Lapple Cyclones A PRACTICAL APPLICATION OF INERTIAL SEPARATION !

Today, we will:

- Introduce **Cyclones**, discuss how they work, and provide equations
- Discuss **Lapple Cyclone Performance** when parameters are varied
- Do an example problem

Introduction to Cyclones/Principle of operation: Make the dusty air flow around in circles so that particles are flung towards the outside of the unit (inertial separation), and then the particles fall to the bottom of the unit by gravity. They come in all sizes.

small

big

Typical **vertical reverse-flow cyclone** geometry and dimensions, rectangular inlet

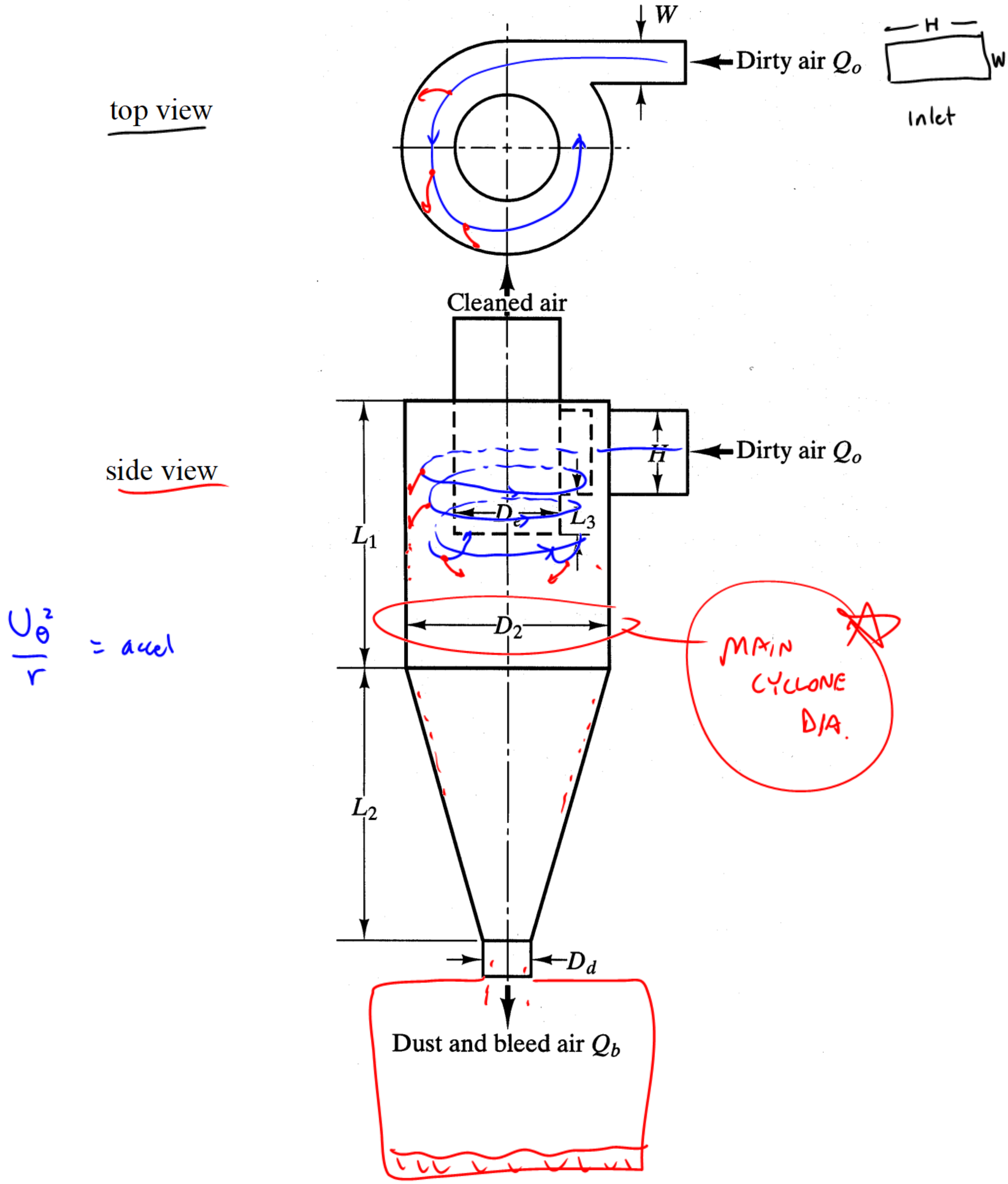


Figure 9.2 Lapple standard reverse-flow cyclone collector with tangential entry, and with characteristic dimensions given by Eqs. (9-5) and (9-6). From H&C textbook.

Equations for a general *Lapple* reverse-flow cyclone of any dimensions:

$$\eta(D_p)=\frac{1}{1+\left(\frac{D_{p,\mathrm{cut}}}{D_p}\right)^2}$$

Grade eff

$$D_{p,\mathrm{cut}}=\sqrt{\frac{9\mu HW^2}{2\pi N_e Q(\rho_p-\rho)}}$$

$\eta = 50\%$

$$\Delta P = 40.96\rho\left(\frac{Q}{WH}\right)^2$$

"minor loss"

$$\dot{W}_{\mathrm{blower}}=\frac{Q\Delta P}{\eta_{\mathrm{blower}}}$$

power

Dimensions for the *standard* Lapple reverse-flow cyclone:

$L_1 = L_2 = 2D_2$ | $W = D_d = D_2/4$ | $H = D_e = D_2/2$ | $L_3 = D_2/8$ | $N_e \approx 6$

# of swirls $= 6$

Plug these into the above general equations to get everything in terms of main cyclone diameter D_2:

e.g. $D_{p,cut}$

$$D_{p,cut}=\sqrt{\frac{9\mu\,\frac{D_2}{2}\left(\frac{D_2}{4}\right)^2}{2\pi(6)Q(\rho_p-\rho)}}$$

$$D_{p,cut}=\sqrt{\frac{9\mu D_2^3}{2\pi(6)(2)(16)Q(\rho_p-\rho)}}$$

$$\boxed{D_{p,cut}=\sqrt{\frac{3\mu D_2^3}{128\pi Q(\rho_p-\rho)}}}$$

We assume spherical particles

Final equations for a *standard* reverse flow Lapple cyclone of *any* size in terms of D_2:

any Q, ρ, ρ_p, μ

$$D_{p,\mathrm{cut}}=\sqrt{\frac{3\mu D_2^3}{128\pi Q(\rho_p-\rho)}}$$

$$\eta(D_p)=\frac{1}{1+\left(\frac{D_{p,\mathrm{cut}}}{D_p}\right)^2}$$

$$\Delta P = 2621.44\rho\frac{Q^2}{D_2^4}$$

$$\dot{W}_{\mathrm{blower}}=\frac{Q\Delta P}{\eta_{\mathrm{blower}}}$$

blower/motor

Grade efficiency for a Lapple standard reverse-flow cyclone:

Good for any Lapple cyclone

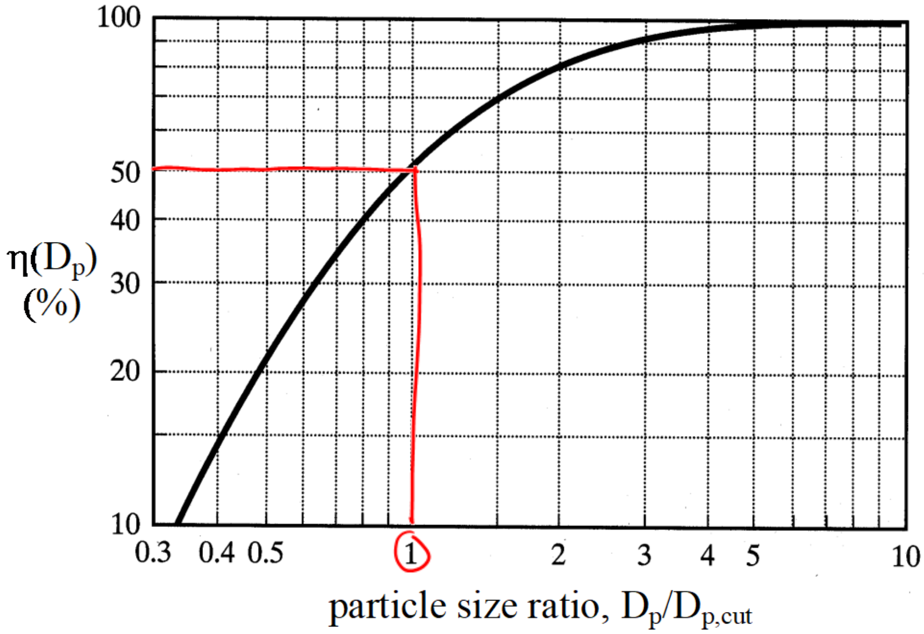
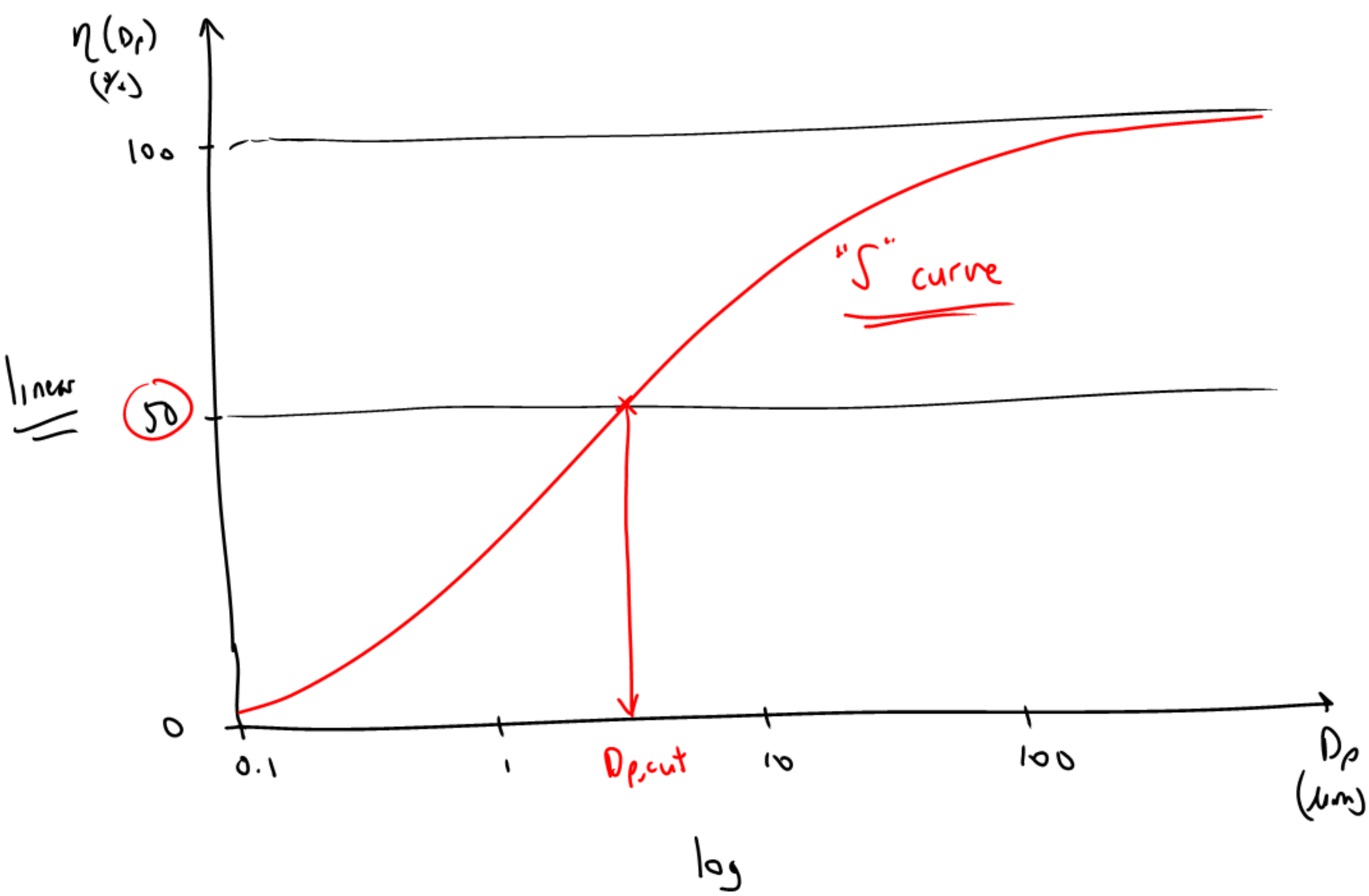


Figure 9.3 Normalized grade efficiency of a Lapple standard reverse-flow cyclone.

log-linear plot:



Example: Lapple Cyclone

Given: A standard reverse flow Lapple cyclone is used to clean up a dusty air flow exhausted by a sanding machine in a wood shop. The main body diameter of the cyclone is D_2 = 45.0 cm (0.450 m).

- Particle density ρ_p = 730 kg/m^3
- Bulk volume flow rate of air Q = 0.550 m^3/s
- Air is at SATP: ρ = 1.184 kg/m^3, μ = 1.849×10^{-5} kg/(m s)
- Blower efficiency (blower/motor combination) = 87.5%

To do: Calculate

(a) The cut diameter of this cyclone in units of microns

(b) The percent grade efficiency $\eta(D_p)$ for 10-µm particles

(c) The electrical power required to run this cyclone in units of kW

Solution: Some equations:

$$D_{p,\text{cut}} = \sqrt{\frac{3\mu D_2^3}{128\pi Q(\rho_p - \rho)}} \qquad \eta(D_p) = \frac{1}{1+\left(\frac{D_{p,\text{cut}}}{D_p}\right)^2} \qquad \Delta P = 2621.44\rho\frac{Q^2}{D_2^4} \qquad \dot{W}_{\text{blower}} = \frac{Q\Delta P}{\eta_{\text{blower}}}$$

.

$$\text{(a)}\ D_{p,\text{cut}} = \sqrt{\frac{3\left(1.849\times10^{-5}\ \frac{kg}{m\cdot s}\right)(0.450\ m)^3}{128\ \pi\ \left(0.550\ \frac{m^3}{s}\right)(730-1.184)\ \frac{kg}{m^3}}} = \boxed{5.59987\times10^{-6}\ m} = 5.59987\ \mu m$$

We this subs. eqs

$$\boxed{D_{p,\text{cut}} = 5.60\ \mu m}$$

(b) @ $D_p = 10\ \mu m$,

$$\eta(D_p) = \frac{1}{1+\left(\frac{5.59987\ \mu m}{10\ \mu m}\right)^2} \simeq 0.7613$$

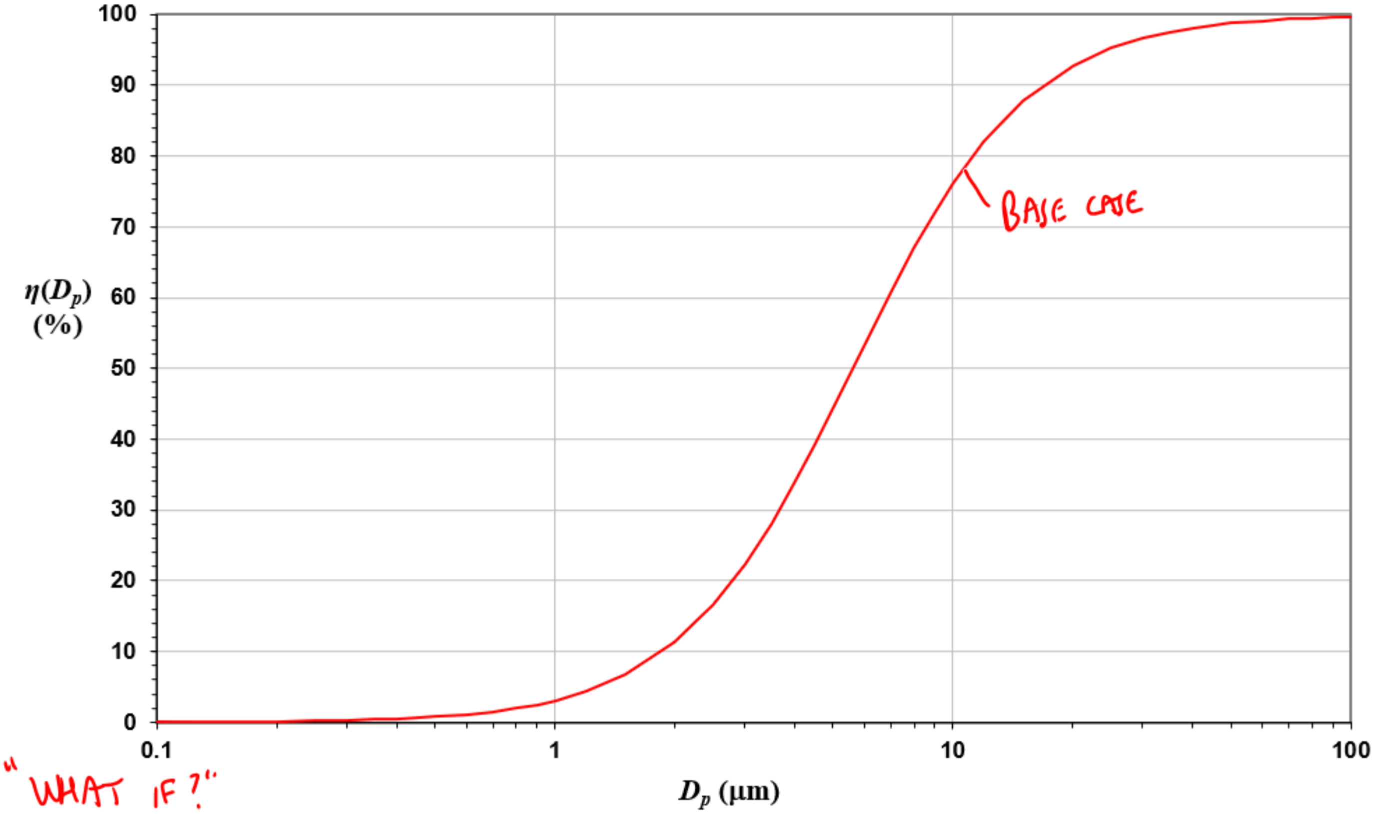
$$\boxed{\eta\,(10\text{-}\mu m) = 76.1\%}$$

$$\text{(c)}\ \Delta P = (2621.44)\left(1.184\ \frac{kg}{m^3}\right)\frac{\left(0.550\ \frac{m^3}{s}\right)^2}{(0.450\ m)^4}\left(\frac{N\cdot s^2}{kg\cdot m}\right) = 22896\ N/m^2$$

$$\dot{W}_{\text{blower}} = \frac{\left(0.550\ \frac{m^3}{s}\right)\left(22896\ \frac{N}{m^2}\right)}{0.875}\left(\frac{W\cdot s}{N\cdot m}\right)\left(\frac{1\ kW}{1000\ W}\right) = \boxed{14.4\ kW = \dot{W}_{\text{blower}}}$$

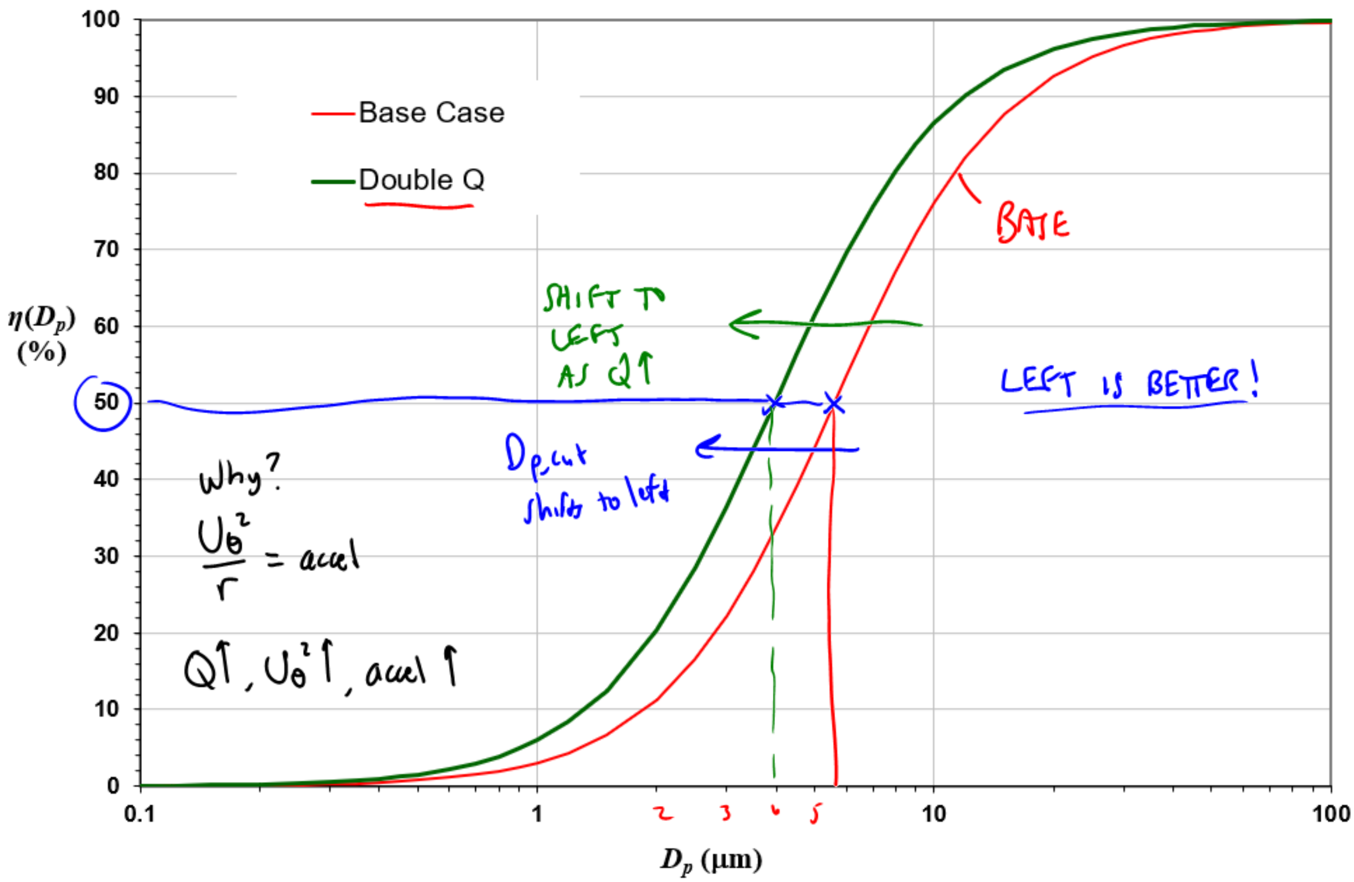
☆ REPEAT FOR MANY D_p's

Grade efficiency plot (from Excel results at various particle diameters):

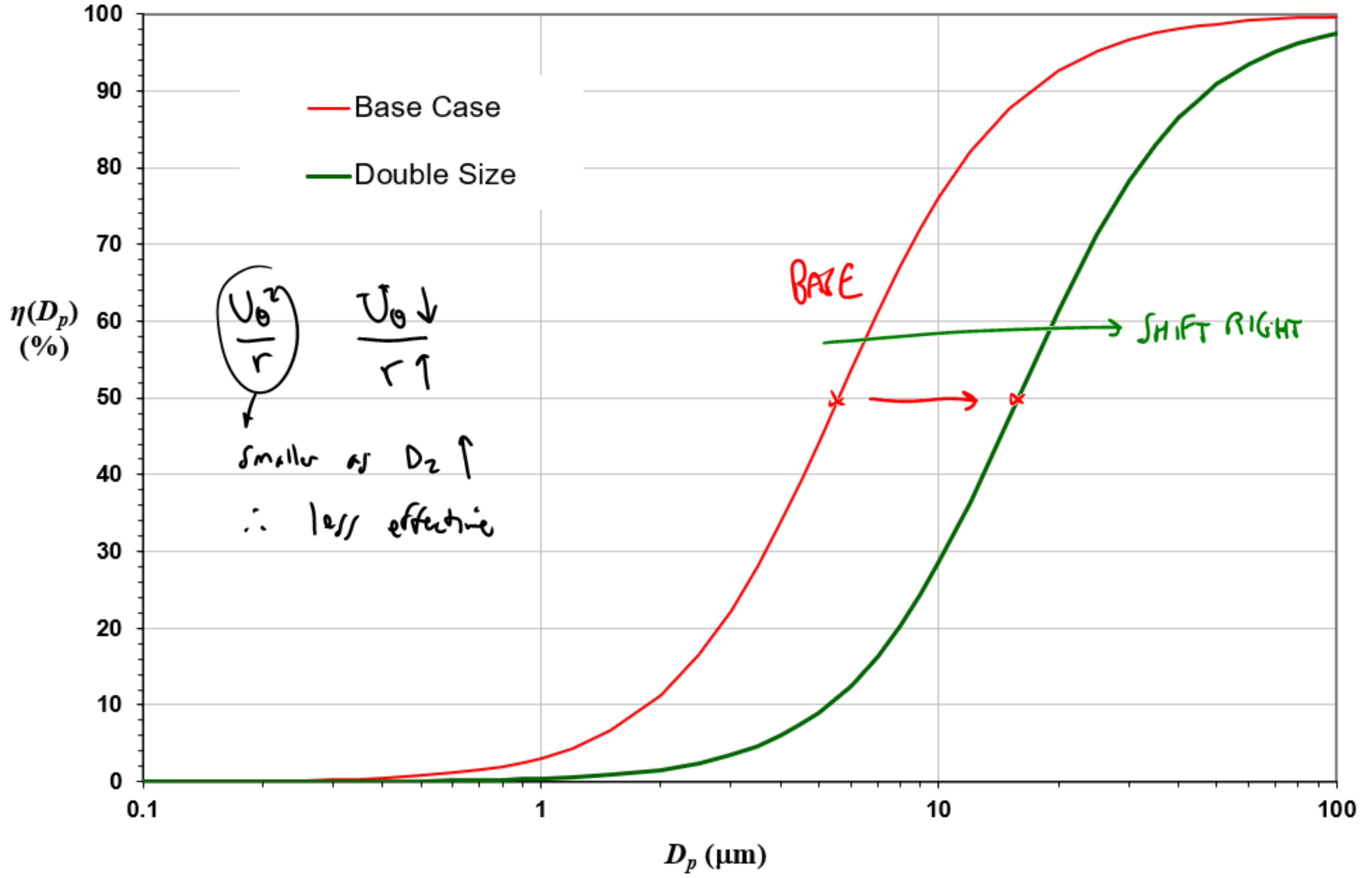


"WHAT IF?"

What happens if we ***double the flow rate*** through the cyclone, all else being the same?



What happens if we ***double the size*** of the cyclone, all else being the same as the base case?



What happens if we ***halve the size*** of the cyclone, all else being the same as the base case?