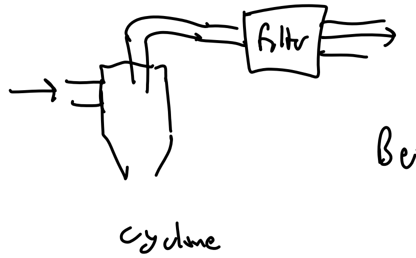




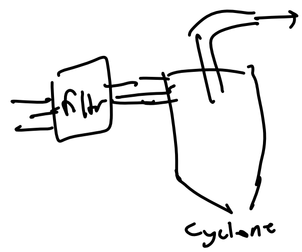
Thus, the overall efficiency changes for each cleaner in series even if the cleaners are all identical !

Common sense rule → Put coarser cleaners first, and then the finer cleaners last when using series cleaners

eg cyclone & a filter



Better choice than



See Example 8.4 in text

$\boxed{\text{SEC } 8.4}$ → Equations of Particle Motion

Assume: • Particles are $\gtrsim 10$ diameters apart [treat each particle independently] ☆

• One-way coupling → particles are affected by the fluid flow, but fluid flow is not affected by the particles ☆

calc.

☆ "frozen flow field" first.

Then, calc. particle trajectories — without affecting the flow