Calculating Nozzle Flow Rate

To work out the flow rate of water from a nozzle we need to work out the volume in a given period of time. To do this we work out the area of the nozzle and then multiply it by the velocity of the water coming from the nozzle to give us volume per unit of time.

So nozzle flow rate is just area of the outlet multiplied by velocity of the water. (Freeman formula)

$Q = AV$

Q = quantity of fluid per unit of time
A = area of nozzle outlet
V = velocity of fluid

We will start with a basic example:

Our nozzle in this case will be square not round. The outlet will be 1m x 1m, this makes the area of the nozzle $1m^2$ The water coming out of the nozzle is travelling at a velocity of 1 metre per second or 1m/s. This means that after 1 second of water flow we will have a block of water come out of the nozzle 1m x 1m x 1m this is equal to 1 cubic metre or $1m^3$ of water.

$1m^3$ of water = 1000 litres therefore we can say the nozzle is flowing 1000L/sec

In the above example we were told that the water velocity was 1 m/sec. There is not a simple gauge for measuring velocity of water so we have to calculate velocity using head calculation or from stagnation pressure which we measure using a pitot tube.

Calculate Velocity from Head

We can use Bernoulli's Equation to calculate velocity of a fluid from head. Head is the distance from outlet to top of water.

$V = \sqrt{2gh}$

V = Velocity m/sec or feet per sec
g = Gravity 9.81 m/sec^2 or 32.2 feet per sec
h = head metres or feet

We will use metric system for our equations.

$V = \sqrt{2}(9.81)h$

$= \sqrt{19.62h}$

$= 4.43\sqrt{h}$

Example: A tank of water holds 10000L and has an outlet 1m from the bottom of the tank. The tank is full and is 4m high. What will be the velocity of the water coming out of the outlet?

Head = 4m – 1m = 3m

$V = 4.43\sqrt{h}$

$V = 4.43\sqrt{3}$

$= 4.43\,x\,1.732$

$= \mathbf{7.67\,m/s}$

Calculate Velocity from Pressure

We will still use the same Bernoulli's Equation $V = \sqrt{2gh}$ but we need to convert our pressure reading (P) to head (h)

$P = gh$

so pressure in kPa is equal to gravity x head, we now add this into Bernoulli's Equation to make things simpler.

$V = \sqrt{2gh}$ Change gravity x head to pressure

$\boldsymbol{V = \sqrt{2P}}$

Area of Nozzle Outlet

Area of a circle can be calculated using either:

$A = \pi r^2$ or $A = d^2\,x\,0.7854$

A = area
r = radius
d = diameter

For our purposes we will use the second option as it is easer to use diameter of the nozzle.

Example: What is the area of an 19mm outlet on a firefighting nozzle?

$A = d^2\,x\,0.7854$ D = 19mm but we need to enter the measurement in metres 0.019m

$A = 0.019^2\,x\,0.7854$

$A = 0.000283529\text{m}^2$

We will later adjust the freeman formula so we can enter diameter in mm rather than meters.

Freeman Formula – putting it all together

$Q = AV$

Q = quantity of fluid per unit of time (Litres per second)
A = area of nozzle outlet (metres²) $A = d^2 x\, 0.7854$
V = velocity of fluid (metres per second) $V = \sqrt{2P}$
1m³ = 1000 litres

$Q = AV$

$Q = d^2 x\, 0.7854\, x \sqrt{2P}\, x\, 1000$ (the 1000 on the end converts volume m³ to litres)

$= d^2 x\, 0.7854\, x\, 1.4142\, x \sqrt{P}\, x\, 1000$

$= d^2 x\, 1110\, x \sqrt{P}$

$= \frac{(d^2 x\, 1110\, x \sqrt{P})}{1000}$ we divide the above formula by 1000 so we can enter diameter in millimetres instead of metres

$\boldsymbol{Q = d^2\, x\, 0.00111\, x \sqrt{P}}$ if you prefer L/min multiply by 60

$\boldsymbol{Q = d^2\, x\, 0.0666\, x \sqrt{P}}$

Example: A 19mm nozzle is delivering water onto a fire. The nozzle pressure is 700 kPa. What is the flow rate of water being delivered.

$Q = d^2 x\, 0.00111\, x \sqrt{P}$ $Q = d^2 x\, 0.0666\, x \sqrt{P}$

$Q = 19^2 x\, 0.00111\, x \sqrt{700}$ or $Q = 19^2 x\, 0.0666\, x \sqrt{700}$

$\boldsymbol{Q = 10.6\, L/s}$ $\boldsymbol{Q = 636\, L/min}$

Check: $10.6 L/s\, x\, 60\, seconds = 636\, L/min$