Calculation Report

Hand Calculation on AquaClimb

PROJECT INFO.

Change History:

Version Number	Date	Prepared by	Reviewed by	Contact
V 1.0	8/30/2024	Bill Bin	Frank Wang	Frank.Wang@feamax.com

CFD Requestor Info.:

Contact name:	Alex Salzman
Email:	Alex@PoolsideAdventures.com
Company name:	PYRAMIDE USA INC.
Address:	PO Box 530. Frederick, MD 21705

PROJECT DESCRIPTION

Project Description:

1. Perform hand calculations on the trolley system with the 6 cases.
2. Calculate the velocity at the water depths shown in the chart. And then compare that to the benchmark velocity.
3. The average vertical jump height of an untrained male = 16-20”. Assume the benchmark velocity to be a 6’ 250lb person jumping 18” above the ground on the sidewalk. The velocity that they hit the sidewalk is our benchmark velocity. No water. A person can jump into the air and land back on the ground safely and the body can be reasonably expected to safely support that. That’s the benchmark.
4. All related documents were received by 8/25/2024

Load Case:

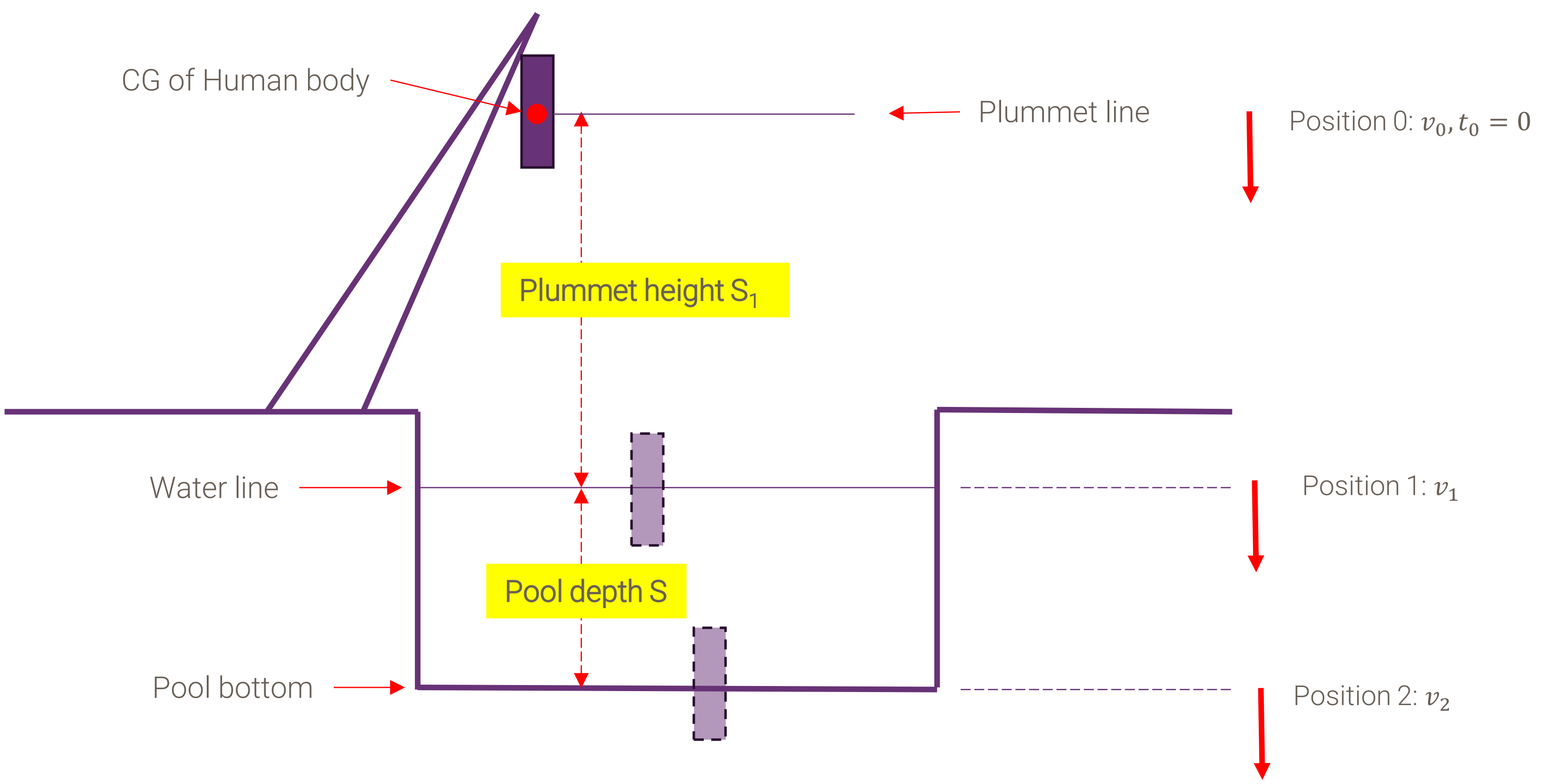
1. The calculations show the center of gravity in the water. Climbing wall chart below.

Model	Water Depth	Highest Handhold above deck level	Minimum Plummet: 48" person, 50lbs (highest foot hold 36" below handhold)	Maximum Plummet: 72" person, 250lbs (highest foothold 48" below handhold)
3H	6'	83	47	35
3H Alt	5'	73	37	25
4H	7'	121	85	73
4H Alt	6'	111	75	63
5H	9'	160	124	112
5H Alt	8'	150	114	102

CALCULATION MODEL

Calculation Model:

1. We chose the CG of human in the calculation. The Plummet Height is the distance between CG and water line.



ASSUMPTIONS

Assumptions and Load Condition:

1. Water density ρ_{water} = 1.0 g/cm^3
2. Human body density ρ_{human} = 0.9 g/cm^3
3. Human body volume = V
4. Human body mass = m
5. The velocity enter the water = V_1
6. Water Resistance coefficient C_D = 1.0
7. Cross-section area of human body enter the water = A
8. The height of human body = H
9. Velocity of human body inside the water = V_x
10. The allowable decent velocity to the pool bottom = V_2
11. Option#1: Minimum H = 48" person, 50lbs
12. Option#2: Minimum H = 72" person, 250lbs

ASSUMPTIONS

Assumptions and Load Condition:

Option #1 - Minimum 48" person, 50lbs:

1. m = 50 lbs = 22.68kg
2. ρ_{human} = 0.9 g/cm^3
3. H = 48" = 1.22 m
4. Human body volume V = m/ρ_{human} = 0.0252 m^3.
5. Assume the cross-section area of human body A = 0.03 m^2.

Option #2 - Minimum 72" person, 250lbs:

1. m = 250 lbs = 113kg
2. ρ_{human} = 0.9 g/cm^3
3. H = 72" = 1.83 m
4. Human body volume V = m/ρ_{human} = 0.125 m^3.
5. Assume the cross-section area of human body A = 0.12 m^2.

Calculation

Calculate the benchmark velocity:

1. Assume the benchmark velocity to be a 6’ 250lb person jumping 18” above the ground on the sidewalk. The velocity that they hit the sidewalk is the benchmark velocity.
2. $V_1^2 = 2 \times 9.8 \times S_1$
3. S_1 = 18” = 0.457m
4. The benchmark velocity V_1 = 2.99 m/s

CALCULATION

Calculation

Force applied to human body inside water:

1. Gravity $G = \rho_{human}\, gV$
2. Buoyancy (floating force) F = $\rho_{water}\, gV$
3. Water resistance force $F_{resistance}$ = 1/2 $\rho_{water}\, {V_x}^2\, AC_D$

According to Newton's second law, we have:

1. The acceleration in the water: $a = \frac{dV_x}{dt} = \frac{F}{m}$
2. $a = \frac{\rho_{human} gV - \rho_{water} gV - \frac{1}{2}\rho_{water} V_x^2 AC_D}{\rho_{human} V} = \frac{0.9\times9.8\times V - 1.0\times9.8\times V - 0.5\times1.0\times V_x^2\times A\times1.0}{0.9\times V} = -(1.09 + 0.56\frac{A}{V}V_x^2)$
3. $\frac{dV_x}{dt} = -(1.09 + 0.56\frac{AV_x^2}{V})$
4. $\mathrm{dt} = -\frac{dV_x}{(1.09+0.56\frac{AV_x^2}{V})}$

Calculation

The displacement for body moving inside the water would be:

$$S = \int_0^t V_x \cdot dt = -\int_{V_2}^{V_1} V_x \cdot \frac{dV_x}{1.09 + 0.56\frac{AV_x^2}{V}}$$

$V_1^2 = 2 \times 9.8 \times S_1$

CALCULATION

RESULTS

Results:

For minimum 48” person, 50 lbs (H = 48” = 1.2 meter), we have:

$$S = \int_0^t V_x \cdot dt = -\int_{V_2}^{V_1} V_x \cdot \frac{dV_x}{1.09+0.56\frac{AV_x^2}{V}};$$

A = 0.03 m^2

V = 0.0252 m^3

$V_1^2 = 2 \times 9.8 \times S_1$

Model	Plummet Height (S_1)	Water Depth (S)	Calculated velocity at pool floor (V_2)	Benchmark velocity
3H	S_1 = 47” = 1.19m	S = 6’ = 1.829m	0.74 m/s	2.99 m/s
3H Alt	S_1 = 37” = 0.94m	S = 5’ = 1.524m	0.99 m/s	2.99 m/s
4H	S_1 = 85” = 2.16m	S = 7’ = 2.134m	0.96 m/s	2.99 m/s
4H Alt	S_1 = 75” = 1.91m	S = 6’ = 1.829m	1.33 m/s	2.99 m/s
5H	S_1 = 124” = 3.15m	S = 9’ = 2.743m	0.15 m/s	2.99 m/s
5H Alt	S_1 = 114” = 2.90m	S = 8’ = 2.438m	0.80 m/s	2.99 m/s

Results:

For Minimum 72" person, 250lbs (H = 72" = 1.83 meter), we have:

$$S = \int_0^t V_x \cdot dt = -\int_{V_2}^{V_1} V_x \cdot \frac{dV_x}{1.09+0.56\frac{AV_x^2}{V}};$$

$A = 0.12\ m^2$ $V = 0.125\ m^3$ $V_1^2 = 2 \times 9.8 \times S_1$

Model	Plummet Height (S_1)	Water Depth (S)	Calculated velocity at pool floor (V_2)	Benchmark velocity
3H	S_1 = 35" = 0.89m	S = 6' = 1.829m	0.84 m/s	2.99 m/s
3H Alt	S_1 = 25" = 0.64m	S = 5' = 1.524m	0.90 m/s	2.99 m/s
4H	S_1 = 73" = 1.85m	S = 7' = 2.134m	1.35 m/s	2.99 m/s
4H Alt	S_1 = 63" = 1.60m	S = 6' = 1.829m	1.63 m/s	2.99 m/s
5H	S_1 = 112" = 2.84m	S = 9' = 2.743m	1.00 m/s	2.99 m/s
5H Alt	S_1 = 102" = 2.59m	S = 8' = 2.438m	1.35 m/s	2.99 m/s

RESULTS

CONCLUSION

Conclusions:

1. For minimum 48” person, 50 lbs (H = 48” = 1.2 meter): the calculated velocity at the pool floor is between 0.15 m/s and 1.33 m/s for all 6 cases.
2. For minimum 72" person, 250lbs (H = 72” = 1.83 meter): the calculated velocity at the pool floor is between 0.84 m/s and 1.35 m/s for all 6 cases.
3. All the calculated velocities at pool floor are less than the benchmark velocity 2.99 m/s.
4. Comparing to the benchmark velocity, all the 12 cases with the provided water depth would be safe.

COMMENTS

Comments:

1. In this hand calculation, we assume that the human body density is approximately 0.9 g/cm^3 (with breath held) and that the water resistance coefficient is around 1.0 under normal conditions. If the actual parameter values differ from these assumptions, the calculated results may vary accordingly.
2. We assume the benchmark velocity to be a 6’ 250lb person jumping 18” above the ground on the sidewalk. The calculated velocity that they hit the sidewalk (2.99 m/s) is the benchmark velocity.