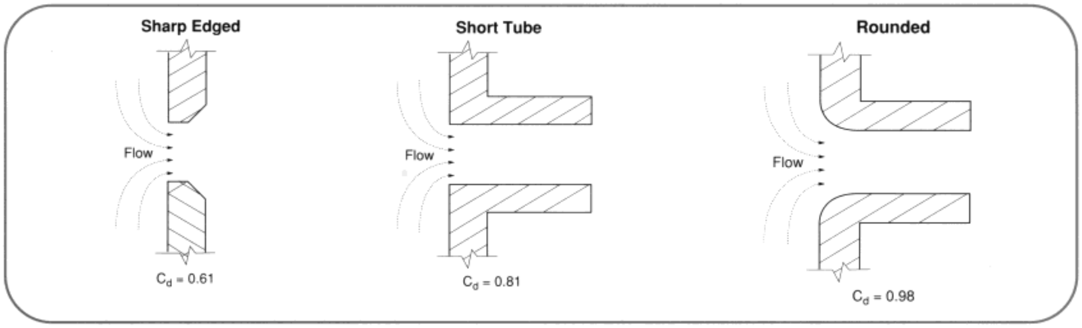
# HAYWARD®

# *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.

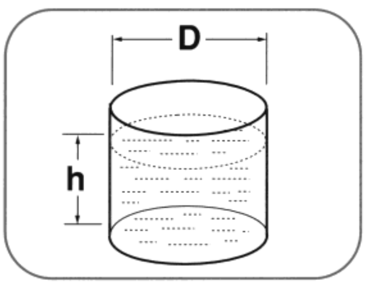



**Variables:**

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

## Vertical Cylindrical Tank

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




**Example 1**

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

$$\Delta t = \frac{\pi D^2_{orf}}{4\,(144)} = \frac{\pi\, 2^2}{4\,(144)} = 0.0218 \text{ ft}^2$$

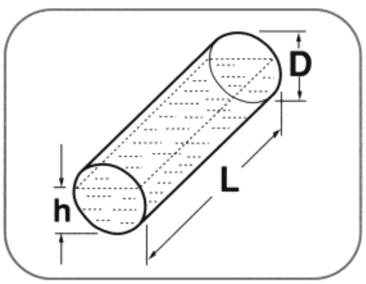
If the tank is filled with water to a height of 20 ft, and we assume turbulent flow, the approximate time to empty the tank is given by:

$$\Delta t = \frac{\pi\, 12^2}{0.81(0.0218)}\sqrt{\frac{20}{8\,(32.2)}} = 7{,}139 \text{ sec}$$

The tank should be empty in about 2 hours.

## Horizontal Cylindrical Tank

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




**Example 2**

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

$$\Delta t = \frac{\pi D^2_{orf}}{4\,(144)} = \frac{\pi\, 4^2}{4\,(144)} = 0.0873 \text{ ft}^2$$

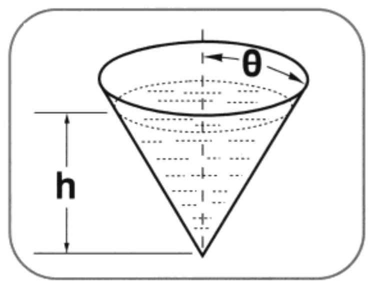
If the tank is filled with water to a height of 5 ft, and we assume turbulent flow, the approximate time to empty the tank is given by:

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

The tank should be empty in about 7 minutes.

## Conical Tank

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




**Example 1**

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:

$$\Delta t = \frac{\pi D^2_{orf}}{4\,(144)} = \frac{\pi\, 2^2}{4\,(144)} = 0.0218 \text{ ft}^2$$

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

$$\Delta t = \frac{\pi\,(28^{5/2})\tan^2 25°}{5\,(0.81)\,0.0128}\sqrt{\frac{2}{32.2}} = 8{,}000 \text{ sec}$$

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