

(10 Pts) 8) A Cylindrical Water Tank Of Radius 10 Feet And Height 30 Feet Is Half Filled With water. If

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Introduction

A cylindrical water tank with a radius of 10 feet and a height of 30 feet is a common structure used for storing large volumes of water. When such a tank is half filled with water, it presents interesting calculations related to volume, surface area, and other related parameters. Understanding these calculations is important for engineers, architects, and environmental planners to manage water resources efficiently. In this article, we will explore the various aspects of this cylindrical tank, including how to determine the volume of water when half filled, the surface area of the water level, and related practical considerations.

Basic Dimensions and Volume of the Tank

Tank Dimensions

- Radius (r): 10 feet
- Height (h): 30 feet

Total Volume of the Tank

The total volume of a cylinder is given by the formula:

$$V = \pi r^2 h$$

Calculating the total volume:

$$V_{\text{total}} = \pi \times (10)^2 \times 30$$

$$V_{\text{total}} = \pi \times 100 \times 30$$

$$V_{\text{total}} = 3000 \pi \text{ cubic feet}$$

Using the approximation $\pi \approx 3.1416$:

$$V_{\text{total}} \approx 3000 \times 3.1416$$

$$V_{\text{total}} \approx 9424.8 \text{ cubic feet}$$

Water Volume When Half Filled

Since the tank is half filled with water, and the volume of a cylinder is proportional to its height, the volume of water is:

$$V_{\text{water}} = \frac{1}{2} \times V_{\text{total}}$$

$$V_{\text{water}} = \frac{1}{2} \times 3000 \pi$$

$$V_{\text{water}} = 1500 \pi \text{ cubic feet}$$

Calculating:

$$V_{\text{water}} \approx 1500 \times 3.1416$$

$$V_{\text{water}} \approx 4712.4 \text{ cubic feet}$$

Practical implication:

This means that when the tank is half filled, it contains approximately 4712.4 cubic feet of water.

Determining the Water Level Height

In a cylindrical tank, the height of the water when half filled corresponds to half the total volume. Since the volume is proportional to height, the water height (h_{water}) when the tank is half filled is:

$$h_{\text{water}} = \frac{h}{2} = \frac{30}{2} = 15 \text{ feet}$$

Therefore, the water level reaches a height of 15 feet.

Surface Area of Water When Half Filled

Area of the Water Surface

The surface area of the water when half filled is the area of the circular cross-section at the water level:

$$A = \pi r^2$$

$$A = \pi \times (10)^2 = 100 \pi \text{ square feet}$$

Numerical approximation:

$$\left[A \approx 100 \times 3.1416 = 314.16 \text{ sq ft} \right]$$

This is the area of the water surface at the half-filled level.

Surface Area of the Water Surface

The surface area is significant for various reasons, such as calculating evaporation, surface water exposure, or designing access points.

Surface Area of the Water's Curved Surface (Lateral Surface Area)

When the tank is half filled, it has a curved surface of water, which is the lateral surface area of the submerged part of the cylinder:

$$\left[\text{Lateral Surface Area} = 2 \pi r h_{\text{water}} \right]$$

Where:

- $(r = 10 \text{ feet})$
- $(h_{\text{water}} = 15 \text{ feet})$

Calculating:

$$\left[\text{Lateral Surface Area} = 2 \pi \times 10 \times 15 = 300 \pi \right]$$

Approximate value:

$$\left[300 \times 3.1416 \approx 942.48 \text{ sq ft} \right]$$

This is the surface area of the water's curved side when the tank is half filled.

Practical Applications and Considerations

1. Water Storage Management

Understanding the volume when the tank is half filled helps in:

- Estimating the remaining capacity
- Planning refilling schedules

- Managing water supply during droughts or high demand

2. Structural Design and Safety

Knowing the height of water at half capacity (15 feet) is crucial for:

- Ensuring the tank's structural integrity under varying loads
- Designing overflow systems to prevent spillage

3. Evaporation and Surface Area

The surface area at the water surface (314.16 sq ft) influences:

- Rate of water evaporation
- Effects of wind and temperature variations

4. Pumping and Water Movement

Calculations of volume and surface area are essential for:

- Designing efficient pumping systems
- Estimating time for filling or draining the tank

Additional Calculations and Related Concepts

A. Volume of Water at Different Fill Levels

If the tank is filled to a height (h') :

$$V' = \pi r^2 h'$$

For example, at 10 feet:

$$V' = \pi \times 100 \times 10 = 1000\pi \approx 3141.6 \text{ cubic feet}$$

B. Surface Area at Different Fill Levels

The surface area of water at height (h') :

$$A' = \pi r^2 = 100\pi \approx 314.16 \text{ sq ft}$$

The area remains constant since the cross-sectional area of the cylinder is constant, regardless of water level.

Summary of Key Points

- Total volume of the tank: approximately 9424.8 cubic feet
- Volume when half filled: approximately 4712.4 cubic feet
- Water height when half filled: 15 feet
- Surface area of water at half fill: approximately 314.16 square feet
- Lateral surface area of the water: approximately 942.48 square feet

Conclusion

Understanding the geometric and volumetric properties of a cylindrical water tank is vital for efficient water resource management. When the tank is half filled, it contains about 4712.4 cubic feet of water, with a water surface area of approximately 314.16 square feet and a water height of 15 feet. These calculations aid in designing effective storage systems, ensuring structural safety, and optimizing water usage. Accurate knowledge of these parameters is essential for engineers, environmentalists, and facility managers involved in water storage and distribution.

FAQs

Q1: How do the volume and surface area change if the tank is filled to a different level?

A: The volume varies linearly with height, calculated by $(V = \pi r^2 h')$. The surface area of the water's top remains constant at (100π) sq ft, since it's the cross-sectional area at the water surface.

Q2: What is the significance of calculating the lateral surface area of water?

A: It helps in understanding the surface exposure of water, which impacts evaporation rates, surface temperature, and potential for surface-based processes.

Q3: How can these calculations assist in designing water systems?

A: They inform decisions related to pump capacities, overflow systems, structural load assessments, and water conservation strategies.

By mastering these calculations, stakeholders can optimize water storage solutions, enhance safety, and promote sustainable water management practices.

Frequently Asked Questions

What is the volume of water currently in the cylindrical tank?

The tank is half filled; first, find the total volume of the tank: $V = \pi \times r^2 \times h = 3.1416 \times 10^2 \times 30 = 9424.8$ cubic feet. Half of this volume is approximately 4712.4 cubic feet.

How do you calculate the volume of water in a half-filled cylindrical tank?

Since the tank is half filled, the volume of water is half the total tank volume: $V = (1/2) \times \pi \times r^2 \times h$.

What is the formula to find the height of water in the tank when it is half filled?

The height of water when half the tank is filled is equal to the tank's height divided by 2, so $h_{\text{water}} = 15$ feet.

How can I find the surface area of the water in the tank?

The surface area of the water is the area of the circular cross-section at the top, which is $A = \pi \times r^2 = 3.1416 \times 10^2 = 314.16$ square feet.

If the tank is filled to the top, what would be its total volume?

The total volume of the tank is $V = \pi \times 10^2 \times 30 = 9424.8$ cubic feet.

What is the significance of the tank being half filled in terms of pressure at the bottom?

The pressure at the bottom depends on the height of the water column: $P = \rho gh$. Since water fills half the tank, the pressure is proportional to 15 feet of water height.

How would the volume change if the water level rises from half to three-quarters of the tank?

The volume would increase from half the total volume (4712.4 ft³) to three-quarters (about 7068.6 ft³), calculated as $V = (3/4) \times \text{total volume}$.

What are common applications of calculating water volume in cylindrical tanks?

Applications include water resource management, designing storage tanks, calculating water supply capacity, and ensuring structural safety.

How does the radius of the tank influence the volume of water stored?

The volume is proportional to the square of the radius (r^2), so increasing the radius significantly increases the tank's capacity for water storage.

Can you determine the height of water if the volume is known for a half-filled tank?

Yes, for a cylindrical tank, the height of water when half filled is simply half of the total height, which is 15 feet, assuming uniform filling.

Additional Resources

Comprehensive Analysis of a Cylindrical Water Tank: Capacity, Structural Aspects, and Practical Implications

Introduction to Cylindrical Water Tanks

Cylindrical water tanks are among the most common storage units employed globally for storing water in residential, commercial, industrial, and municipal settings. Their popularity stems from their structural efficiency, ease of construction, and ability to withstand internal and external pressures. In this detailed review, we explore a specific cylindrical water tank with a radius of 10 feet and a height of 30 feet, which is half filled with water. We delve into the mathematical calculations, structural considerations, practical implications, and potential applications associated with this tank configuration.

Fundamental Geometric and Mathematical Aspects

Dimensions and Basic Parameters

- Radius (r): 10 feet
- Height (h): 30 feet
- Full Capacity Volume (V_{full}): To be calculated
- Half-Filled Volume (V_{half}): To be calculated
- Water Height When Half-Filled (h_{water}): 15 feet (since half the height)

Understanding the geometric properties of the tank is essential for capacity calculations, structural assessments, and operational planning.

Calculating the Total Capacity of the Tank

The total volume of a cylinder is given by the formula:

$$V_{\text{full}} = \pi r^2 h$$

Where:

- $\pi \approx 3.1416$
- $r = 10$, feet
- $h = 30$, feet

Plugging in the values:

$$V_{\text{full}} = 3.1416 \times (10)^2 \times 30 = 3.1416 \times 100 \times 30 = 3.1416 \times 3000$$

$$V_{\text{full}} \approx 9424.8, \text{ cubic feet}$$

Therefore, the full capacity of the tank is approximately 9,425 cubic feet.

Calculating the Capacity When Half-Filled

Since the tank is half filled, the water level reaches a height of 15 feet. The volume of water when half-

filled is:

$$V_{\text{half}} = \pi r^2 h_{\text{water}}$$

Where $(h_{\text{water}} = 15\text{ feet})$:

$$V_{\text{half}} = 3.1416 \times 100 \times 15 = 3.1416 \times 1500 \approx 4712.4\text{ cubic feet}$$

Thus, the volume of water present when the tank is half filled is approximately 4,712 cubic feet.

Converting Volume to Equivalent Water Mass and Other Units

Understanding the volume in terms of water mass, weight, and other units is crucial for practical applications such as supply management, engineering calculations, and safety considerations.

Water Density and Weight

- Density of water: Approximately 62.4 pounds per cubic foot at standard conditions.
- Total weight of water when half filled:

$$W = V_{\text{half}} \times \text{density}$$

$$W \approx 4712.4 \times 62.4 \approx 294,529\text{ pounds}$$

- Conversion to tons:

$$\text{Tons} = \frac{294,529}{2000} \approx 147.26\text{ tons}$$

Implication: The water weight when half filled is approximately 147.3 tons, which significantly influences the structural load on the tank.

Conversion to Other Units

- Gallons: 1 cubic foot $\approx$ 7.48 gallons

$$V_{\text{half}} = 4712.4 \times 7.48 \approx 35,245 \text{ gallons}$$

- Liters: 1 cubic foot $\approx$ 28.3168 liters

$$V_{\text{half}} = 4712.4 \times 28.3168 \approx 133,583 \text{ liters}$$

Summary:

Quantity	Approximate Value
Full volume	9,424.8 cubic feet (~71,923 gallons, ~268,958 liters)
Half volume	4,712.4 cubic feet (~35,245 gallons, ~133,583 liters)
Water weight (half fill)	~147.3 tons

Structural and Engineering Considerations

Material and Construction Aspects

Constructing a cylindrical tank of this magnitude requires careful selection of materials, including reinforced concrete, steel, or composite materials. The choice depends on factors such as:

- Environmental conditions: Exposure to weather, corrosion potential
- Water pressure: Internal hydrostatic pressure at different heights
- Durability and maintenance: Longevity, ease of inspection, repair

Hydrostatic Pressure Distribution

Understanding pressure distribution is vital for structural integrity.

- At the bottom of the tank:

$$P_{\text{bottom}} = \rho g h_{\text{water}}$$

Where:

- ρ : density of water ($\sim 1000 \text{ kg/m}^3$ or 62.4 lb/ft^3)
- g : acceleration due to gravity ($\sim 9.81 \text{ m/s}^2$ or 32.2 ft/s^2)
- h_{water} : height of water column (15 ft when half filled)

Using imperial units:

$$P_{\text{bottom}} = 62.4 \frac{\text{lb}}{\text{ft}^3} \times 32.2 \frac{\text{ft}}{\text{s}^2} \times 15 \text{ ft}$$

Alternatively, hydrostatic pressure at the bottom:

$$P = \rho g h$$

Expressed in pounds per square foot:

$$P = 62.4 \frac{\text{lb}}{\text{ft}^3} \times 15 \text{ ft} = 936 \frac{\text{lb}}{\text{ft}^2}$$

Implication: The maximum internal pressure at the tank's bottom when half filled is approximately 936 pounds per square foot (psf). This pressure influences wall thickness, reinforcement, and foundation design.

Structural Safety and Reinforcement

- Design codes: Engineers must adhere to safety standards such as ACI, Eurocode, or local building codes.
- Wall thickness and reinforcement: Calculated based on maximum hydrostatic pressure, material strength, and safety margins.

- Base and foundation: Must withstand the combined weight of the tank structure plus water, considering soil bearing capacity.

Potential Stress and Strain Factors

- Vertical stresses: From water and tank wall weight
- Lateral stresses: Due to water pressure acting horizontally
- Dynamic forces: Wind, seismic activity, or fluctuating water levels

Engineers must analyze these stresses to prevent structural failure, leakage, or deformation.

Practical Implications and Operational Aspects

Filling and Draining Logistics

- Filling rate considerations: To prevent stress concentration or structural damage, filling should be controlled.
- Drainage: When emptying, ensure uniform flow to avoid erosion or damage.
- Half fill advantage: Allows for maintenance, inspection, and emergency management with reduced risk.

Water Quality and Maintenance

- Corrosion prevention: Use of protective coatings, cathodic protection, or corrosion-resistant materials.
- Sediment control: Regular cleaning to prevent sediment accumulation.
- Monitoring: Installing gauges, sensors for water level, pressure, and leak detection.

Applications and Usage Scenarios

- Municipal water supply: Storage for city water distribution
- Industrial processes: Raw water storage, process water, or cooling water
- Agricultural irrigation: Reservoirs for farm water needs
- Fire safety systems: On-site storage to support firefighting efforts

The half-fill state is often used during maintenance or low-demand periods, providing flexibility in operations.

Environmental and Safety Considerations

- Overflow management: Installing overflow outlets and drainage systems
- Structural safety: Regular inspections for cracks, corrosion, or deformation
- Seismic resilience: Reinforcements and flexible joints in earthquake-prone areas
- Environmental impact: Preventing leaks to avoid soil or water contamination

Conclusion: Summary of Key Insights

This detailed exploration of a cylindrical water tank with a radius of 10 feet and height of 30 feet, currently half filled, underscores the importance of meticulous calculations, structural design, and operational planning. The tank's total capacity of approximately 9,425 cubic feet, with about 4,712 cubic feet of water when half filled, translates to roughly 35,245 gallons or 133,583 liters, weighing around 147.3 tons of water.

From a structural perspective, understanding hydrostatic pressures and reinforcement needs ensures safety and longevity. Operationally, careful management of filling and draining procedures, along with regular maintenance, guarantees consistent performance. The application of this knowledge extends across various sectors, emphasizing the

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