STORAGE TANK CALCULATOR

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Contents

Introduction

This document describes the basis and operation of the Blackmonk Engineering Storage Tank Calculator.

The calculator determines the volume and alarm levels for a cylindrical vertical storage tank given the tank diameter, height and filling rate. The methodology is based on the recommendations presented in the Buncefield Investigation Reports and the UK HSE Tank Integrity Advice documents.

Calculation Inputs

The following parameters are user specified inputs to the calculation:

Input	Description	Units
Tank diameter	Mandatory user specified tank diameter	m
Tank height	Mandatory user specified tank height	m
Maximum filling rate	Mandatory user specified maximum filling rate into the tank	m^3/hr
Low liquid level	Mandatory user specified low liquid level in the tank	m
High level response time	Mandatory user specified time required to respond before the tank level rises from the normal level to the high level	min
High high level response time	Mandatory user specified time required to respond before the tank level rises from the high level to the high high level	min
Overflow level response time	Mandatory user specified time required to respond before the tank level rises from the high high level to the overflow level	min

Calculation Outputs

The following parameters are calculated by the software and displayed to the user:

Output	Description	Units
Liquid surface area	Upper surface of area of liquid in the tank	m^2
Maximum rate of level rise	Rate of liquid level rise at the maximum filling rate	m/min
Normal liquid fill level	Normal liquid fill level allowing for the specified high, high high and overflow response times	m
High liquid level	High liquid liquid level allowing for the specified high, high high and overflow response times	m
High high liquid level	High high liquid level allowing for the specified high, high high and overflow response times	m
Low level volume	Volume of liquid in tank when filled to the low level	m^3
Normal level volume	Volume of liquid in tank when filled to the normal level	m^3
High level volume	Volume of liquid in tank when filled to the high level	m^3
High high level volume	Volume of liquid in tank when filled to the high high level	m^3

Total tank volume	Volume of liquid in tank when filled to the overflow level	m^3
Tank working capacity	Volume in tank between the low and normal levels	m^3

Liquid Surface Area

The liquid surface area in a cylindrical vertical tank is given by:

$$A = \frac{\pi D^2}{4}$$ **Equation 1**

Maximum Rate of Level Rise

The maximum rate of level rise is calculated from the liquid surface area and the maximum filling rate:

$$\Delta l_{\max} = \frac{Q_{\max}}{A}$$ **Equation 2**

Liquid Levels

The normal, high and high high liquid levels are calculated using the specified response times and the tank height. The specified tank height corresponds to the overflow level. The levels are determined from the following relationships:

$$l_{hihi} = h - \Delta l_{\max} t_{overflow}$$ **Equation 3**

$$l_{hi} = h - \Delta l_{\max} \left(t_{overflow} + t_{hihi} \right)$$ **Equation 4**

$$l_{norm} = h - \Delta l_{\max} \left(t_{overflow} + t_{hihi} + t_{hi} \right)$$ **Equation 5**

Cylindrical Vertical Tank Volumes

The total volume of a cylindrical vertical tank is given by:

$$V_{total} = \frac{\pi D^2 h}{4}$$ **Equation 6**

The liquid volume in a cylindrical vertical tank at a specified liquid level is given by:

$$V = \frac{\pi D^2 l}{4}$$ **Equation 7**

Tank Working Capacity

The tank working capacity is the difference in volume between the low and normal liquid levels:

$$V_{working} = V_{norm} - V_{low}$$ **Equation 8**

Calculation Procedure

The calculation routine is described in the following steps:

1. Calculate liquid surface area using Equation 1
2. Calculate maximum rate of level rise using Equation 2
3. Calculate the high high level using Equation 3
4. Calculate the high level using Equation 4
5. Calculate the normal liquid fill level using Equation 5
6. Calculate the normal level, high level and high high level volumes using Equation 7 for the appropriate levels
7. Calculate the total tank volume using Equation 6
8. Calculate the tank working volume using Equation 8

Nomenclature

$D =$ Tank diameter (m)

$h =$ Tank height (m)

$A =$ Liquid surface area (m^2)

$Q_{\max} =$ Maximum filling rate ($m^{-3}.s^{-1}$)

$\Delta l_{\max} =$ Maximum rate of level rise ($m.s^{-1}$)

$l =$ Liquid level (m)

$l_{low} =$ Low liquid level (m)

$l_{norm} =$ Normal liquid level (m)

$l_{hi} =$ High liquid level (m)

$l_{hihi} =$ High high liquid level (m)

$V =$ Liquid volume in tank (m^3)

$V_{low} =$ Liquid volume in tank at low liquid level (m^3)

$V_{norm} =$ Liquid volume in tank at normal liquid level (m^3)

$V_{hi} =$ Liquid volume in tank at high liquid level (m^3)

$V_{hihi} =$ Liquid volume in tank at high high liquid level (m^3)

$V_{working} =$ Working volume in tank between low and normal liquid levels (m^3)

Example

A tank 25m in diameter, 12m high is filled at a maximum rate of 500 m^3/hr.
The low liquid level is 1.75m. The level response times are as follows:

High level response time: 2 mins
High high level response time: 5 mins
Overflow level response time: 10 mins

Determine the tank working capacity.

Solution:

The tank working capacity = 4889.8 m^3

Storage Tank Calculator Screenshot:

INPUTS

Tank diameter	D	25	m	
Tank height	h	12	m	
Maximum filling rate	Q_{max}	500	m3/hr	
Low liquid level	l_{low}	1.75	m	
High level response time	t_{hi}	2	mins	between normal and high liquid evels
High high level response time	t_{hihi}	5	mins	between high and high high liquid levels
Overflow level response time	$t_{overflow}$	10	mins	between high high and overflow liquid levels

OUTPUTS

Liquid surface area	A	490.9	m2	
Maximum rate of level rise	Δl_{max}	1.019	m/hr	
Normal liquid fill level	l_{norm}	11.71	m	from base of tank
High liquid level	l_{hi}	11.75	m	from base of tank
High high liquid level	l_{hihi}	11.83	m	from base of tank
Low level volume	V_{lo}	859.0	m3	
Normal level volume	V_{norm}	5748.8	m3	
High level volume	V_{hi}	5765.5	m3	
High high level volume	V_{hihi}	5807.2	m3	
Total tank volume	V_{total}	5890.5	m3	
Tank working capacity	**$V_{working}$**	**4889.8**	**m3**	between low and normal liquid levels