Mixer Sizing Methods

Four different sizing criteria

- ***Velocity***
- ***Shear Stress***
- ***Yield Stress***
- ***Mixing Time***

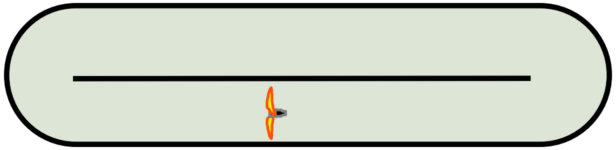
Velocity

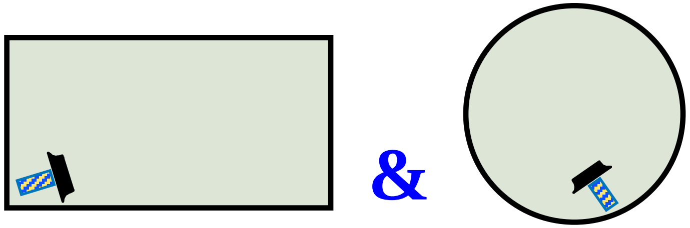
Mixing Duties

- Circulation
  - u specified
  - heat or mass transfer specified
  - ...
- Homogeneous suspension
  - u depends on u_{settl} and tank geometry
  - Standard u values in biological treatment systems

Velocity

Required thrust = (Size of Mixer) = $F_{req} \sim u^2 k$





- **Losses (k) - Racetrack**
  - Bends
  - Friction wall & bottom
  - Aeration
  - Obstacles
- **Losses (k) - Other tanks**
  - Tank factor (geometry)
  - Propeller factor
  - Aeration
  - Obstacles

Shear Stress

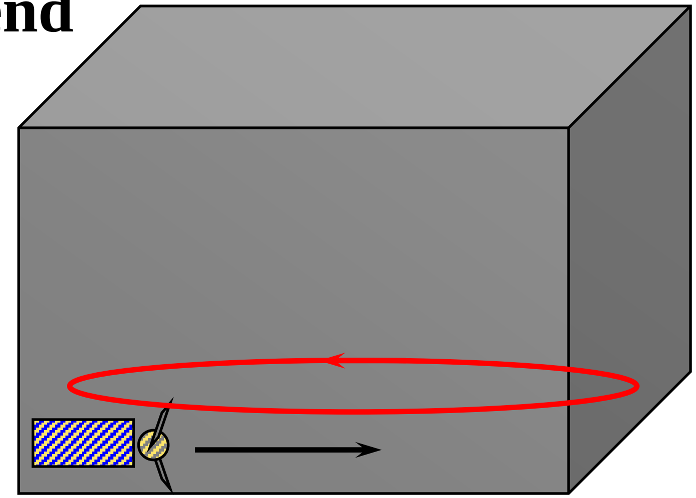
Mixing Duties

- Off bottom suspension & Resuspension of sediment
  - Shear Stress calculated
  - Shear Stress measured
  - By experience
- Erosion and transport of sediments

Shear Stress

Required thrust = (Size of Mixer) = $F \sim \tau_s$

- τ_s **= Requires Shear stress to resuspend**
  - measured
  - calculated
  - Experience



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Yield Stress

For mixing to be possible, the fluid must move at all. If it has a finite Yield Stress, this must be overcome. <u>Hence this is an additional mixing criterion</u>, often decisive.

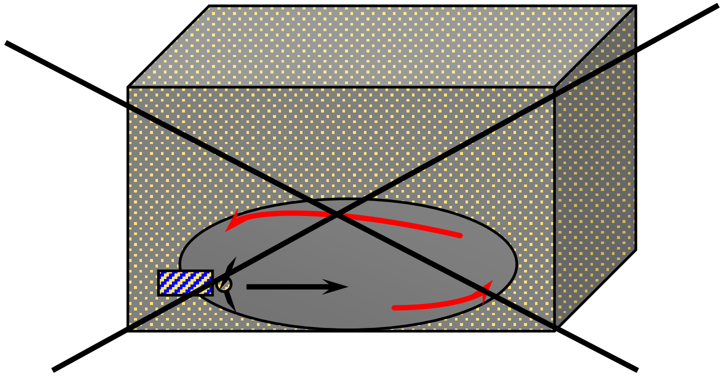
Applications

– Thickened sludge

– Paper pulp

– Drilling mud

– Slurries ...



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Yield Stress

Required thrust = (Size of Mixer) = $F \sim \tau_y$

- **where τ_y is**
  - Calculated or measured for municipal sludge, drilling mud & paper pulp
  - Specified by client
  - Measured by e.g. ITT Flygt Application Lab / known otherwise

Mixing Time

Mixing Duties

– Required blending time Θ specified or given by

- **Throughflow**; fluid leaving tank is mixed to a certain homogeneity ξ_b.
- **Batch**; customer requires a certain maximum time Θ and a certain minimum homogeneity ξ_b.

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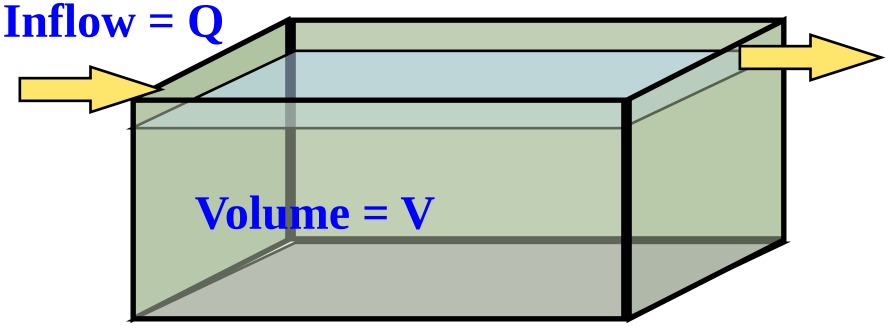
Mixing Time

Required thrust = (Size of Mixer) = $F \sim 1 / \Theta^2$

- **Θ^2 Specified mixing time**
  - Given by customer
  - Given by process
  - Retention time



Retention time = V/Q

Quantified mixing demands

- **Velocity** $F \sim u^2$
- **Shear stress** $F \sim \tau_s$
- **Yield stress** $F \sim \tau_y$
- **Time** $F \sim 1 / \Theta^2$

Extra study

Extra study

Channels - Required thrust

"The velocity Solver"

The required thrust is

$$F_{req} = \frac{\rho u^2}{2} A_b k$$

ρ **is the liquid density (1000 kg/m^3 for water)**

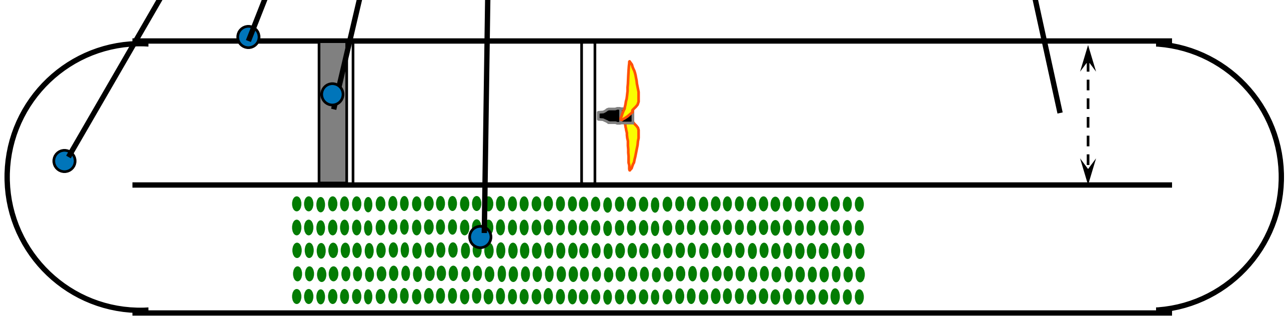
$k = k_f + k_b + k_{aer} + k_o$ **are loss factors due to friction, bends, aerators, other obstacles.**

A_b **is the bulk flow area (projected area of cross section of main flow)**

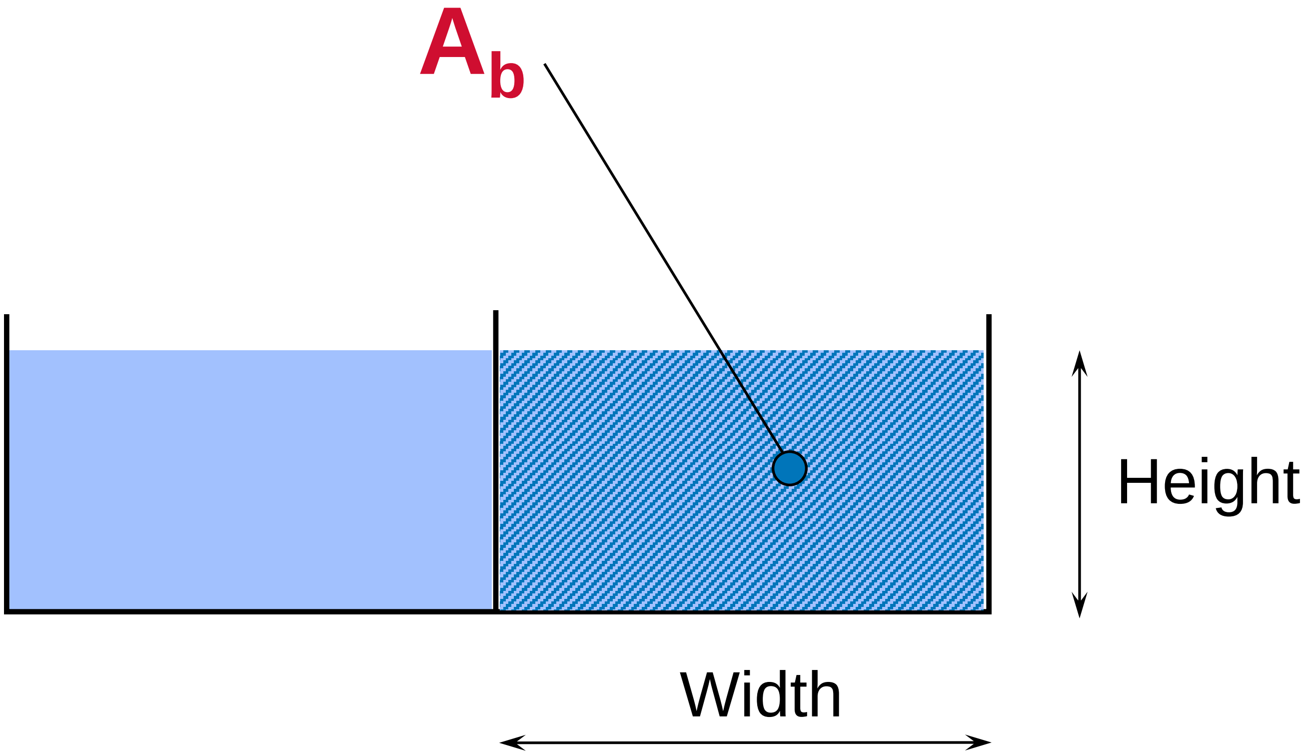
A racetrack example

$$F = k \cdot \frac{\rho u^2}{2} \cdot A_b$$

- Wall friction
- Bends
- Aerators
- Obstacles

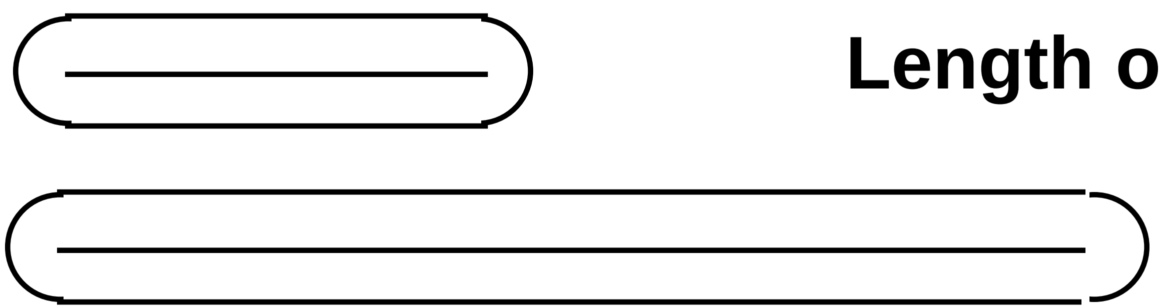


Bulk flow area



Wall friction

Surface roughness



Length of flow loop

Friction loss factor

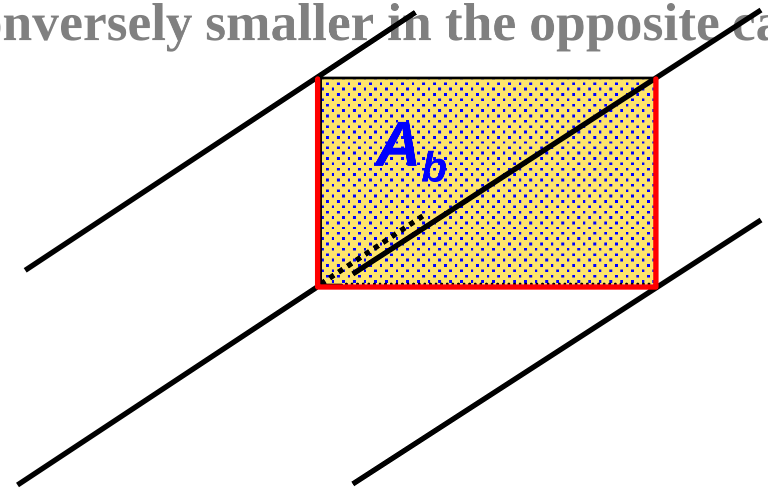
$$k_f = L_{tot} / (M\, R_h)$$

L_{tot} **total mean length of channel**

$R_h = A_b / P_w$ **hydraulic radius**

$M \approx 80$ **(Inverse) Manning number**

M **is larger for very small channels or very smooth surfaces, and conversely smaller in the opposite cases.**



Wet perimeter

$P_w = 2\,H + W$

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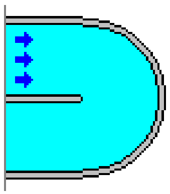
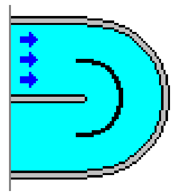
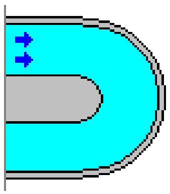
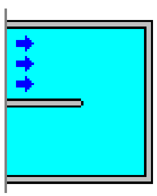
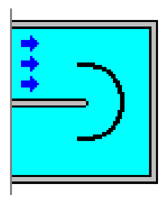
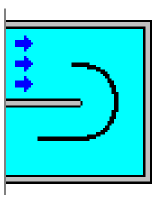
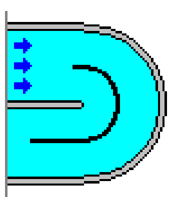
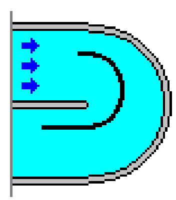
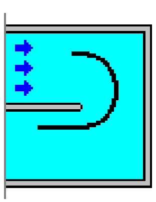
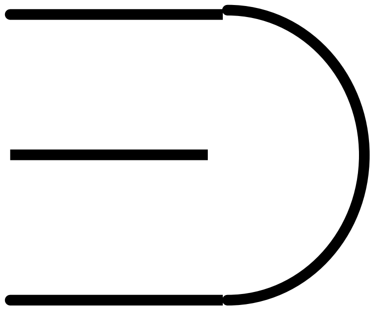
Bend loss factors k_b

 1.5	 0.6	 0.3 -- 1.5
 2.5	 1.0	 0.8
 0.5	 1.1	 1.4

Bend losses



$k_b = 1,5$

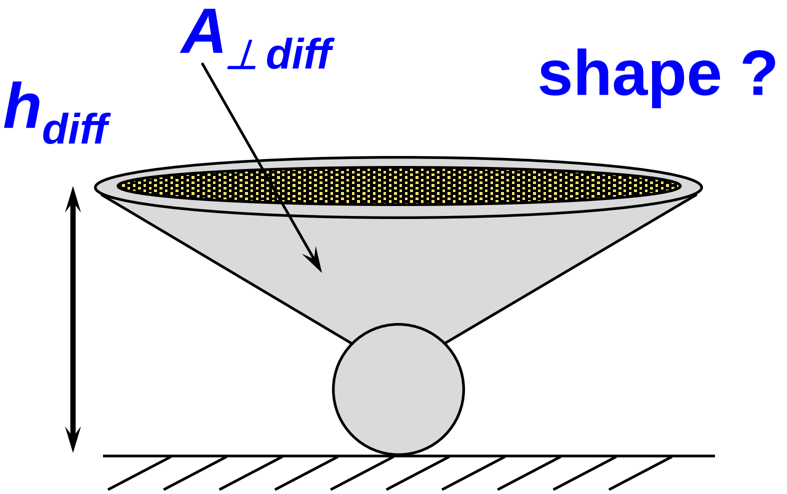
Aerator losses

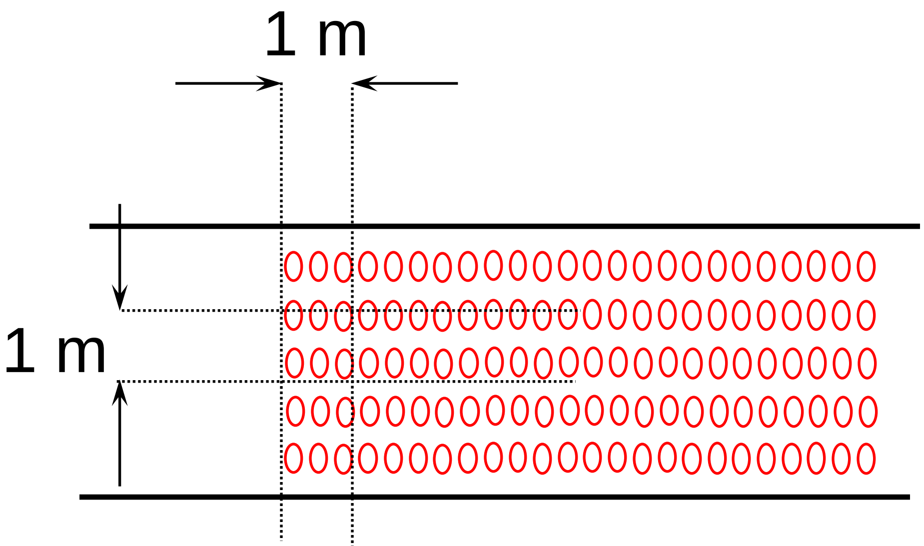
- **Diffusers act as flow obstacles**
- **Bubble columns increase the hydraulic losses by**
  - causing counterflow to the bulk flow
  - causing velocity distributions that increase losses on the bottom and on the diffusers

Aeration loss factor k_{aer}

Bottom diffuser geometry

Bottom diffuser density in grid (m^{-2})





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Aeration loss factor k_{aer}

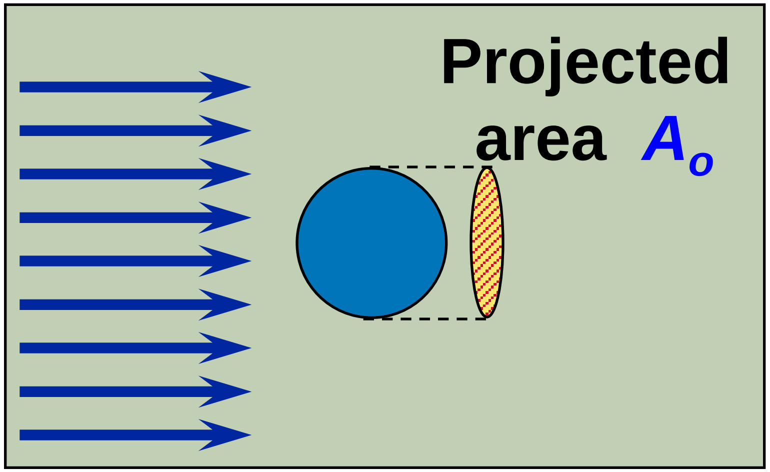
- # grids
- Bottom coverage (%)
- Air flow Q_{air} (Nm^3/h)
- Bulk flow velocity u

$$\rightarrow k_{aer}$$

Obstacle loss factor k_o

The loss force from an obstacle is

$$F_o = \frac{\rho\, u^2}{2} A_o\, c_D,$$



And, to use A_b in the F_{req} - formula,

$k_o = c_D\, A_o / A_b$.

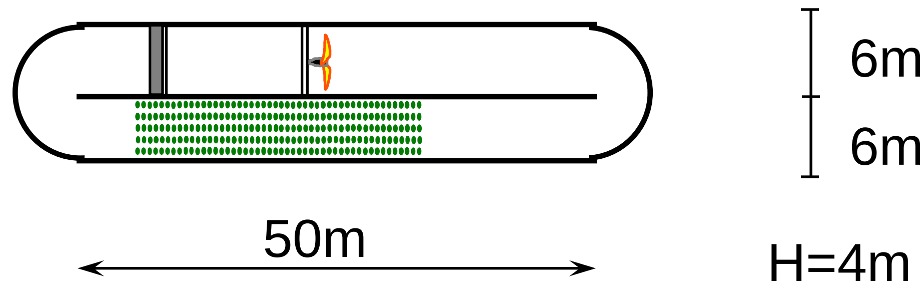
c_D is typically between 1.0 and 2.0.

For the pipe, say $A_o = 6.0 \times 0.5$ m², $c_D = 1.0$

$$k_o = c_D\, A_o / A_b = 0.125$$

A racetrack example

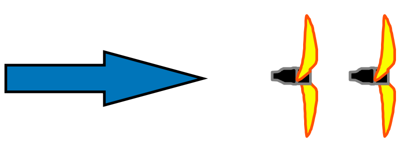
1 grid Sanitaire diff,
20% covered area



$$F = k \cdot \frac{\rho u^2}{2} \cdot A_{bulk}$$

$$F = (0.87 + 2 \cdot 1.5 + 0.55 + 0.125) \cdot 1000 \cdot \frac{0.30^2}{2} \cdot (6 \cdot 4) = 4774\ \text{N}$$

friction bends aerators obstacle



2 units 4430

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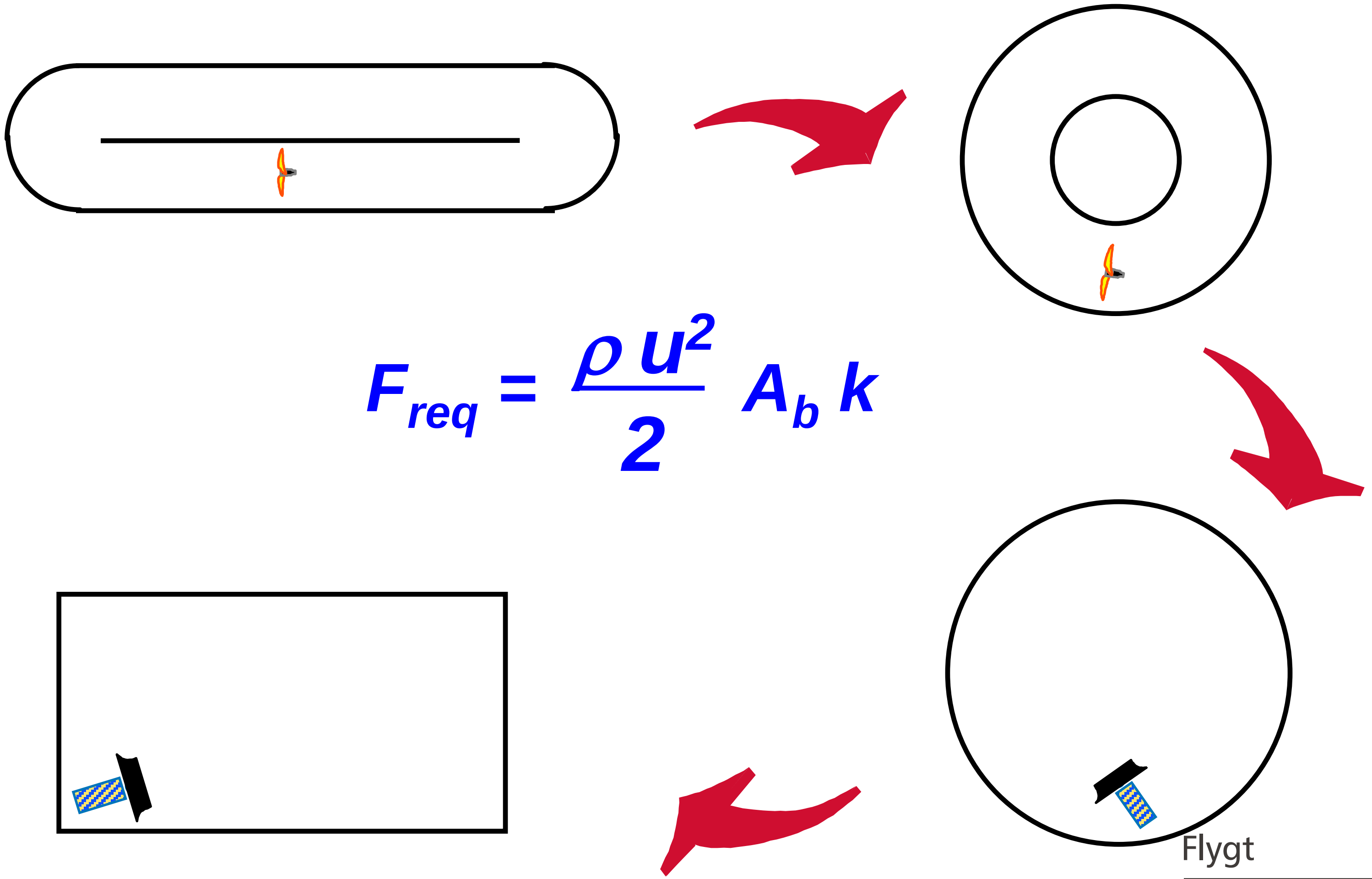
Other tank shapes

The same principles as in channels....



$$F_{req} = \frac{\rho u^2}{2} A_b k$$