INFILTRATOR®
water technologies

Septic Tank Buoyancy Control 101

David Lentz, P.E.

Nobody Wants This…

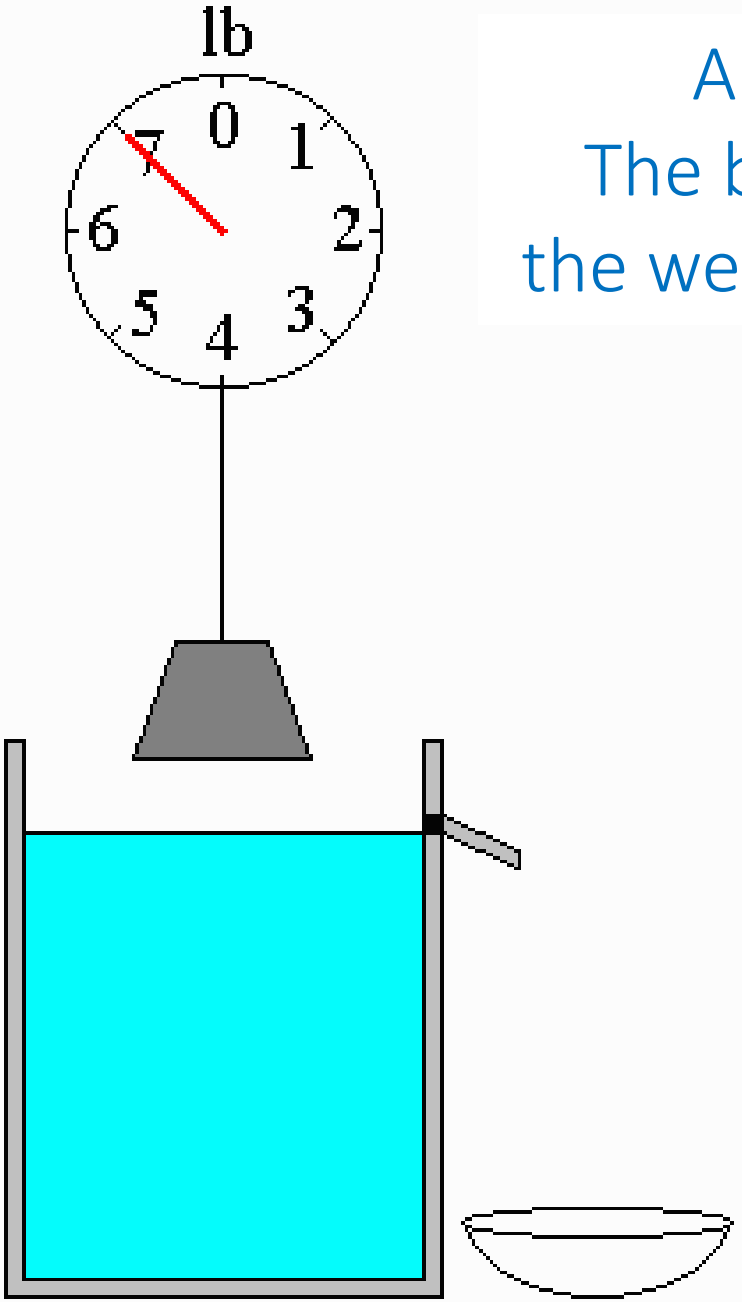

Or This…

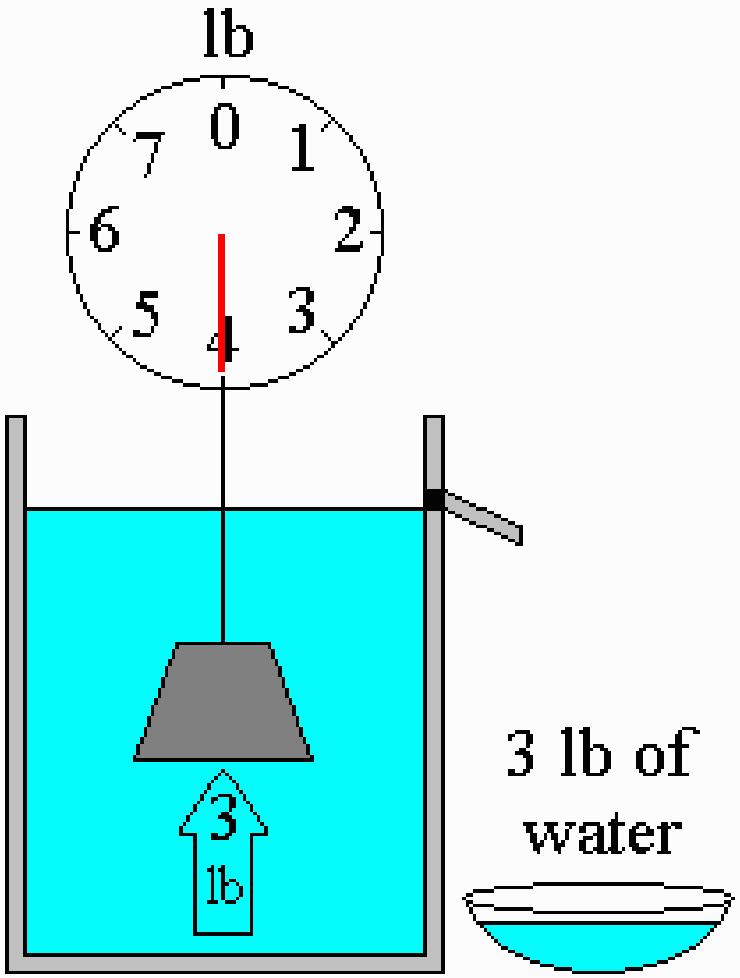
Or This…

Why Do Tanks Float?

Archimedes' Principle

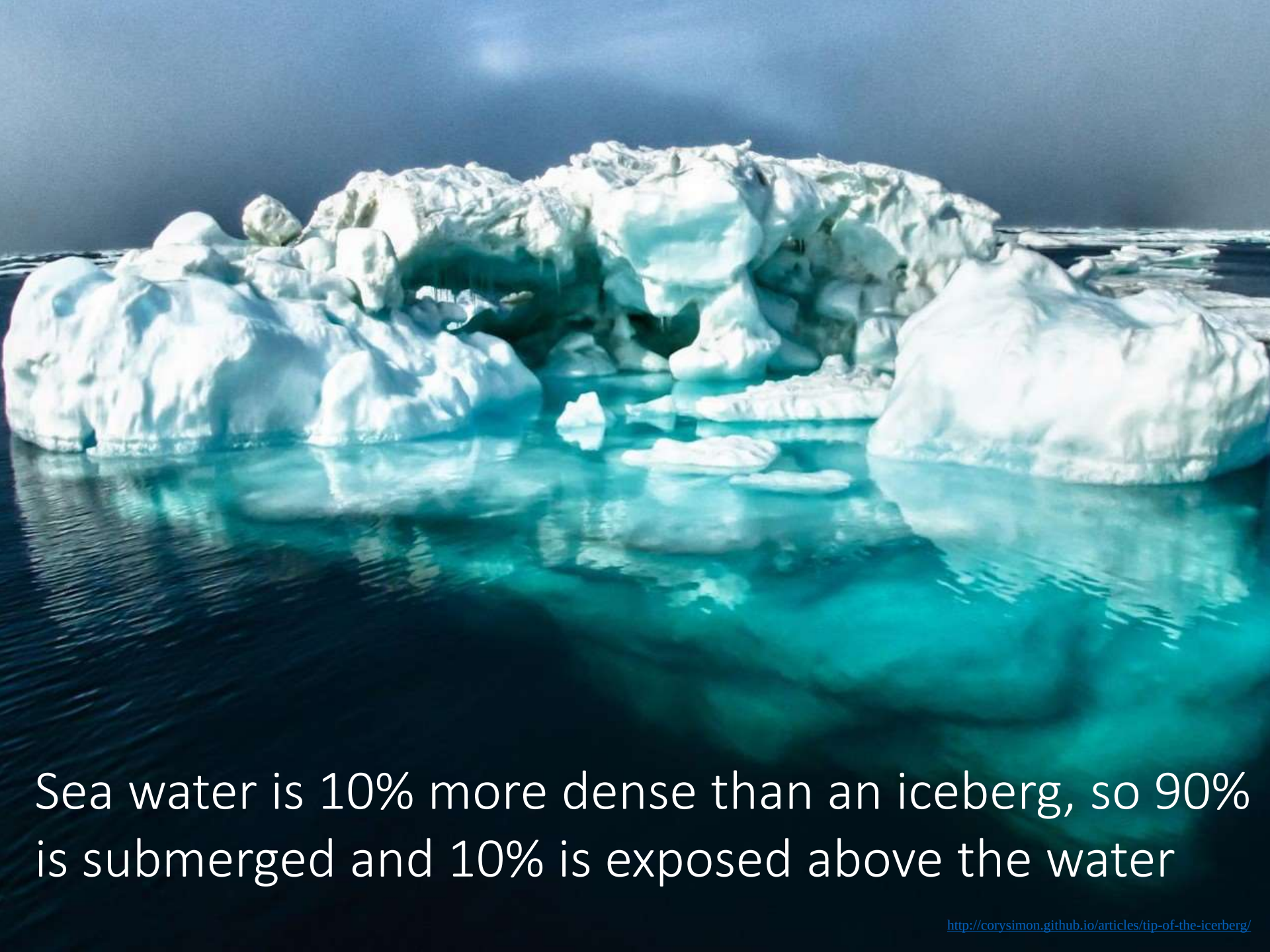
Archimedes' Principle:
The buoyant force is equal to the weight of the displaced water





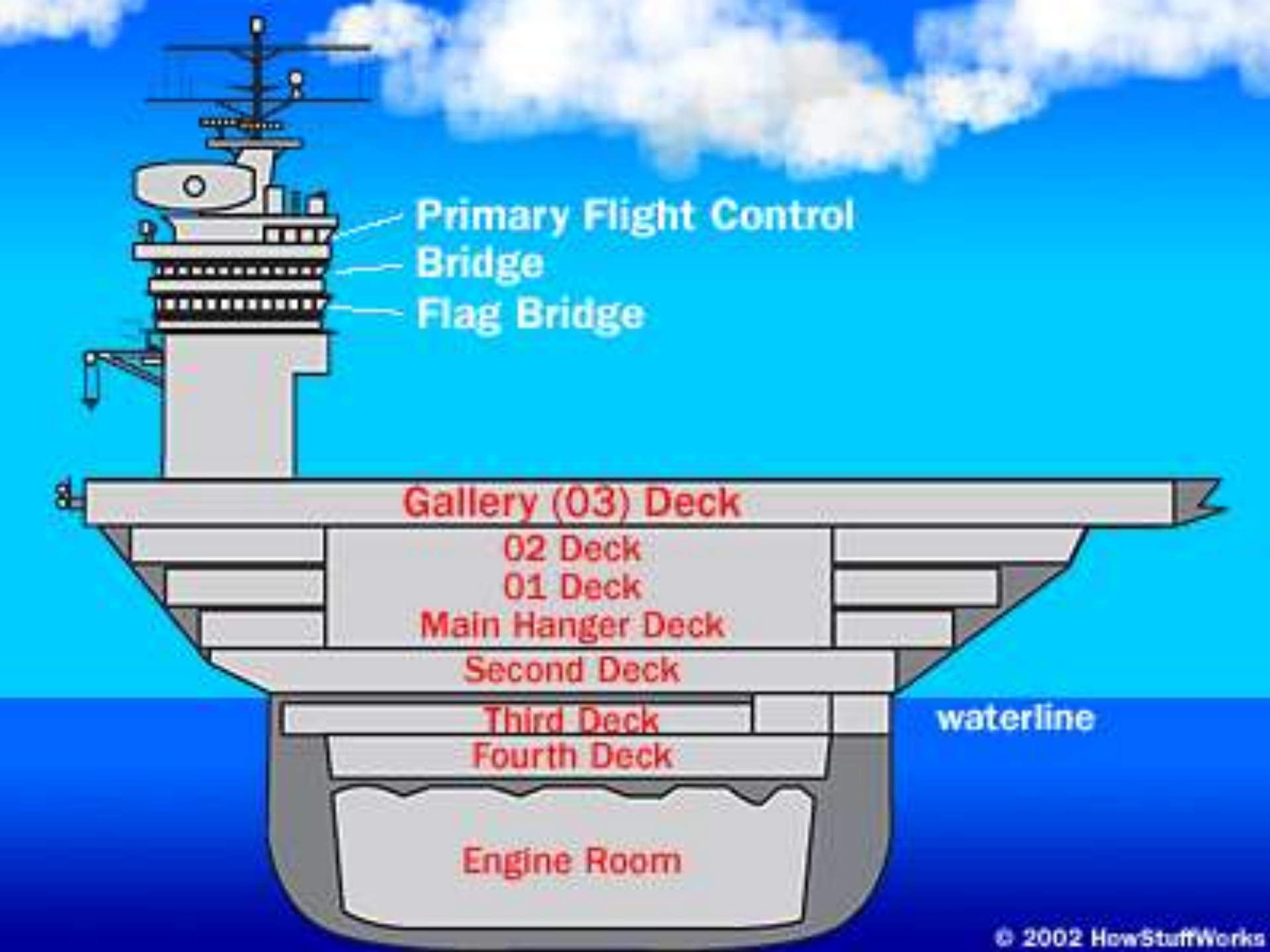
https://physics.weber.edu/carroll/archimedes/principle.htm

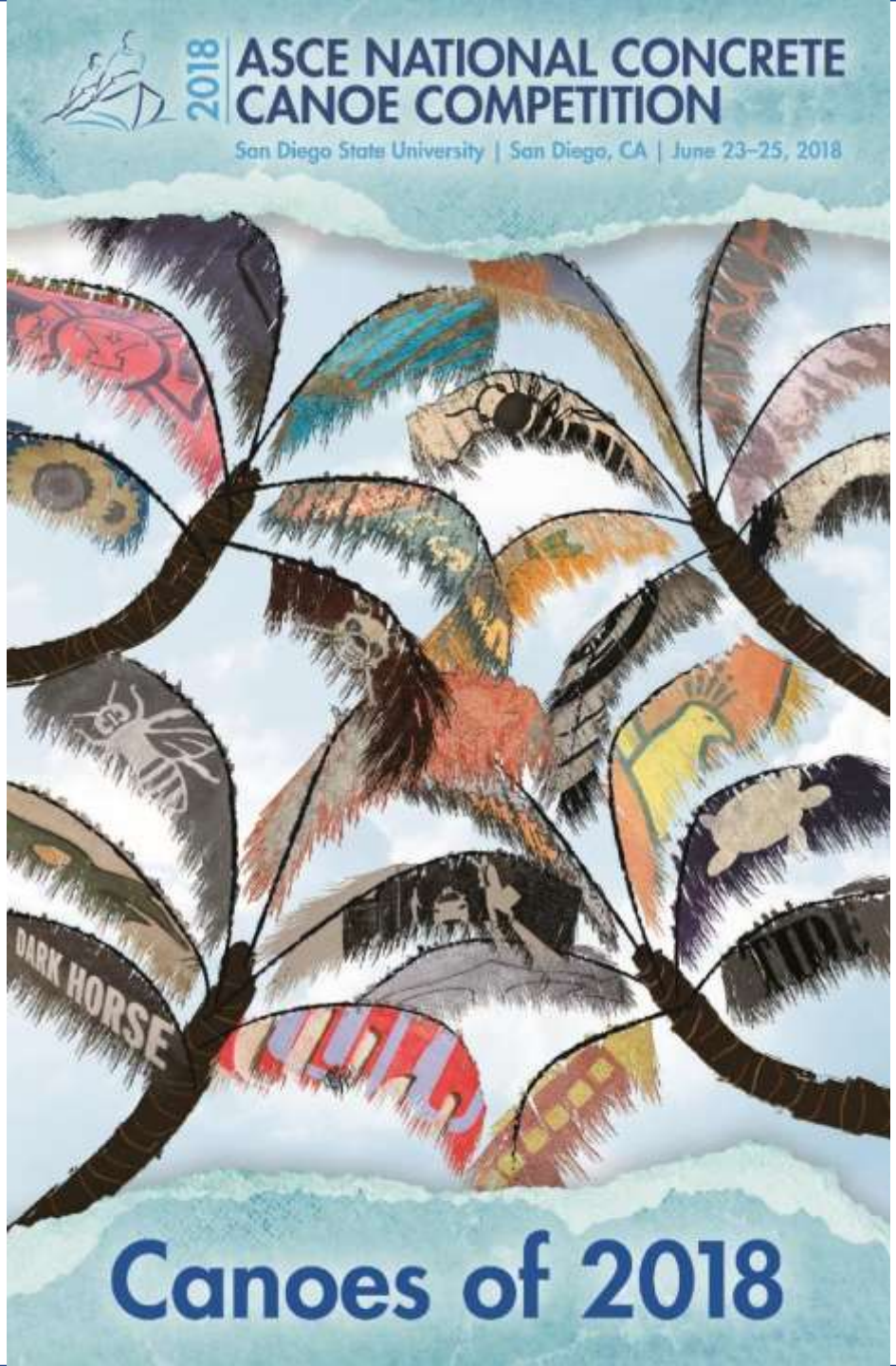
https://www.youtube.com/watch?v=UGWB_Mvzd5A



Sea water is 10% more dense than an iceberg, so 90% is submerged and 10% is exposed above the water

http://corysimon.github.io/articles/tip-of-the-icerberg/





https://www.asce.org/uploadedimages/conferences_and_events/event_subpages/content_pieces/canoes_of_2018_poster.jpg

https://www.engg.ksu.edu/asce/concrete%20canoe

https://www.unr.edu/nevada-today/news/2012/concrete-canoe-results

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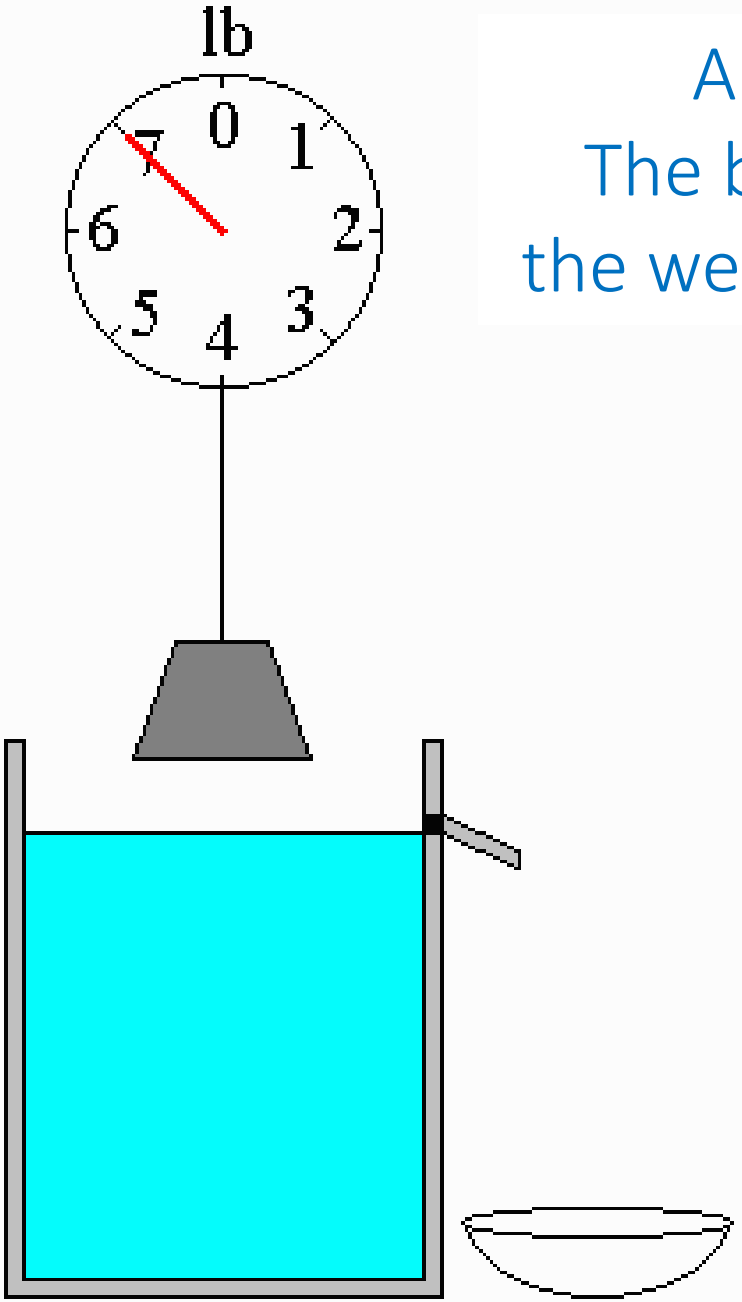

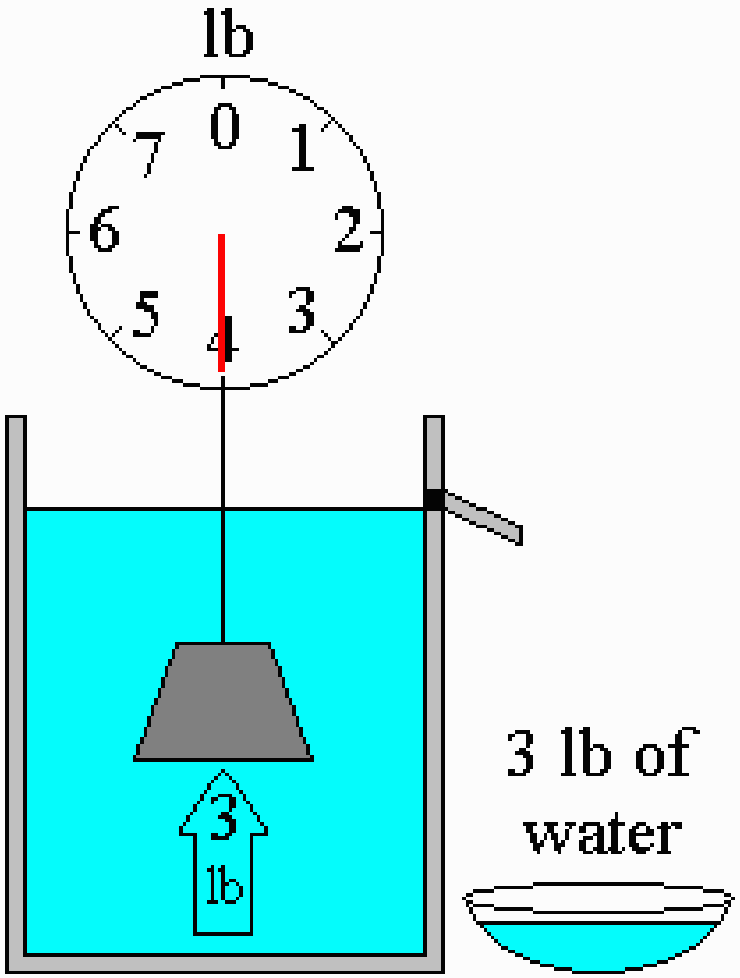

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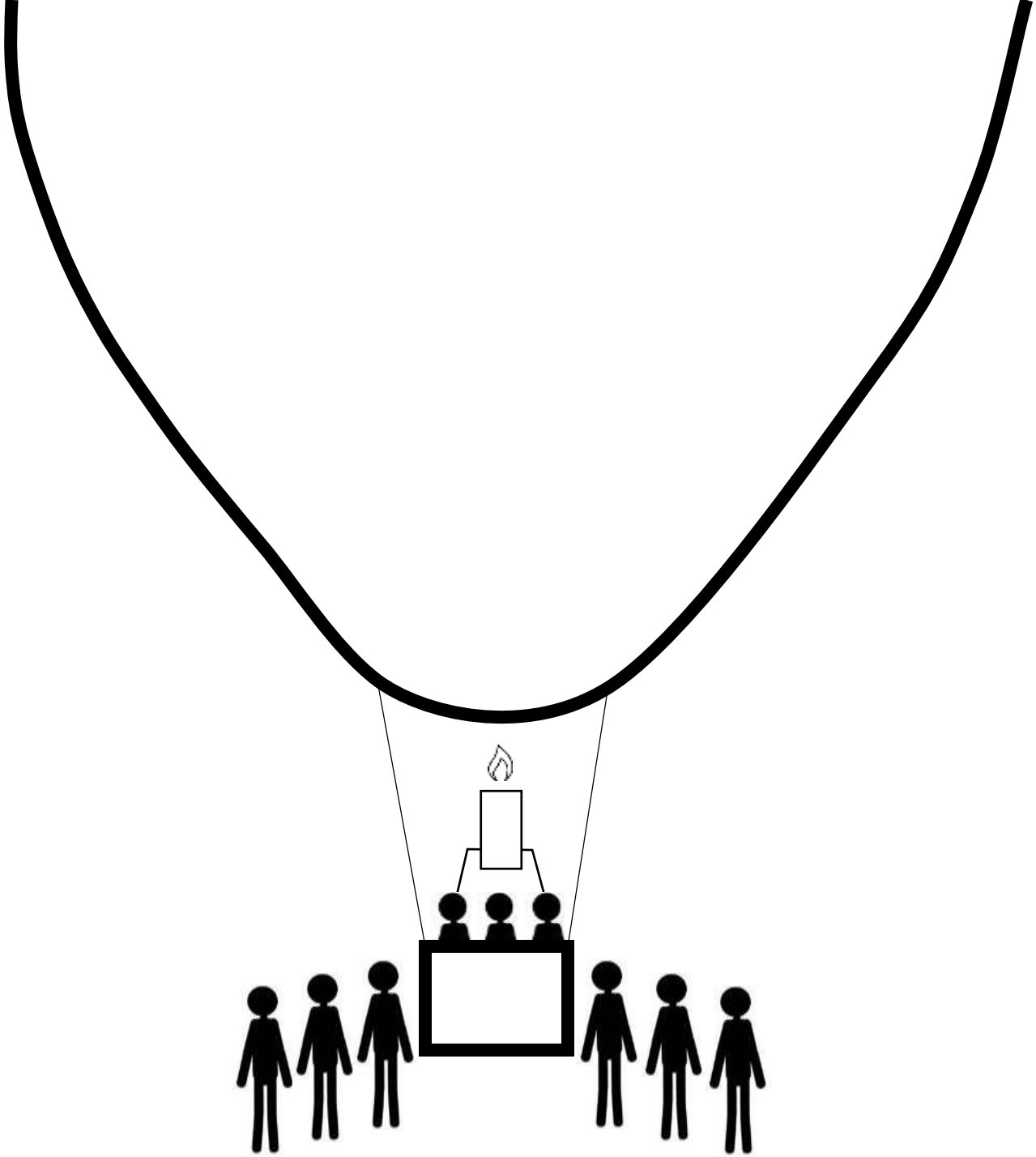
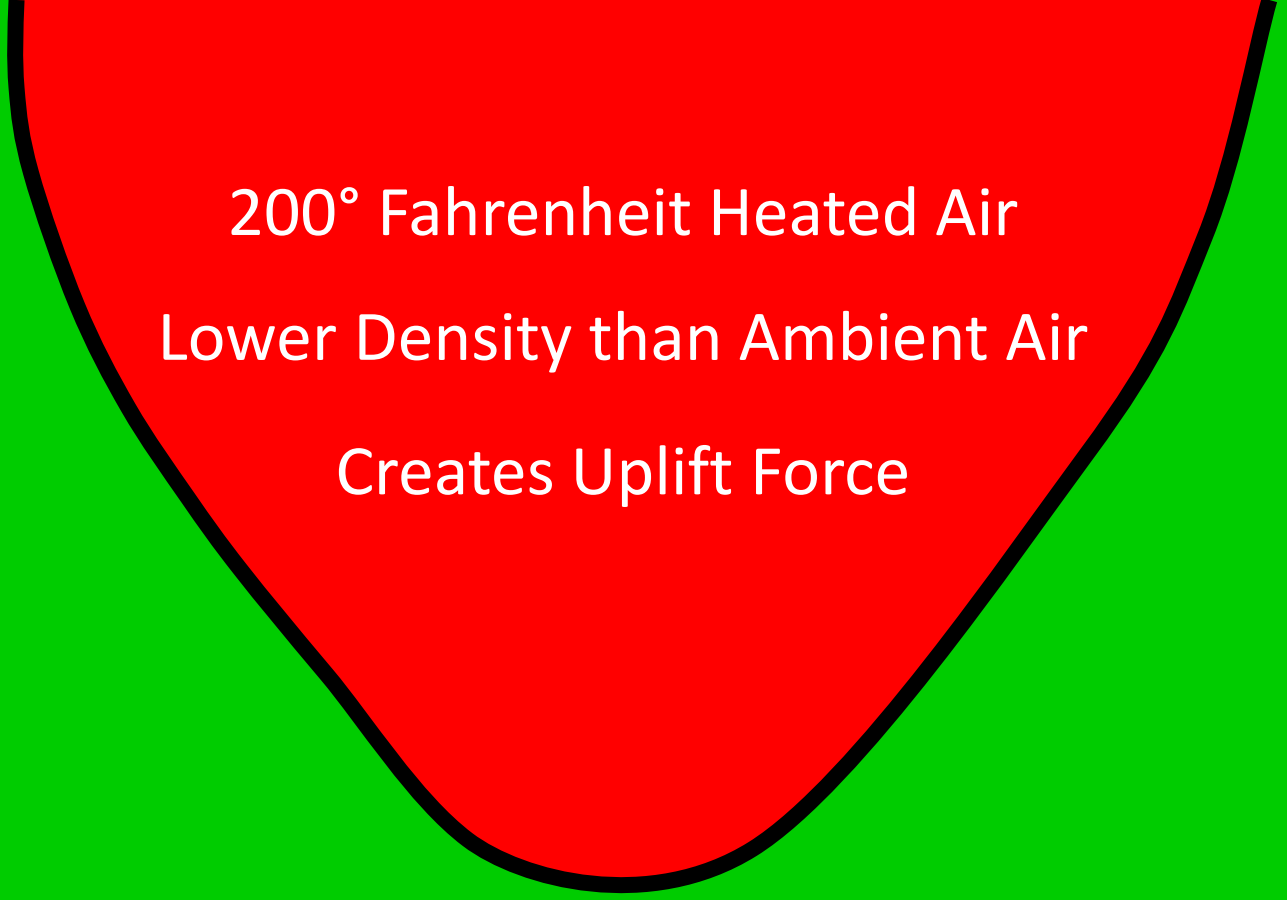
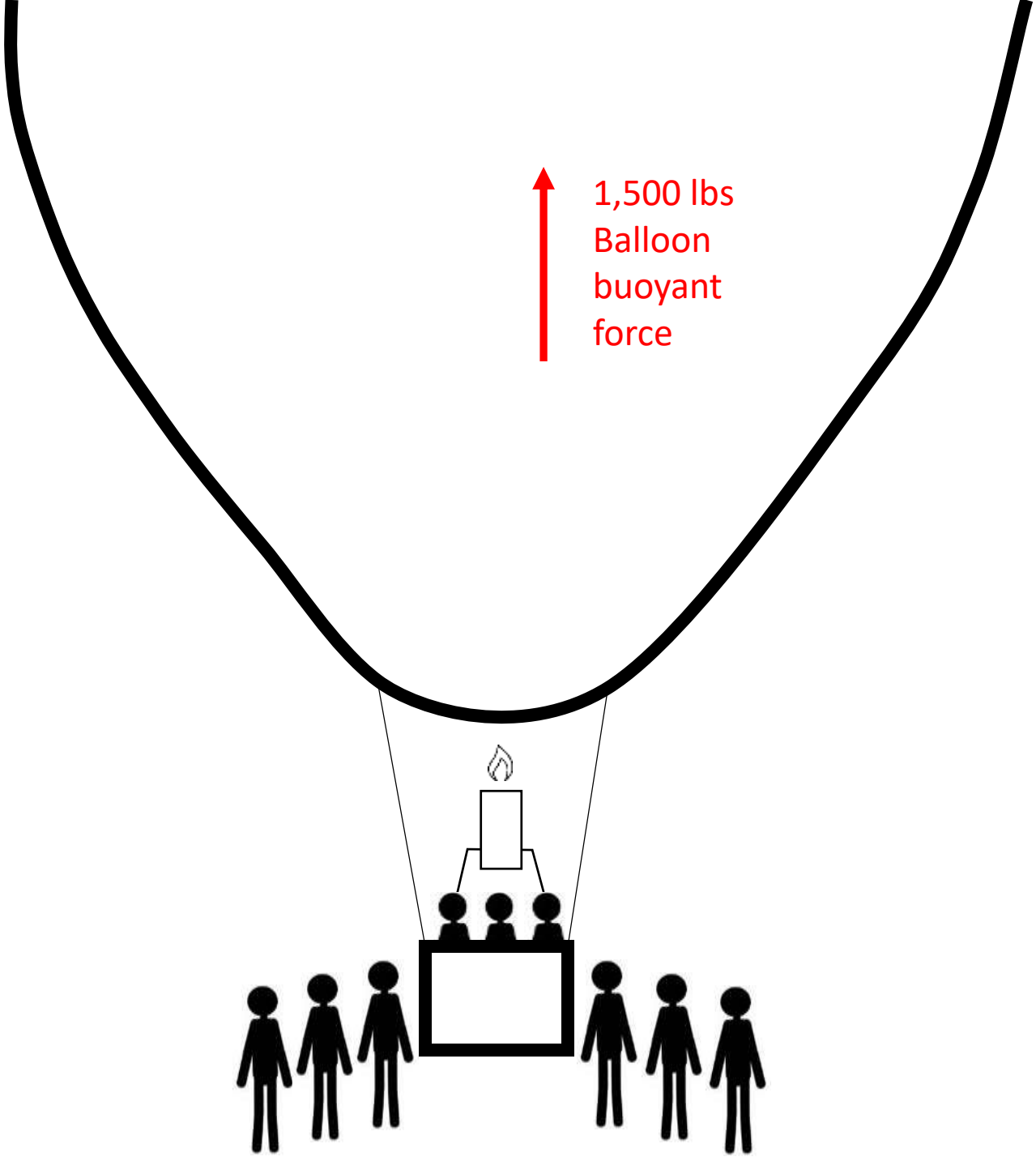
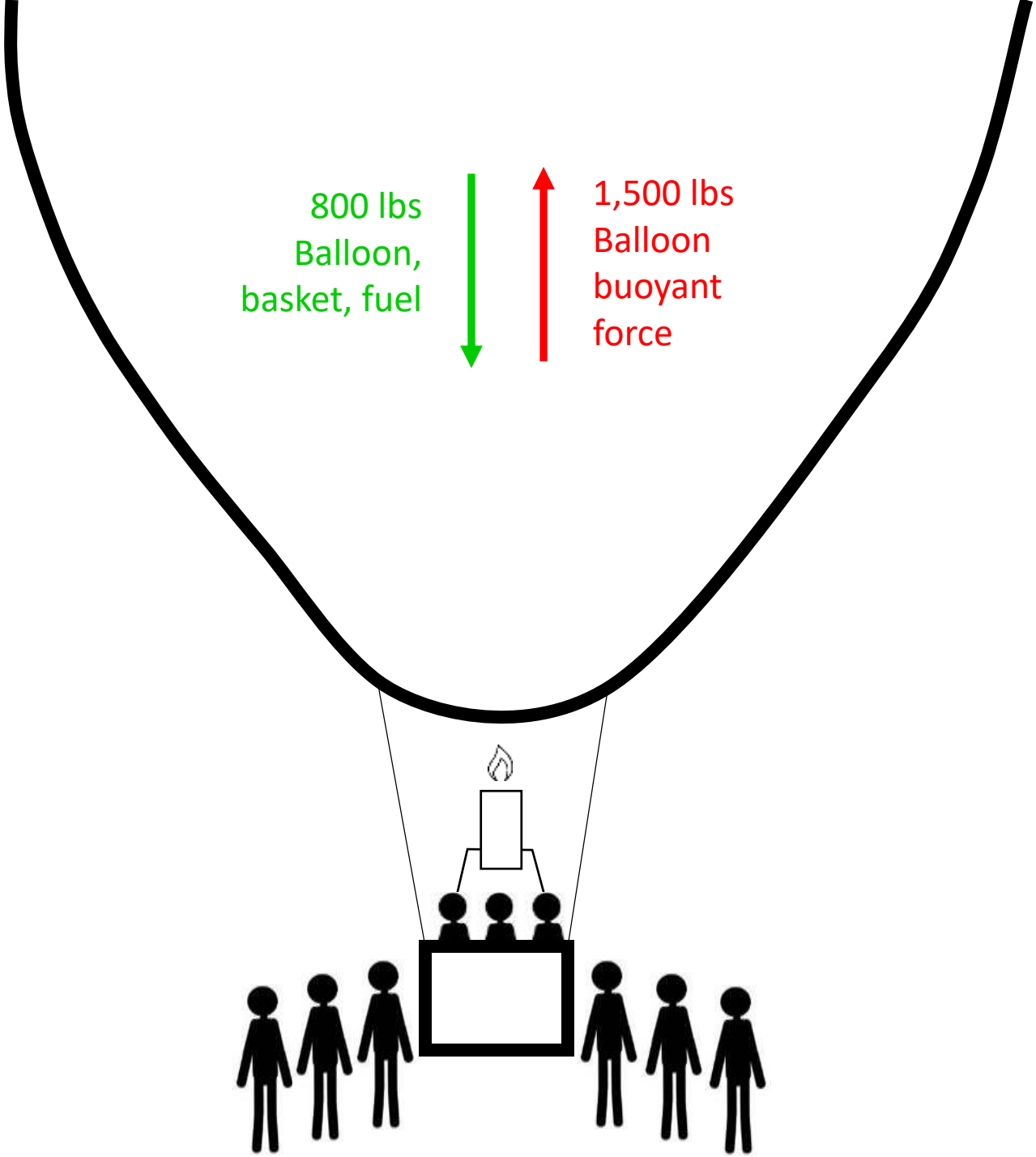
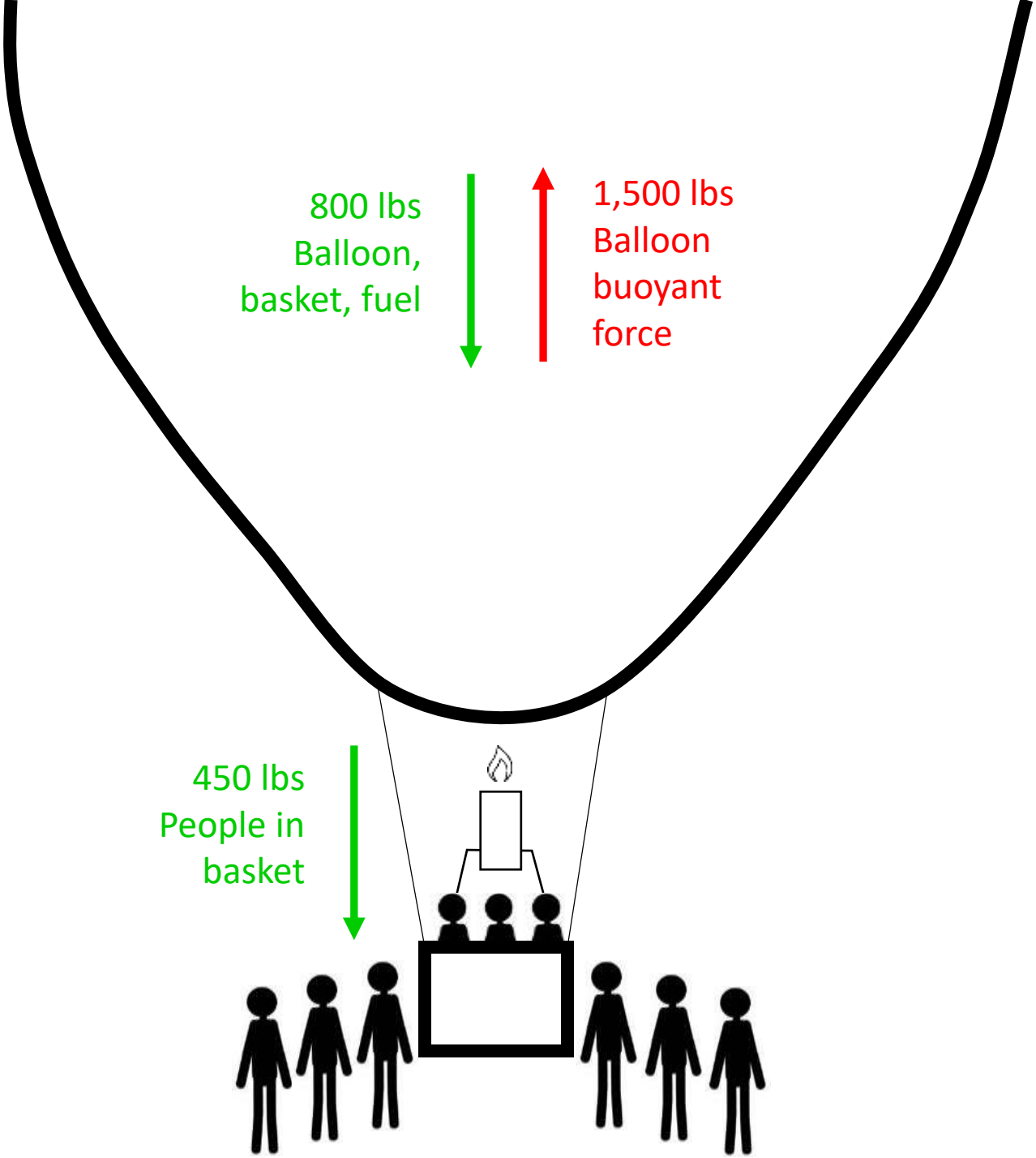


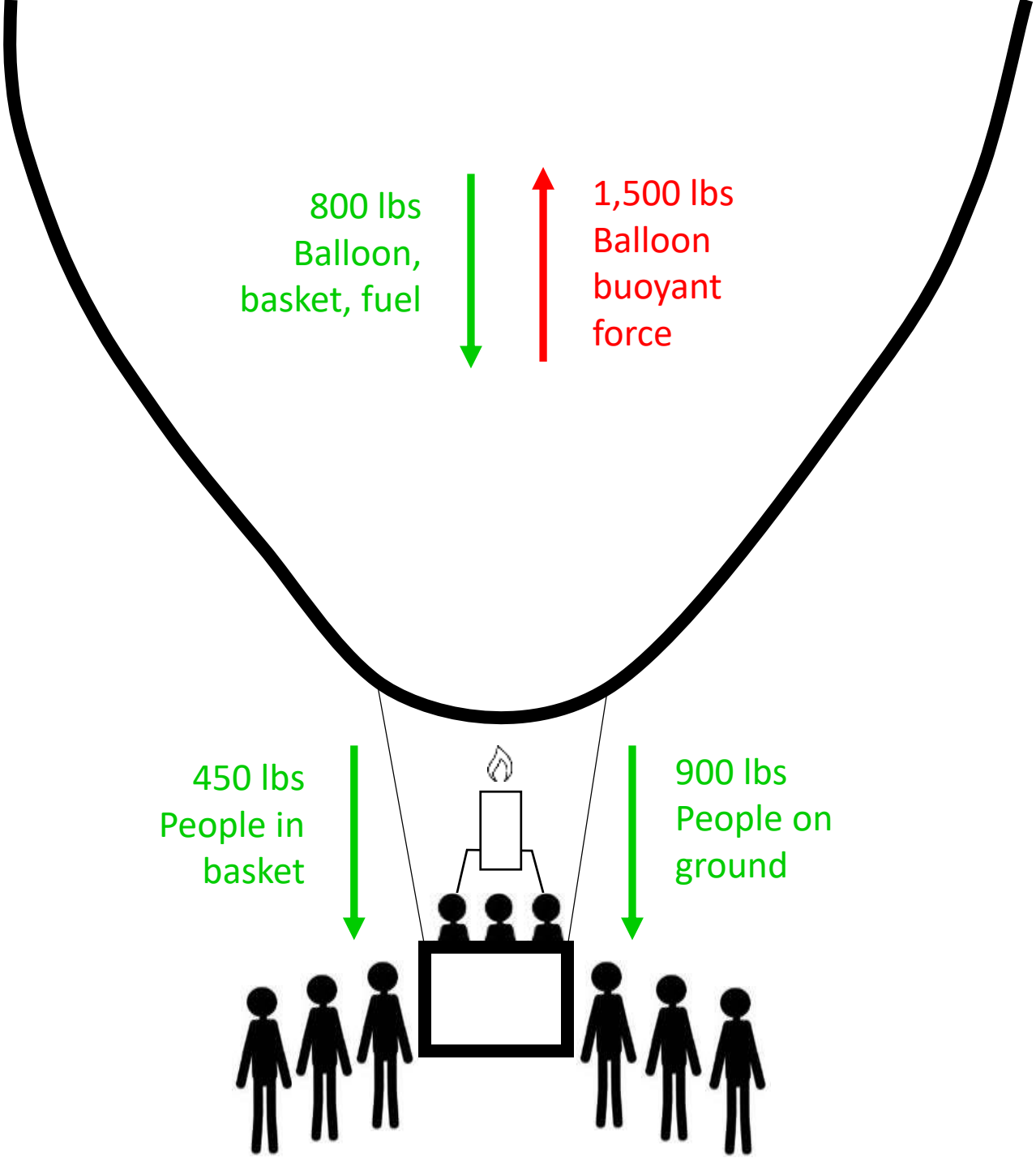


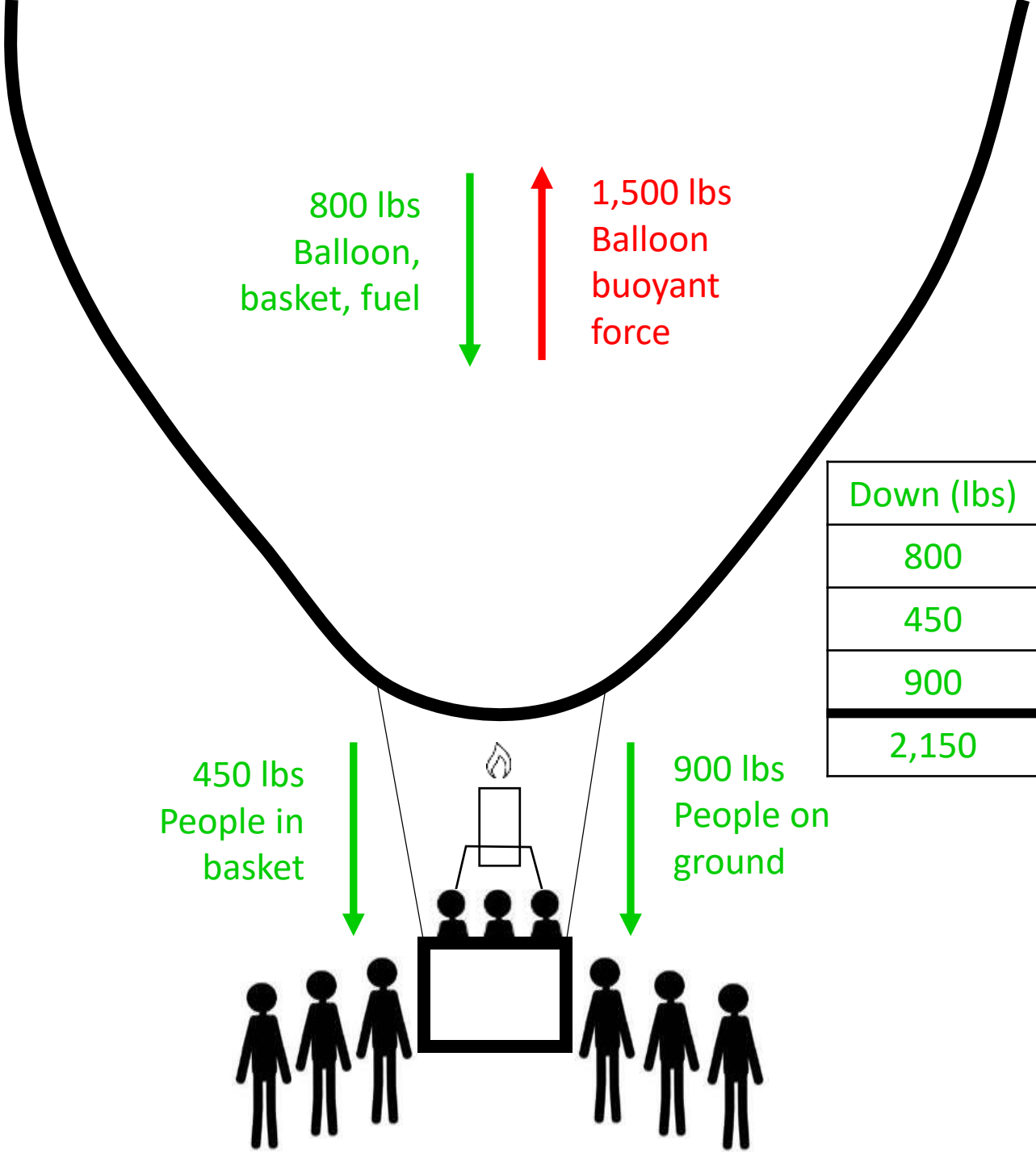
70° Fahrenheit Ambient Air
Higher Density than Heated Air


1,500 lbs
Balloon
buoyant
force

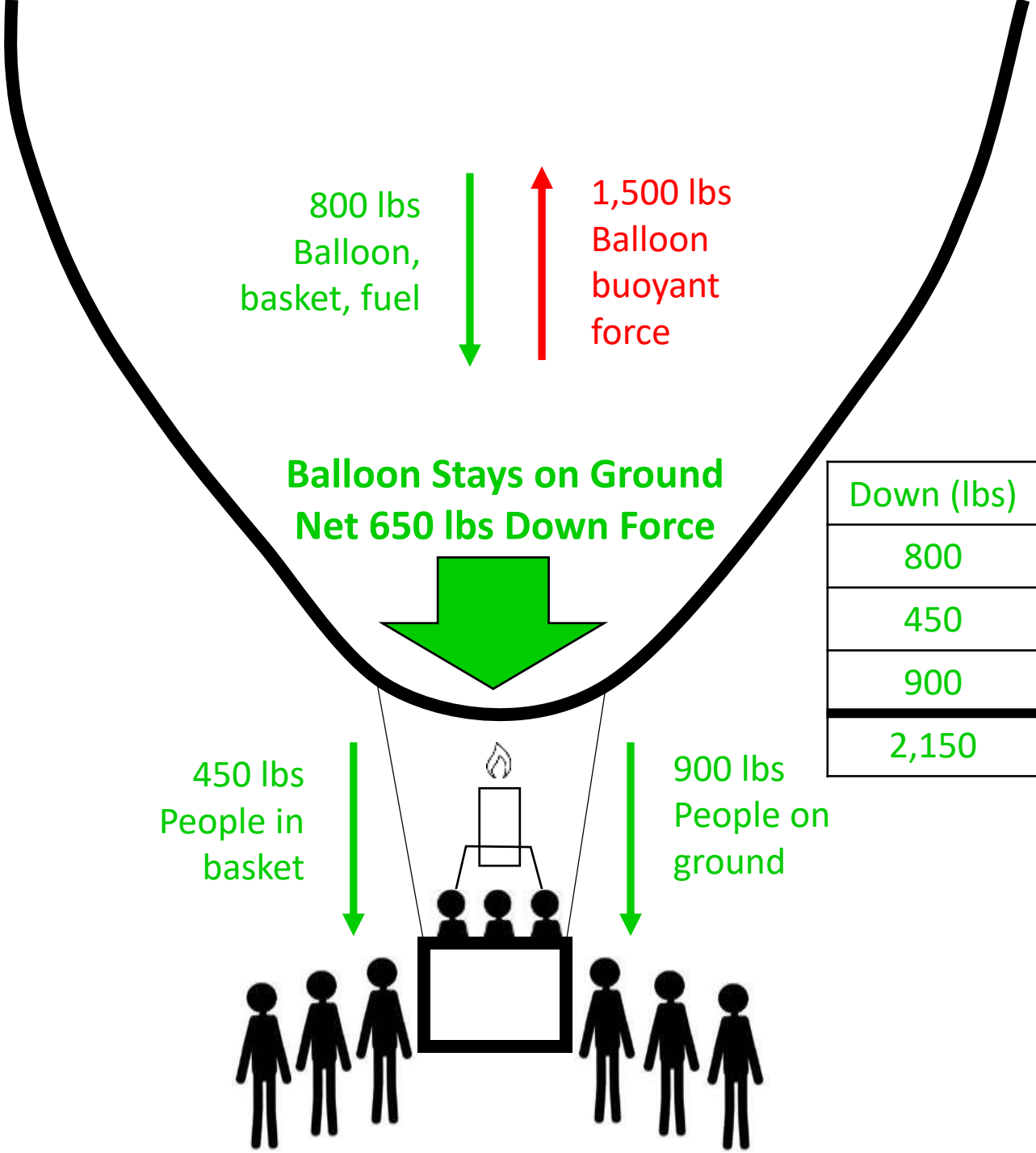

800 lbs
Balloon,
basket, fuel
1,500 lbs
Balloon
buoyant
force


800 lbs
Balloon,
basket, fuel
1,500 lbs
Balloon
buoyant
force
450 lbs
People in
basket

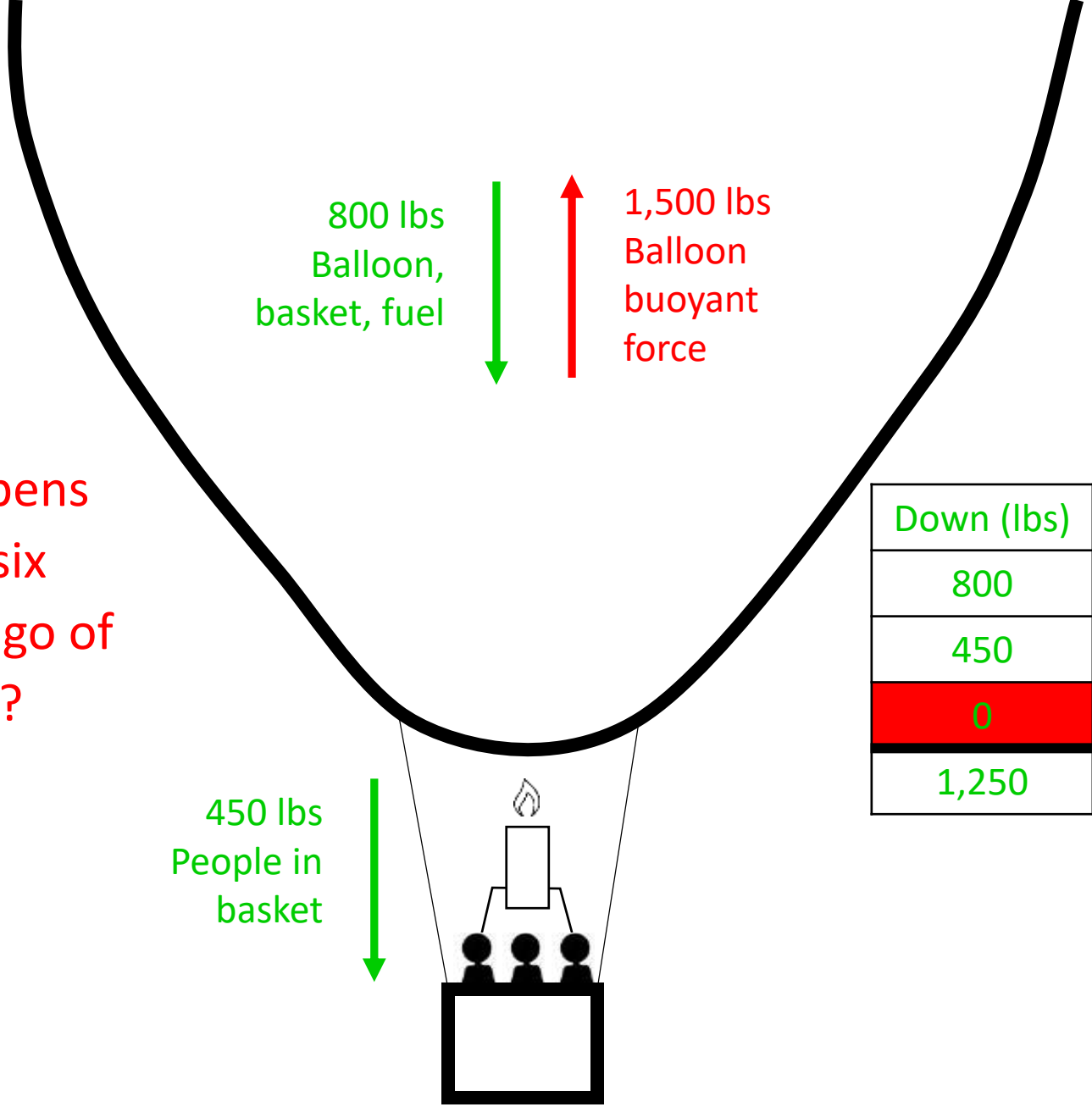

800 lbs
Balloon,
basket, fuel
1,500 lbs
Balloon
buoyant
force
450 lbs
People in
basket
900 lbs
People on
ground



Down (lbs)	Up (lbs)
800	1,500
450	
900	
2,150	1,500

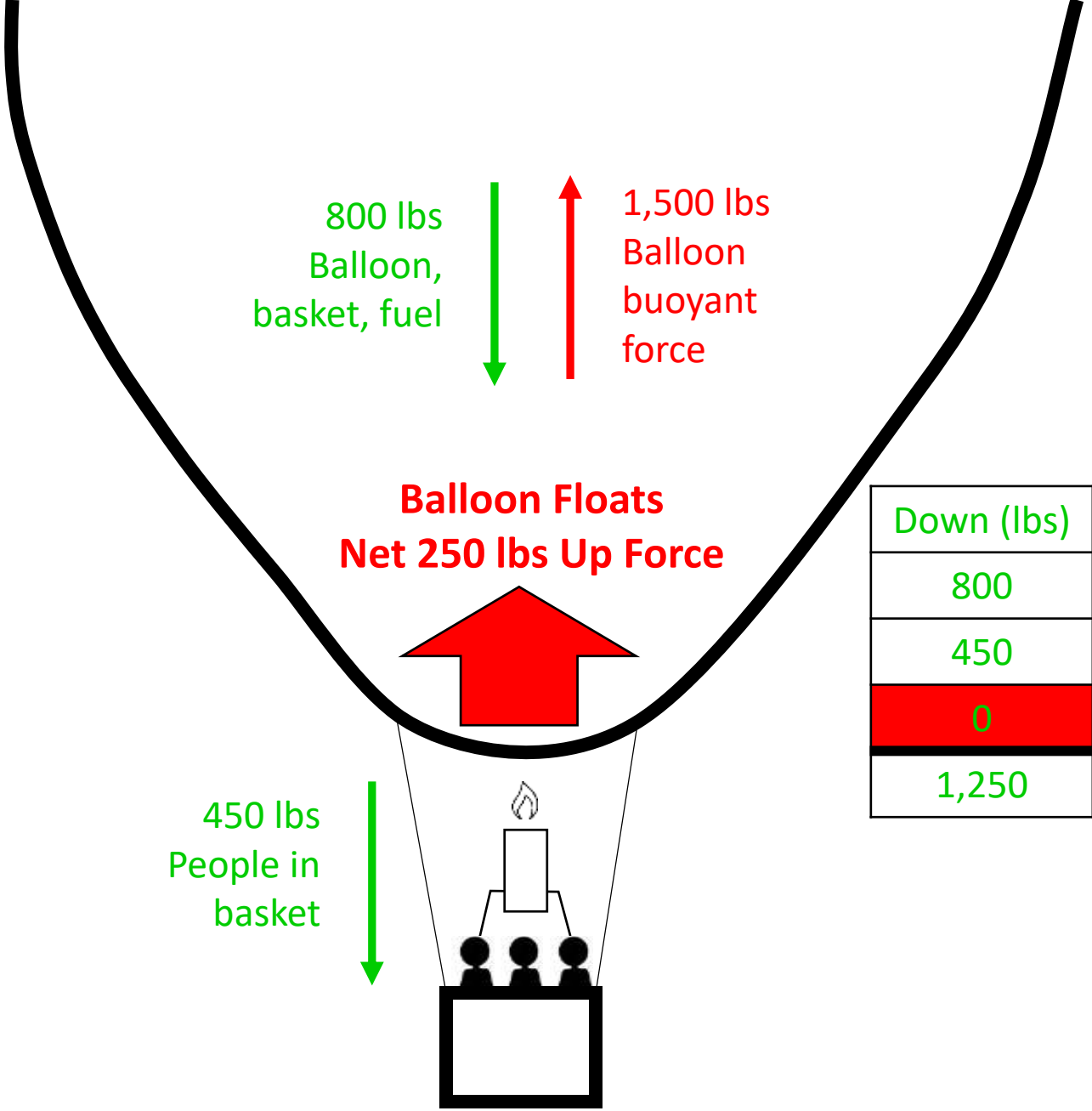


Down (lbs)	Up (lbs)
800	1,500
450	
900	
2,150	1,500

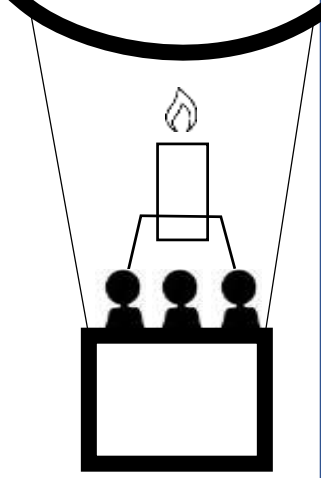


What happens when the six people let go of the basket?

Down (lbs)	Up (lbs)
800	1,500
450	
0	
1,250	1,500



Down (lbs)	Up (lbs)
800	1,500
450	
0	
1,250	1,500



800 lbs
Balloon,
basket, fuel

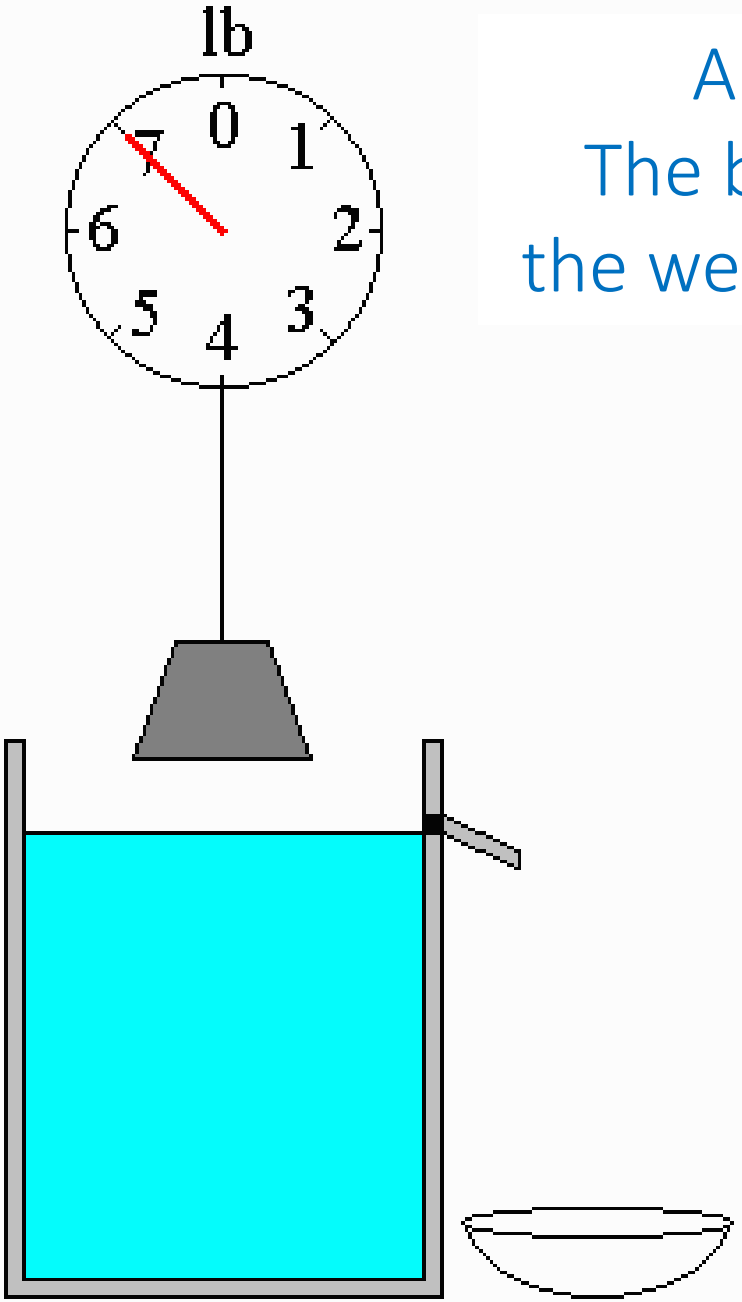
1,500 lbs
Balloon
buoyant
force

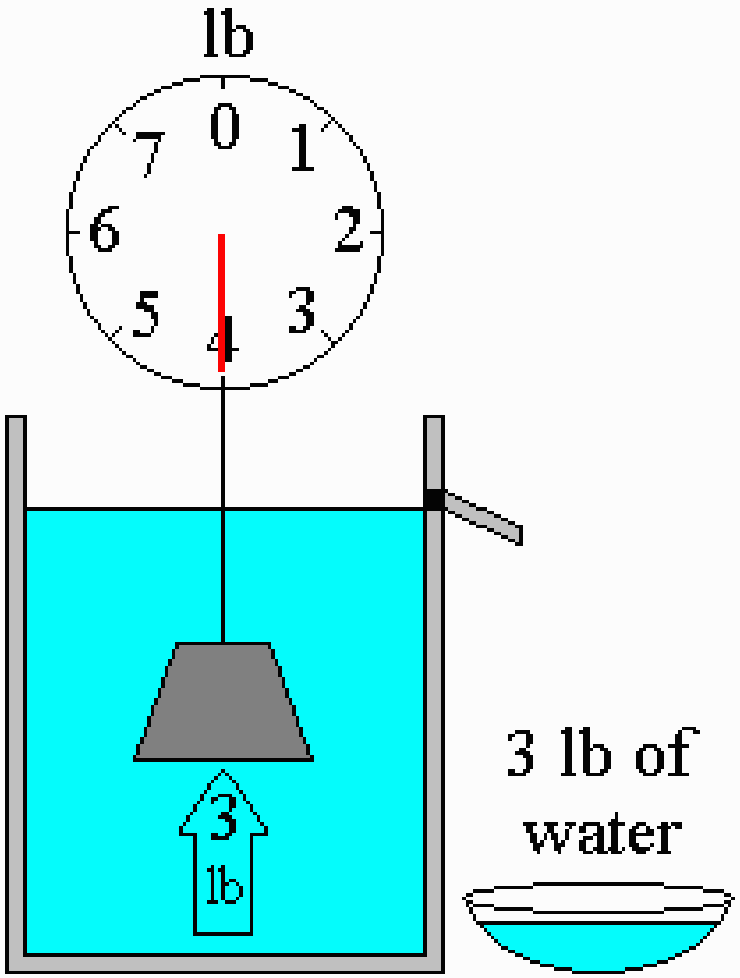
Balloon Floats
Net 250 lbs Up Force

450 lbs
People in
basket

Down (lbs)	Up (lbs)
800	1,500
450	
0	
1,250	1,500

Archimedes' Principle:
The buoyant force is equal to the weight of the displaced water





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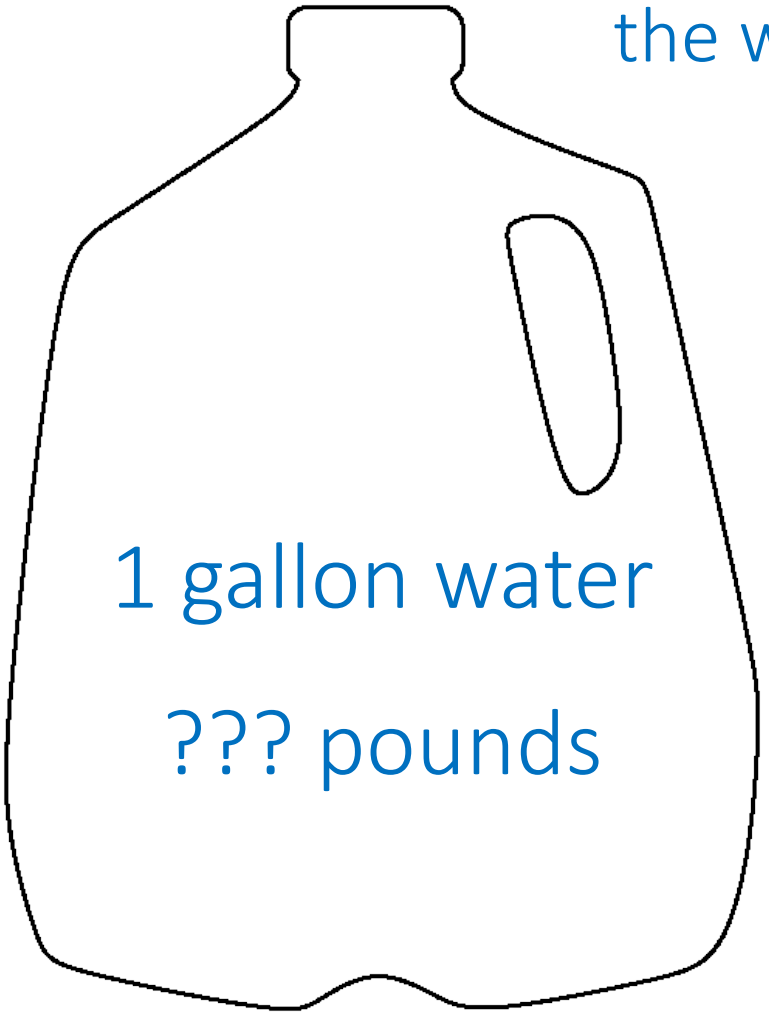

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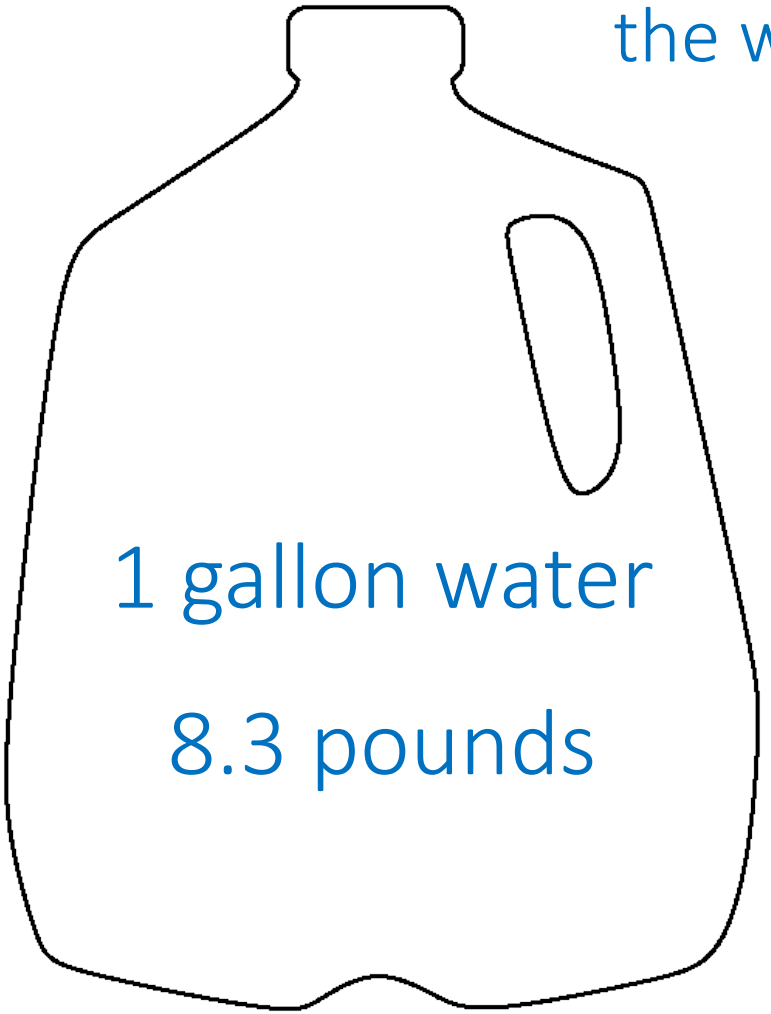

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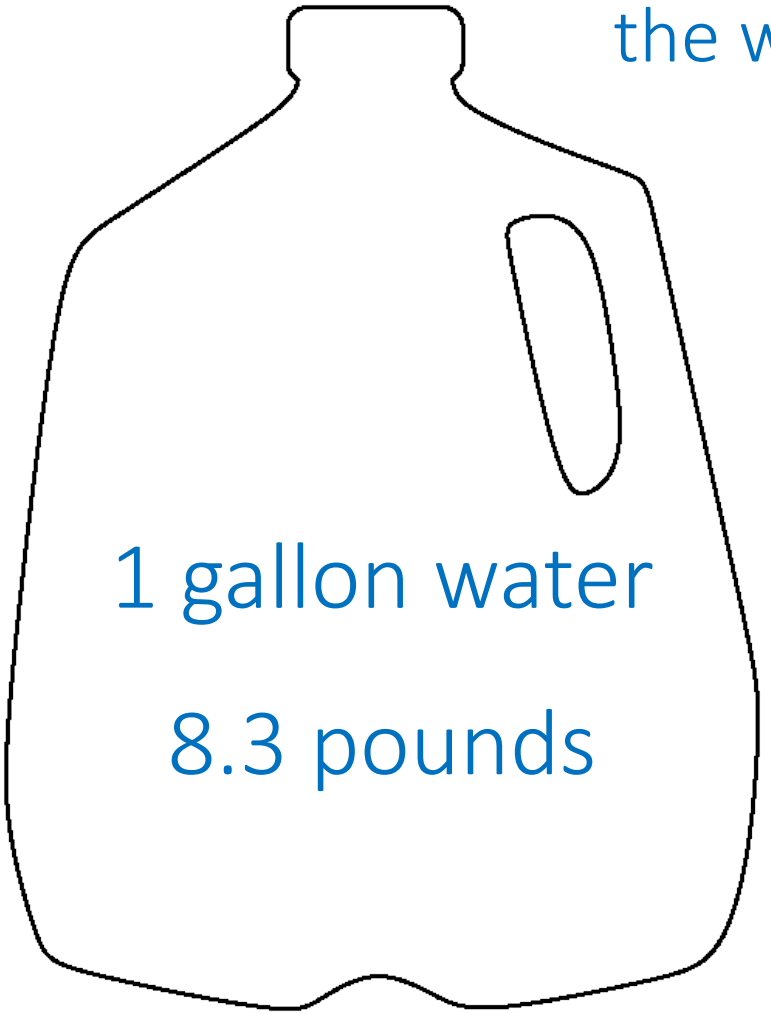
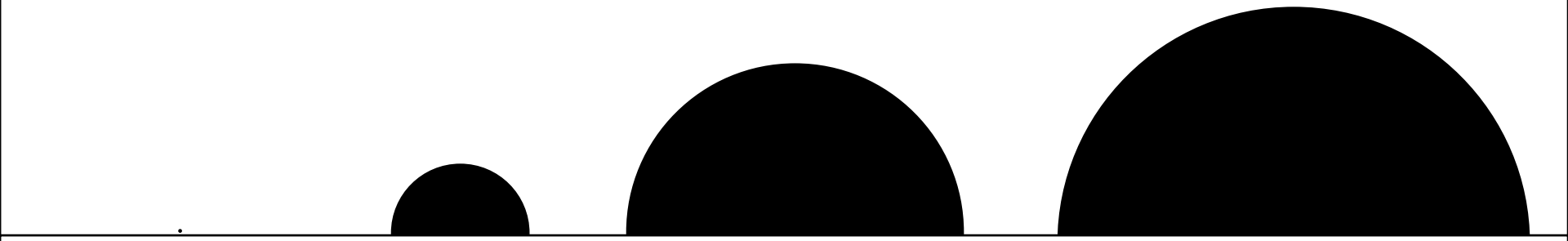


- 4 gals ~ 33 lbs
- 500 gals ~ 4,000 lbs
- 1,200 gallons ~ 10,000 lbs
- 1,700 gallons ~ 14,000 lbs

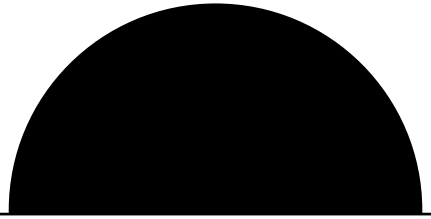
Tank Buoyant Force Comparison

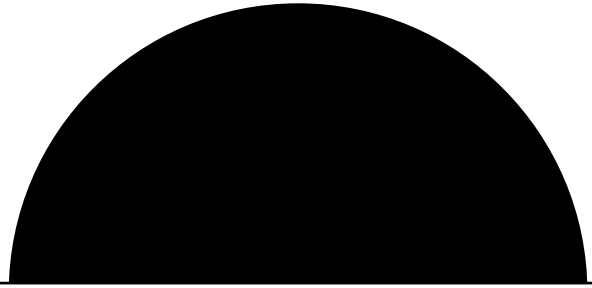


33 lbs	4,000 lbs	10,000 lbs	14,000 lbs
Beach Ball	500-gal Pump Tank	1,000-gal Septic Tank	1,500-gal Septic Tank

Tank Buoyant Force Comparison

Beach ball





33 lbs
Beach Ball

4,000 lbs
500-gal
Pump Tank

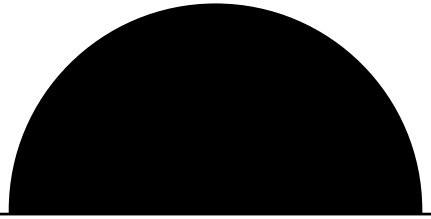
10,000 lbs
1,000-gal
Septic Tank

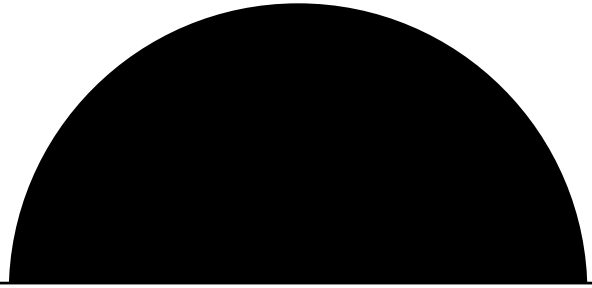
14,000 lbs
1,500-gal
Septic Tank

Tank Buoyant Force Comparison

Beach ball

Ford F150





33 lbs
Beach Ball

4,000 lbs
500-gal
Pump Tank

10,000 lbs
1,000-gal
Septic Tank

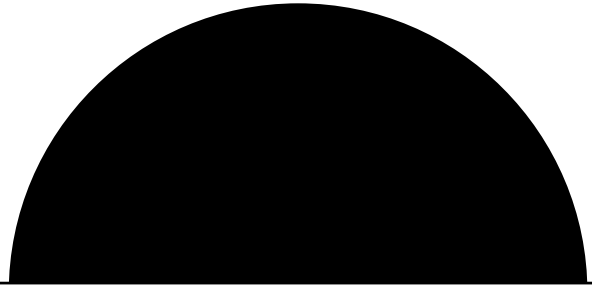
14,000 lbs
1,500-gal
Septic Tank

Tank Buoyant Force Comparison

Beach ball

Ford F150

Skid steer



33 lbs
Beach Ball

4,000 lbs
500-gal
Pump Tank

10,000 lbs
1,000-gal
Septic Tank

14,000 lbs
1,500-gal
Septic Tank

Tank Buoyant Force Comparison

Beach ball

33 lbs
Beach Ball

Ford F150

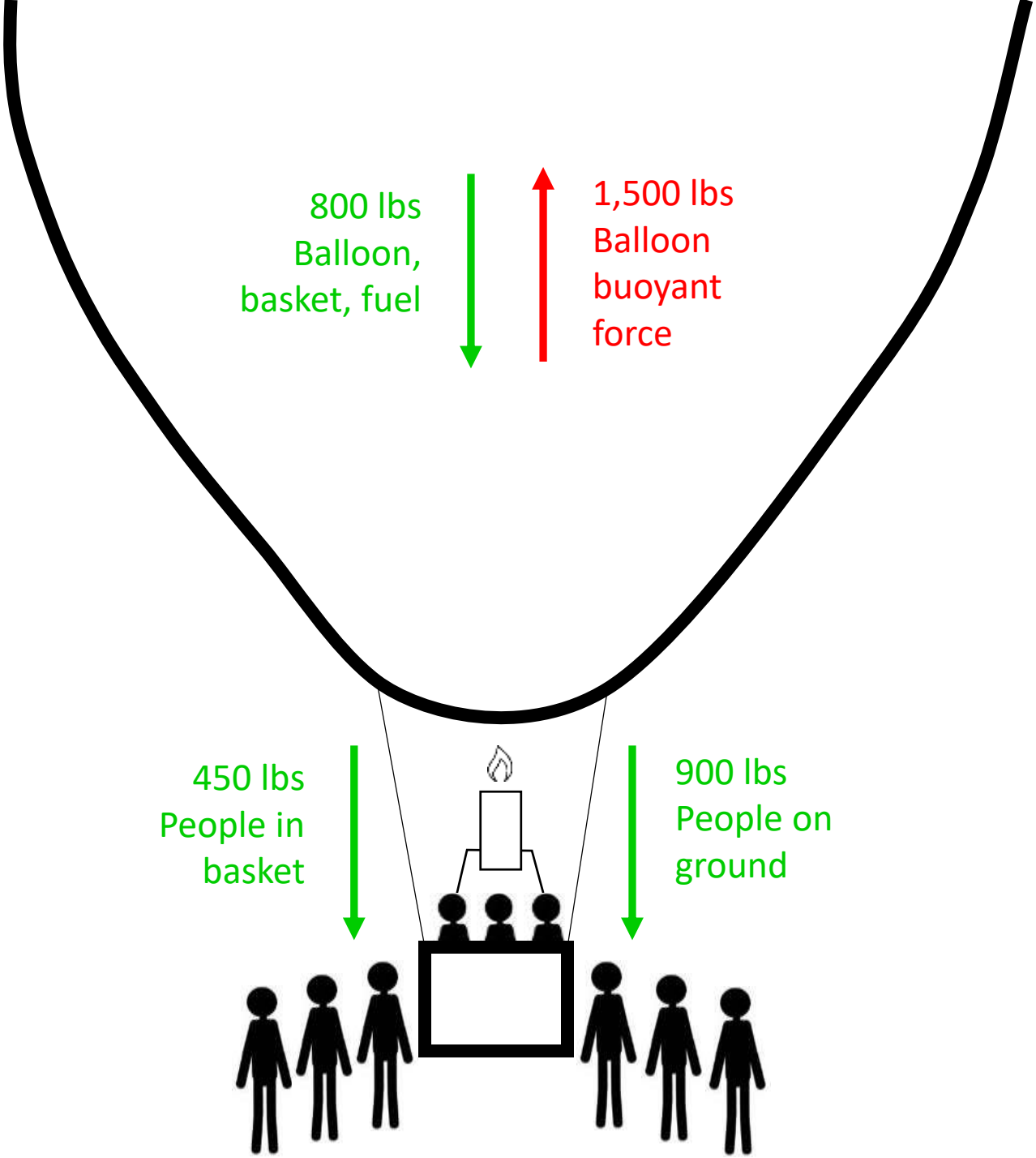
4,000 lbs
500-gal
Pump Tank

Skid steer

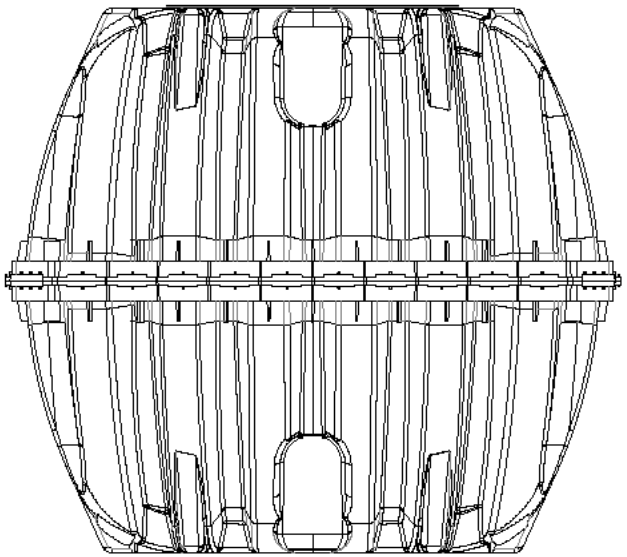
10,000 lbs
1,000-gal
Septic Tank

Mini-Excavator

14,000 lbs
1,500-gal
Septic Tank


800 lbs
Balloon,
basket, fuel
1,500 lbs
Balloon
buoyant
force
450 lbs
People in
basket
900 lbs
People on
ground

Buried Tank Force Analysis



Key Buoyancy Control Factors

- Depth of soil cover over tank

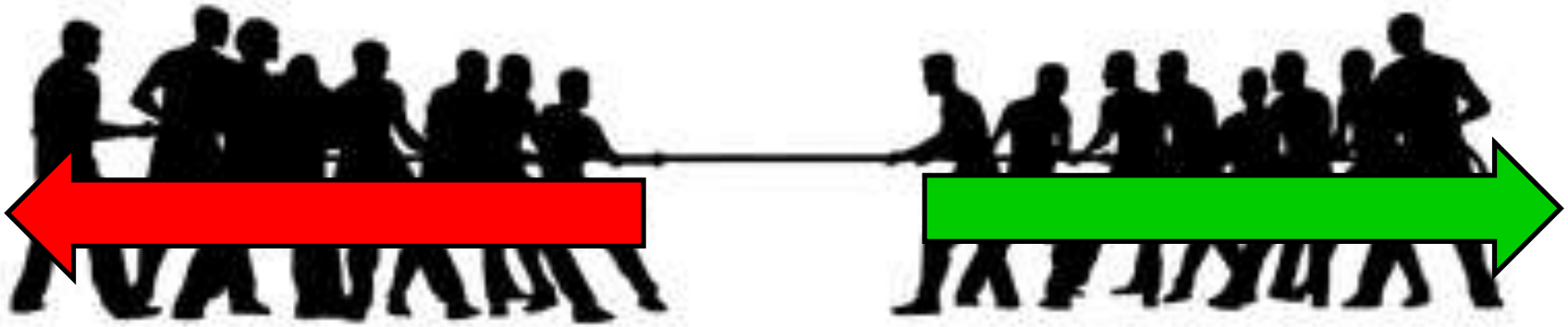
  More soil over tank top = more resisting force ↓

- Expected position of groundwater outside of tank

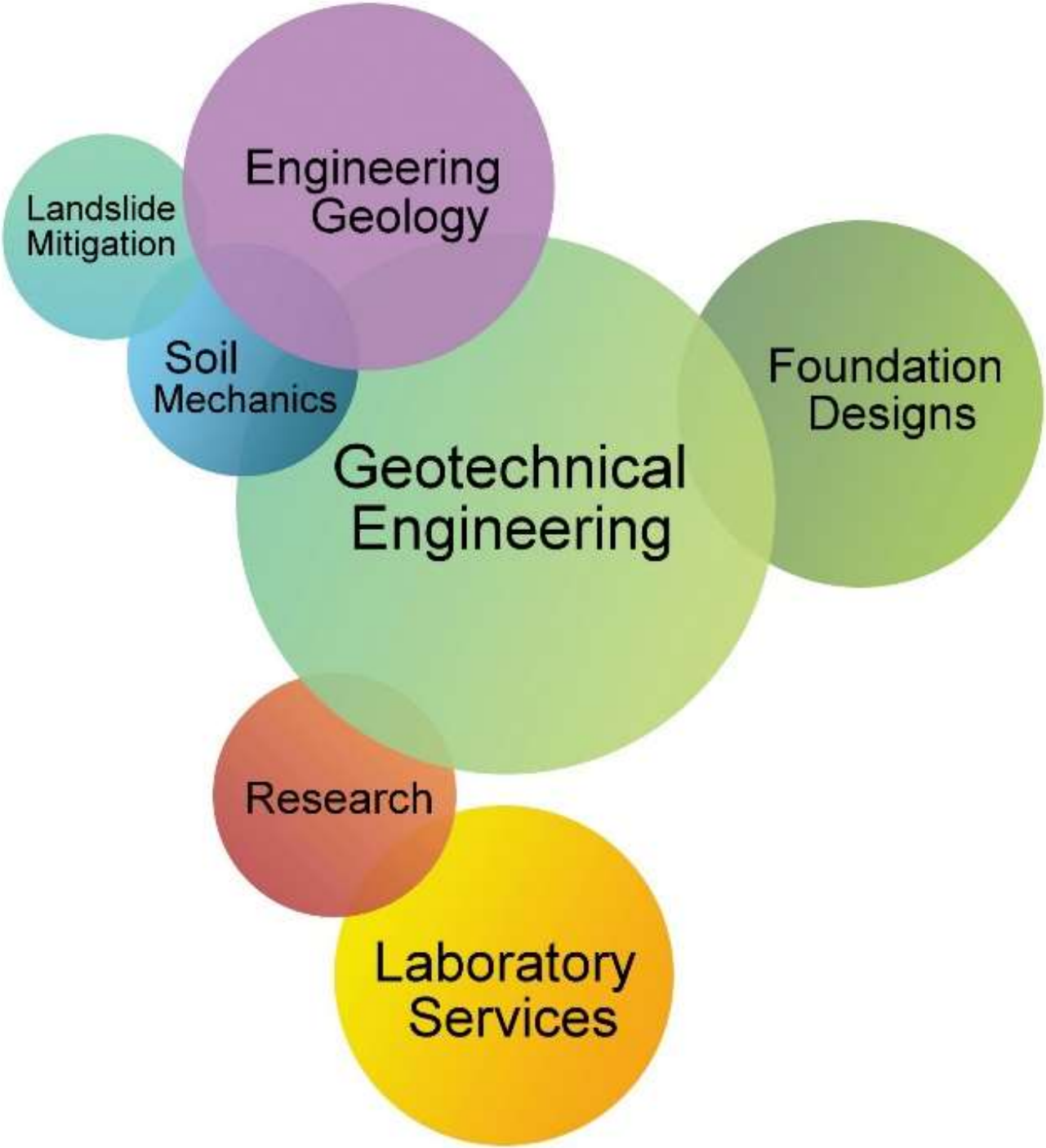
  Shallower groundwater = greater buoyant force ↑

Buried Tank Force Analysis

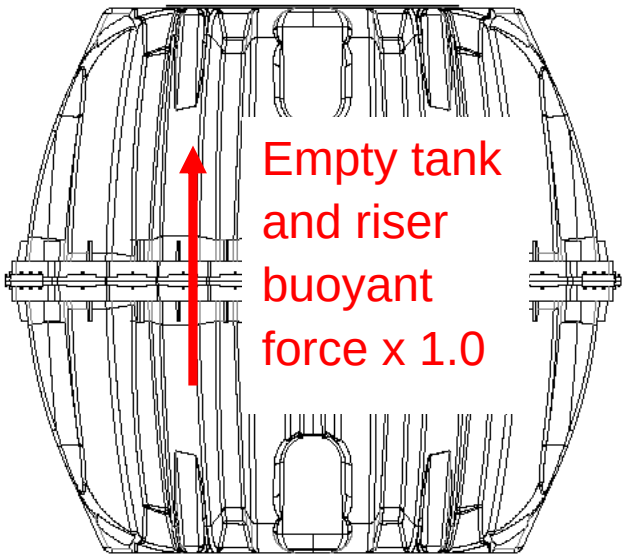
Buoyancy is like a tug of war, except vertical



Upward buoyant force vs. Downward resisting forces

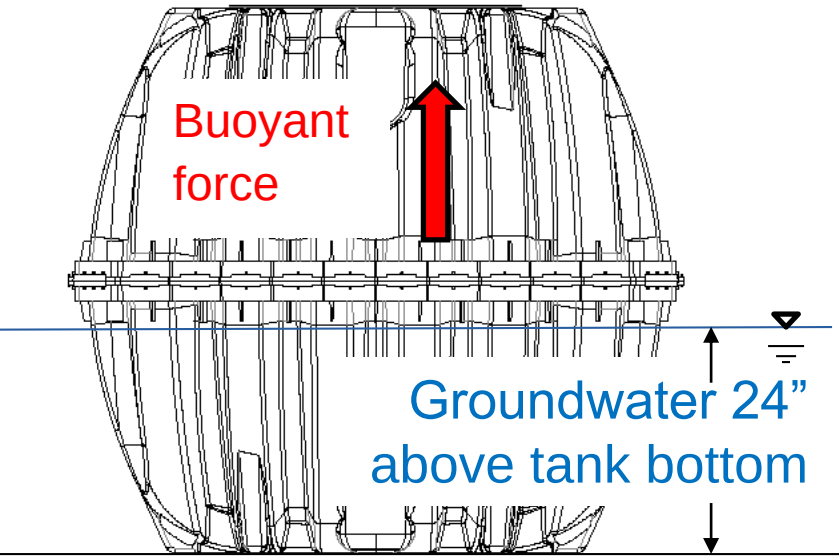

Landslide Mitigation
Engineering Geology
Soil Mechanics
Foundation Designs
Geotechnical Engineering
Research
Laboratory Services

Buried Tank Force Analysis

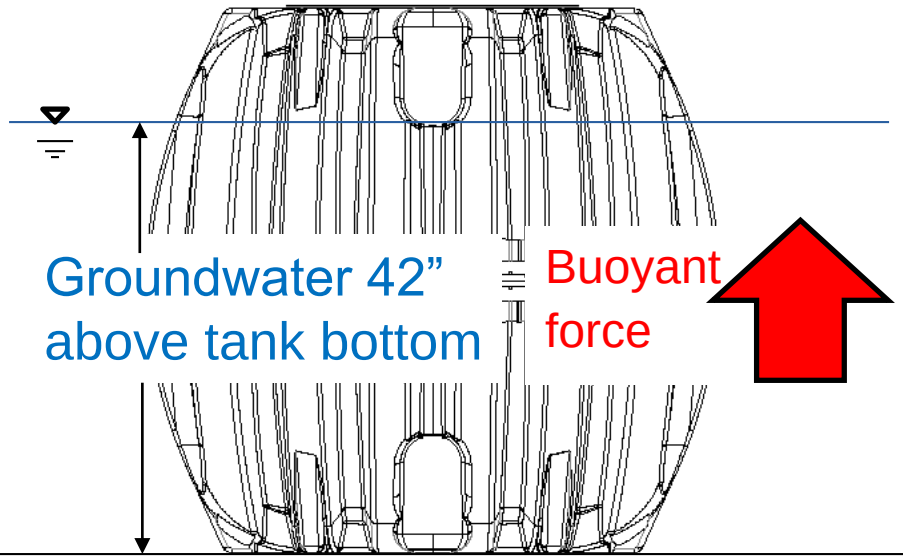


Buried Tank Force Analysis

Installation A



Installation B



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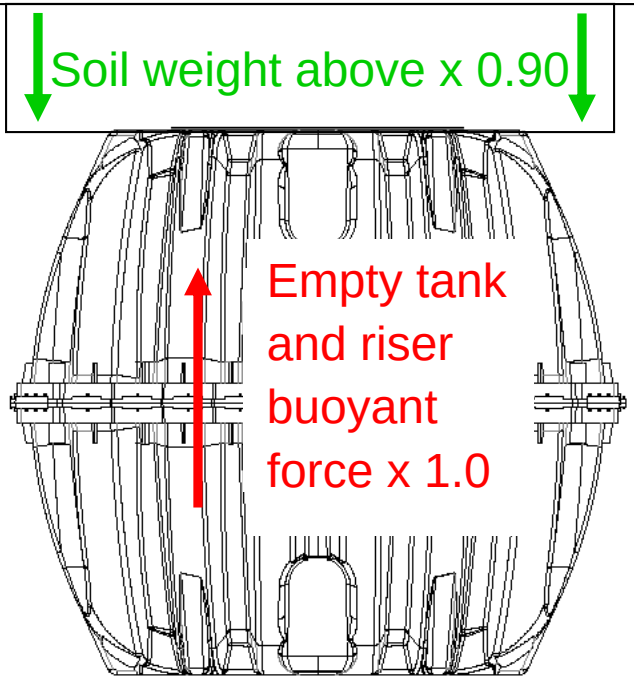

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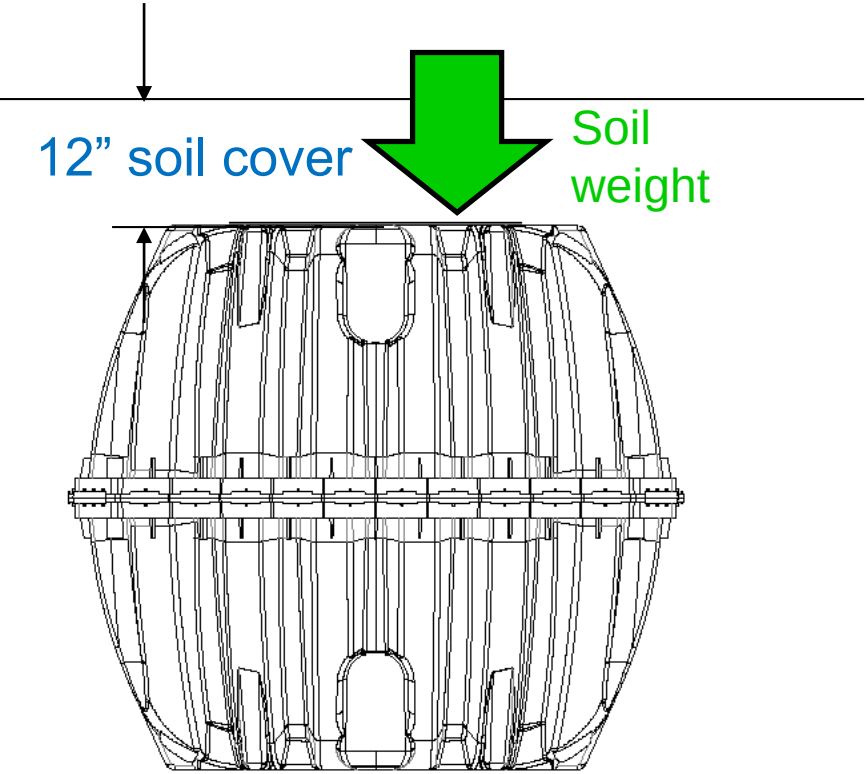
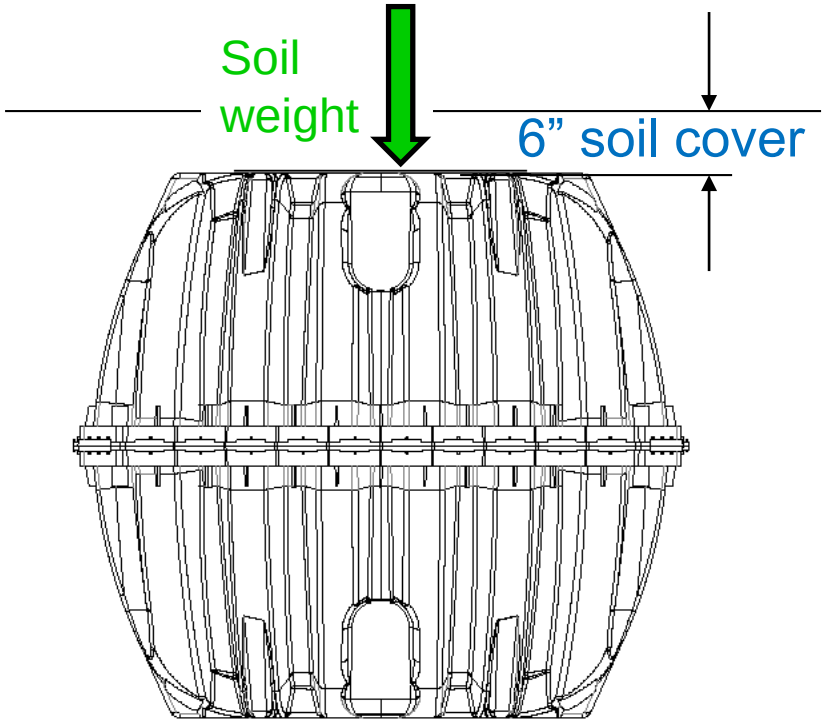


Installation B



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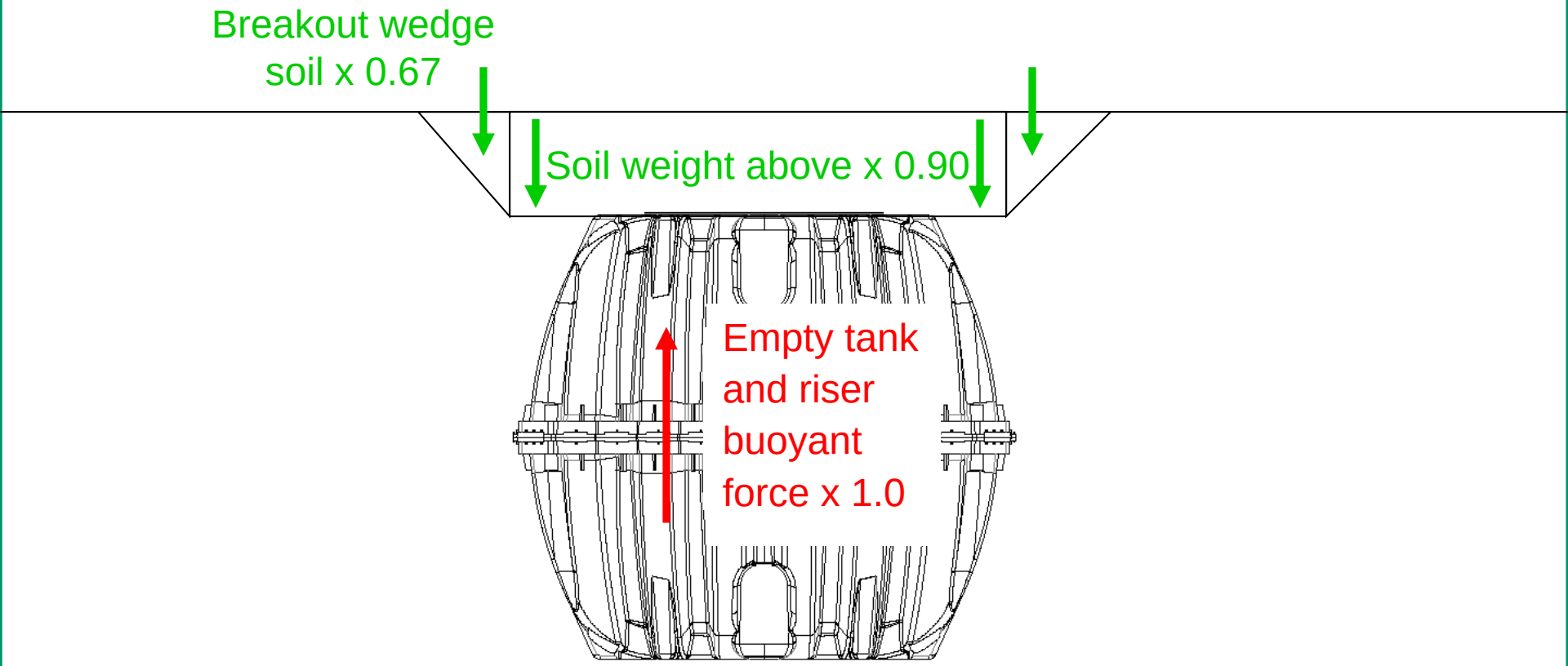

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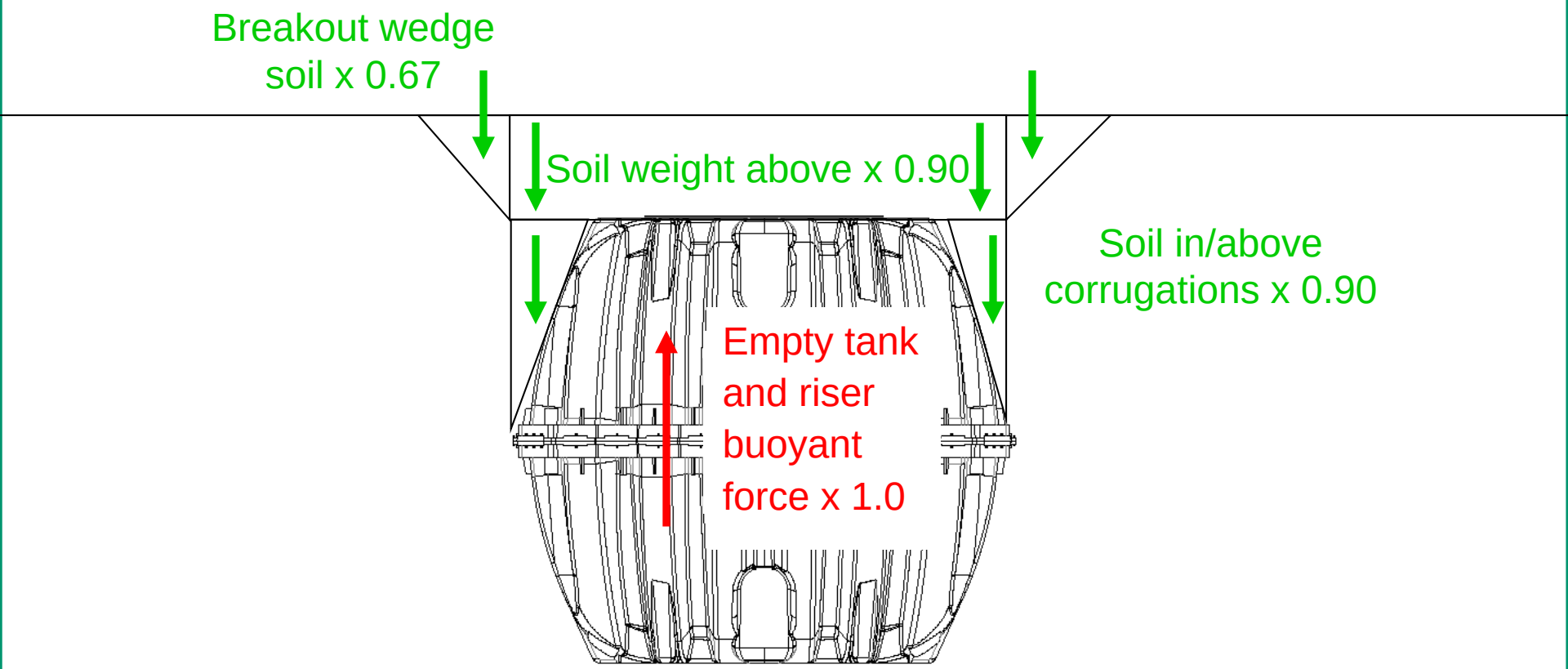

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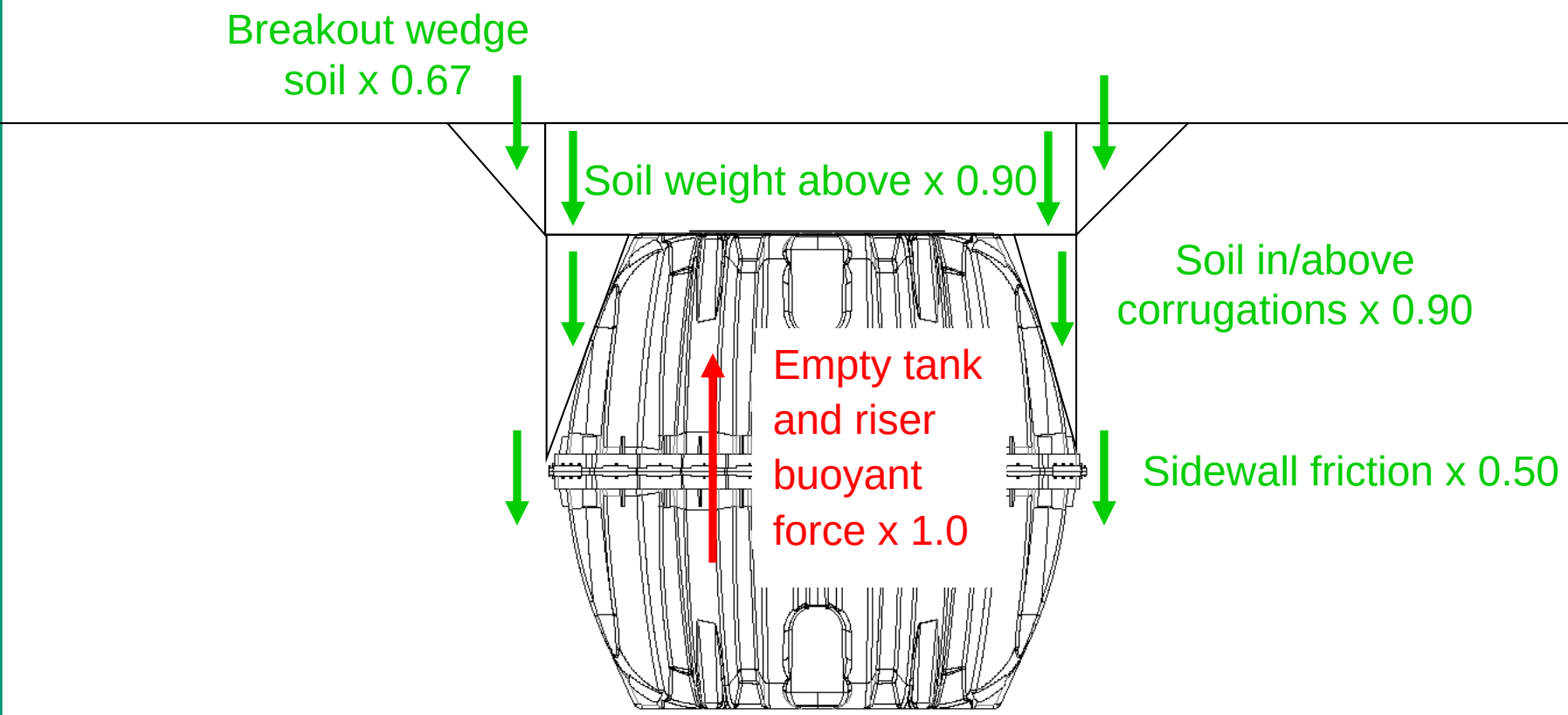

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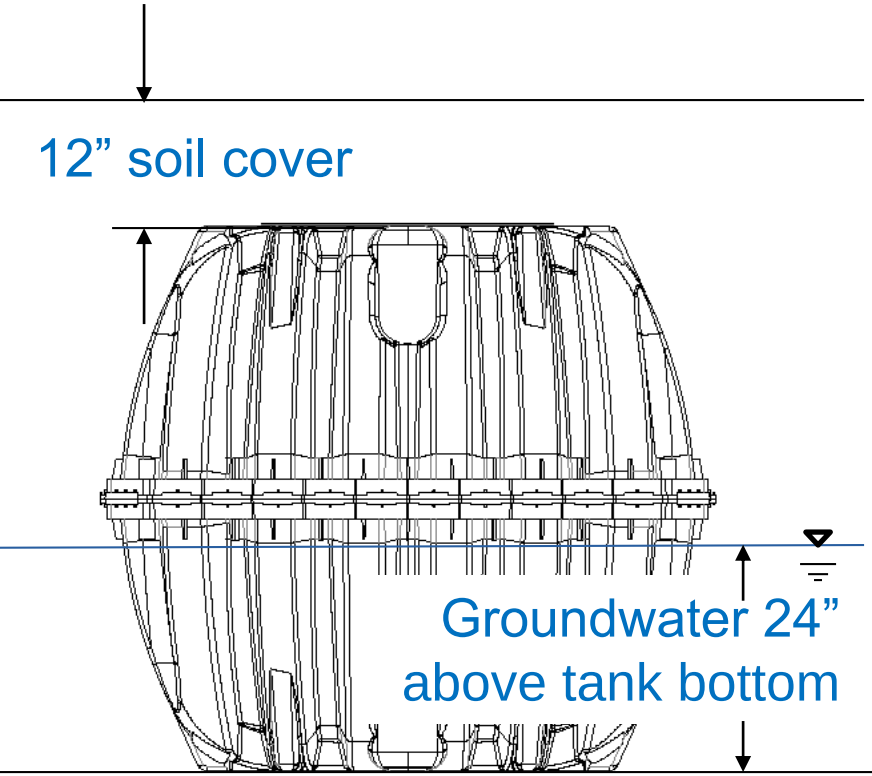
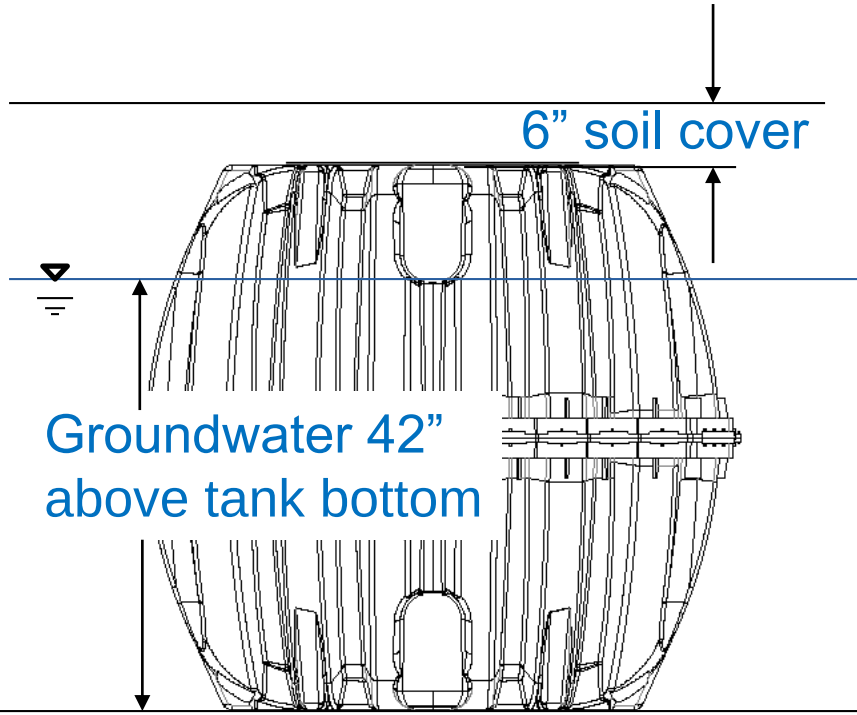
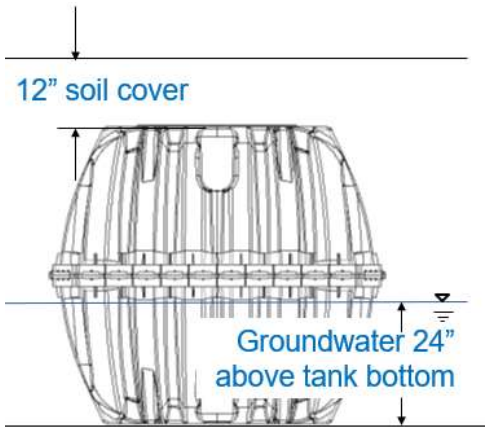
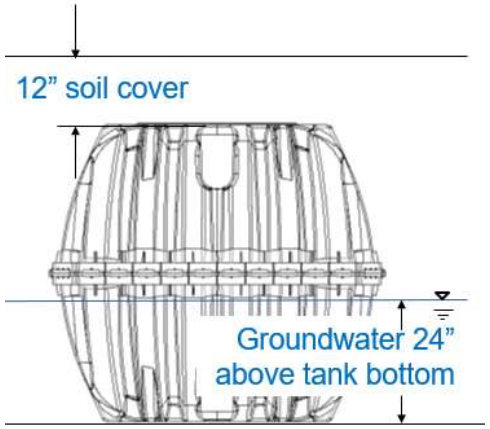


Installation B





Force	Installation A	
	Down (lbs)	Up (lbs)
Soil cover	5,130	0
Corrugation soil	3,126	0
Failure wedge	664	0
Friction	2,960	0
Corrugation water	371	0
Riser voids	0	659
Tank uplift	0	4,489
Total	12,251	5,148
Net force	**Net 7,103 lbs down** **NO CONTROLS NEEDED**	

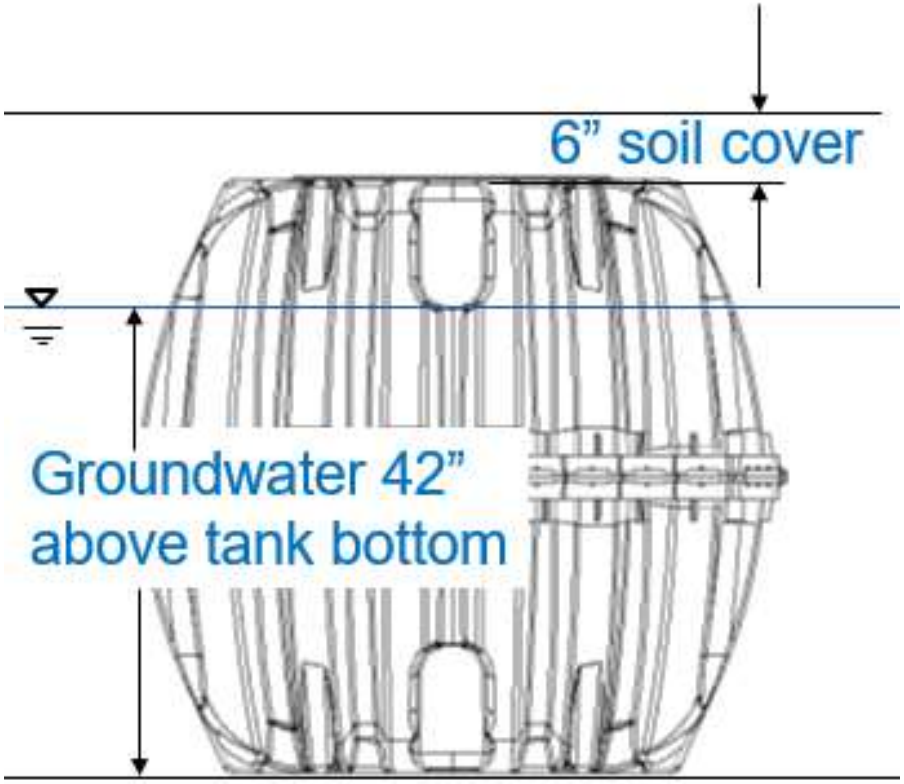


Force	Installation A		Installation B	
	Down (lbs)	Up (lbs)	Down (lbs)	Up (lbs)
Soil cover	5,130	0	2,565	0
Corrugation soil	3,126	0	2,018	0
Failure wedge	664	0	162	0
Friction	2,960	0	1,925	0
Corrugation water	371	0	371	0
Riser voids	0	659	0	330
Tank uplift	0	4,489	0	8,516
Total	12,251	5,148	7,041	8,846
Net force	**Net 7,103 lbs down** ↓ **NO CONTROLS NEEDED**		**Net 1,805 lbs up** ↑ **CONTROLS REQUIRED**	

Buried Tank Force Analysis

SOLUTION:

- Provide minimum 1.5 factor of safety for design
- Minimum buoyancy control force = 1,805 lbs x 1.5 = 2,707 lbs

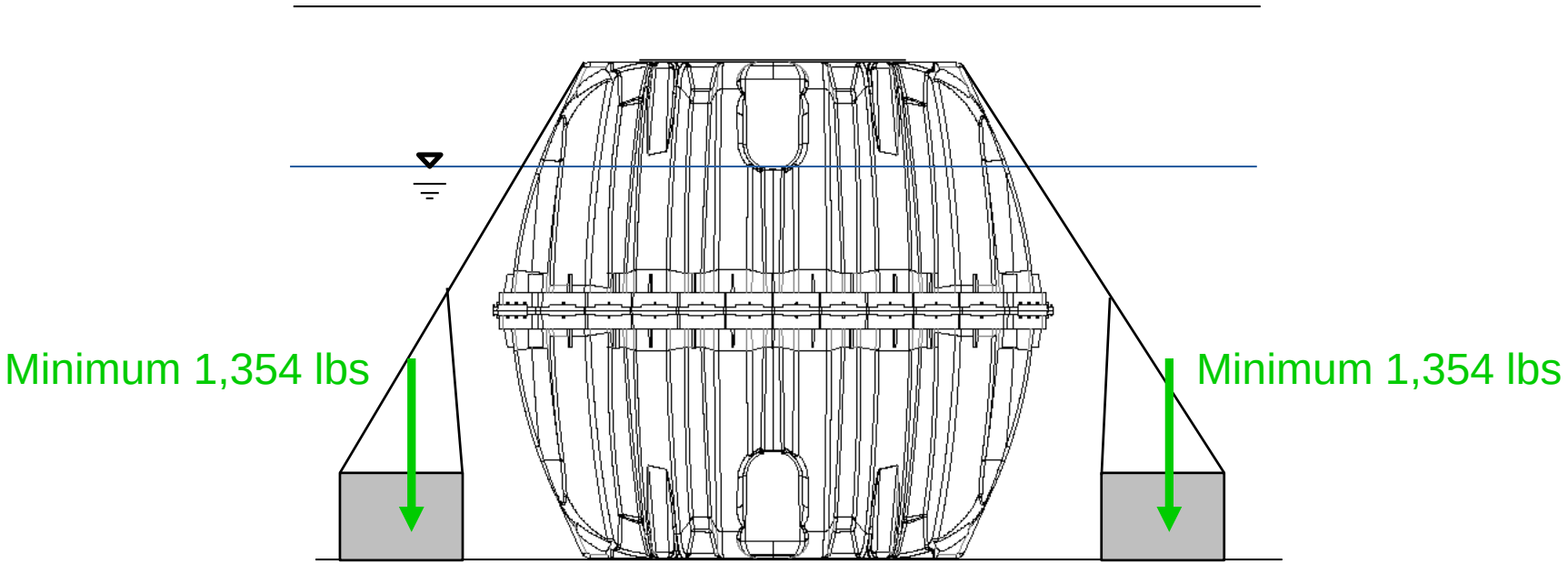


Buried Tank Force Analysis

SOLUTION:

- Minimum buoyancy control force = 2,707 lbs
- Minimum force per tank side = 2,707 lbs / 2 sides = 1,354 lbs

Installation B



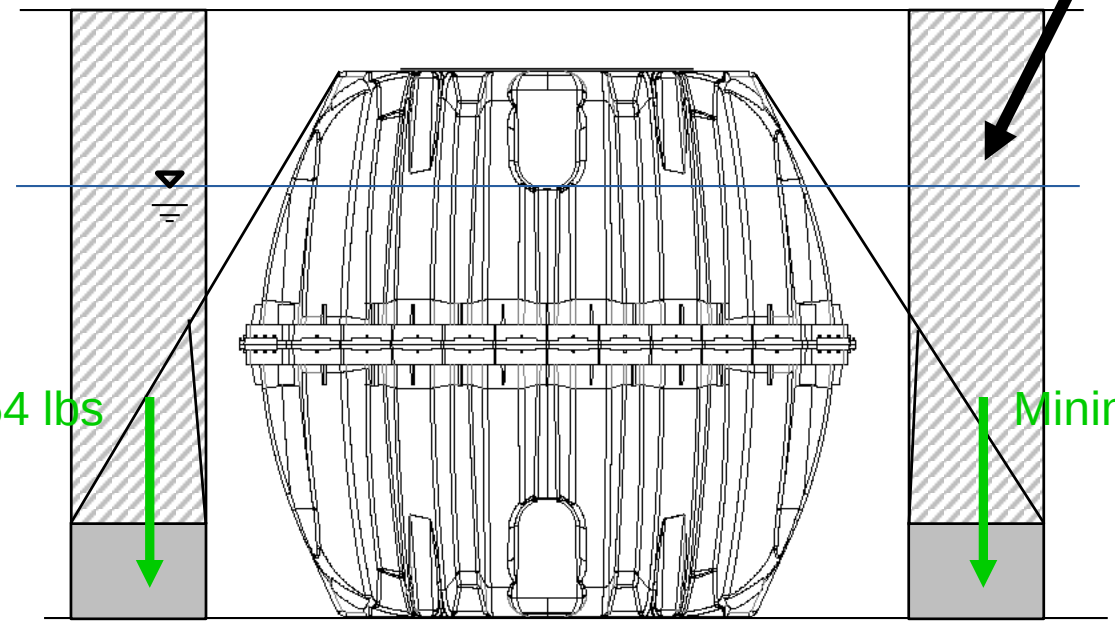
Buried Tank Force Analysis

SOLUTION:

- Minimum buoyancy control force = 2,707 lbs
- Minimum force per tank side = 2,707 lbs / 2 sides = 1,354 lbs

Installation B

Soil columns above control provide downward force



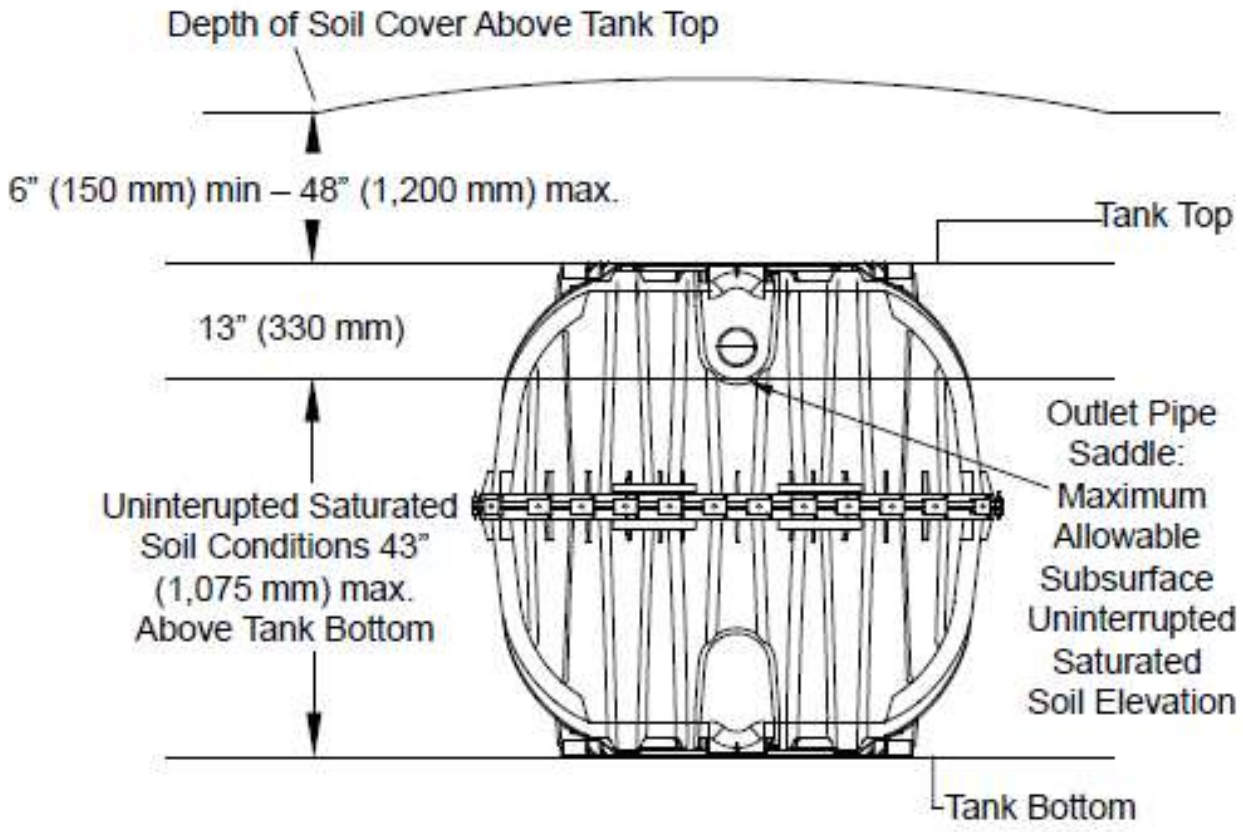
Minimum 1,354 lbs

Minimum 1,354 lbs

Infiltrator IM-Series Tank Design Method

1. Final amount of soil cover over tank?

2. Groundwater position above tank bottom?
   - If the uninterrupted saturated soil outside the tank exceeds the height of the outlet pipe saddle, then do not install



Infiltrator IM-Series Tank Design Method

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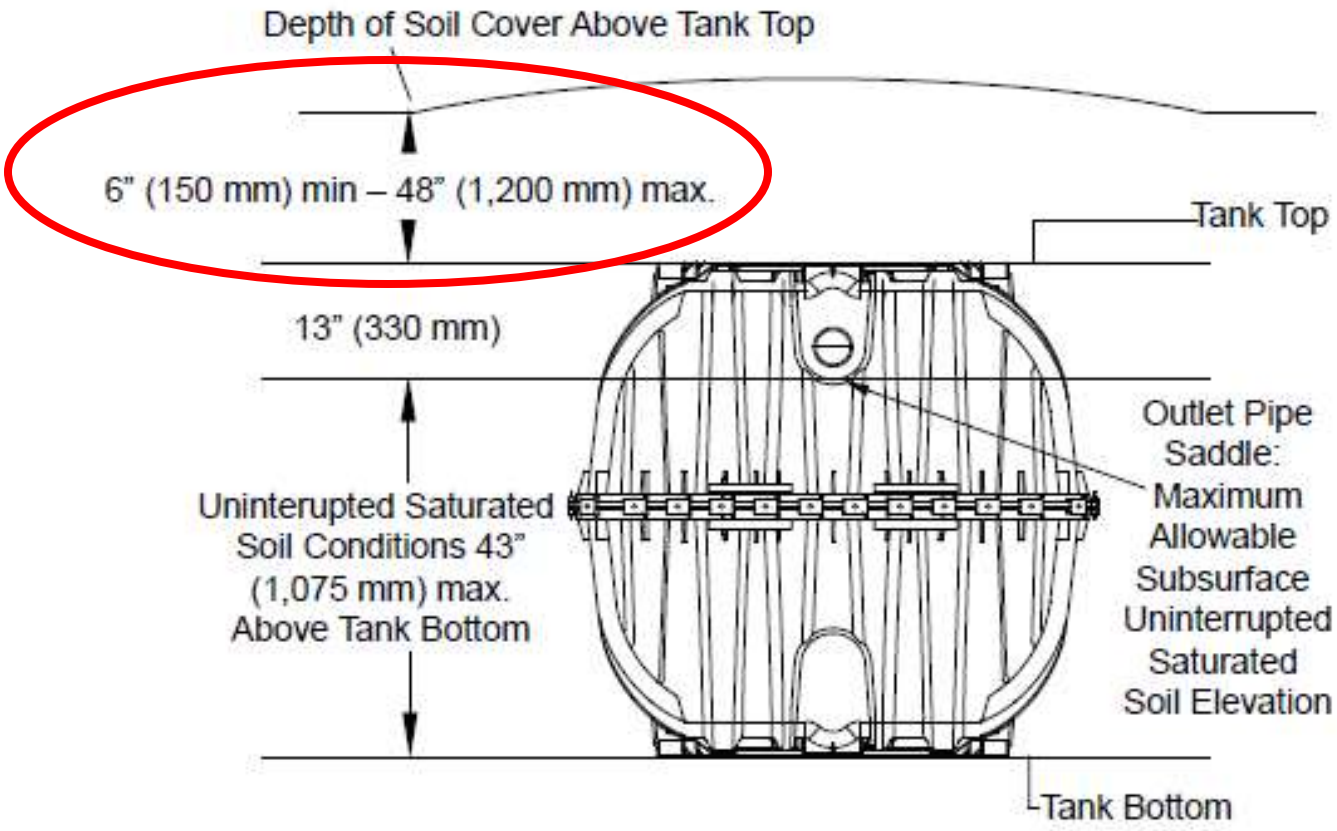

Infiltrator IM-Series Tank Design Method

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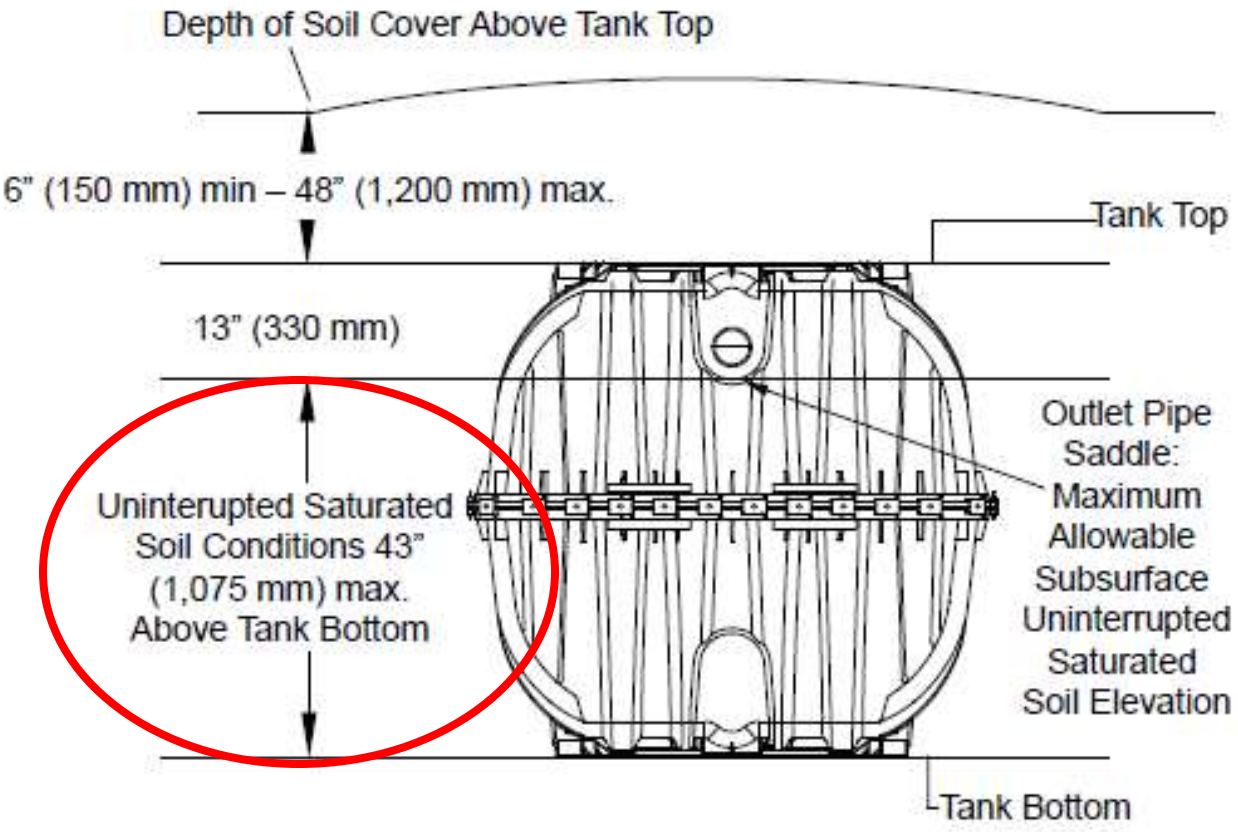


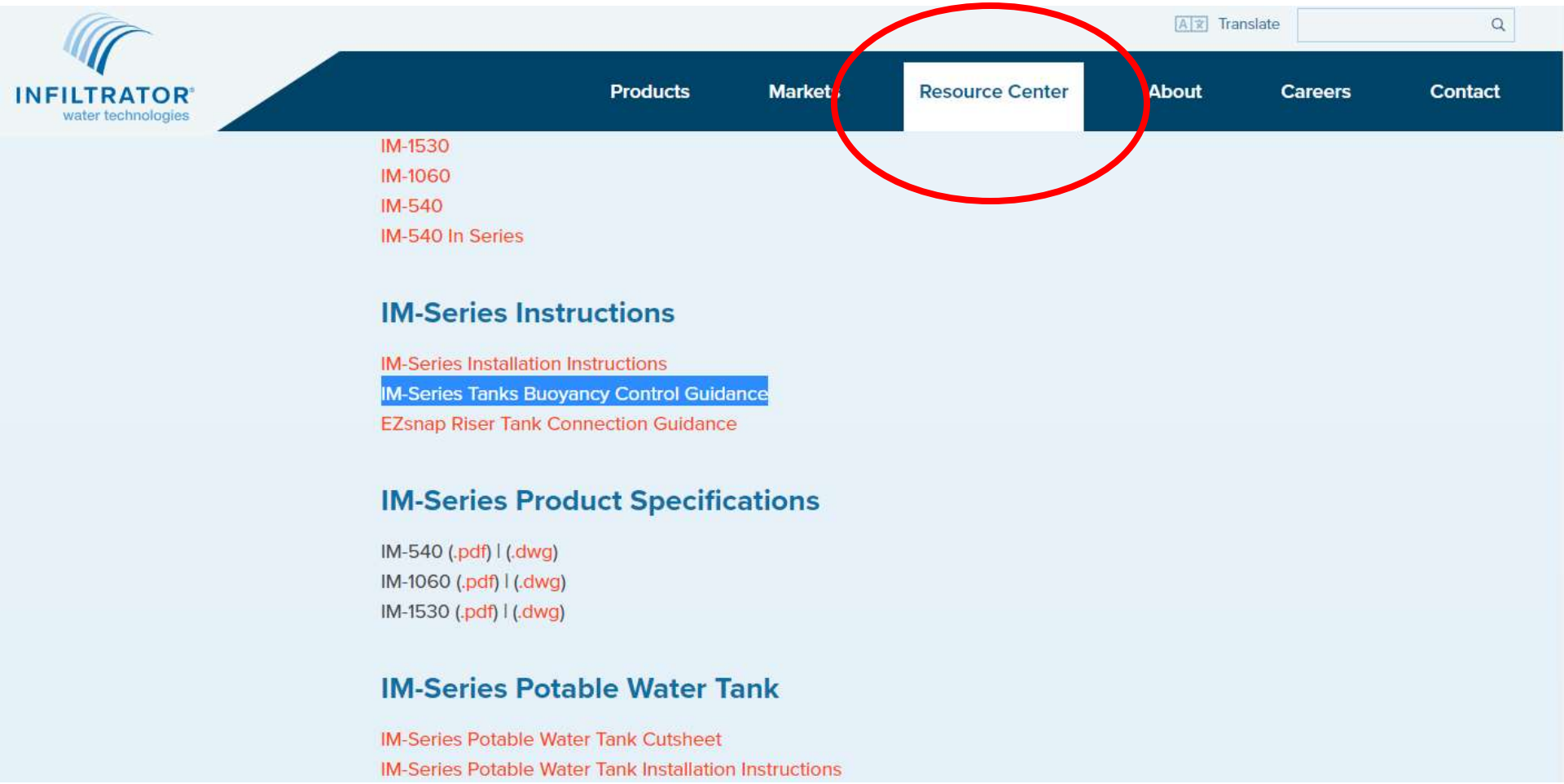
NO Buoyancy Control is Required if…

- *Soil cover is greater than 12 inches over the top of tank*

Table 1:
Infiltrator Tank Models* and Conditions Requiring Buoyancy Control

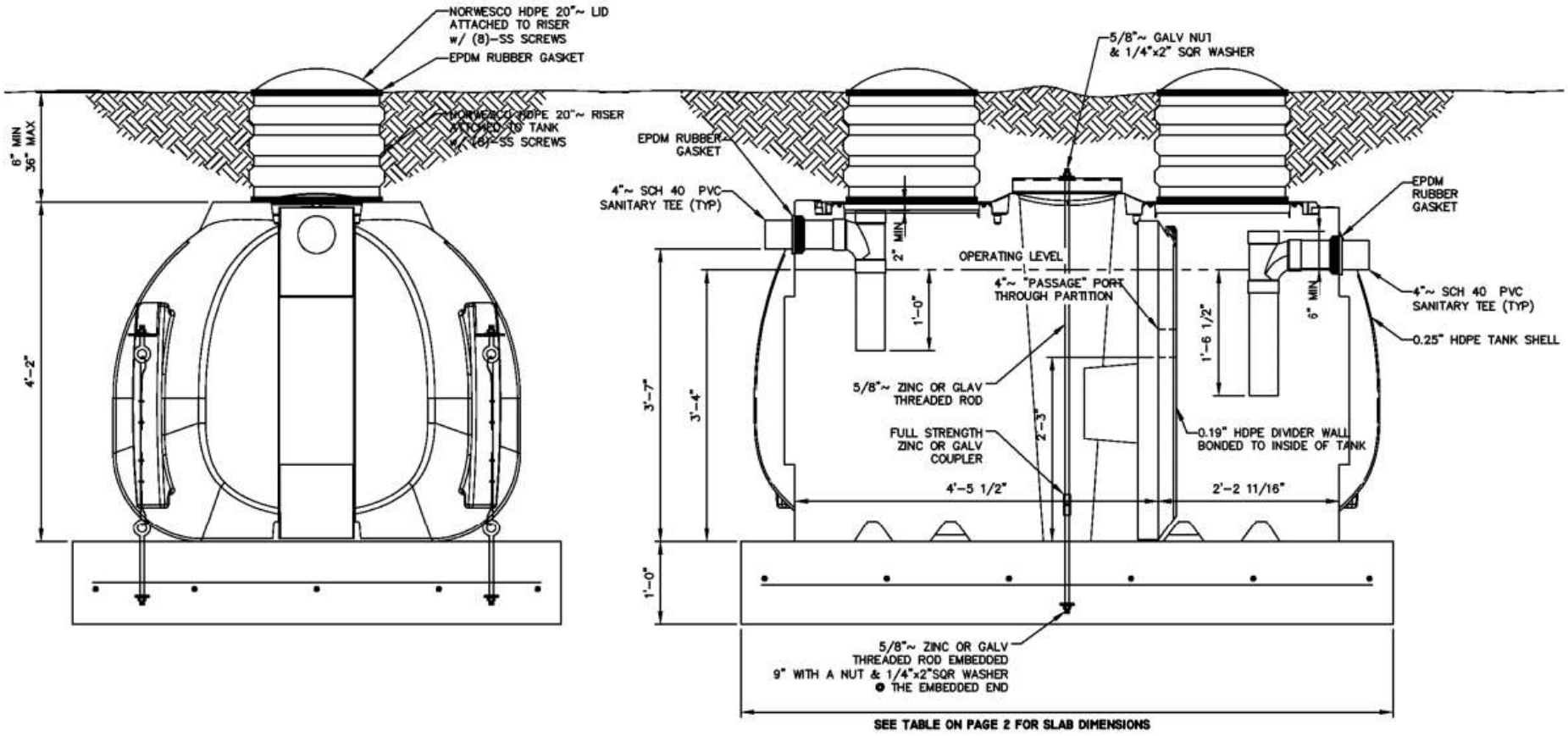
Parameter I: Position of uninterrupted saturated soil conditions above tank bottom		Parameter II: Soil cover depth above tank top*	
		A	B
		6 in (150 mm) to 12 in (300 mm)	Above 12 in (300 mm)
1	Above outlet pipe saddle* (greater than 43" [1,075 mm])	Do not install	Do not install
2	36" (900 mm) to 43" (1,075 mm) (to outlet pipe saddle)	All models	Not Required
3	30" (750 mm) to 36" (900 mm)	IM-1530	Not Required
4	Less than 30" (750 mm)	Not Required	Not Required

www.infiltratorwater.com



Buoyancy Control Methods

Snyder/Norwesco Concrete Slab System



https://www.norwesco.com/_site_components/uploads/pdfs/WWM%20Below%20Ground/Installation%20Instructions/CounterBuoyancy.pdf

Roth Multi-Tank Buoyancy Calculations

BUOYANCY CALCULATIONS

YOUR ENVIRONMENT IS OUR BUSINESS.

MATERIAL	#/CF	#/GAL
SOIL (dry)	100	
SOIL (saturated)	117	
SOIL (net)	83	
WATER	62.4	8.34
CONCRETE	150	

VESSEL	WEIGHT (POUNDS) W	VOLUME (GALLONS) V	AREA (SQ FT) A	COVER (#/INCH) CW	WEIGHT DISPLACED WD=V*8.34	BUOYANT FORCE (POUNDS) BF=WD-W	COVER REQUIRED (INCHES) BF/CW
ST-500	225	537	21.8	150.8	4478.58	4253.58	28.2
ST-750	360	1007	36.8	254.5	8398.38	8038.38	31.6
ST-900	450	1147	43.3	299.5	9565.98	9115.98	30.4
ST-1060	520	1337	50	345.8	11150.58	10630.58	30.7
ST-1250	560	1464	56.3	389.4	12209.76	11649.76	29.9
ST-1500	640	1771	68.9	476.6	14770.14	14130.14	29.7

NOTES:

1. AREA OF TANKS IS CALCULATED WITHOUT MANHOLES.
2. BUOYANCY FORCE IS ASSUMING SATURATED SOIL (WORST CASE SCENARIO).
3. THE NUMBERS CAN BE CHANGED BY CHANGING THE DRY SOIL WEIGHT FOR SITE CONDITIONS..
4. WET SOIL WEIGHT IS INDEXED TO DRY SOIL.
5. TANK IS ASSUMED TO BE FULLY SUBMERGED, IF ONLY 50% SUBMERGED, FORCES ARE HALVED.
6. ALL CALCULATIONS ARE BASED ON AN EMPTY TANK.
7. PLEASE SEE THE ROTH RESTRAINING COLLAR DRAWING FOR HIGH GROUNDWATER . THE SAFETY FACTOR NOTED ON THE DRAWING DOES NOT CONSIDER THE LOADING OF THE EARTH ON TOP OF THE TANK.

http://www.roth-usa.com/PDF_Download_Files/RMT_buoyancy_calc.pdf

Roth Multi-Tank Restraining Collar Design

Details Provided by APPIAN Consulting Engineers – www.appianengineers.com 12/06/2005 – 10:07:05 AM

RESTRAINING COLLAR FOR HIGH GROUNDWATER

TOP

GENERAL NOTE:

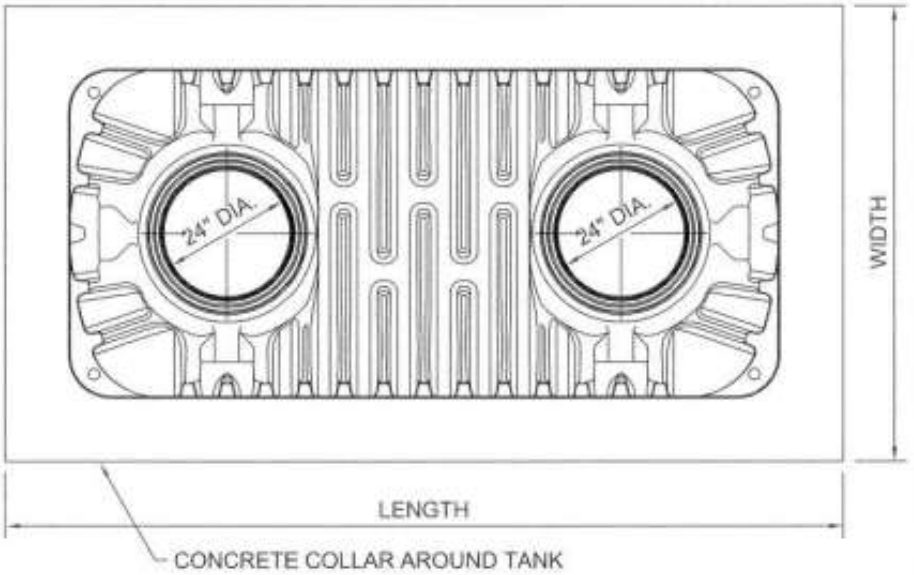
1. THE BUOYANCY RESTRAINING COLLAR DESIGN IS BASED ON BUOYANCE CALCULATIONS AVAILABLE ON REQUEST FROM FRALO PLASTECH, LLC.

CONCRETE NOTES:

1. PROVIDE CONCRETE TO OBTAIN THE MINIMUM COMPRESSIVE STRENGTH OF 3000 PSI AT 28 DAYS.
2. CONCRETE MATERIALS AND WORKMANSHIP SHALL BE IN ACCORDANCE WITH ACI-318-99 (BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE) AND ACI-301-LATEST EDITION (SPECIFICATIONS FOR STRUCTURAL CONCRETE FOR BUILDINGS).

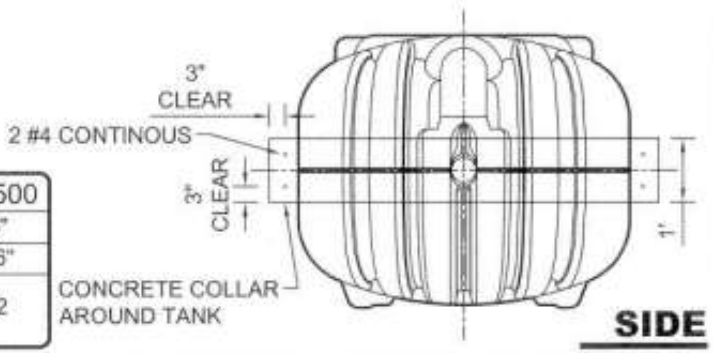
REINFORCING STEEL:

1. ALL REINFORCING STEEL SHALL BE BILLET STEEL CONFORMING TO STANDARDS OF ASTM A615, GRADE 60.



CONCRETE COLLAR SPECS

TANK MODEL	ST-500	ST-750	ST-1060	ST-1250	ST-1500
WIDTH (FEET)	7'-0"	7'-0"	7'-6"	7'-6"	7'-6"
LENGTH (FEET)	7'-0"	10'-6"	12'-0"	14'-0"	16'-6"
FACTOR-OF-SAFETY AGAINST FLOATING	2.96	2.15	2.09	2.10	2.02



SIDE

DWG SCALE: 1:1
PLOT SCALE: 1:2
SHEET # 1 OF 1

SEPTECH™ TANK BUOYANCY RESTRAINING SYSTEM
THE NEXT GENERATION OF ONSITE WASTEWATER PRODUCTS

FRALO Plastech

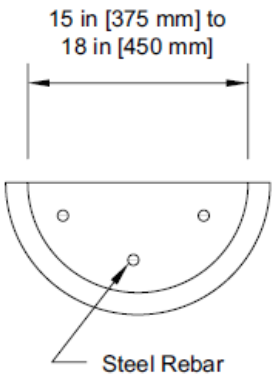
FRALO PLASTECH
One General Motors Drive
Syracuse N.Y. 13209
Call Toll Free 866.943.7256
www.fralo.net

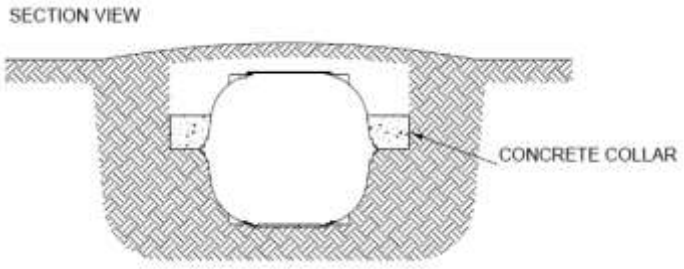
http://www.roth-usa.com/PDF_Download_Files/RMT_buoyancy_calc.pdf

Infiltrator IM-Series Tank Design Method

Table 2: Buoyancy Control Method Selection

Tank Model	Parameter I: Position of uninterrupted saturated soil conditions above tank bottom	Parameter II: Soil cover depth above tank top	Minimum supplemental downward force required[1] (total, both tank sides)	Buoyancy Control Methods				
				Concrete-filled half pipe (min. length/ side)	Concrete parking bumpers (min. length/ side)	Concrete traffic barriers (min. length/ side)	Helical anchors (min. no./side)	Concrete collar (min. width x min. height)
IM-540	36 in (900 mm) to outlet pipe saddle[2]	6 in (150 mm) to 12 in (300 mm)	2,200 lbs (1,000 kg)	3.8 ft (1.2 m)	3.8 ft (1.2 m)	3.8 ft (1.2 m)	2	6 in (150 mm) x 9 in (225 mm)
IM-1060	36 in (900 mm) to outlet pipe saddle[2]	6 in (150 mm) to 12 in (300 mm)	2,700 lbs (1,225 kg)	4.2 ft (1.3 m)	4.5 ft (1.4 m)	4.2 ft (1.3 m)	2	12 in (300 mm) x 9 in (225 mm)
IM-1530	30 in (750 mm) to outlet pipe saddle[2]	6 in (150 mm) to 12 in (300 mm)	4,300 lbs (1,955 kg)	6.3 ft (2.0 m)	6.5 ft (2.0 m)	6.3 ft (2.0 m)	2	12 in (300 mm) x 9 in (225 mm)





Parking Bumpers

Spare 24-inch Concrete Tank Lid

6” x 6” Pressure-Treated Wood

Installation Best Practices

Installation Best Practices – Excavation Size

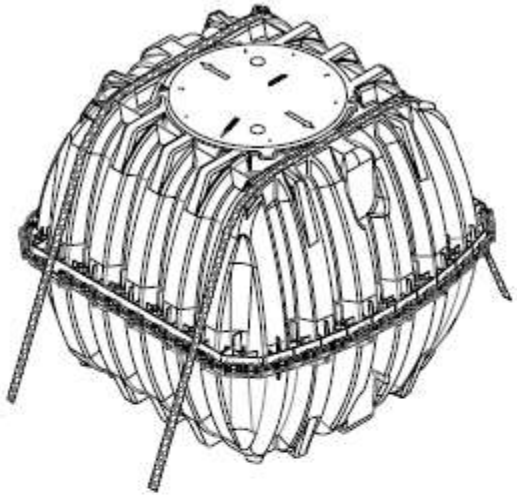
Adjust excavation width to accommodate anchors

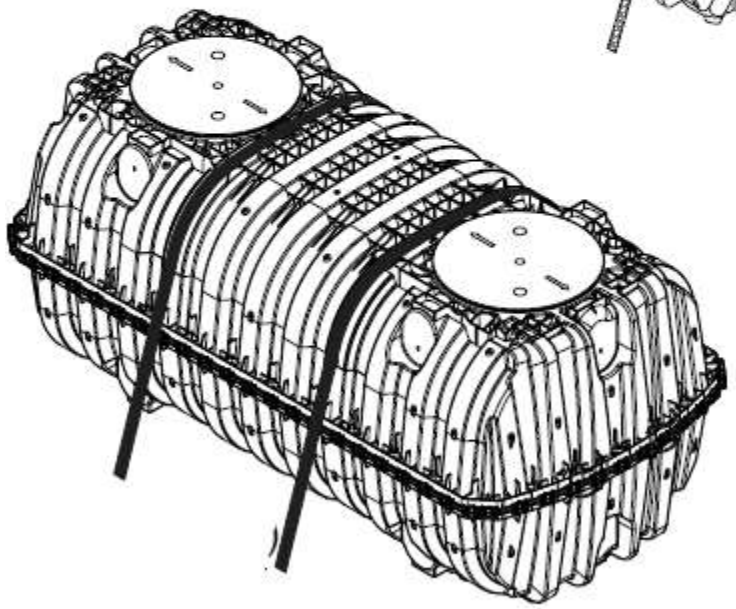
- Anchors must be offset from side of tank
- Additional excavation width required
- Adjust to allow workers to operate
- Adhere to OSHA excavation safety requirements

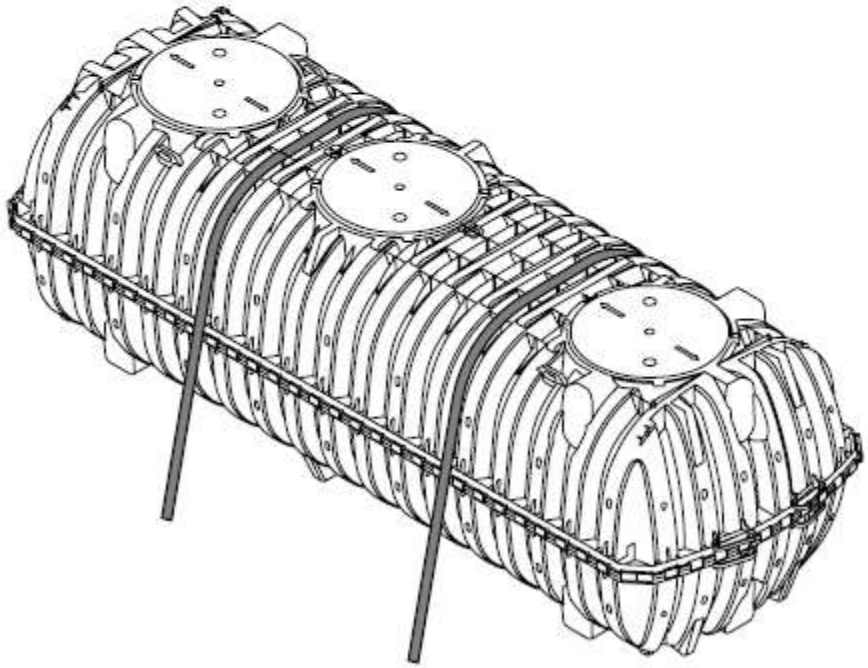
Installation Best Practices – Strap Placement

Balance straps along tank axis

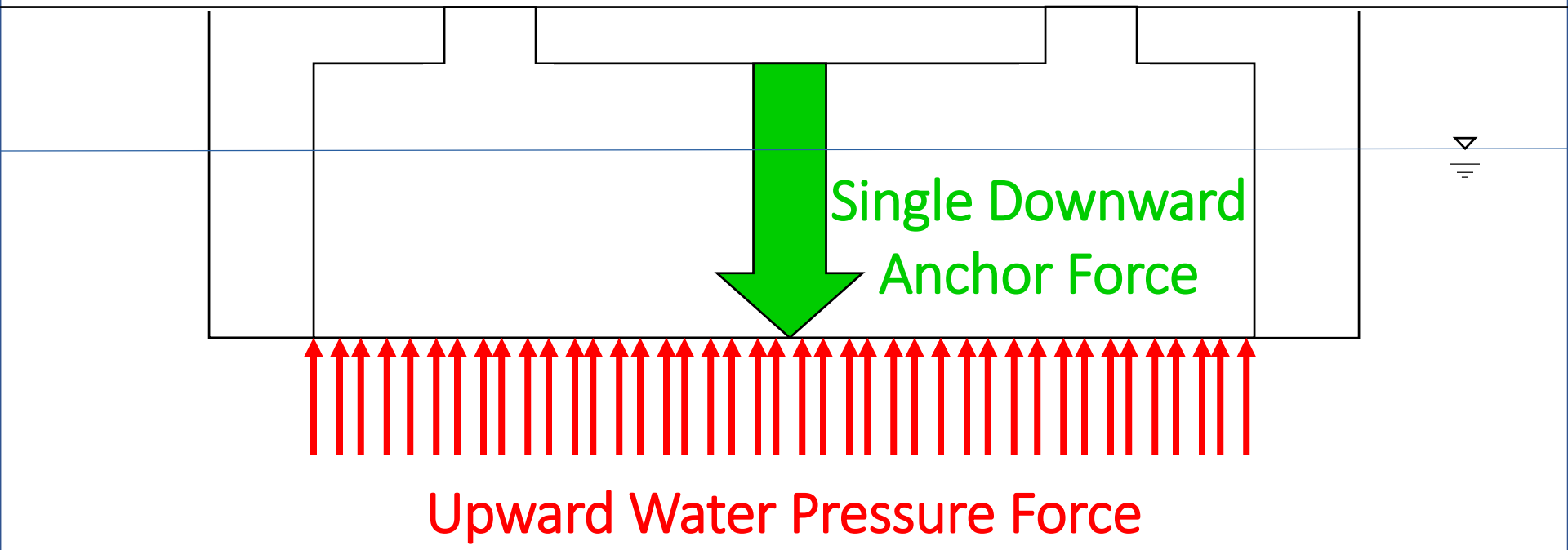
- Balanced loading to tank
- Balance resisting force
- Uniform connection to buoyancy controls



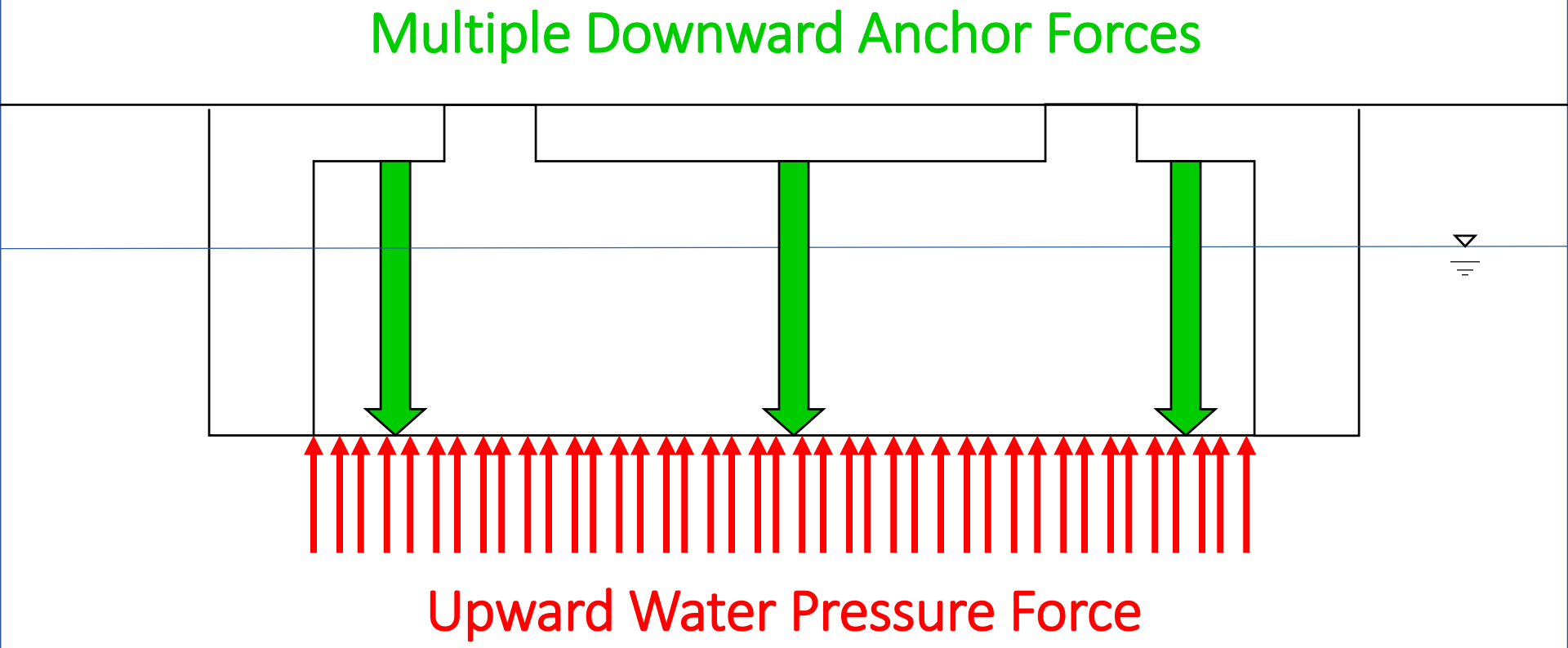




Installation Best Practices – Strap Placement



Installation Best Practices – Strap Placement



Balanced anchor placement

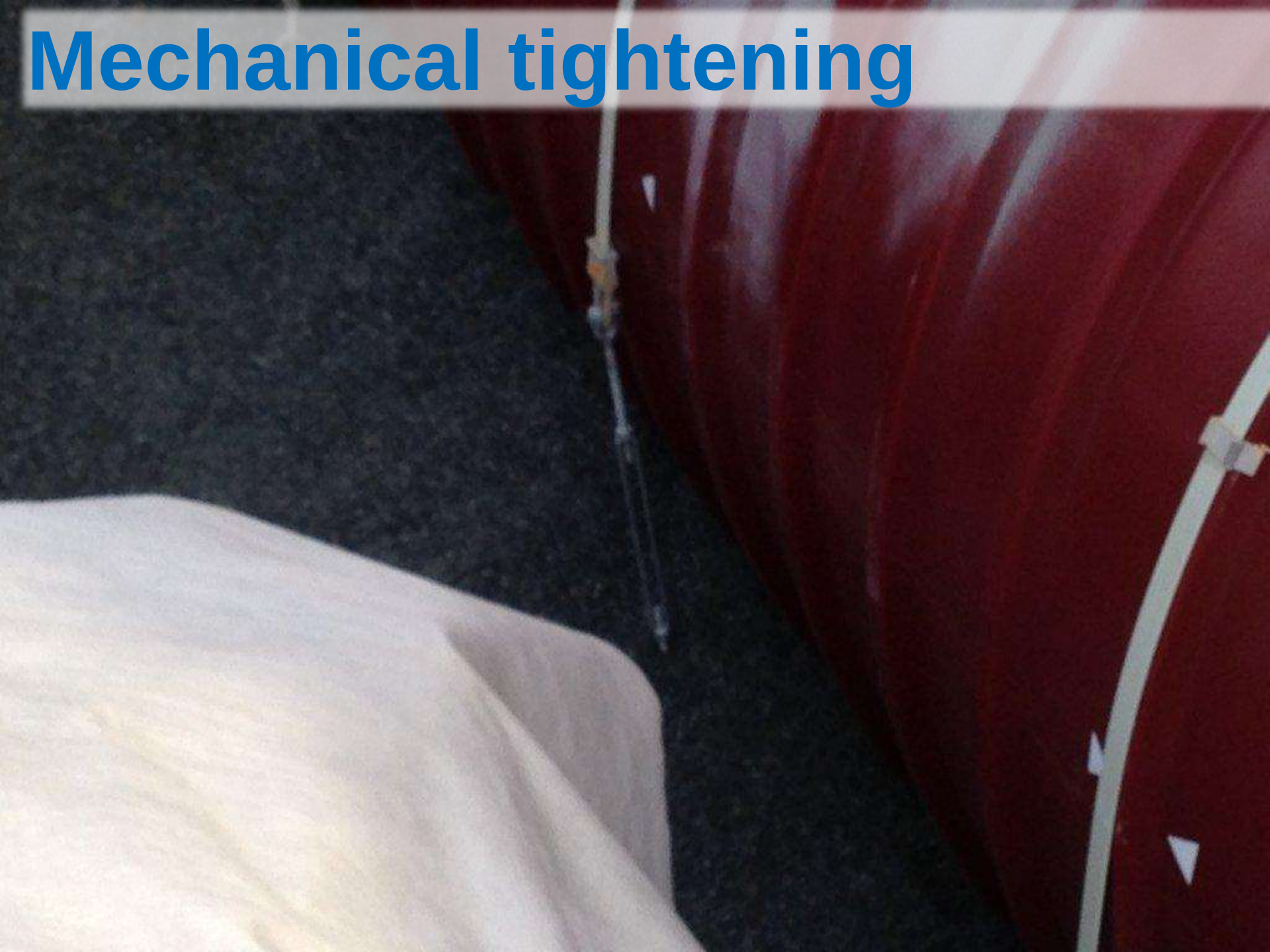
Installation Best Practices – Strap Tightening

Establish tight strapping

- Prevents tank uplift
- Prevents change to inlet-to-outlet invert drop
- Prevents breakage of inlet and outlet piping
- Tighten using ratchet or turnbuckle

Tight straps

Mechanical tightening



Installation Best Practices – Strap Capacity

Verify strap capacity

- Determine tank uplift
- Determine tension in straps
- Verify that adequate strap safety factor exists

$$\text{Safety Factor} = \frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{\text{10,000 lb capacity}}{\text{5,000 lb uplift}} = 2.0$$


KOMATSU

Installation Best Practices – Anchor Placement

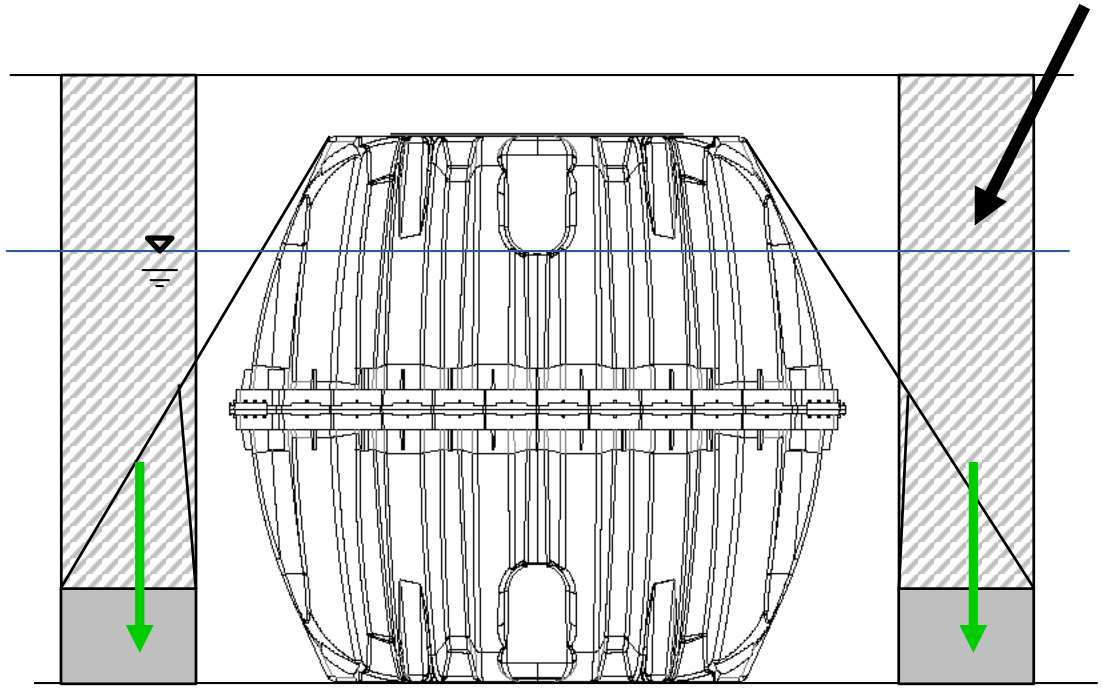
Place anchors per manufacturer's instructions

- Some anchor designs require several feet of soil coverage to function properly
- Weight of soil cover over anchor resists uplift
- Weight of anchor is small compared to soil resistance

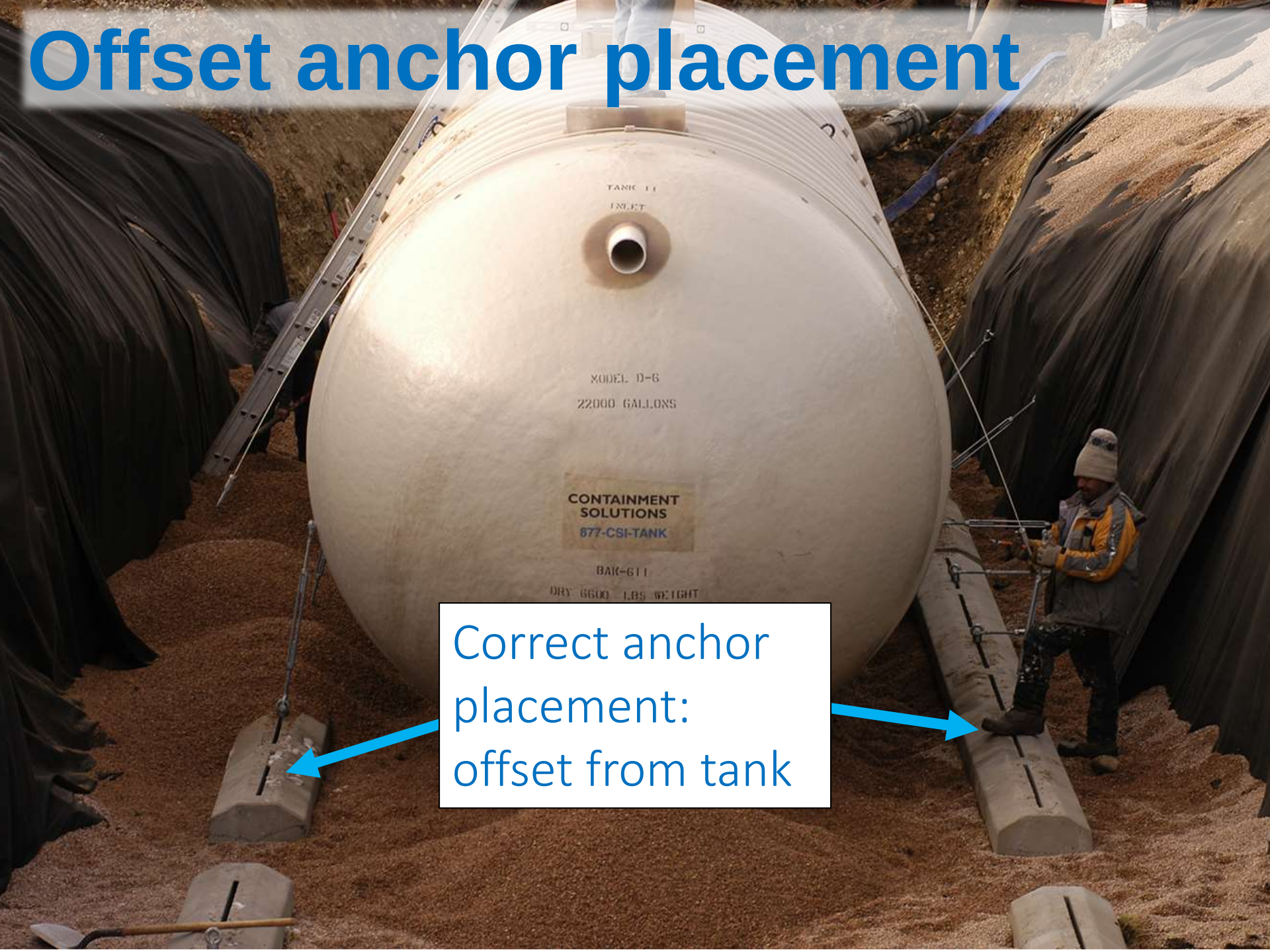
Installation Best Practices – Anchor Placement

Installation B

Soil columns above control provide downward force



Offset anchor placement

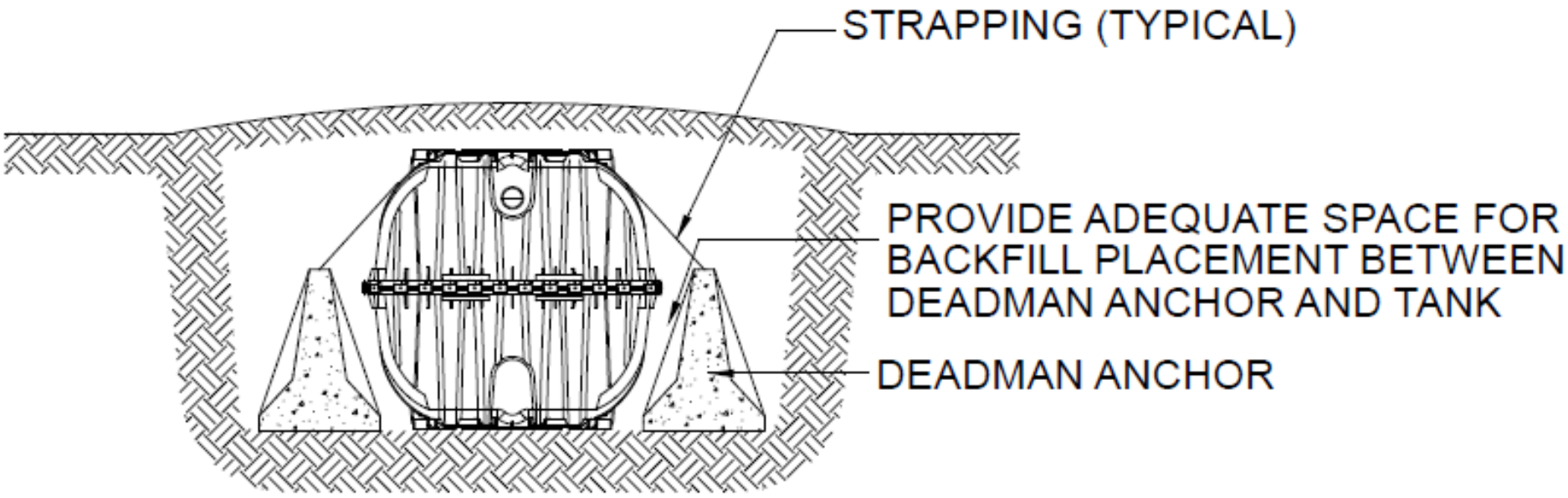



Correct anchor placement: offset from tank
Improper anchor placement: tucked under tank, so no soil column above anchor

Installation Best Practices – Backfilling

Backfill between anchors and tank

- Place backfill around entire tank
- Work soil into space between tank and anchors
- Compact soil per manufacturer's instructions




Correct anchor placement: offset from tank
Improper anchor placement: tucked under tank – no space for backfill placement

How to Use this Information

- Consider buoyancy for any type of tank material
- Check the two biggest factors:
  - Soil cover depth over tank
  - Height of water above tank bottom
- Follow manufacturer installation instructions
- Make sure buoyant force loses the tug-of-war

Final Exam

This buoyancy control design should be effective.

A. True
B. False

INFILTRATOR®
water technologies

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