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HDR

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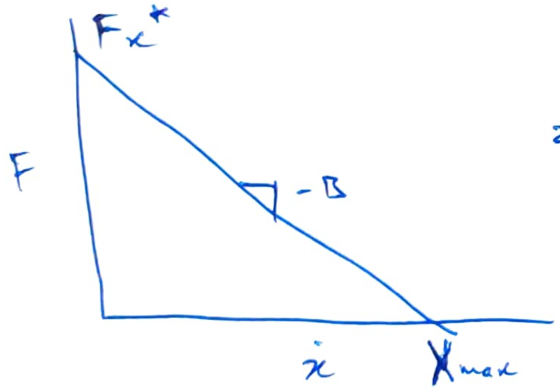
# Handheld Sprayer

Design → lever ratio; piston pump area; nozzle dia to get pressure-flow characteristic for a sprayer of own specifications.
Derive simplified equations for flow delivery neglecting things done to refill the pump.

$$F_x = F_x^* - B\dot{x}$$




⇒ Here, max Power is achieved at $F = \frac{F_x^*}{2}$ and $\dot{X} = \frac{\dot{X}_{max}}{2}$

Neglecting the pump refill terms,

$$\dot{y} = \dot{a}\,\dot{x} \qquad \text{and} \qquad P = \frac{F_y - k(y+y_0)}{A_p}$$

$$F_x = \dot{a}\,F_y \qquad\qquad \dot{y} = \frac{Q}{A_p}$$

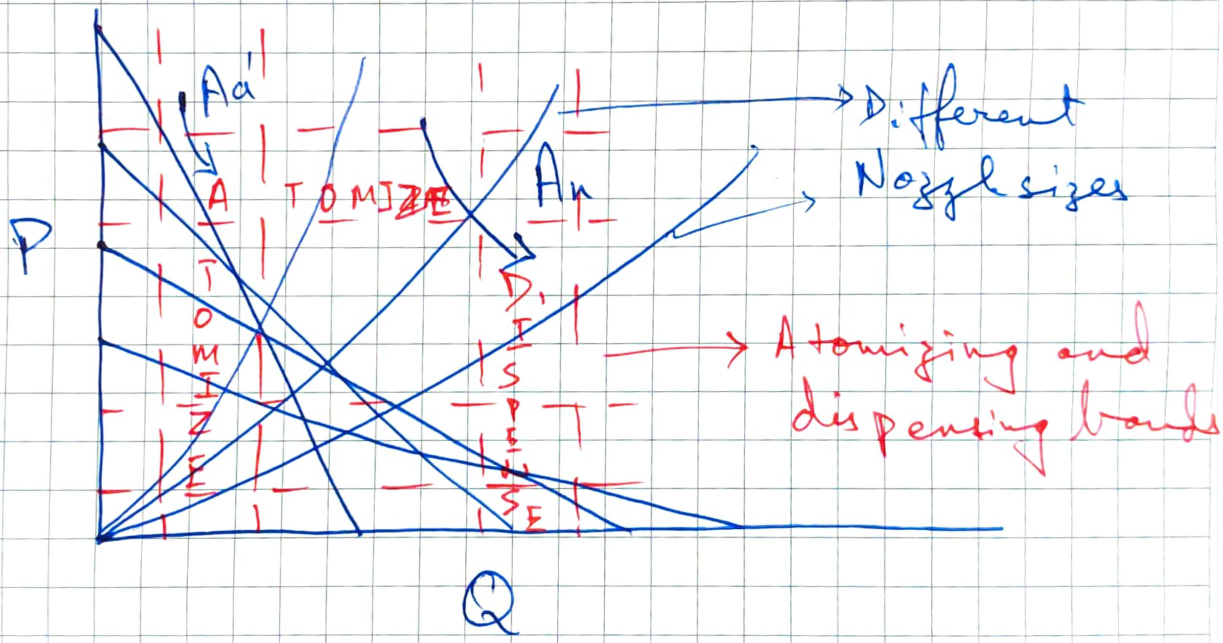
where $A_p$ is the area of the piston.

~~I will neglect the area of piston (changes in $A_p$) and take it as fixed because it wasn't asked in class question neither mentioned under considerations in class~~

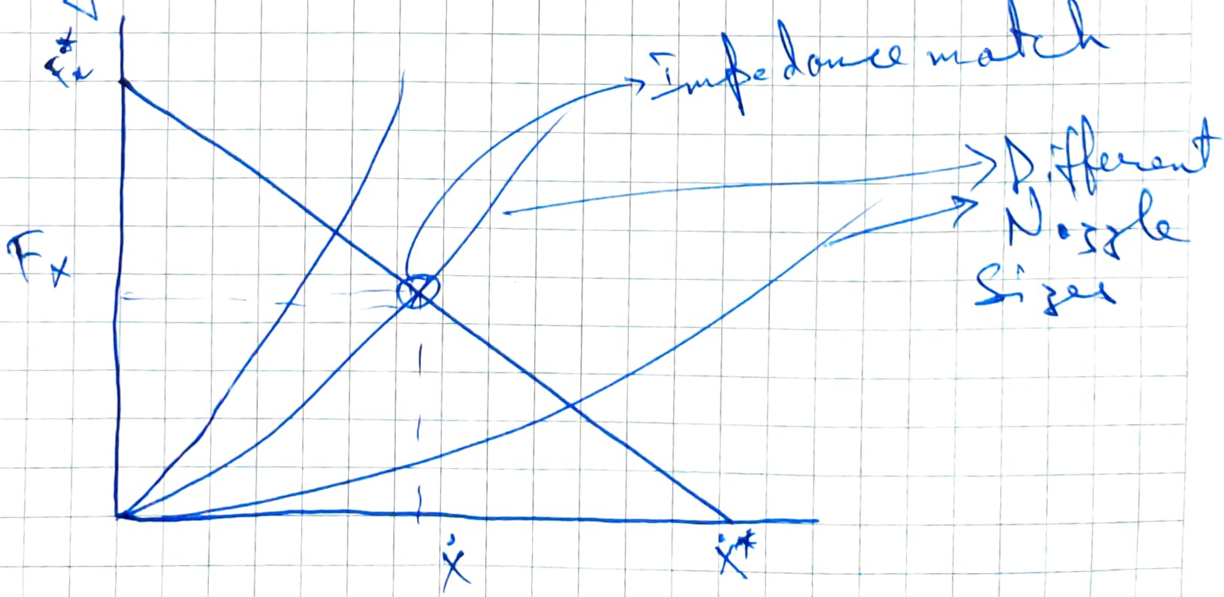
$$P = \frac{F_x - k\dot{a}(y+y_s)}{\dot{a} A_p} \; ; \quad Q = \dot{a} A \dot{x}$$

$$Q_n = C_d A_n \sqrt{\frac{2 \delta P}{\rho}}$$

Reflecting Source to Load




Reflecting Load to Source



The source to load plot tells about pressure and flow. It is marked with atomizing (small droplets) bands which require low flow but high pressure.

Dispensing bands are also marked for dispensing large amounts of fluid which require high flow and low pressure.

The load to source plot tells how it will feel when operating the sprayer.

From the previous mathematical model,

$$F_x = F_x^* - B\dot{x}$$

$$\Rightarrow \dot{a}(P A_p) = F_x^* - B\left(\frac{\dot{y}}{\dot{a}}\right) - \dot{a}k(y+y_0)$$

$$\Rightarrow \dot{a} P A_p = F_x^* - \frac{B}{\dot{a}}\left(\frac{Q}{A_p}\right) - \dot{a}k(y+y_0)$$

Note, I have used $Q$ and $Q_n$ interchangebly they represent "flow through nozzle"

$$\Rightarrow \boxed{P = \frac{F_x^* - k\dot{a}(y+y_0)}{\dot{a} A_p} \quad \frac{B}{(\dot{a} A_p)^2} Q}$$

$P^*$ is max pump pressure possible and output impedance of Pump ($R_o$), then:

$$P = P^* - R_o Q \qquad \text{where,}$$

$$P^* = \frac{F_x^* - a' k (y + y_o)}{a' A_p}$$

and $$R_o = \frac{B}{(a' A_p)^2}$$

I will consider better ergonomics which allows pump operators to stroke their fingers by about 2".

Picking $a = 3"$ and $b = 1.2"$. thus,

$$a' = 0.7142$$

$$\theta = \sin^{-1}\left(\frac{\delta x/2}{a+b}\right) = \cancel{\sin^{-1}\left(2/2\right)}$$

$$\boxed{\theta = \sin^{-1}\left(\frac{2/2}{4.2}\right) = 13.768^\circ}$$

$$\delta z = a(1-\cos\theta) = 3(1-\cos 13.768^\circ) = 0.086\,in$$

$$\phi = \tan^{-1}\left(\frac{\delta z}{l_p}\right) = \tan^{-1}\left(\frac{0.086}{2}\right) = 2.46^\circ$$

taking max piston length as 2".

$\phi$ is much less than max allowable of 13°.

Thus, the pump stroke will be

$$\boxed{\delta_p = \dot{a}\,\dot{x} = 0.7142 \times 2 = 1.428\,\text{inches}}$$

Taking pressure during spraying at 15 psi and max pressure at 30 psi,

$$30 = p^* = \frac{F_x^* - k\dot{a}(y+y_0)}{\dot{a}A_p} = \frac{15 - k(0.7142)(3\times1.428)}{0.7142 \times A_p}$$

$$\Rightarrow \cancel{\phantom{xx}} \frac{15 - k\,3.06}{0.7142\,A_p} = 30$$

$$\Rightarrow \frac{21}{A_p} - 4.2852\frac{k}{A_p} = 30$$

assuming $C_d = 0.95$,



$$\boxed{D_N = \sqrt{\frac{4}{\pi} C_d A_n} = 0.1527 \text{ in}}$$

$$-P_s = \frac{k \, 3 \, S_p}{A_p} = \frac{k(3 \times 1.428)}{A_p} = 2$$

thus, $\frac{k}{A_p} = 0.466$

combining above equations,

$$\frac{21}{A_p} - 2 = 30$$

$$\Rightarrow \quad A_p = \frac{21}{32} = 0.65625 \text{ in}^2$$

$$\boxed{\text{Piston diameter } (D_p) = \sqrt{\frac{4}{\pi} A_p} = 0.914 \text{ in}}$$

$$\Rightarrow \boxed{k = 0.3058} \ \text{lbf/in}$$

$$\boxed{R_o = \frac{B}{(a' A_p)^2} = \frac{0.3}{(0.7142 \times 0.65625)^2} = 1.37}$$

$$\Rightarrow C_d A_n = \frac{\sqrt{62.4 \times \frac{1}{386.2} \times \frac{1}{1728} \times 30}}{2 \times 1.37} = 0.0193 \text{ in}^2$$

Nozzle dia at <u>TOP</u>