olume (V) = Area (A) x Average Depth (AD)

I Gotta Know What?

FR = FA times FMR or FR = FA x FMR

Volume (V)gallons = Volume (V)cubic feet x 7.5

A Math Tutorial For Prospective CPO® Students

AD = (D1 + D2) divided by 2

BTU's = 8.33 x number of gallons x number of

A = L x W

BL A divided by 10

F temperature rise

Getting Ready For the CPO® Class

You will have to know basic things like:

- Square Foot – A square that is 12 inches wide and 12 inches long.
  Square Foot is abbreviated (sq.ft.).
- Cubic Foot – A square foot that has a depth of 12 inches.
  Cubic Foot is abbreviated (cu.ft.).
- Meter – One meter is the equivalent of 3.28 feet.
  Number of meters x 3.28 = number of feet
- Yard – One Yard is the equivalent of 3 feet.
  Number of yards x 3 = number of feet
- One cubic foot of water contains 7.5 gallons (gal)
  Number of Cubic Feet x 7.5 = number of gallons

Topics

- Area
- Depth
- Volume
- Gallons
- User Load
- Heater Sizing
- Turnover Rate
- Flow Rate
- Filter Area
- Media Rate

Area

Knowing how to calculate area is important for determining heat loss, sizing pool covers, bather loads in spas, and in some states, bather loads in pools.

Things to know

Area of a square or rectangle:

Area (A) = Length (L) x Width (W)

The x is a way to indicate the word(s) multiply or times.

The formula is simplified as: A = L x W

Area of a circle:

Area (A) = π x r^2

The π is a constant number 3.14.

The r stands for radius which is the distance from the center of the circle to the outer edge of the circle. The radius is ½ of the diameter.

r^2 means radius squared, or simply r times r.

The formula is better understood if written as: A = 3.14 x r x r

Examples:

(1) You have a pool with a length of 60 feet and a width of 35 feet.

What is the area?

The formula is A = L x W

L (Length) = 60 ft, W (Width) = 35 ft

A = L x W

A = 60 ft x 35 ft

A = 2,100 ft^2

(2) You have a circle with a diameter of 8 feet.

What is the area?

The formula is A = 3.14 x r x r

But what is r? Well, the radius is ½ of the diameter.

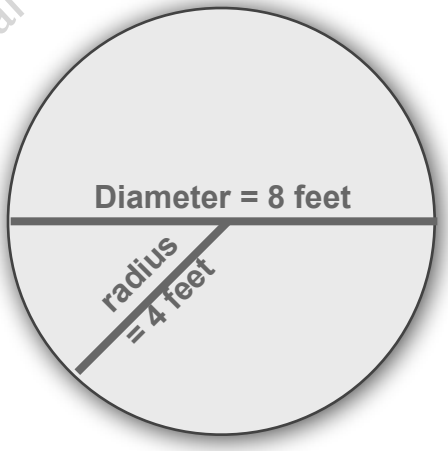
Therefore r = ½ of 8, or 4 feet

A = 3.14 x r x r

A = 3.14 x 4 ft x 4 ft

A = 3.14 x 16 ft^2

A = 50.24 sq. ft.



Depth

Depths are never even throughout a pool or spa. They may be sloped or if the depth is "constant", there is usually a coved or radius at the wall junctions.

Things to know

Volume of any pool shape (as measured in cubic feet):

> Depths are never even throughout a pool or spa. They may be sloped or if the depth is "constant", there is usually a coved or radius at the wall junctions.
>
> Volume (V) = Area (A) x Depth (D)

What about a pool with different depths?:

> Divide the pool shape into areas of constant depth, or constant slopes.
>
> Then calculate each area separately, using the average depth for each area.

Average Depth

Average Depth (AD) = (Shallow Depth + Deep Depth) divided by 2.

The Shallow Depth is called D_1 The Deep Depth is called D_2

AD = (D_1 + D_2) divided by 2

Example:

You have a pool with a shallow depth of 3 feet, and a deep depth of 8 feet.

What is the average depth?

The formula is AD = (D_1 + D_2) divided by 2

D_1 = 3 ft, D_2 = 8 ft

AD = (D_1 + D_2) divided by 2 AD = (3 feet+ 8 feet) divided by 2

AD = 11 feet divided by 2 AD = 5.5 feet

Volume

Volume is the space inside of an object. When talking about the volume of a pool, we express it in cubic feet. In metric terms, volume would be cubic meters.

Things to know

Volume of any pool shape:

> Volume is the space inside of an object. When talking about the volume of a pool, we express it in cubic feet. In metric terms, volume would be cubic meters.
> Volume (V) = Area (A) x Average Depth (AD)

Volume is how many cubic feet can fit into an object. For the purposes of pools and spas, all dimensions must be given in feet so as to calculate cubic feet.

From *page i*:

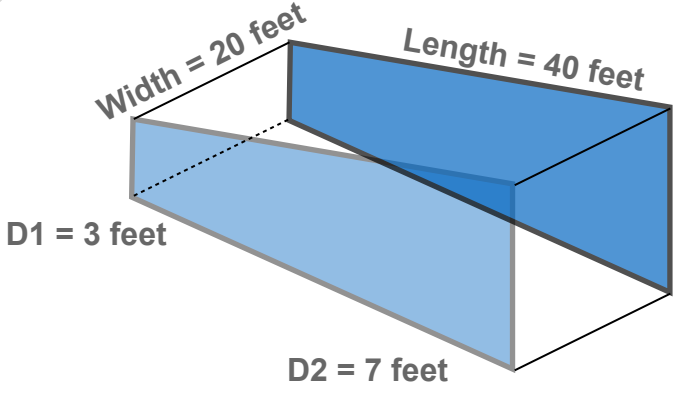
- Meters times 3.28 = feet
- Yards times 3 = feet
- Inches divided by 12 = feet (or fraction thereof)

Example:

You have a pool with a length of 40 feet and a width of 20 feet.

The shallow depth is 3 feet, and the deep depth is 7 feet

What is the volume?



The formula is V = A times AD

A = L x W

AD = (D_1 + D_2) divided by 2

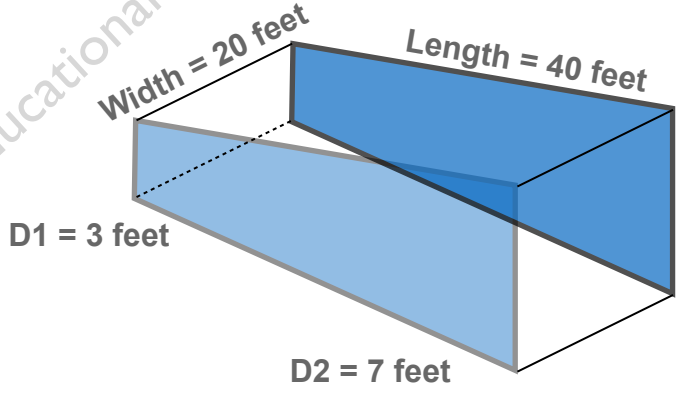
A = 40 ft x 20 ft = 800 sq.ft.

AD = (3 + 7) divided by 2 = 5 feet

V = A times AD

V = 800 sq.ft. times 5 feet

V = 4,000 cubic feet (cu.ft.)



Ok. So we have cubic feet, or perhaps cubic meters. What good is it? The section on Gallons will provide a meaningful use for cubic feet.

Gallons

Cubic feet or cubic meters are not useful in everyday discussions. So we take it one step further and convert to gallons or liters, things we know.

Things to know

The pool volume as expressed in gallons:

$$\text{Volume (V)}_{\text{gallons}} = \text{Volume (V)}_{\text{cubic feet}} \times 7.5$$

The actual number of gallons in a cubic foot is 7.48. The number 7.5 is used to make calculations easier. The amount of error in a 60,000 gallon pool would be only 160.5 gallons

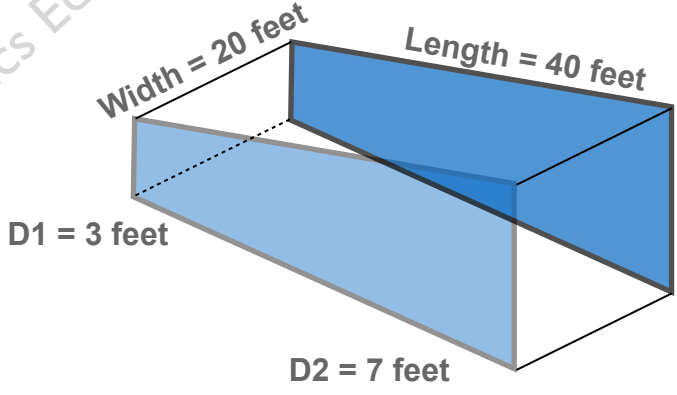
Example:

How many gallons are in the pool from the previous section:

The formula is: Volume $(V)_{gallons}$ = Volume $(V)_{cubic\ feet}$ x 7.5

$(V)_{gallons}$ = 4,000 cubic feet x 7.5

$(V)_{gallons}$ = 30,000 gallons



User Load

Usually user load is defined by local codes. Commonly, it is the number of bathers (or users) in the body of water at any specific time. Not all states or municipalities use the same method in determining maximum bather load (BL).

Some illustrations are:

Square foot of water surface area

Flow Rate (usually Flow Rate divided by 5)

Gallons of water in the pool

Different factors for areas of shallow, deep and diving portions of the pool as well as the deck.

Always operate in compliance
with your local or state code requirements.

The commonly accepted bather load calculation for spas is:

10 sq.ft. for every user or BL = A divided by 10

Example:

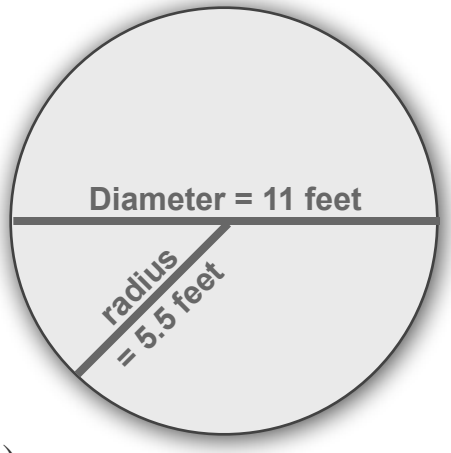
You have a spa with a diameter of 11 feet. What is the bather load?

The formula is BL = A divided by 10 But what is A?
Diameter = 11 feet Therefore r = ½ of 11, or 5.5 feet

A = 3.14 x r x r A = 3.14 x 5.5 ft x 5.5 ft

A = 3.14 x 30.25 ft2 A = 95 sq.ft.
BL = A divided by 10

BL = 95 sq.ft. divided by 10 = 9 bathers
(always round in the direction of safety, in this case, down)



Heater Sizing

A British Thermal Unit (BTU) is the amount of heat that will raise the temperature of one pound of water, one degree Fahrenheit.

Things to know

One gallon of water weighs 8.33 pounds. Therefore:

8.33 BTU's will heat one gallon of water 1 °F in one hour.

The amount of BTU's necessary to heat water is given as:

BTU's = 8.33 x number of gallons x number of °F temperature rise.

Example:

How many BTU's are required to raise the temperature of an 1,100 gallon spa from 94 °F to 102 °F?

Formula is BTU's = 8.33 x number gallons x number of °F temperature rise

What is the temperature rise?

From 94 °F to 102 °F is 8 °F temperature rise

Number of gallons = 1,100

BTU's = 8.33 x number gallons x number of °F temperature rise

BTU's = 8.33 x 1,100 gallons x 8 °F = 73, 304 BTU's

Turnover Rate

When the number of gallons in a pool goes through a filter, in 24 hours, that is one turnover a day. Most states require 3, 4, or even more turnovers a day.

Things to know

Codes require more than one turnover per day. The common accepted standards for one turnover are:

Pools – 6 hours

Spas – 30 minutes

Wading pools – between 1 and 2 hours

Therapy pools – 2 hours

Hospital and health club pools – as low as 3 hours

Turnover Rate

The way to achieve turnover rate is with Flow Rate (FR). The minimum Flow Rate is that which will realize the turnover rate (TR) requirements.

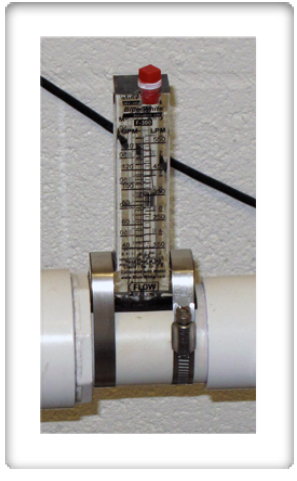
Formula for Turnover Rate:

Turnover Rate(TR) = Gallons (in the pool) divided by Flow Rate (FR) divided by 60.

Or written as:

TR = Gallons ÷ FR ÷ 60

Flow Rate (FR) is measured by a flow meter.



Example:

You have a 65,000 gallon pool, and the flow meter is reading 240 GPM (gallons per minute). What is the Turnover Rate (TR)?

Turnover Rate(TR) = Gallons divided by Flow Rate (FR) divided by 60

TR = Gallons ÷ FR ÷ 60

Gallons = 65,000; FR = 240 GPM

TR =	65,000	÷	240 GPM	÷ 60 =	4.5 hours
	Gallons		Flow rate		Answer

The standard for a swimming pool is 6 hours. This pool is well within the code standards. Remember, Always operate in compliance with your local or state code requirements.

Flow Rate

The way to achieve turnover rate is with Flow Rate (FR). The minimum Flow Rate is that which will realize the turnover rate (TR) requirements.

Things to know

Flow Rate is expressed in gallons per minute (GPM)
or liters per minute (LPM):

Flow Rate is measured by a flow meter.

A decrease in flow rate is usually caused by some form of obstruction, such as a dirty filter.

Formula for Flow Rate:

Flow Rate (FR) = Gallons divided by Turnover Rate (in hours) divided by 60

Simplified:

The formula is FR = Gallons ÷ TR ÷ 60

Formula for Turnover Rate:

Turnover Rate(TR) = Gallons divided by Flow Rate (FR) divided by 60.

Simplified:

The formula is TR = Gallons ÷ FR ÷ 60

Examples:

(1) The pool has a volume of 65,000 gallons. The pool has excessive loads on the weekend, and was designed for a 4.2 hour turnover.
What should the flow rate be?

The formula is FR = Gallons ÷ TR ÷ 60

FR = 65,000 ÷ 4.2 hours ÷ 60 = 258 GPM

Gallons | Turnover Rate | Answer

Examples:

(2) The pool has a volume of 65,000 gallons. The pool filter is dirty from the weekend, and the flow rate is down to 165 GPM.
What is the actual Turnover Rate?

The formula is TR = Gallons ÷ FR ÷ 60

TR = 65,000 (Gallons) ÷ 165 GPM (Flow rate) ÷ 60 = 6.6 hours (Answer)

This pool would be out of code compliance.
See the previous section.

Filter Area

There are three basic filter types: sand; cartridge; and diatomaceous earth. For the same Flow Rate, each type of filter has a different filter area requirement.

Things to know

The area of a sand filter is measured as the top of the sand.

The area of a pleated cartridge filter is usually taken from the manufacturer's specification on the top cap.

The area of a D.E. filter is the total surface area of all of the grids that the water flows through.

Example:

20 circular D.E. grids measuring 19 inches in diameter.

Each grid has 3.75 sq. ft. of total surface area.

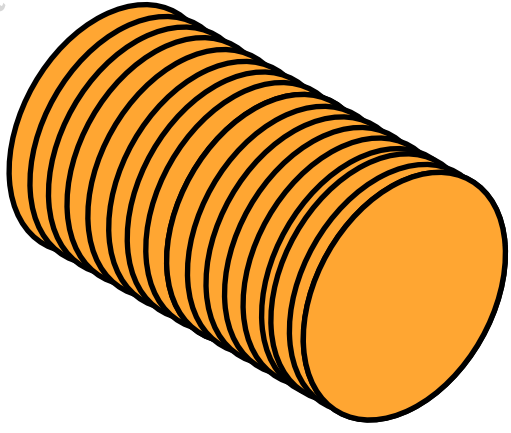
What is the filter area (FA)?

One grid is 3.75 sq. ft.

There are 20 grids

FA = 20 grids x 3.75 sq. ft. per grid

FA = 75 sq.ft.



Filter Area is very much related to the manufacturer's specification for the amount of water flow through the filter in question. These specifications are governed by standards as established by the National Sanitation Foundation International (NSFI). The CPO® student should review the next section covering Filter Media Rates before any further examples are offered regarding filter sizing.

Filter Media Rate

Filter Media Rate (FMR) is a NSFI standard that determines how fast water can flow through a given filter type.

Things to know

The flow rate through any filter should not exceed the filter's capacity to handle the water. Filter areas are calculated to handle the maximum possible flow of water through the system.

Manufacturer's develop specifications for the amount of water flow through the filter in question. These specifications are governed by standards as established by the National Sanitation Foundation International (NSFI). These standards are referred to as Filter Media Rate also known as FMR. The chart shows the FMR for the various filter types.

Filter Type	Filter Media Rate
High Rate Sand	5 – 20 GPM/ft^2
Cartridge	0.375 GPM/ft^2
Diatomaceous Earth (DE)	2.0 GPM/ft^2
Diatomaceous Earth (DE) with Slurry	2.5 GPM/ft^2
Rapid Rate Sand	3 GPM/ft^2

Filter Media Rate Formulas

Filter Area (FA) = Flow Rate (FR) divided by Filter Media Rate (FMR)

Consider what we have already discussed. Turnover Rate is a minimum code established by health officials for the purpose of maintaining a healthy swim environment. As you saw on the Flow Rate page, Flow Rate calculations are based on Turnover requirements (FR = Gallons ÷ TR ÷ 60). Pumps are sized to provide the Flow Rate to meet Turnover. Now, the filter must be sized to handle the Flow Rate, as pump output. The filter size will depend on the type of filter, or the Filter Media Rate. Therefore, FA = FR ÷ FMR. This will determine the minimum Filter Area for any given Flow Rate.

The Filter Area formula may be written so as to express the Flow Rate:

FR = FA times FMR or FR = FA x FMR.

Examples:

(1) Your maximum pump output is 275 GPM and you wish to change to a sand filter rated at 15 GPM/sq.ft. filter media rate.
How much filter area do you need?

The formula is FA = FR ÷ FMR

FR = 275 GPM; FMR (from chart and problem) = 15 GPM/sq.ft.

FA = 275 GPM divided by 15 GPM/sq.ft.

FA = 18.33 sq.ft.

(2) Your pool has a cartridge filter of 851 square feet.
What is the maximum flow rate allowed?

The formula is FR = FA x FMR

FA = 851 sq.ft.; From the chart for a cartridge filter FMR = 0.375 GPM/sq.ft.

FR =	851 sq.ft.	x	0.375 GPM/sq.ft.	=	319 GPM
	Filter Area		Filter Media Rate		Answer

This Is The Conclusion of The Math Tutorial

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Thank you for your interest in pool operations.

Scott Ford
Ron Ford