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Obtaining of the drying time of a vertical cylindrical tank

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Abstract: The work is devoted to the finding of the formula for calculating the drying time of a vertical cylindrical tank. The structure, applications and main types of this vertical tank and its advantages in comparison to the horizontal tank are described. The figuring out of the formula is based on the method of solving a differential equation of first order for pump capacity (performance), a time-dependent operation of the pump and liquid volume, depending on the height of the decreasing liquid.

Introduction

Currently, steel tanks are widely used for oil depots and gas stations, namely for long-term storage of oil, petroleum products and other liquids. Most tanks for oil depots consist of several parts: a cylindrical enclosure made of metal (horizontal or vertical type) with additional components: flanges, rings and technological man ways.

Many modern publications [1–5] are enlightened in the calculation of various hydraulic systems. In particular, some of them [6–10] are devoted to numerical modeling of hydraulic processes. However, the issues of integrating the drying time of various vessels are not sufficiently covered.

We consider a detailed structure of a vertical one on the example of a steel cylindrical tank with a volume of 1000 m^3 Figure 1, which consists of a enclosure, outer and inner tank shells, a spacer angel, has a ladder and a base plates. And in order to keep the substances stored in the tanks from freezing at low ambient temperature, the tanks are equipped with a heater and thermal insulation. In addition, the outer surface of the walls is treated with soil, covered with anti-corrosion paint and sheathed with galvanized (or aluminum) steel sheets to protect the tanks from the environment.

There are ground and underground types of tanks (according to technological features) that are installed vertically or horizontally. However, it is worth considering that the vertical canister will take several times less area than the horizontal.

The most common types of vertical (metal) tanks are:

- The tank of VSR (vertical standard reservoir). It's vertical steel canister with a cone-shaped bottom, designed for filling various types of liquids, including water, aggressive acids and alkalis.
- Underground gas station tanks. Such tanks are manufactured for storage of dark and light oil products in oil storage facilities, gas stations and gas stations. Moreover, modern tanks for gas stations can have two-layer tanks, which are two metal cylinders, one of which is installed inside the other, and the inter-wall space is filled with a liquid that is more dense than the density of stored fuel. This construction of the tank allows you to prevent leakage of fuel into the environment in the event of damage to its enclosure.
- Fire metal tanks. Fire containers are filled with drinking, technical or waste water with a volume of 5 to 60 cubic meters. They can be installed both vertically and horizontally, but above the ground.

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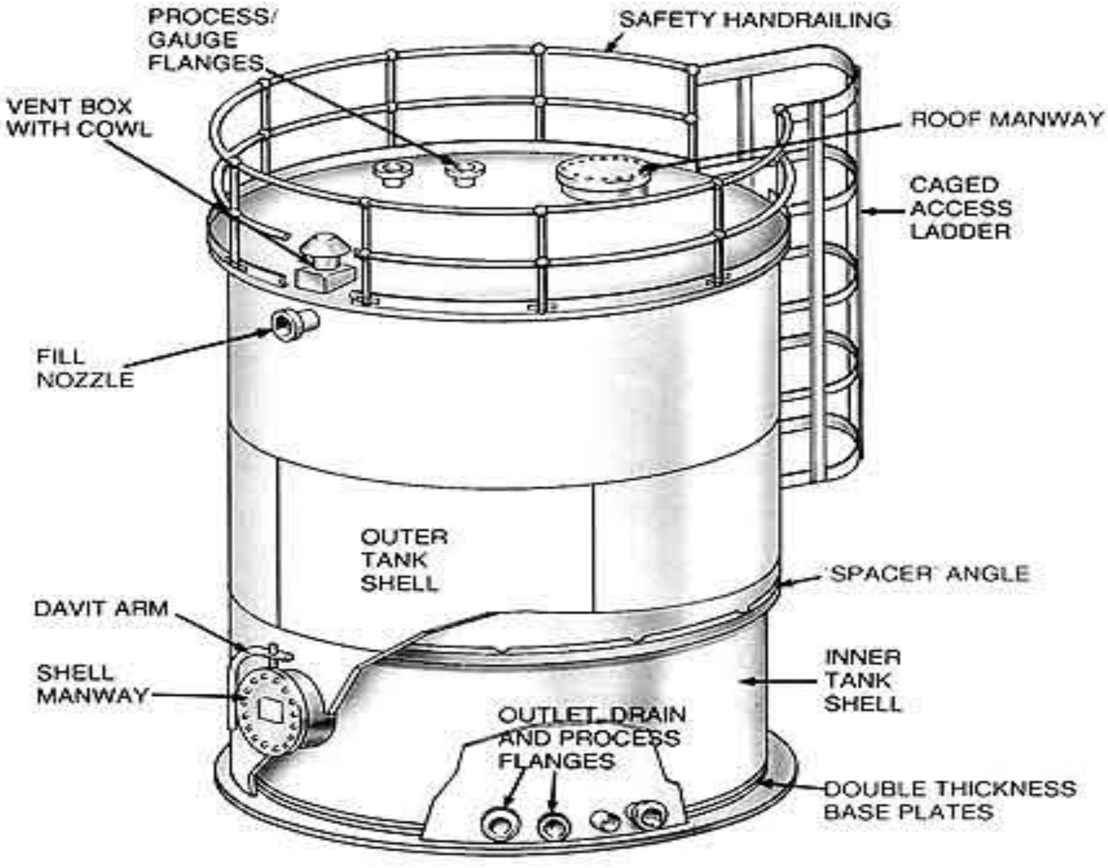

Figure 1. Structure of vertical tank by the vertical cylindrical tank VCR-1000 m^3 example

In this article we attempt to use mathematical analysis methods to derive a general formula for determining the drying time of vertical cylindrical tanks.

Method

The method of mathematical analysis is based on differentiation and integration. In our model $y(0)=0, y(T)=h.$ In figure Figure 2we show a scheme of the drainage tank.

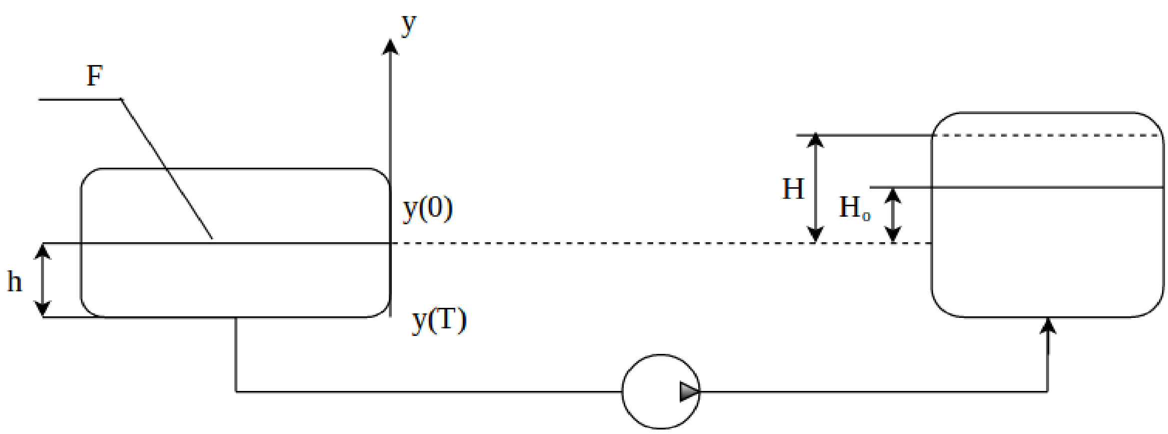

Figure 2. High-quality scheme of the drainage tank

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A differential equation of first order for volume flow rate Q and area F:

$$-Q(t)dt = F(y)dy$$

where dt — pump operating time;

dy —height of the liquid in the draining tank.

The height of the pump, depending on flow rate:

$$H_{pump}(Q) = A + B\cdot Q + C\cdot Q^2$$

where A, B, C — pump constants.

So the height is equal to:

$$H = H_o + y + \alpha\cdot Q^2$$

where $\alpha = 0,0827\dfrac{x\cdot l}{d^5}$ — the constant.

If we equate the above heights and express flow rate Q, we get:

$$Q(y) = \frac{-B \pm \sqrt{B^2 - 4(\alpha - C)(H_o + y - A)}}{2(\alpha - C)}$$

Analysis of the obtained formula for flow rate Q to the sign before the square root:

$$\alpha > 0,\ C < 0$$

It means that:

$$\alpha - C > 0$$

$$H_{static}^{friction} = H_o + y$$

$$H_{pump}^{o} = A$$

$$H_{static}^{friction} < H_{pump}^{o}$$

Also:

$$H_o + y - A < 0$$

Then:

$$\sqrt{B^2 - 4(\alpha - C)(H_o + y - A)} = \sqrt{B^2 + 4\left|(\alpha - C)(H_o + y - A)\right|} > |B|$$

$$Q(y) = \frac{-B + \sqrt{B^2 - 4(\alpha - C)(H_o + y - A)}}{2(\alpha - C)}$$

We substitute the final formula for the volume flow rate Q(y) in the differential equation $-Q(t)dt = F(y)dy$ under the condition that $F = const$:

$$-dt = F\frac{-B + \sqrt{B^2 - 4(\alpha - C)(H_o + y - A)}}{2(\alpha - C)}dy$$

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We get the desired formula for the time of the draining tank, having integrated:

$$T = -F\int_0^h \frac{2(\alpha - C)dy}{\sqrt{B^2 - 4(\alpha - C)(H_o + y - A)} - B}$$

Results

During the study working formula was obtained for determining the drying time of the tank, which depends only on the pump constants and initial heights in the tanks. The ultimate formula is as follows:

$$T = -F\int_0^h \frac{2(\alpha - C)dy}{\sqrt{B^2 - 4(\alpha - C)(H_o + y - A)} - B}$$

where A, B, C — pump constants;

F — the area of the tank, from which the liquid is pumped;

α — the constant;

$H_o, y = h$ — the initial height of the fill and drained the tank, respectively.

Conclusion

The obtained method allows us to determine the time of drying of the tank under the condition of the cylindrical shape of its walls, which narrows down its capabilities, but nevertheless it can find its application in various fields of hydraulic engineering.

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