Calculating the Time Required to Empty a Vessel

The following formulas are based on turbulent flow of a Newtonian fluid through an outlet (orifice) in a tank. The discharge coefficient $C_d$ depends on the configuration of the outlet. Some typical values for discharge coefficient are shown at right.

**Variables:**
- $h =$ elevation of tank
- $D =$ diameter of tank
- $A =$ orifice area ($\text{ft}^2$)
- $G =$ gravitational acceleration = 32.2 ft/sec$^2$
- $\Delta t =$ time required to empty tank (sec)

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**EXAMPLES**

**EXAMPLE ONE**
**VERTICAL CYLINDRICAL TANK**

$$\Delta t = \frac{\pi D^2}{C_d A} \sqrt{\frac{h}{8G}}$$

A vertical cylindrical tank 12’ in diameter is fitted with a 2” Hayward bulkhead fitting (comparable to a short tube outlet). The area of the outlet is:

$$\Delta t = \frac{\pi D^2}{C_d A} = \frac{\pi 2^2}{0.61} = 0.0218 \text{ ft}^2$$

If the tank is filled with water to a height of 20’, and we assume turbulent flow, the approximate time to empty the tank is given by:

$$\Delta t = \frac{\pi 12^2}{0.81 (0.0218)} \sqrt{\frac{20}{8(32.2)}} = 7.139 \text{ sec}$$

The tank should be empty in about 2 hours.

**EXAMPLE TWO**
**HORIZONTAL CYLINDRICAL TANK**

$$\Delta t = \frac{L (D^{3/2} - (D - h)^{3/2})}{3C_d A} \sqrt{\frac{8}{G}}$$

A 7” diameter by 9’ long horizontal cylindrical tank has a 4” diameter sharp edged orifice outlet. The area of the outlet is:

$$\Delta t = \frac{\pi D^2}{C_d A} = \frac{\pi 4^2}{0.61} = 0.0873 \text{ ft}^2$$

If the tank is filled with water to a height of 5’, and we assume turbulent flow, the approximate time to empty the tank is given by:

$$\Delta t = \frac{9 (7^{3/2} - (7 - 5)^{3/2})}{3(0.61)0.0873} \sqrt{\frac{8}{32.2}} = 440 \text{ sec}$$

The tank should be empty in about 7 minutes.

**EXAMPLE THREE**
**CONICAL TANK**

$$\Delta t = \frac{\pi h^{5/2} \tan^2 \theta}{5C_d A} \sqrt{\frac{8}{G}}$$

A conical tank with a taper angle of 25° is fitted with a 2” diameter short tube type outlet. The area of the outlet is:

$$\Delta t = \frac{\pi 2^2 (285/2) \tan^2 25°}{5(0.61)0.0218} \sqrt{\frac{8}{32.2}} = 8,000 \text{ sec}$$

If the tank is filled with water to a height of 28’, and we assume turbulent flow, the approximate time to empty the tank is given by:

$$\Delta t = \frac{\pi h^{5/2} \tan^2 \theta}{5C_d A} = \frac{\pi 2^2}{0.61} = 0.0218 \text{ ft}^2$$

The tank should be empty in about 2-1/4 hours.