CHAPTER 2
VOLUME CALCULATIONS

This chapter of the book moves on to cover many of the volume related calculations you will come across on a drilling rig and in particular those related to well control. It starts slowly building a basic picture of volume before focusing on some practical field applications. Topics covered include:

- Pit volume
- String and hole volume
- Annular volume
- Pump output
- Stroke and time calculations
- Annular velocity
- Capacities and displacements
- Trip sheet calculations
- Kill sheet - volume calculations

There is a final chapter test at the end to check you understanding.

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DON'T PANIC

Welcome to the second chapter in the Introduction to Well Control Calculations for Drilling Operations.

This time we are going to look at using the skills you learned in the first chapter in some volume calculations. Having successfully completed the first chapter you should have no problems with the calculations. You will be able to concentrate on learning how they relate to volumes and where they are used.

This chapter is laid out exactly as the first one was. There are a number of lessons which make up a subject. Each lesson will be no more than two pages long which means you always have a complete lesson to view. You never need to turn the page to complete a learning point.

There are worked examples - go through them using your own calculator to see how they work. There are a number of calculations for you to try yourself. Make sure you do them all.

Fully worked-out answers are given for each question - make sure you try the questions before looking at the answers.

When working out calculations remember to write them down ensuring everything is clearly written and identified. Write down all the stages of a calculation, including the final answer with its correct unit.

By the time you have completed this chapter, and done so honestly, you will be ready for the third chapter which introduces pressure calculations. You will only be able to do this, though, if you:

Take your time. **Do not skip anything.** **Read every word.**

Do every calculation.

A QUICK REFRESHER

Before you start on volume calculations it is worth quickly refreshing what you learned in the first chapter. The subjects that were covered included:

Fractions and decimals
Squaring a number
Percentages
Rounding your answers
Figuring out the order of a calculation
Using and rearranging formulas
Converting units

You will need to be ably to apply all these calculation skills when working with volumes. Here are a few to get you warmed up. The answers, as always, are over the page.

a) BHCP = Hydrostatic Pressure + APL.

How would you work out APL?

b) Use the following data to work out MAASP to the nearest whole psi.

TVD = 12,689 ft	Shoe TVD = 9,700 ft
Test Mud Weight = 11.8 ppg	Current Mud Weight = 14.7 ppg
LOT Pressure = 1,950 psi	Max Mud Weight = 15.6 ppg

MAASP (psi) = (Max Mud Weight (ppg) - Current Mud Weight (ppg)) x 0.052 x Shoe TVD (ft)

c) What would be the volume in bbls if you added an extra 18%? Work this out to the nearest whole bbl.

Strokes = 3,650	Pump Output = 0.119 bbl/stk

Strokes = Volume (bbl) ÷ Pump Output (bbl/stk)

ANSWERS

a) BHCP = Hydrostatic Pressure + APL.

How would you work out APL?

BHCP = Hydrostatic Pressure + APL

BHCP - Hydrostatic Pressure = APL flipped to give

APL = BHCP - Hydrostatic Pressure

OR by using a simple calculation to rearrange the formula

BHCP = Hydrostatic Pressure + APL

10 = 6 + 4

4 = 10 - 6

APL= BHCP - Hydrostatic Pressure

---

b) Use the following data to work out MAASP to the nearest whole psi.

TVD = 12,689 ft	Shoe TVD = 9,700 ft
Test Mud Weight = 11.8 ppg	Current Mud Weight = 14.7 ppg
LOT Pressure = 1,950 psi	Max Mud Weight = 15.6 ppg

MAASP (psi) = (Max Mud Weight (ppg) - Current Mud Weight (ppg)) x 0.052 x Shoe TVD (ft)

MAASP = (15.6 - 14.7) x 0.052 x 9,700

= 0.9 x 0.052 x 9,700

= 453.96

= 454 psi

c) What would be the volume in bbls if you added an extra 18%? Work this out to the nearest whole bbl.

Strokes = 3,650 Pump Output = 0.119 bbl/stk

Strokes = Volume (bbl) ÷ Pump Output (bbl/stk)

Strokes x Pump Output (bbl/stk) = Volume flipped to read

Volume (bbls) = Strokes x Pump Output (bbl/stk)

= 3,650 x 0.119

= 434.35

= 434.35 + 18%

= 512.533 which rounds to

= 513 bbl

No real problems with these hopefully.

Write things down before picking up the calculator. This will allow you to plan the calculation before jumping into it.

Work out calculations in stages to help keep them clear.

Take your time - there is no hurry.

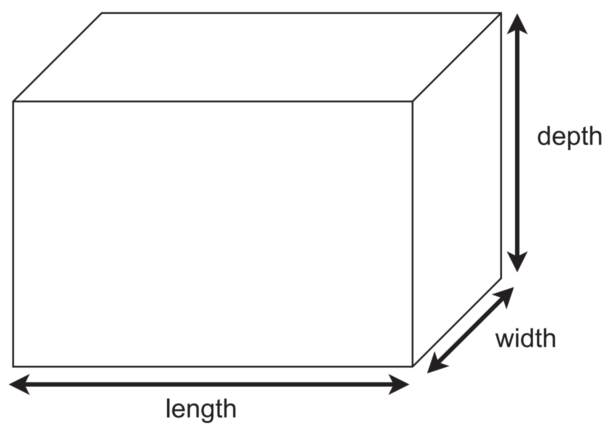
PIT VOLUME

This chapter is going to deal exclusively with volumes. Volume is how much space something takes up. The two main volumes we are concerned with are hole volumes and pit volumes.

We use mud (drilling fluid) for a number of different reasons in our industry with hole cleaning and well control being two of the main ones. We need to know what volume of mud there should be in the hole. This will tell us if we have our well control correct. It can also help us work out things for hole cleaning.

We also need to know how much mud we have in our pits at surface and how much spare capacity we have in our pits at surface.

Generally speaking, a mud pit is a square-sided tank like the one shown below.



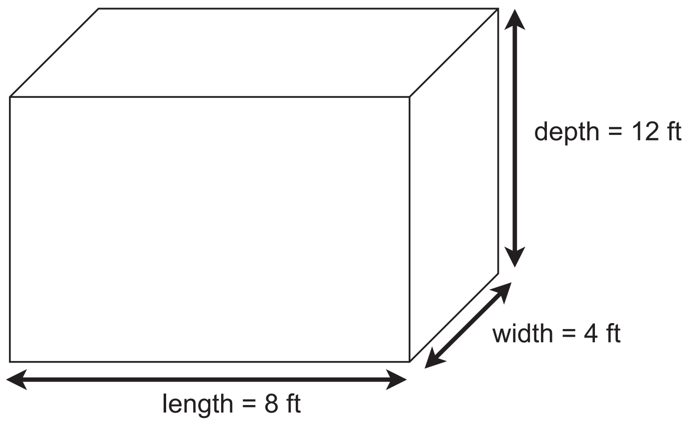
As you can see the pit has length, width and depth, these are its dimensions - how long it is, how wide it is and how deep it is.

If you know what these dimensions are you can work out the volume of the pit simply by multiplying the three figures together:

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth}$$

In order to get a meaningful answer, however, you need to know what units of measurement are being used. If we measured the mud pit dimensions in feet we would be able to work out the volume in cubic feet - ft^3.

Work out the volume in cubic feet for the pit shown below:



Volume (ft^3) = Length (ft) x Width (ft) x Depth (ft)

= 8 x 4 x 12

= 384 ft^3

If the dimensions had been measured in metres what would the volume of the mud pit be? This time the answer will be in cubic metres - m^3

Volume (m^3) = Length (m) x Width (m) x Depth (m)

= 8 x 4 x 12

= 384 m^3

The number is the same - 384 - but the unit is different, m^3 as opposed to ft^3.

In order to work out the volume of a square-sided mud pit you multiply the length by the width by the depth.

If all of the dimensions are in feet you will get an answer in cubic feet.

If all of the dimensions are in metres you will get an answer in cubic metres.

We are going to work mainly in field units through this book. Volumes are usually measured in barrels (bbl). When working out volumes in barrels, answer to two decimal places throughout this book.

In order to convert the answer to barrels you have to use the correct conversion factor.

To convert from left to right multiply by conversion factor		
To convert from right to left divide by conversion factor		
Unit	**Conversion Factor**	**Unit**
Cubic Feet	0.1781	Barrels
Cubic Metres	6.2905	Barrels

Convert 384 ft^3 and 384 m^3 to barrels.

$$384\ ft^3 \times 0.1781 = 68.39\ bbl$$

$$384\ m^3 \times 6.2905 = 2417.28\ bbl$$

As you will see the volume in barrels is very different! Well over 2,300 barrels different!! It is important to use the correct units in a formula. Make sure you check the bit in the brackets.

In field units we normally measure volume in barrels and lengths (& widths & depths) in feet. We can use the conversion factor, 0.1781, as a constant to give us a formula for working out the volume in bbls of any square-sided tank:

Square-sided Tank Volume (bbls) = Length (ft) x Width (ft) x Depth (ft) x 0.1781

Answer the following:

a) What is the volume in barrels of a mud pit with the following dimensions?

Length 14 ft, width 7.5 ft, depth 8 ft

b) What is the volume in barrels of a mud pit with the following dimensions?

Length 2.5 m, width 1.6 m, depth 2.2 m

c) What is the volume in cubic metres of a mud pit with the following dimensions?

Length 4.75 ft, width 2.8 ft, depth 11 ft

d) How many barrels per foot will there be in the following pit?

Length 6.5 ft, width 4 ft, depth 13.75 ft

ANSWERS

a) What is the volume in barrels of a mud pit with the following dimensions?

Length 14 ft, width 7.5 ft, depth 8 ft

Square-sided Tank Volume (bbls) = Length (ft) x Width (ft) x Depth (ft) x 0.1781

= 14 x 7.5 x 8 x 0.1781

= 149.604

= 149.6 bbls

---

b) What is the volume in barrels of a mud pit with the following dimensions?

Length 2.5 m, width 1.6 m, depth 2.2 m

Work out cubic metres and then convert to barrels:

Volume (m^3) = Length (m) x Width (m) x Depth (m)

= 2.5 x 1.6 x 2.2

= 8.8 m^3 now convert to barrels

8.8 x 6.2905

= 55.396

= 55.4 bbls

If you knew the conversion factor from metres to feet you could convert length, width & depth to feet and then use the Volume Formula.

To convert metres to feet you multiply by 3.281. Try it to see what the volume works out to. Convert feet to 2 decimal places.

c) What is the volume in cubic metres of a mud pit with the following dimensions?

Length 4.75 ft, width 2.8 ft, depth 11 ft

Square-sided Tank Volume (bbls) = Length (ft) x Width (ft) x Depth (ft) x 0.1781

= 4.75 x 2.8 x 11 x 0.1781

= 26.1 bbls now convert to cubic metres

26.1 ÷ 6.2905

= 4.15 m^3 ***(from here on in the answer will be rounded by this stage)***

---

d) How many barrels per foot will there be in the following pit?

Length 6.5 ft, width 4 ft, depth 13.75 ft

Sneaky one - we haven't covered this! Work out the volume in barrels then divide it by the depth in feet to find out what volume of mud there will be for every foot in the pit.

Square-sided Tank Volume (bbls) = Length (ft) x Width (ft) x Depth (ft) x 0.1781

= 6.5 x 4 x 13.75 x 0.1781

= 63.67 bbls now divide by pit depth

63.67 ÷ 13.75

= 4.63 bbl/ft

On the rig you will most likely have foot and tenth foot markers in your pits so you can quickly work out how much mud is in any pit. Check it out on your rig when you get a chance.

STRING & HOLE VOLUME

Ok, you can work out the volume of a mud pit quite easily because it is square-sided. It will be a different matter when you have to work out the volume of something that is not square-sided - say, like a round hole in the ground!

We are going to look at open hole volume next - how much mud it will take to completely fill the hole.

Before we look at open hole volume, however, let's take a different look at how we calculated the tank volume.

To start we said that:

Volume = Length x Width x Depth

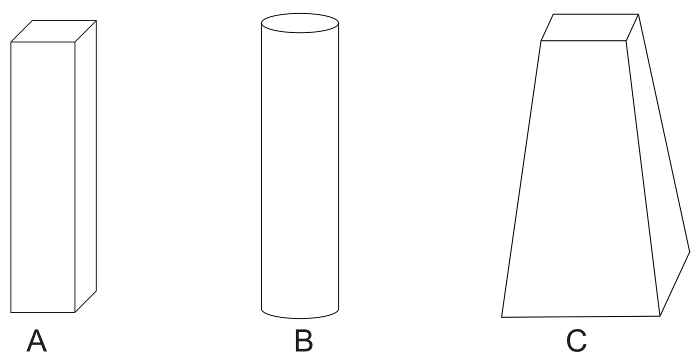
When you multiply Length by Width you get Area.

Area is the size of a flat surface. We could rewrite the volume formula to read:

Volume = Area x Depth

This formula could be used to work out the volume of any three-dimensional space as long as long as it's shape stays the same throughout its length.

The formula could be used to work out the volume of which of the following?



The formula could be used to work out the volumes of A & B but not for C. The good news is that in this book you will not be asked to work out the area for an odd-shaped space!

AREA OF A CIRCLE

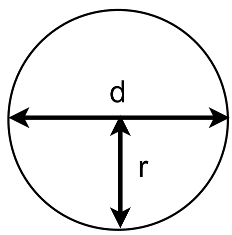
You can work out the volume of any space if you know its area and its depth by using the formula:

$$\text{Volume} = \text{Area} \times \text{Depth}$$

Given that a hole is round you need to work out the area of a circle to be able to work out hole volume. Over 2,000 years ago a Greek fellow called Archimedes worked out a formula for the area of a circle. He had little else to do other than sit around thinking about things (probably a mud logger to trade!) but he said:

$$\text{Area of a Circle} = (\pi d^2) \div 4$$

where π is the Greek letter pi, which is approximately 3.1416, and d is the diameter of the circle. Pi is how many times the diameter will go around the circumference (the outside of the circle). The diameter is the distance across a circle from one edge to the other in a straight line through the centre. For information, the radius (r) is the distance from the middle to the edge and is half the size of the diameter.



Replacing π with its value the formula could be rewritten as:

$$\text{Area of a Circle} = (3.1416 \times d^2) \div 4$$

or even rearranged mathematically to read:

$$\text{Area of a Circle} = d^2 \times (3.1416 \div 4)$$

3.1416 and 4 are constants so we can do the division to leave us with:

$$\text{Area of a Circle} = d^2 \times 0.7854$$

You will not need to use this formula but knowing how we got it will help with what follows.

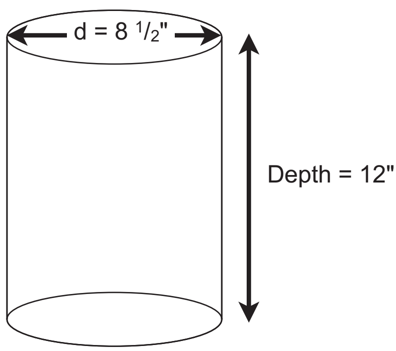
DERIVATION OF 1029.4

Stick with this next bit. You will not have to repeat this in any test but it is worth following as it explains where we get the constant 1029.4 from.

You can work out the volume of any space if you know its area and its depth by using the formula:

$$\text{Volume} = \text{Area} \times \text{Depth}$$

To calculate the volume of a cylinder (which is effectively what a section of open hole is) you must multiply its Area by its Depth. What is the volume of the cylinder shown?



$$
\begin{aligned}
\text{Volume} &= \text{Area} \times \text{Depth} \\
&= d^2 \times 0.7854 \times \text{Depth} \\
&= 8.5^2 \times 0.7854 \times 12 \\
&= 72.25 \times 0.7854 \times 12 \\
&= 680.94 \text{ in}^3
\end{aligned}
$$

We have just worked out the volume of this cylinder in cubic inches - we use inches as our measurement for diameters, after all.

We use inches for diameter and feet for length so if we wanted to know the volume in cubic feet we would have to divide our answer by 144 (12 x 12, which is the number of square inches in a square foot).

So the formula could be written:

$$\text{Volume of Cylinder (ft}^3) = (d^2 \text{ (in)} \times 0.7854) \times \text{Depth (in)} \div 144$$

Given we are working in field units then we measure volume in barrels. To convert cubic feet to barrels you multiply by the conversion factor 0.1781. This gives us a formula that reads:

$$\text{Volume of Cylinder}_{(bbls)} = (d^2_{(in)} \times 0.7854) \times \text{Depth}_{(in)} \div 144 \times 0.1781$$

We measure depth in feet and tend to express volume as a capacity in barrels per foot (bbl/ft). This means we can remove Depth (in) from the formula so it reads:

$$\text{Volume of Cylinder}_{(bbl/ft)} = (d^2_{(in)} \times 0.7854) \div 144 \times 0.1781$$

Still here hopefully because now comes the clever bit! Let's rearrange the formula so we get all the variables on one side and all the constants on the other:

$\text{Volume of Cylinder}_{(bbl/ft)} = (d^2_{(in)} \times 0.7854) \div 144 \times 0.1781$ ***move 144***

$\text{Volume of Cylinder}_{(bbl/ft)} \times 144 = (d^2_{(in)} \times 0.7854) \times 0.1781$ ***move 0.1781***

$\text{Volume of Cylinder}_{(bbl/ft)} \times 144 \div 0.1781 = d^2_{(in)} \times 0.7854$ ***move 0.7854***

$\text{Volume of Cylinder}_{(bbl/ft)} \times 144 \div 0.1781 \div 0.7854 = d^2_{(in)}$ ***move Volume***

$144 \div 0.1781 \div 0.7854 = d^2_{(in)} \div \text{Volume of Cylinder}_{(bbl/ft)}$

If we now work out the calculation on the left hand side we get:

$144 \div 0.1781 \div 0.7854 = d^2_{(in)} \div \text{Volume of Cylinder}_{(bbl/ft)}$

$1029.4 = d^2_{(in)} \div \text{Volume of Cylinder}_{(bbl/ft)}$ ***which rearranges back to***

$1029.4 \times \text{Volume of Cylinder}_{(bbl/ft)} = d^2_{(in)}$ ***volume has been moved***

$\text{Volume of Cylinder}_{(bbl/ft)} = d^2_{(in)} \div 1029.4$ ***1029.4 has been moved***

This is an important formula in drilling calculations - it is used to work out the capacity of hole sections and also of the drill string.

HOLE CAPACITY

Things ease up a bit now - but on the flip side you have to do more calculations!

We have just worked out the following formula:

$$\text{Volume of Cylinder}\ (\text{bbl/ft}) = d^2\ (\text{in}) \div 1029.4$$

A section of hole is a cylinder so we could rename the formula:

$$\text{Hole Capacity}\ (\text{bbl/ft}) = d^2\ (\text{in}) \div 1029.4$$

where the small d is the inside diameter (ID) of the hole. For open-hole sections of the well this will be the bit diameter.

What will the hole capacity be if we are drilling with a 12 $^1/_2$" bit?

$$\text{Hole Capacity}\ (\text{bbl/ft}) = d^2\ (\text{in}) \div 1029.4$$

$$= 12.5^2 \div 1029.4$$

$$= 156.25 \div 1029.4$$

$$= 12.5^2 \div 1029.4$$

$$= 0.151787448$$

What should this answer be rounded to? Capacities need to be taken to a fair degree of accuracy, as we will see shortly, so we generally go to four or five decimal places. In this case take it to five decimal places:

$$= 0.151787448$$

$$= 0.15179\ \text{bbl/ft}$$

The same formula can also be used to work out the capacity of cased-hole sections. In this case you need to know the ID of the casing. This varies depending on the weight per foot of the casing, which is usually measured in pounds per foot (lb/ft). The greater the lb/ft the more steel there will be for a given size of casing, therefore the smaller the ID.

9 $^5/_8$" Casing that weighs 32.3 lb/ft has an ID of 9.001". What is the capacity of this casing in bbl/ft. Round to five decimals as before.

$$\text{Hole Capacity (bbl/ft)} = d^2\,(\text{in}) \div 1029.4$$

$$= 9.001^2 \div 1029.4$$

$$= 81.018001 \div 1029.4$$

$$= 0.0787 \text{ bbl/ft}$$

Work out the capacity in bbl/ft of the following cased and open-hole sections to five decimal places.

a) Open-hole section using a 26" bit.

b) Open-hole section using a 17 $^1/_2$" bit.

c) Open-hole section using a 12 $^1/_4$" bit.

d) Cased-hole section - 18 $^5/_8$" casing with an ID of 17.755"

e) Cased-hole section - 9 $^5/_8$" casing with an ID of 8.535"

ANSWERS

Hole Capacity (bbl/ft) $= d^2$ (in) $\div$ 1029.4

a) $26^2 \div 1029.4 = 676 \div 1029.4 = 0.65669$ bbl/ft

b) $17.5^2 \div 1029.4 = 306.25 \div 1029.4 = 0.2975$ bbl/ft

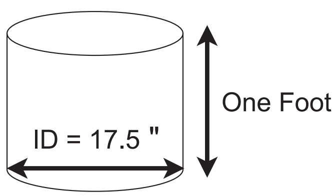
c) $12.25^2 \div 1029.4 = 150.0625 \div 1029.4 = 0.14578$ bbl/ft

d) $17.755^2 \div 1029.4 = 315.240025 \div 1029.4 = 0.30623$ bbl/ft

e) $8.535^2 \div 1029.4 = 72.846225 \div 1029.4 = 0.07077$ bbl/ft

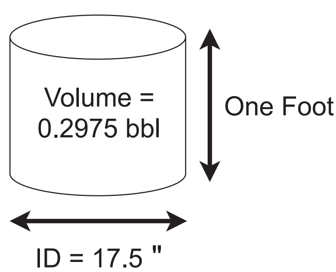
HOLE VOLUME

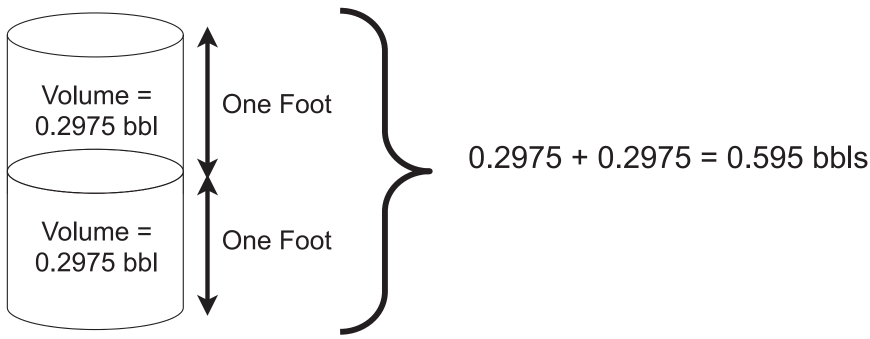
A barrels per foot capacity tells you the volume of one foot of a particular hole section:



The volume to fill this section of hole is 0.2975 bbl

What volume would be needed to fill two feet of this hole section?





You can work out the volume for any hole section simply by multiplying the capacity of the section by the length of the section:

Hole Volume (bbl) = Capacity (bbl/ft) x Length (ft)

Work out the volume required to fill the following sections of hole. All volumes in barrels should be rounded to two decimal places.

a) 1,500 ft long open-hole section with a capacity of 0.65669 bbl/ft.

b) Open-hole section that is 3,782 ft long with a capacity of 0.14578 bbl/ft.

c) Cased-hole section that is 7,896 ft long with a capacity of 0.07077 bbl/ft.

d) We have used an 8 $^{1}/_{2}$" bit to drill an open-hole section of 2,768 ft. How much mud is required to fill the open-hole section?

e) We have run 13 $^{3}/_{8}$" casing (ID = 12.515") to a depth of 8,246 ft. How much mud is required to fill the casing?

ANSWERS

Hole Volume (bbls) = Capacity (bbl/ft) x Length (ft)

a) 0.65669 x 1,500 = 985.03 bbl

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b) 0.14578 x 3,782 = 551.34 bbl

---

c) 0.07077 x 7,896 = 558.8 bbl

---

d) First work out capacity: Hole Capacity (bbl/ft) = d^2 (in) ÷ 1029.4

= $8.5^2 \div 1029.4$

= 72.25 ÷ 1029.4 = 0.07019 bbl/ft

Hole Volume (bbls) = Capacity (bbl/ft) x Length (ft)

= 0.07019 x 2,768 = 194.86 bbl

---

e) Capacity = $12.515^2 \div 1029.4$

= 156.625225 ÷ 1029.4 = 0.15215 bbl/ft

Hole Volume (bbls) = Capacity (bbl/ft) x Length (ft)

= 0.15215 x 8,246 = 1,254.63 bbl

STRING CAPACITY

The bit is run to the bottom of the hole on the Drill String. The drill string is usually made up of Drill Pipe, Hevi Weight Drill Pipe (HWDP) and the Bottom Hole Assembly (BHA).

The BHA can have many different components in it such as stabilisers, subs, motors, jars etc with the main component usually Drill Collars. For the sake of simplicity when working out volume calculations we are going to assume that the entire BHA is Drill Collars. The margin of error is so small that it can be safely ignored.

All the components of the drill string are hollow pipe. We need to be able to pump mud down the inside of the drill string in order to be able to do a number of things. The drill string is in effect a number of cylinders connected together. If we know the ID of the drill string component we can work out its capacity in bbl/ft using the same formula we used for hole capacity:

$$\text{String Capacity (bbl/ft)} = d^2 \text{(in)} \div 1029.4$$

Work out the capacity, in bbl/ft, of the following sections of drill string:

a) 5" OD Drill Pipe with an ID of 4.276"

b) 5" OD HWDP with an ID of 3"

c) 6 $^3/_4$" OD Drill Collars with an ID of 2.8125"

ANSWERS

String Capacity (bbl/ft) = d^2 (in) ÷ 1029.4

a) $4.276^2 \div 1029.4 = 18.284176 \div 1029.4 = 0.01776$ bbl/ft

b) $3^2 \div 1029.4 = 9 \div 1029.4 = .00874$ bbl/ft

c) $2.8125^2 \div 1029.4 = 7.91015625 \div 1029.4 = .00768$ bbl/ft

STRING VOLUME

By now you will have figured out that the next thing you can do with this information is calculate how much mud will be required to fill the drill string. You need to know the lengths of each section of the drill string to be able to do this.

Using the previous examples let's see what volume will be required to fill the drill string if we have 7,000 ft of drill pipe, 980 ft of HWDP and 650 ft of drill collars.

String Volume (bbl) = Capacity (bbl/ft) x Length (ft)

Drill Pipe Volume = 0.01776 x 7,000 = <u>124.32 bbl</u>

HWDP Volume = 0.00874 x 980 = <u>8.57 bbl</u>

Drill Collar Volume = 0.00768 x 650 = <u>4.99 bbl</u>

To work out total drill string volume you need to add together the volumes of the three sections:

Total String Volume = 124.32 + 8.57 + 4.99 = <u>137.88 bbl</u>

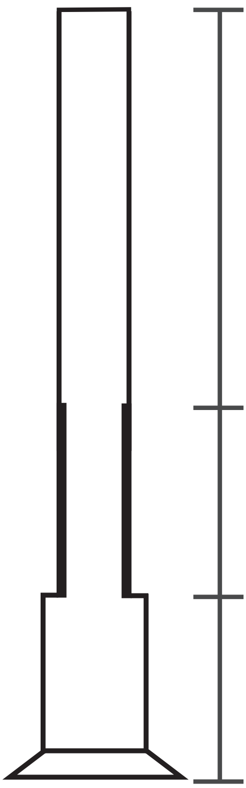
Notice how the section volumes have been underlined, as has the final answer. As questions have more parts this is a good way of identifying key answers.

A drawing of the drill string is very useful when tackling this type of problem as it will help you clearly see where everything is. The drawing does not need to be to scale - it just needs to be clearly set out and labelled.

What is volume of the following drill string - 4,700 ft of drill pipe, 820 ft of HWDP and 715 ft of drill collars? We will use the drill string capacities opposite.

Start off with a simple drawing of a drill string. Opposite the relevant section work out the volume then add up all the sections at the bottom.

String Volume (bbl) = Capacity (bbl/ft) x Length (ft)



Drill Pipe Volume

0.01776 x 4,700 = 83.47 bbl

HWDP Volume

0.00874 x 820 = 7.17 bbl

Drill Collar Volume

0.00768 x 715 = 5.49 bbl

Total Drill String Volume = 83.47 + 7.17 + 5.49 = 96.13 bbl

Open-hole capacity and drill string capacity, in barrels per foot, can be worked out using the same formula:

$$\text{Capacity (bbl/ft)} = d^2 \text{ (in)} \div 1029.4$$

Total volume in barrels can be worked out by multiplying the capacity by the length of the section:

$$\text{Volume (bbl)} = \text{Capacity (bbl/ft)} \times \text{Length (ft)}$$

A simple drawing of the drill string can help with the problem solving.

Using the page opposite (or a blank sheet if you prefer) draw a picture of a drill string and work out how much mud will be required to fill it.

Drill String Data

Well Measured Depth = 14,890 ft

Drill Pipe: 5" OD, ID of 4.408"

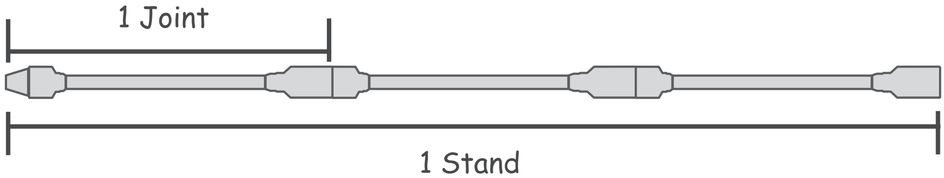
HWDP: 5" OD, ID of 2 3/4"

Drill Collars: 5 3/4" OD, ID of 1 3/4"

Each joint of drill collars is 29 ft long. Each joint of HWDP is 32 ft long. There are 7 stands of drill collars and 12 stands of HWDP. The remainder of the drill string is made up of drill pipe. The bit is on bottom.

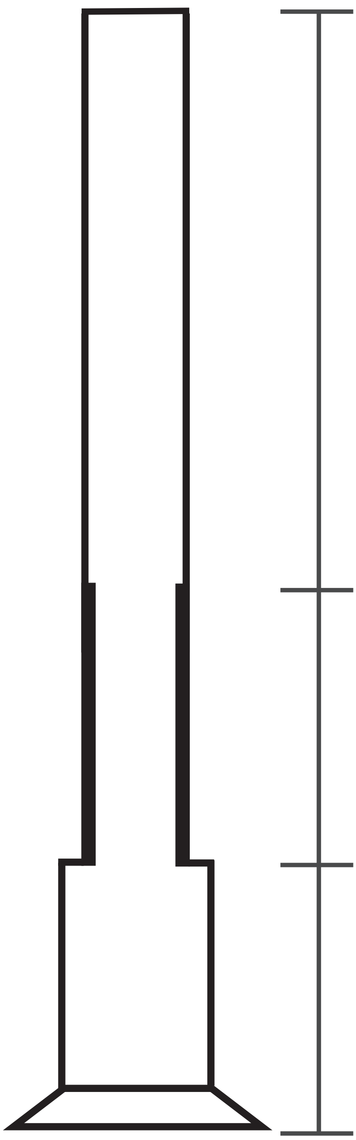
Attention Mud Loggers:

A joint is a single length of pipe - *OK!* Three joints make up a stand. See below:



ANSWERS

You first need to work out the lengths of the Drill Collars and HWDP. Subtract both of these from the Well Measured Depth to get the length of the Drill Pipe. I always start at the bottom and work up.



Drill Pipe

Length = 14,890 - 609 - 1,152 = 13,129 ft

Capacity = $4.408^2 \div 1029.4 = 0.01888$ bbl/ft

Volume = 0.01888 x 13,129 = 247.88 bbl

HWDP

Length = 32 x 3 x 12 = 1,152 ft

Capacity = $2.75^2 \div 1029.4 = 0.00735$ bbl/ft

Volume = 0.00735 x 1,152 = 8.47 bbl

Drill Collars

Length = 29 x 3 x 7 = 609 ft

Capacity = $1.75^2 \div 1029.4 = 0.00298$ bbl/ft

Volume = 0.00298 x 609 = 1.81 bbl

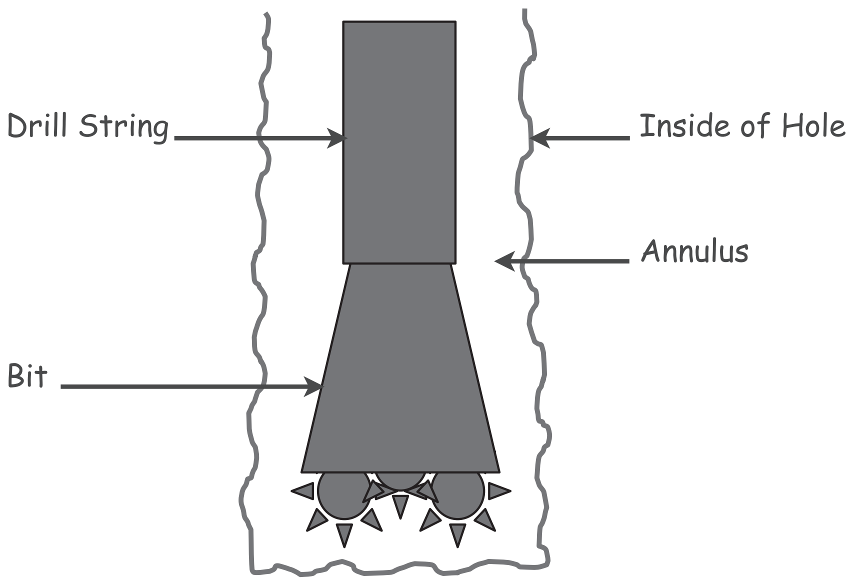
Total Drill String Volume = 247.88 + 8.47 + 1.81 = 258.16 bbl

ANNULAR VOLUMES

You can now work out open-hole, cased-hole & string capacities and volumes. Throughout these books the term capacity means barrels per foot (bbl/ft) and the term volume means barrels (bbl).

In the field and other reference manuals they are sometimes used the other way round. Always look for the unit (the bit in brackets) as this will tell you what you are dealing with.

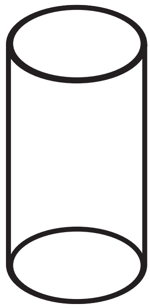
By pumping the mud down the drill string you have it at the bit. It will come out the bit and to get it back to surface you have to pump it up the annulus. This is the space between the outside of the drill string and the inside of the hole or casing.



How do you work out the capacity of the annulus?

Have a think about it before turning the page.

A section of hole, whether open or cased, is a cylinder.



The capacity of this cylinder is:

Capacity (bbl/ft) = D^2 (in) ÷ 1029.4

where D is the ID of the cylinder

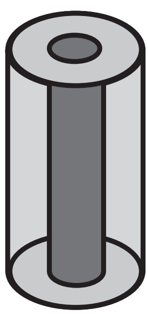
If our drill string was solid it would also be a cylinder.

The capacity of this cylinder is:

Capacity (bbl/ft) = d^2 (in) ÷ 1029.4

where d is the OD of the cylinder. Here we are working out the displacement capacity of the cylinder.

If we put one cylinder inside the other we create a space between them - an annular space.



We could say the annular capacity is:

Annular Capacity (bbl/ft) = (D^2 ÷ 1029.4) - (d^2 ÷ 1029.4)

where the first calculation is for the hole section and the second one is for the string.

This formula can be tidied up to read:

Annular Capacity (bbl/ft) = (D^2- d^2) ÷ 1029.4

We can now take this formula to the rig to work out the annular capacities for any section of the well.

We need to know the ID of the particular section of the well which we call D (Big D as it is known) and the OD of the drill string component (let's use the term tubular from here on in) which we call d (or little d).

The formula can also be written like this:

$$\text{Annular Capacity (bbl/ft)} = \frac{D^2 - d^2}{1029.4}$$

You used this version in the first section of this book and you do the calculation exactly the same way. In this book the formula will always be given the way we just worked it out:

$$\text{Annular Capacity (bbl/ft)} = (D^2 - d^2) \div 1029.4$$

Work out the annular capacities in the following sections of a well. Round to four decimal places.

a) 6 $^5/_8$" OD drill pipe in 12 $^1/_4$" open hole.

b) 6 $^1/_4$" OD drill collar in 8 $^1/_2$" open hole.

c) 5" OD drill pipe in 9 $^5/_8$" casing (ID - 8.755").

d) 3 $^1/_2$" OD drill pipe in 7" casing (ID - 6.276").

ANSWERS

Annular Capacity (bbl/ft) = $(D^2 - d^2) \div 1029.4$

a) $(12.25^2 - 6.625^2) \div 1029.4$

$= (150.0625 - 43.890625) \div 1029.4$

$= \underline{0.1031 \text{ bbl/ft}}$

Don't forget that memory function on your calculator - the key strokes are:

6.625 x = M+ C 12.25 x = - MR = ÷ 1029.4 = to get 0.103139571

---

b) $(8.5^2 - 6.25^2) \div 1029.4$

$= (72.25 - 39.0625) \div 1029.4$

$= \underline{0.0322 \text{ bbl/ft}}$ ***or use the memory***

---

c) $(8.755^2 - 5^2) \div 1029.4$ ***remember Big D is casing ID!***

$= (76.650025 - 25) \div 1029.4$

$= \underline{0.0502 \text{ bbl/ft}}$

---

d) $(6.276^2 - 3.5^2) \div 1029.4$

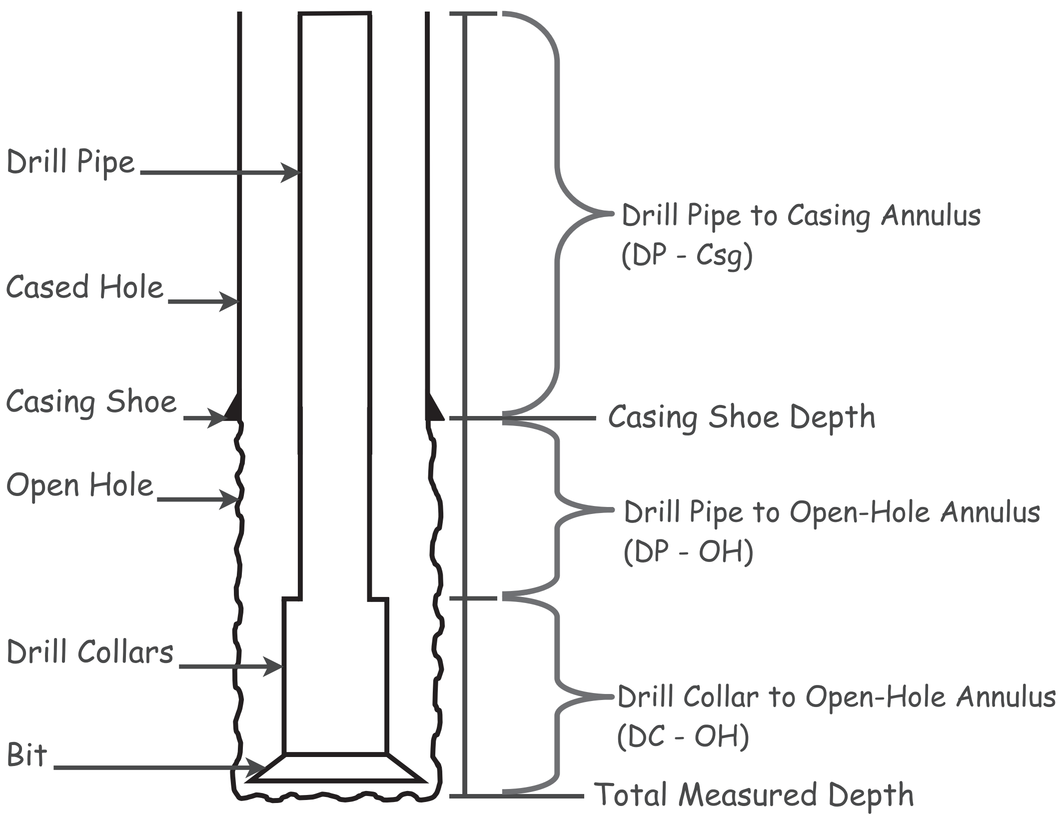
$= (39.388176 - 12.25) \div 1029.4$

$= \underline{0.0264 \text{ bbl/ft}}$

Logically, the next thing we can do is use the annular capacity to work out annular volume using the same formula we used for hole and drill string volumes:

Volume (bbl) = Capacity (bbl/ft) x Length (ft)

As with the drill string volumes a simple drawing can help. This time it will look a bit more complex.



Note there is no HWDP shown in this particular diagram. Through this book where HWDP is used in a question the OD of the HWDP will be the same as the OD of the Drill Pipe therefore the Annular Capacity will be the same. We will ignore the extra length of the tool joint and hard-banding in our volume calculations.

Annular Capacity can be worked out using the formula:

$$\text{Annular Capacity (bbl/ft)} = (D^2 - d^2) \div 1029.4$$

Annular Volume can be worked out using the formula:

$$\text{Volume (bbl)} = \text{Capacity (bbl/ft)} \times \text{Length (ft)}$$

A simple drawing of the well can help with the problem solving.

Using the page opposite (or a blank sheet if you prefer) draw a well schematic and work out how much mud will be required to fill the annulus.

Well Data

Well Measured Depth = 12,870 ft

Shoe Measured Depth = 8,540 ft

Drill Pipe: 5" OD, ID of 4.408"

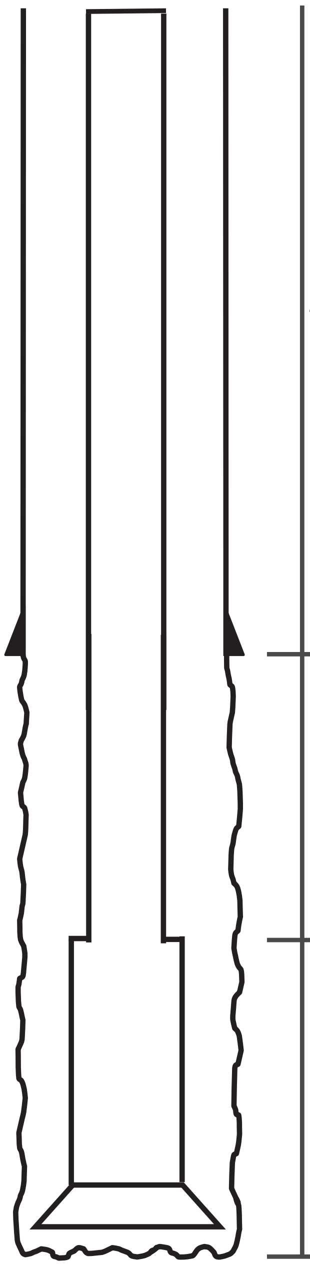
Drill Collars: 5 $^3/_4$" OD, ID of 1 $^3/_4$", 28 ft joints

Casing: 13 $^3/_8$" OD, ID of 12.715"

Bit Size: 12 $^1/_4$"

There are five stands of drill collars and the bit is on bottom.

ANSWERS



DP - Csg Annulus

Length = 8,540 ft

Annular Capacity $= (12.715^2 - 5^2) \div 1029.4$

$= (161.671225 - 25) \div 1029.4$

$= 0.1328$ bbl/ft

Volume $= 0.1328 \times 8{,}540 =$ 1,134.11 bbl

Shoe Measured Depth - 8,540 ft

DP - OH Annulus

Length = 12,870 - 8,540 - 420 = 3,910 ft

Annular Capacity $= (12.25^2 - 5^2) \div 1029.4$

$= (150.0625 - 25) \div 1029.4$

$= 0.1215$ bbl/ft

Volume $= 0.1215 \times 3{,}910 =$ 475.07 bbl

DC - OH Annulus

Length $= 28 \times 3 \times 5 = 420$ ft

Annular Capacity $= (12.25^2 - 5.75^2) \div 1029.4$

$= (150.0625 - 33.0625) \div 1029.4$

$= 0.1137$ bbl/ft

Volume $= 0.1137 \times 420 =$ 47.75 bbl

Well Measured Depth - 12,870 ft

Total Annular Volume = 1,134.11 + 475.07 + 47.75 = 1,656.93 bbl

There are a couple of points worth noting here.

Note how the length of the Drill Pipe to Open-Hole Annulus was worked out. Casing Shoe Measured Depth is subtracted away from Well Measured Depth - this will give the total length of the open hole section. The Drill Collar length is then subtracted from that to give the DP-OH annular length.

Also note that the drawing is starting to get very busy and it would be easy to get confused with all the numbers. You need to keep things clear and separate. See how a box has been drawn round the two measured depths to keep them apart from the calculations. Each calculation has been labelled and each answer has been underlined. You could use a highlighter pen if you have one to help with this.

Now it's time to join the two halves together, Drill String and Annulus, to get a complete well calculation. If you do this as one drawing then take care with the drawing as it will be busy! Do the drawing in the middle of the page with the string calculations on one side of it and the annular ones on the other. Alternatively use two drawings.

Well Data

Well Measured Depth = 10,525 ft

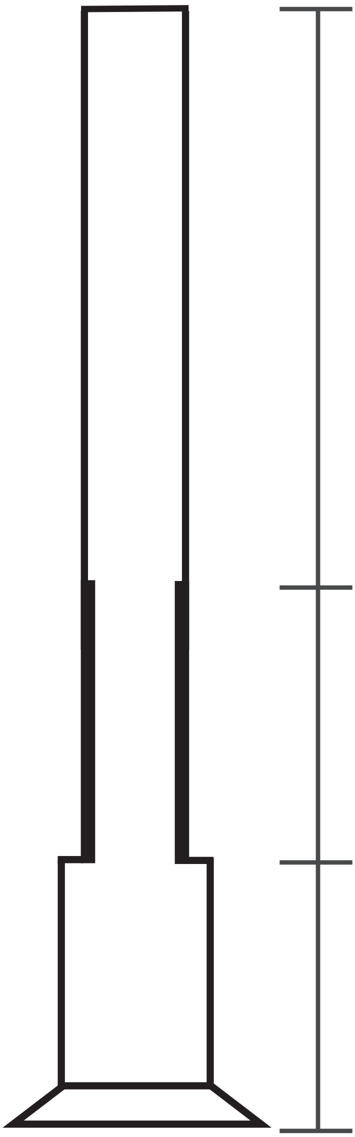
Shoe Measured Depth = 7,466 ft

Drill Pipe:	4 $^1/_2$" OD, ID of 3.958"
HWDP:	4 $^1/_2$" OD, ID of 2 $^3/_4$", 31 ft joints
Drill Collars:	6 $^3/_4$" OD, ID of 3 $^1/_4$", 28 ft joints
Casing:	9 $^5/_8$" OD, ID of 8.835"
Bit Size:	8 $^1/_4$"

There are six stands of drill collars, eight stands of HWDP and the bit is on bottom. What is the total well volume? All capacities to four decimal places.

ANSWERS

DRILL STRING VOLUMES



Drill Pipe

Length = 10,525 - 744 - 504 = 9,277 ft

Capacity = $3.958^2 \div 1029.4 = 0.0152$ bbl/ft

Volume = 0.0152 x 9,277 = 141.01 bbl

HWDP

Length = 31 x 3 x 8 = 744 ft

Capacity = $2.75^2 \div 1029.4 = 0.0073$ bbl/ft

Volume = 0.0073 x 744 = 5.43 bbl

Drill Collars

Length = 28 x 3 x 6 = 504 ft

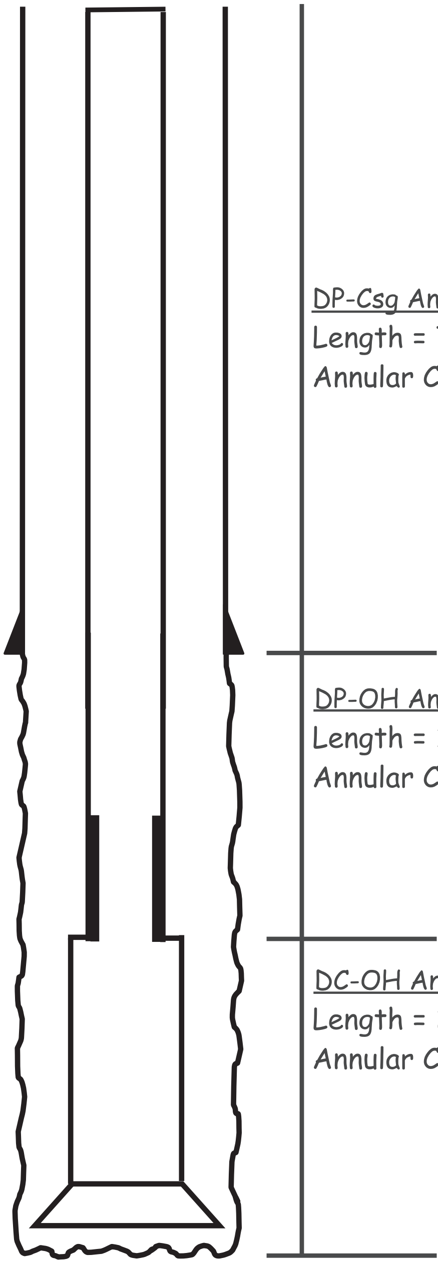
Capacity = $3.25^2 \div 1029.4 = 0.0103$ bbl/ft

Volume = 0.0103 x 504 = 5.19 bbl

Total Drill String Volume = 141.01 + 5.43 + 5.19 = 151.63 bbl

ANSWERS

ANNULAR VOLUMES



DP-Csg Annulus

Length = 7,466 ft

Annular Capacity $= (8.835^2 - 4.5^2) \div 1029.4$

$= (78.057225 - 20.25) \div 1029.4$

$= 0.0562$ bbl/ft

Volume = 0.0562 x 7,466 = 419.59 bbl

Shoe Measured Depth - 7,466 ft

DP-OH Annulus *(remember DP & HWDP have the same OD)*

Length = 10,525 - 7,466 - 504 = 2,555 ft

Annular Capacity $= (8.25^2 - 4.5^2) \div 1029.4$

$= (68.0625 - 20.25) \div 1029.4$

$= 0.0464$ bbl/ft

Volume = 0.0464 x 2,555 = 118.55 bbl

DC-OH Annulus

Length = 28 x 3 x 6 = 504 ft

Annular Capacity $= (8.25^2 - 6.75^2) \div 1029.4$

$= (68.0625 - 45.5625) \div 1029.4$

$= 0.0219$ bbl/ft

Volume = 0.0219 x 504 = 11.04 bbl

Well Measured Depth - 10,525 ft

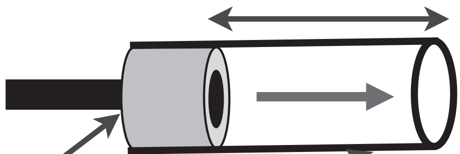
Total Annular Volume = 419.59 + 118.55 + 11.04 = 549.18 bbl

Total Well Volume = 151.63 + 549.18 = 700.81 bbl

PUMP OUTPUT

You now know how to work out drill string and annular volumes. It's time to look at the rig pumps. In this book we will look at the most common type of rig pump used in drilling - the triplex pump.

A pump works by using a tight-fitting piston to force the mud through a liner:



You will have noticed that the pump liner is a cylinder. The capacity of a cylinder can be worked out using the formula:

$$\text{Capacity (bbl/ft)} = d^2 \text{ (in)} \div 1029.4$$

The formula could be used to work out the barrels per foot output of the cylinder where d is the ID of the pump liner. The formula will work if the piston stroke length is one foot (12").

What is the liner output for a pump with a stroke length of 12" and an ID of 6"?

$$\text{Pump Liner Output} = 6^2 \div 1029.4 = \underline{0.035 \text{ bbl}}$$

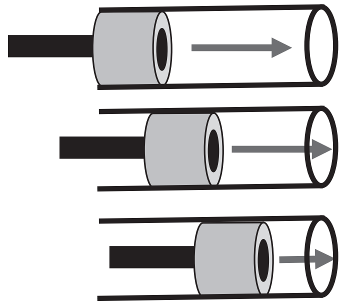
If the piston stroke length is not one foot then you need to multiply the answer by the length in feet.

$$\text{Pump Liner Output (bbl)} = d^2 \text{ (in)} \div 1029.4 \times \text{stroke length (ft)}$$

For instance, if the pump had a 10" stroke you would need to multiply the answer by 0.833 (10 ÷ 12).

$$\text{Pump Liner Output} = 6^2 \div 1029.4 \times 0.833 = \underline{0.029 \text{ bbl}}$$

A Triplex Pump has three liners and pistons all working at the same time.



In field units pump output is expressed as barrels per stroke (bbl/stk). One stroke is completed when all three liners have emptied. Writing this as a formula we get:

$$\text{Pump Output (bbl/stk)} = d^2 \text{ (in)} \div 1029.4 \times \text{stroke length (ft)} \times 3$$

Using our original information - stroke length of 12" and an ID of 6" - what is the pump output in bb/stk? (3 decimal places)

$$\text{Pump Output} = 6^2 \div 1029.4 \times 1 \times 3$$

$$= 36 \div 1029.4 \times 1 \times 3 = \underline{0.105 \text{ bbl/stk}}$$

You will have noticed that with a 12" the stroke length is 1. When you multiply something by 1 it stays the same so this part could be removed from the calculation and you would still get the same answer:

$$6^2 \div 1029.4 \times 3 = 36 \div 1029.4 \times 3 = \underline{0.105 \text{ bbl/stk}}$$

What is the pump output in bbl/stk of the following pumps? (3 decimal places)

a) stroke length = 12"; ID = 6 $^1/_2$"
b) stroke length = 8"; ID = 7"
c) stroke length = 12"; ID = 4 $^3/_4$"
d) stroke length = 12"; ID = 5 $^1/_4$"; the pump operates at 97% efficiency
e) stroke length = 10"; ID = 5 $^3/_4$"; the pump operates at 95% efficiency

ANSWERS

Pump Output (bbl/stk) = d^2 (in) ÷ 1029.4 x stroke length (ft) x 3

a) $6.5^2 \div 1029.4 \times 3$ ***(remember a 12" stroke is 1 ft so the x 1 is not needed)***

= 42.25 ÷ 1029.4 x 3 = <u>0.123 bbl/stk</u>

---

b) $7^2 \div 1029.4 \times 0.666 \times 3$ ***(remember 8 ÷ 12 = 0.666)***

= 49 ÷ 1029.4 x 0.666 x 3 = <u>0.095 bbl/stk</u>

---

c) $4.75^2 \div 1029.4 \times 3$

= 22.5625 ÷ 1029.4 x 3 = <u>0.066 bbl/stk</u>

---

d) $5.25^2 \div 1029.4 \times 3$

= 27.5625 ÷ 1029.4 x 3 = 0.08 bbl/stk

Pumps generally do not work at 100% efficiency - you will not get 100% of the theoretical volume discharged - it will be less. You need to work out the percentage:

0.08 x 97% = <u>0.078 bbl/stk</u>

---

e) $5.75^2 \div 1029.4 \times 0.833 \times 3$

= 33.0625 ÷ 1029.4 x 0.833 x 3 = 0.08 bbl/stk

0.08 x 95% = <u>0.076 bbl/stk</u>

DESCRIPTIONS OF THE WELL

There are different terms used to describe different sections of the well. So far we have seen the terms drill string volume and annular volume. When circulating mud we use some others.

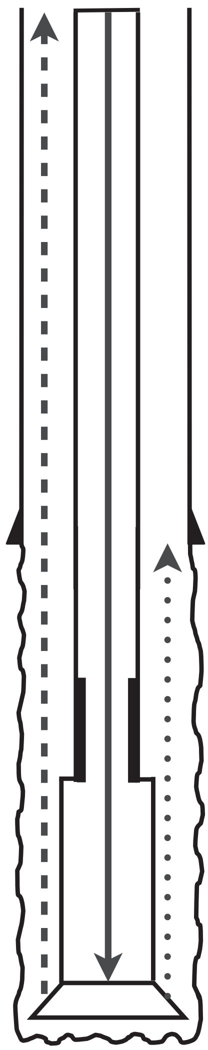
The drill string volume can also be called:

Surface to Bit

This term describes the flow path that the mud will take when it is circulated.

Generally you start at surface and pump mud to the bit.

Surface to Bit is shown as:



Annular volume can also be called:

Bit to Surface OR

Bottoms Up

These terms describe the the flow path the mud takes when it is circulated.

Once mud reaches the bit it is then circulated back up to surface.

Bit to surface (Bottoms Up) is shown as:

There is another term used in the annulus and that is:

Bit to Shoe

The mud travels from the bit to the shoe - this is the Open-Hole section of the Annulus.

Bit to Shoe is shown as:

Be aware of the different terms used.
Think about what the words are saying and visualise it in a well.

STROKE & TIME CALCULATIONS

You now know how to calculate string volume, annular volume and pump output. You also know what the various sections of the well are called.

With this information you can quite easily work out how many strokes will be needed to circulate mud round various sections of the well.

If you know the volume in barrels, and you know how many barrels per stroke you get from your pump, you simply divide the volume by the pump output and you will get the number of strokes required.

The formula for this is:

Strokes = Volume (bbl) ÷ Pump Output (bbl/stk)

If the volume required to fill the Drill String was 180.65 bbls, and the Pump Output was 0.12 bbl/stk, how many strokes (round to nearest whole stroke) would be required to pump mud from surface to bit?

Strokes = Volume (bbl) ÷ Pump Output (bbl/stk)

= 180. 65 ÷ 0.12

= <u>1505 stk</u>

The formula can be used to work out how many strokes are required to circulate any volume, not just string or annular volumes.

How many strokes would be required to pump a 25 barrel slug if the pump output was 0.115 bbl/stk? (a slug is a volume of heavier mud than regular)

Strokes = Volume (bbl) ÷ Pump Output (bbl/stk)

= 25 ÷ 0.115

= <u>217 stk</u>

Having calculated how many strokes it will take to circulate a given volume of mud the next thing you can do is work out how long this will take.

To do this you need to know how fast you are pumping, in strokes per minute (spm), then simply divide the total strokes by the spm to get the time:

Time (min) = Strokes ÷ Pump Speed (spm)

On the previous page we worked out that there were 1505 stks needed to circulate from Surface to Bit. How long would this take at 80 spm? (nearest minute)

Time (min) = Strokes ÷ Pump Speed (spm)

= 1505 ÷ 80

= 19 min

Knowing how long a circulation will take is important for planning purposes. You may circulate bottoms up before pulling out the hole. The driller will work out how long this will take and may decide to send the roughnecks off for a meal break during the circulation so everyone is ready to start tripping once bottoms up has been circulated.

Calculate the total strokes and circulation times for the following:

a) String Volume = 127.36 bbl, Pump Output = 0.119 bbl/stk, 65 spm

b) Annular Volume = 263.33 bbl. Using the information from a) above work out total well volume strokes and circulation time.

c) How many strokes, and how long, to pump a 35 bbl slug chased by the same volume of regular mud at 45 spm using the pump above?

d) String Volume = 199.54 bbl, Annular Volume = 337.29 bbl,
Pump Liner ID = 7 $^{1}/_{2}$", Pump Stroke Length = 12", 94% efficiency
What are well strokes and circulation time at 35 spm?

ANSWERS

Strokes = Volume (bbl) ÷ Pump Output (bbl/stk)

Time (min) = Strokes ÷ Pump Speed (spm)

---

a) Strokes = 127.36 ÷ 0.119 = 1,070 stk

Time = 1,070 ÷ 65 = 16 min

---

b) Well Volume = 127.36 + 263.33 = 390.69 bbl

Strokes = 390.69 ÷ 0.119 = 3,283 stk

Time = 3,283 ÷ 65 = 51 min

---

c) Total Volume = 35 + 35 = 70 bbl

Strokes = 70 ÷ 0.119 = 588 stk

Time = 588 ÷ 45 = 13 min

d) You first need to work out the pump output in bbl/stk at the given efficiency:

$$\text{Pump Output (bbl/stk)} = d^2\ (\text{in}) \div 1029.4 \times \text{stroke length (ft)} \times 3$$

$$= 7.5^2 \div 1029.4 \times 3$$

Remember, if the stroke length is 12" you don't need to multiply by stroke length

$$= 56.25 \div 1029.4 \times 3$$

$$= 0.1639 \text{ bbl/stk @ 100\% efficient}$$

$$= 0.1639 \times 94\% = \underline{0.154 \text{ bbl/stk}}$$

$$\text{Total Volume} = 199.54 + 337.29 = \underline{236.83 \text{ bbl}}$$

$$\text{Strokes} = 236.83 \div 0.154 = \underline{3{,}486 \text{ stk}}$$

$$\text{Time} = 3{,}486 \div 35 = \underline{100 \text{ min}}$$

ANNULAR VELOCITY

We have looked at pump output in terms of volume and described it as barrels per stroke (bbl/stk).

Pump output can be looked at in terms of flow and described as barrels per minute (bbl/min) - how much fluid is being pumped every minute. Monitoring return flow from the well is key to good well control. You should be getting the same return mud flow out of the well as you are pumping into the well.

We now have a situation where the same words are being used to describe two different units. This is where it becomes very important to look at the unit when using a formula. Remember the unit is the bit in brackets.

Pump Output (bbl/min) = Pump Output (bbl/stk) x SPM

If our pump speed is 80 spm and the pump output is 0.119 bbl/stk what is the bbl/min pump output?

Pump Output (bbl/min) = Pump Output (bbl/stk) x SPM

= 0.119 x 80

= <u>9.52 bbl/min</u>

This tells you that every minute you are pumping 9.52 barrels of mud into the hole. If you are in control of the well then you should be getting 9.52 barrels of mud back out the hole every minute.

If you are getting a greater return of mud from the hole every minute then the well may be kicking on you.

If you are getting less return flow from the well then you may be taking losses somewhere.

In both situations you would have to investigate what is happening but that’s not for this book to discuss.

Knowing how much mud you are pumping every minute will allow you to calculate how quickly the mud is travelling back up the annulus. This can be important for hole cleaning.

Annular Velocity in feet per minute (ft/min) can be calculated as follows:

Annular Velocity (ft/min) = Pump Output (bbl/min) ÷ Annular Capacity (bbl/ft)

Note: The pump output used in this formula is **barrels per minute (bbl/min)**.

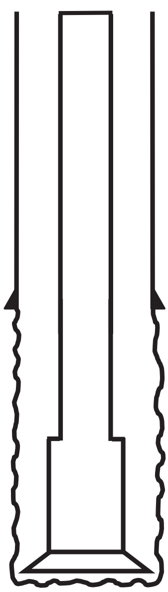
What is the Annular Velocity if the Pump Output is 9.52 bbl/min and the Annular Capacity is 0.03 bbl/ft? (nearest foot per minute)

Annular Velocity (ft/min) = Pump Output (bbl/min) ÷ Annular Capacity (bbl/ft)

= 9.52 ÷ 0.03 = 317 ft/min

As you travel up the annulus the annular capacity generally gets bigger. This means the annular velocity will slow down the closer the mud gets to surface.

Work out the annular velocity in the following hole sections if the pump speed is maintained at 120 spm:



Pump Output = 0.117 bbl/stk

a) DP - Csg: Annular Capacity = 0.0562 bbl/ft

b) DP - OH: Annular Capacity = 0.0464 bbl/ft

c) DC - OH: DC OD = 6", Bit Size = $8^1/_2$"

ANSWERS

Pump Output (bbl/min) = Pump Output (bbl/stk) x SPM

Annular Velocity (ft/min) = Pump Output (bbl/min) ÷ Annular Capacity (bbl/ft)

a) Pump Output = 0.117 x 120 = 14.04 bbl/min

Annular Velocity = 14.04 ÷ 0.0562 = 250 ft/min

---

b) Annular Velocity = 14.04 ÷ 0.0464 = 303 ft/min

---

c) You must first work out Annular Capacity:

Annular Capacity (bbl/ft) = $(D^2 - d^2) \div 1029.4$

$= (8.5^2 - 6^2) \div 1029.4$

$= (72.25 - 36) \div 1029.4$

= 0.0352 bbl/ft

Annular Velocity = 14.04 ÷ 0.0352

= 399 ft/min

Notice how the Annular Velocity decreases as you travel up the annulus. You are pumping at the same flow rate and as the annular capacity increases (the gap between the outside of the tubular and the inside of the hole or casing gets bigger) then the velocity of the mud drops.

A QUICK RECAP

The last few subjects have a strong link running through them and it is worth taking a few moments here to look at what has been covered.

The link running through them is that they are all to do with string and annular volumes. These have been described in a few different ways:

String Capacity and Volume
Annular Capacity and Volume
Pump Output
Strokes and Time
Annular Velocity

You have learned how to work out many different things from some basic well data. You will have noticed that much of the data is used across several of the calculations and that one piece of data can lead into several others.

For instance, the sizes of the hole and pipe lead to annular capacity which in turn leads to annular volume which in turn can lead to strokes, time or velocity.

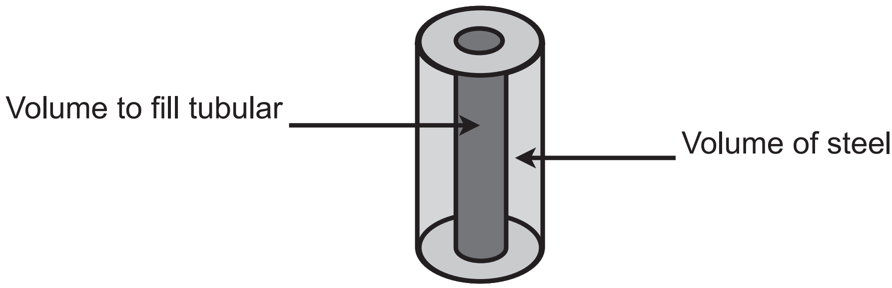
This grounding in how string and annular capacities are worked out is important in understanding the make-up of the well.

You have formulas that can help you but you are now in a position to logically work through a problem in stages even if you don't have formulas. Don't worry though, you will be given them through this book.

CAPACITIES AND DISPLACEMENTS

Let's now take a closer look at the drill string and see what it looks like. A tubular is a metal pipe with a hole through the middle of it.

There are two volumes in a tubular - the volume to fill it and the volume of the steel that actually makes up the tubular.



There are many different names used to describe these volumes. In this book the volume to fill the pipe will be called its Capacity and the volume of the steel will be called its Displacement. The unit used for both will be barrels per foot (bbl/ft).

Pipe capacity has already been talked about in great detail but why is the volume of steel called pipe displacement?

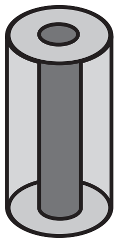
Do you remember our Greek mud logger, Archimedes? Well, he climbed into a bath full of water once and noticed that as he got in water spilled out over the side on to the floor. He then famously shouted Eureka and ran through the streets naked. Mud loggers eh - most of us would have cursed once about the mess but then carried on with our bath regardless!

The volume of water that came out the bath was equal to the volume of Archimedes - it was his displacement.

If you lower an open-ended tubular into a hole that is full of mud the pipe will fill up with mud as it is lowered. A volume of mud will be displaced out of the hole, however.

The volume of mud displaced out of the hole will be equal to the volume of the steel run into the hole - this is pipe displacement (sometimes also called steel displacement).

How can you work out Pipe Displacement? Looking at a tubular it would appear that the volume of steel could be worked out the same way you worked out Annular Capacity:



Pipe Displacement or
Annular Capacity (bbl/ft) = $(D^2 - d^2) \div 1029.4$

where Big D is the OD of the pipe and little d is its ID

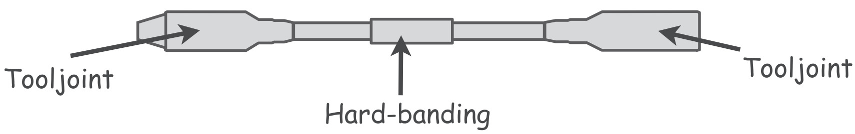
Try it for HWDP with an OD of 5" and an ID of 3".

$$\text{Pipe Displacement} = (5^2 - 3^2) \div 1029.4$$

$$= (25 - 9) \div 1029.4 = \underline{0.01554 \text{ bbl/ft}}$$

The actual displacement value for this type of HWDP is 0.01795 bbl/ft. What has caused the difference in figures?

The answer is that the actual volume of steel in a length of HWDP is more than you can calculate using the formula above due to the tooljoint and hard-banding.



So how are displacement values worked out?

Through measurement we know that one barrel of steel weighs 2,747 pounds. If we know the pounds per foot (lb/ft) weight of a tubular, we can divide that value by 2,747 to get the bbl/ft displacement.

The HWDP above weighs 49.3 lb/ft - its displacement is:

$$49.3 \div 2{,}747 = \underline{0.01795 \text{ bbl/ft}}$$

This can be done for any tubular - 2,747 is used as a conversion factor to change lb/ft into bbl/ft.

You now know how to work out string capacity, hole capacity, annular capacity and pipe displacement. There is one other term used and that is something called Closed-end Displacement.

What would happen if you were to close off the bottom end of a pipe and then run it into a hole full of mud? Would the pipe fill with mud from the hole as you run it in?

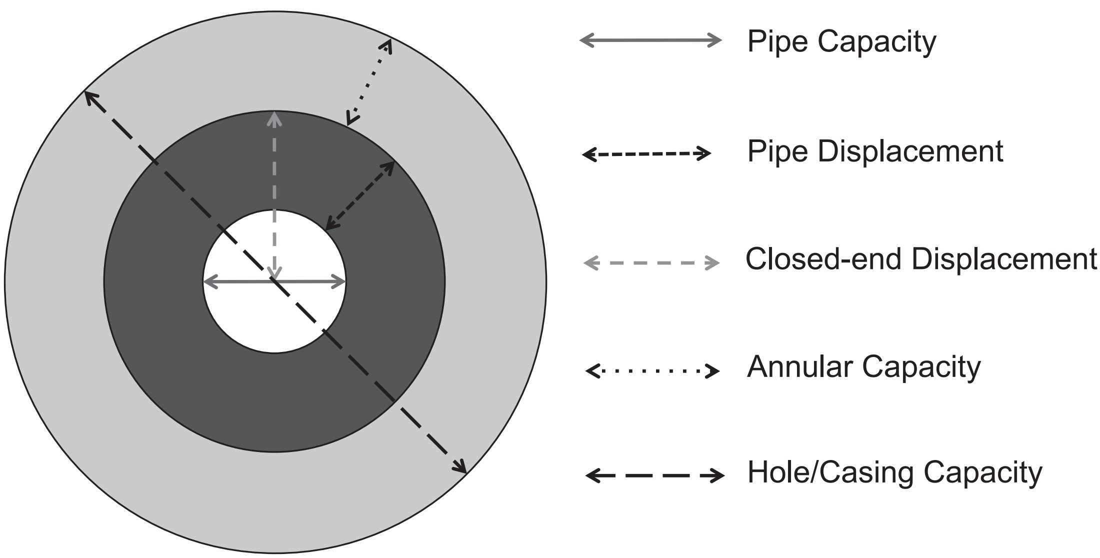
Obviously the pipe would not fill with mud from the hole because the end has been closed off and there is no way for the mud to enter the pipe from below.

What volume of mud would therefore be displaced out of the hole? The volume would be the volume of the steel (pipe displacement) **and** the volume to fill the pipe (pipe capacity). Closed-end displacement therefore is:

Closed-end Displacement (bbl/ft) = Pipe Capacity (bbl/ft) + Pipe Displacement (bbl/ft)

Closed end displacement is the volume of fluid that will be displaced when you run in the hole and the pipe cannot fill up from the hole. This will be the case if you run with a float in the string for instance.

There are five different bbl/ft capacities in a well. If you took a cross section of a well you would see the following:



CAPACITIES & DISPLACEMENTS IN THE FIELD

In the field the sizes of equipment and tools used are standard. We drill with $8^1/_2$", $12^1/_4$" & $17^1/_2$" bits across the world. Casing sizes are standard - $18^5/_8$", $13^3/_8$", $9^5/_8$" being just a few. Typical size tubulars include 5" drill pipe, 5" HWDP and drill collars ranging from $4^1/_2$" through to 12".

There are lots more than those described above but the dimensions are all known - ODs, IDs and weights in lb/ft. The capacity and displacement values are also known.

All this information is written down and can be found in data tables. These data tables are available from a number of different sources including books and on-line. There may even be some data tables in your tally book.

When you attend well control school capacities and displacement figures will also be given to you. You may, however, have to do a bit of work to get the actual number you need to answer a question!

What is the annular volume for the following section of hole?

Data: Section Length = 895 ft; Hole Capacity = 0.0702 bbl/ft;
Pipe Capacity = 0.0049 bbl/ft Pipe Displacement = 0.0332 bbl/ft

Annular Volume (bbl) = Annular Capacity (bbl/ft) x Length (ft)

You have the section length but not the annular capacity. If you subtract closed end displacement from hole capacity you will get annular capacity. Have a look at the diagram opposite if you're not sure about this.

Closed End Displacement (bbl/ft) = Pipe Capacity (bbl/ft) + Pipe Displacement (bbl/ft)

= 0.0049 + 0.0332 = <u>0.0381 bbl/ft</u>

Annular Capacity = Hole Capacity - Closed End Displacement

= 0.0702 - 0.0381 = <u>0.0321 bbl/ft</u>

Annular Volume = 0.0321 x 895 = <u>28.73 bbl</u>

TRIP SHEET CALCULATIONS

You will know from experience that the hardest physical job on a drilling rig is when you are tripping pipe in and out of the hole. You will also know that you count the pipe in and you count the pipe out. The reason for counting the pipe is so the driller knows where the bit is in relation to the well (BOP, Shoe etc). The pipe count is also used to check that nothing untoward is happening in the well during the trip.

We have already seen that mud will be displaced out of the hole as you run pipe into the hole. This mud is displaced into the trip tank and as a result the trip tank volume will go up.

The driller will calculate how much the volume should go up by and will check this against how much the actual increase is.

The pipe displacement for a certain grade of 5" drill pipe is 0.0076 bbl/ft and the stand length is 93 ft. How much mud will one stand displace into the trip tank?

Volume (bbl) = Capacity (bbl/ft) x Length (ft)

(the formula asks for capacity - displacement is the same thing a bbl/ft number)

= 0.0076 x 93 = <u>0.71 bbl</u>

In this example the trip tank volume will go up by almost $^3/_4$ of a barrel for every stand run into the hole. This could be a little tricky to check on a stand-by-stand basis so the driller will usually monitor the displacement volume every 5 stands when tripping drill pipe.

= 0.71 x 5 = <u>3.55 bbl</u>

What will the displacement per stand be for the HWDP and Drill Collars below?

HWDP Displacement - 0.0179 bbl/ft, stand length 92 ft
Drill Collar Displacement - 0.0349 bbl/ft, stand length 88 ft

HWDP: = 0.0179 x 92 = <u>1.65 bbl</u>
DC: = 0.0349 x 88 = <u>3.07 bbl</u>

Displacement volume is usually monitored every stand for HWDP & Drill Collars due to the much larger volumes displaced per stand.

The driller will work out the calculated displacement volumes for the drill pipe, HWDP & Drill Collars run into the hole and will record them on a trip sheet. During the trip the driller will then monitor the actual volume of mud displaced into the trip tank - it should be the same as he has calculated. If there are any major differences, then those will be investigated as there could be a problem down hole, such as a kick or losses.

The actual volume of mud the trip tank holds will depend on the type of rig you are working on, but will be relatively small compared to your main mud system. As mud is displaced out of the hole the trip tank is going to fill up. At some point it will be almost full and you will need to transfer some to the active system. The actual amount transferred will need to be recorded on the trip sheet so the count can continue accurately.

Trip sheets vary from company to company but will look a bit like this:

Displacement Figures	**Drill Pipe 0.0076 bbl/ft**		**HWDP 0.0179 bbl/ft**		**Drill Collars 0.0349 bbl/ft**		
Stand No	**Length Run/~~Pulled~~**	**Total Length**	**Calculated Displacement**	**Trip Tank Volume**	**Actual Displacement**	**Total Displacement**	**Difference**
0	0	0	0	5	0	0	-
5	465	465	3.5	8.5	3.5	3.5	0
10	465	930	3.5	12	3.5	7	0
15	460	1,390	3.5	15.5	3.5	10.5	0
20	463	1,853	3.5	19	3.5	14	0

In this example note how the length per 5 stands and the total (or accumulated) length run have both been recorded. The total length is worked out by adding the length just run to the previous total.

Also note that the actual displacement per 5 stands and the total displacement have both been recorded. The actual displacement has been worked out by subtracting the previous trip tank reading from the current one. Displacement is to one decimal place - as accurate as you will get on a trip tank.

Any difference between calculated and actual is noted and should be investigated.

If you had a 20 barrel trip tank you would now need to think about transferring some mud to the active pit. You would have to accurately measure how much you transferred and make a note of this on the sheet.

Displacement Figures	Drill Pipe 0.0076 bbl/ft		HWDP 0.0179 bbl/ft		Drill Collars 0.0349 bbl/ft		
Stand No	Length Run/~~Pulled~~	Total Length	Calculated Displacement	Trip Tank Volume	Actual Displacement	Total Displacement	Difference
0	0	0	0	5	0	0	-
5	465	465	3.5	8.5	3.5	3.5	0
10	465	930	3.5	12	3.5	7	0
15	460	1,390	3.5	15.5	3.5	10.5	0
20	463	1,853	3.5	19	3.5	14	0
15 bbl transferred to Active				4	-	14	0
25	468	2,321	3.6	7.6	3.6	17.6	0

Complete the trip sheet opposite to run the following drill string in the hole. Assume that all actual displacements are as calculated. The trip tank holds 20 barrels. The trip tank start volume is 4 barrels. You should transfer mud out the trip tank if you cannot displace the next amount into it. Transfer 15 bbl out each time.

Drill pipe displacement should be monitored every 5 stands. HWDP and drill collar displacement should be monitored every stand.

Drill Collars: Stand 1 = 90ft; Stand 2 = 92ft; Stand 3 = 88ft

HWDP: Stand 1 = 94ft; Stand 2 = 90ft; Stand 3 = 91ft

Drill pipe Stands: 1-5 = 465ft; 6-10 = 466ft; 11-15 = 460ft; 16-20 = 462ft

21-25 = 467ft; 26-30 = 470ft; 31-35 = 466ft; 36-40 = 461ft

41-45 = 462ft; 46-50 = 452ft; 51-55 = 462ft;

Mud Loggers remember, drill collars go in first, then HWDP then drill pipe!

Displacement Figures	Drill Pipe 0.0076 bbl/ft		HWDP 0.0179 bbl/ft		Drill Collars 0.0349 bbl/ft		
Stand No	Length Run/~~Pulled~~	Total Length	Calculated Displacement	Trip Tank Volume	Actual Displacement	Total Displacement	Difference

ANSWERS

Displacement Figures	Drill Pipe 0.0076 bbl/ft		HWDP 0.0179 bbl/ft		Drill Collars 0.0349 bbl/ft		
Stand No	Length Run/~~Pulled~~	Total Length	Calculated Displacement	Trip Tank Volume	Actual Displacement	Total Displacement	Difference
0	-	-	-	4	-	-	-
DC1	90	90	3.1	7.1	3.1	3.1	0
DC2	92	182	3.2	10.3	3.2	6.3	0
DC3	88	270	3.1	13.4	3.1	9.4	0
HWDP1	94	364	1.7	15.1	1.7	11.1	0
HWDP2	90	454	1.6	16.7	1.6	12.7	0
HWDP3	91	545	1.6	18.3	1.6	14.3	0
15 bbl transferred to active				3.3	-	14.3	0
5	465	1,010	3.5	6.8	3.5	17.8	0
10	466	1,476	3.5	10.3	3.5	21.3	0
15	460	1,936	3.5	13.8	3.5	24.8	0
20	462	2,398	3.5	17.3	3.5	28.3	0
15 bbl transferred to active				2.3	-	28.3	0
25	467	2,865	3.5	5.8	3.5	31.8	0
30	470	3,335	3.6	9.4	3.6	35.4	0
35	466	3,801	3.5	12.9	3.5	38.9	0
40	461	4,262	3.5	16.4	3.5	42.4	0
45	462	4,724	3.5	19.9	3.5	45.9	0
15 bbl transferred to active				4.9	-	45.9	0
50	452	5,176	3.4	8.3	3.4	49.3	0
55	462	5,638	3.5	11.8	3.5	52.8	0

As you trip into the hole mud is displaced out and must be monitored to ensure the correct amount is being displaced.

As you pull pipe out of the hole the level of mud will drop as you remove the pipe. One of the golden rules of well control is to ensure that the hole is kept full at all times. This is done by circulating the trip tank across the top of the hole. Mud is circulated from the trip tank, across the top of the hole and back into the trip tank thus ensuring the hole is always full.

As you pull pipe out the hole you remove a volume from the hole and this will be replaced by mud from the trip tank. This means the trip tank volume will go down. The driller will monitor the drop in the trip tank level to ensure it is as calculated. Every now and again the driller will have to transfer mud into the trip tank as it falls towards empty.

Complete the trip sheet below for a trip out the hole. Transfer 15 bbl in when the trip tank volume falls below 5 bbl. Monitor as before - trip in order shown.

DP 1-5 = 465ft; DP 6-10 = 466ft; HWDP1 = 94ft; HWDP2 = 90ft;
DC1 = 90ft; DC2 = 88ft; DC3 = 89ft

Displacement Figures	**Drill Pipe 0.0076 bbl/ft**		**HWDP 0.0179 bbl/ft**		**Drill Collars 0.0349 bbl/ft**		
Stand No	**Length ~~Run~~/Pulled**	**Total Length**	**Calculated Displacement**	**Trip Tank Volume**	**Actual Displacement**	**Total Displacement**	**Difference**
-	-	-	-	10	-	-	-

ANSWERS

Displacement Figures	Drill Pipe 0.0076 bbl/ft		HWDP 0.0179 bbl/ft		Drill Collars 0.0349 bbl/ft		
Stand No	**Length ~~Run~~/Pulled**	**Total Length**	**Calculated Displacement**	**Trip Tank Volume**	**Actual Displacement**	**Total Displacement**	**Difference**
-	-	-	-	10	-	-	-
DP5	465	465	3.5	6.5	3.5	3.5	0
DP10	466	931	3.5	3	3.5	7	0
15 bbl transferred from active				18	-	7	0
HWDP1	94	1,025	1.7	16.3	1.7	8.7	0
HWDP2	90	1,115	1.6	14.7	1.6	10.3	0
DC1	90	1,205	3.1	11.6	3.1	13.4	0
DC2	88	1,293	3.1	8.5	3.1	16.5	0
DC3	89	1,382	3.1	5.4	3.1	19.6	0

Accurate trip monitoring both in and out of the hole is one of the key responsibilities of the driller. The calculations involved are not difficult to do but accuracy and neatness are important.

When you get back to the rig have a look at some completed trip sheets. Get one of your supervisors to explain how it works on your rig. Find out what information is different from the example you have used here.

If you have never filled one in on the rig ask for a blank one and complete it either for a real trip or just make some figures up. Get one of your supervisors to check it over.

KILL SHEET VOLUME CALCULATIONS

Maintaining accurate trip monitoring is important in well control. If the displacement or hole fill are wrong on a trip then you could have a well kick situation on your hands. A kick is when formation fluid (gas in many cases) enters the well bore. We will look at well control in Book Four of this series.

However the kick got in, it will need to be circulated out. In order to circulate the kick out you need to know what your string and annular volumes are. This could be done as covered earlier, but on the rig is usually done using a kick sheet.

Your company will either have its own kick sheet or it will use one of the many standard kick sheets that are available, such as those provided by IADC or IWCF.

The kick sheet is a simple form that helps you work out the string and annular volumes for the well. The number of strokes required to circulate various sections of the well are also usually worked out on the kick sheet. It is also used to calculate some pressure calculations but these will be dealt with in Book Four.

A lot of companies require that a kill sheet is partially prepared every shift and is maintained ready in the event of a kick situation.

While kick sheets may look different and be laid out in different ways the key volume information on them all will be the same. You will always calculate:

Drill Pipe volume
HWDP volume
Drill Collar volume
drill string volume

open-hole volume
DC-OH annular volume
DP-OH annular volume
DP-Csg annular volume
annular volume

Pump output will be recorded somewhere and you can then calculate the required strokes for each section. If you know the kill rate you can calculate how long it will take. All kick sheets will have these calculations on them somewhere. We will only look at a surface kick sheet in this book.

When you attend well control school you will have to complete a kick sheet as part of the final written exam and in many cases you will also have to complete one for the practical.

The kick sheet is nothing to be scared about, particularly if you have worked honestly through this book as far as here.

You will be given some information and a blank kick sheet to complete. To work out the volume calculations you need only find two key pieces of information for each section:

the length of the section and the capacity of the tubular or annulus

Once you have this information simply put the figures into the appropriate place on the kick sheet then go ahead and do the calculations.

Usually there will be a little bit of problem solving to do first, however. You are not normally given drill pipe length for instance but you will be given the measured depth of the well and the lengths of the HWDP and drill collars.

The same goes for the annular lengths - you will have to work them out from the information given. Some kick sheets have a well diagram to help with this. If there isn't one then draw one on a sheet of paper.

Complete the volume calculations on the kick sheet opposite:

Well Measured Depth = 13,783 ft
Drill Pipe Capacity = 0.01776 bbl/ft
HWDP Capacity = 0.0087 bbl/ft; Length = 728 ft
Drill Collars Capacity = 0.0061 bbl/ft; Length = 534 ft
Shoe Measured Depth = 8,776 ft;
DP-Csg Annular Capacity = 0.0502 bbl/ft
DP-OH Annular Capacity = 0.0459 bbl/ft
DC-OH Annular Capacity = 0.0322 bbl/ft
Pump Output = 0.117 bbl/stk
Pump Kill Rate will be 35 spm

Pump Output

bbl/stk

Pump Kill Rate

spm

Strokes = Volume ÷ Pump Output

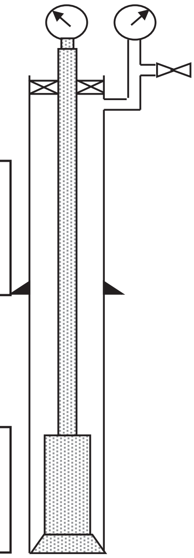
Time = Strokes ÷ Pump Kill Rate

Casing Shoe Measured Depth

feet

Well Measured Depth

feet



Volume Data	Length (feet)	x	Capacity (bbl/ft)	=	Volume (bbl)	Strokes	Time (min)
Drill Pipe							
HWDP							
Drill Collars							
Total Drill String Volume = DP + HWDP + DC							
Drill Collars - Open-Hole							
Drill Pipe - Open-Hole							
Total Open-Hole Volume = DC-OH + DP-OH							
Drill Pipe - Cased Hole							
Total Annulus Volume = DC-OH + DP-OH + DP-Csg							
Total Well Volume = Total String + Total Annulus							

ANSWERS

Pump Output	Pump Kill Rate
0.117 bbl/stk	35 spm

Strokes = Volume ÷ Pump Output

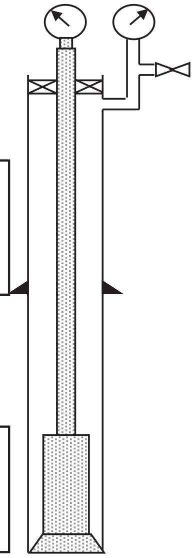
Time = Strokes ÷ Pump Kill Rate

Casing Shoe Measured Depth

8,776 feet

Well Measured Depth

13,783 feet



Volume Data	Length (feet)	x	Capacity (bbl/ft)	=	Volume (bbl)	Strokes	Time (min)
Drill Pipe	12,521		0.01776		222.37		
HWDP	728		0.0087		6.33		
Drill Collars	534		0.0061		3.26		
Total Drill String Volume = DP + HWDP + DC					231.96	1983	57
Drill Collars - Open-Hole	534		0.0322		17.19		
Drill Pipe - Open-Hole	4,473		0.0459		205.31		
Total Open-Hole Volume = DC-OH + DP-OH					222.5	1902	54
Drill Pipe - Cased Hole	8,776		0.0502		440.56		
Total Annulus Volume = DC-OH + DP-OH + DP-Csg					663.06	5,667	162
Total Well Volume = Total String + Total Annulus					895.02	7,650	219

Try to get a hold of a copy of a different type of kick sheet - ideally the one in use on your rig - and complete the volume calculations using the same data. You have the correct answers to check against.

See where the differences are but also see that the main calculations are the same on both types of kick sheet. Knowing this means you can change quickly from one kick sheet to another - all you need to do is find where the calculations are on the new sheet.

Well, it's almost test time again. This chapter has been about volumes and some of the associated calculations around volumes. Subjects have included:

Pit Volume
Hole Volume
String Capacity and Volume
Annular Capacity and Volume
Pump Output
Strokes and Time
Annular Velocity
Trip Sheet Calculations
Kill Sheet Volume Calculations

Many of these skills will now be tested. If you're unsure about any of the topics have a look back now before you start the test. All formulas needed will be given one way or another so there's no need to memorise them.

Before you start get everything ready - calculator, pen & paper and a clear space on your desk. Take a quick break then make a start. Fully worked-out answers follow the test but finish the test before looking at them.

Remember, write everything down and take your time - there is no hurry or time limit.

CHAPTER TEST

Using the data and formulas below complete the following:

1) Fill in the kick sheet opposite.

2) What is the annular velocity at kill rate in the DC-OH, DP-OH and DP-Csg annular sections?

3) How much mud will every 92ft stand of drill pipe displace into the trip tank.

4) How many barrels of mud does the trip tank hold?

Round answers as follows:

Capacities (bbl/ft) - 5 decimal places; Volume (bbl) 2 decimal places
Pump Output (bbl/stk) - 3 decimal places Strokes - whole strokes
Pump Output (bbl/min) - 2 decimal places Time (min) - whole minutes
Annular Velocity (ft/min) - whole ft/min

Well Measured Depth = 9,224 ft
Drill Pipe ID = 4.408"; Displacement = 0.0059 bbl/ft,
HWDP ID = $3^1/_4$"; Length = 566 ft
Drill Collar OD = $8^3/_4$"; ID = 2.8125"; Length = 442 ft
Shoe Measured Depth = 5,445 ft;
DP-Csg Annular Capacity = 0.1304 bbl/ft
DP-OH Annular Capacity = 0.1215 bbl/ft
Open Hole ID = $12^1/_4$"
Triplex Pump with 12" stroke, ID of $6^1/_4$" & 96% efficiency
Pump Kill Rate will be 30 spm
Trip Tank Dimensions: L = 4ft; W = 4ft; D = 10ft

String Capacity (bbl/ft) = d^2 (in) ÷ 1029.4
Annular Capacity (bbl/ft) = $(D^2 - d^2)$ ÷ 1029.4
Pump Output (bbl/stk) = d^2 (in) ÷ 1029.4 x stroke length (ft) x 3
Pump Output (bbl/min) = Pump Output (bbl/stk) x SPM
Annular Velocity (ft/min) = Pump Output (bbl/min) ÷ Annular Capacity (bbl/ft)
Volume (bbl) = Capacity (bbl/ft) x Length (ft)
Square-sided Tank Volume (bbl) = Length (ft) x Width (ft) x Depth (ft) x 0.1781

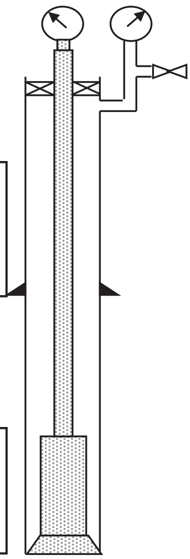
Pump Output	Pump Kill Rate
bbl/stk	spm

Strokes = Volume ÷ Pump Output

Time = Strokes ÷ Pump Kill Rate

Casing Shoe Measured Depth

feet



Well Measured Depth

feet

Volume Data	Length (feet) x	Capacity (bbl/ft) =	Volume (bbl)	Strokes	Time (min)
Drill Pipe					
HWDP					
Drill Collars					
Total Drill String Volume = DP + HWDP + DC					
Drill Collars - Open-Hole					
Drill Pipe - Open-Hole					
Total Open-Hole Volume = DC-OH + DP-OH					
Drill Pipe - Cased Hole					
Total Annulus Volume = DC-OH + DP-OH + DP-Csg					
Total Well Volume = Total String + Total Annulus					

ANSWERS

1) Before the kick sheet can be completed you will have to work out some of the data that goes on it. The information you need to work out is:

Pump Output
The capacities of all the tubulars
The drill collar to open hole annular capacity

Pump Output (bbl/stk) = d^2 (in) ÷ 1029.4 x stroke length (ft) x 3 x 96%

= $6.25^2 \div 1029.4 \times 3 \times 96\%$ = <u>0.109 bbl/stk</u>

Remember when the stroke length is 12 inches, or 1 foot, you do not need to multiply by stroke length

---

String Capacity (bbl/ft) = d^2 (in) ÷ 1029.4

Drill pipe capacity = $4.408^2 \div 1029.4$ = <u>0.01888 bbl/ft</u>

HWDP capacity = $3.25^2 \div 1029.4$ = <u>0.01026 bbl/ft</u>

Drill collar capacity = $2.8125^2 \div 1029.4$ = <u>0.00768 bbl/ft</u>

Annular Capacity (bbl/ft) = $(D^2 - d^2) \div 1029.4$

= $(12.25^2 - 8.75^2) \div 1029.4$ = <u>0.0714 bbl/ft</u>

Pump Output	Pump Kill Rate
0.109 bbl/stk	30 spm

Strokes = Volume ÷ Pump Output

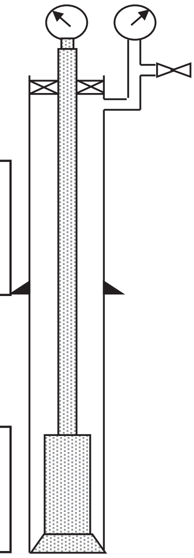
Time = Strokes ÷ Pump Kill Rate

Casing Shoe Measured Depth

5,445 feet

Well Measured Depth

9,224 feet



Volume Data	Length (feet)	x Capacity (bbl/ft)	= Volume (bbl)	Strokes	Time (min)
Drill Pipe	8,216	0.01888	155.12		
HWDP	566	0.01026	5.81		
Drill Collars	442	0.00768	3.39		
Total Drill String Volume = DP + HWDP + DC			164.32	1,507	50
Drill Collars - Open-Hole	442	0.0714	31.56		
Drill Pipe - Open-Hole	3,337	0.1215	405.45		
Total Open-Hole Volume = DC-OH + DP-OH			437.01	4,009	134
Drill Pipe - Cased Hole	5,445	0.1304	710.03		
Total Annulus Volume = DC-OH + DP-OH + DP-Csg			1,147.04	10,523	351
Total Well Volume = Total String + Total Annulus			1,311.36	12,031	401

2) Annular Velocity (ft/min) = Pump Output (bbl/min) ÷ Annular Capacity (bbl/ft)

Pump Output (bbl/min)= Pump Output (bbl/stk) x SPM

= 0.109 x 30 = <u>3.27 bbl/min</u>

Annular Velocity DC-OH = 3.27 ÷ 0.0714 = <u>46 ft/min</u>

Annular Velocity DP-OH = 3.27 ÷ 0.1215 = <u>27 ft/min</u>

Annular Velocity DP-Csg = 3.27 ÷ 0.1304 = <u>25 ft/min</u>

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3) Volume (bbl) = Capacity (bbl/ft) x Length (ft)

= 0.0059 x 92 = <u>0.54 bbl</u>

---

4) Square-sided Tank Volume (bbl) = Length (ft) x Width (ft) x Depth (ft) x 0.1781

= 4 x 4 x 10 x 0.1781

= <u>28.5 bbl</u>

FINAL SCORE

Use the marking table below to score how well you did in the chapter test.

Question	Answer	Correct or Incorrect	Value	Your Score
1 pump output	0.109 bbl/stk		3	
1 DP capacity	0.01888 bbl/ft		3	
1 HWDP capacity	0.01026 bbl/ft		3	
1 DC capacity	0.00768 bbl/ft		3	
1 DC-OH Ann Cap	0.0714 bbl/ft		3	
1 kill sheet drill string stks	1,507 stks		3	
1 kill sheet open hole stks	4,009 stks		3	
1 kill sheet total well stks	12,031 stks		3	
2 DC-OH Annular velocity	46 ft/min		3	
2 DP-OH Annular velocity	27 ft/min		3	
2 DP-Csg Annular velocity	25 ft/min		3	
3	0.54 bbl		3	
4	28.5 bbl		3	
Total Score Available = 39 Points			Your Total Score =	

Your Score = ____________ ÷ 39 x 100 = [%]

Round to the nearest whole percentage. If you scored 70% or above then you passed.

LAST WORD

So you made it to the end of the second chapter - well done again.

You are now halfway through the book, which is even better news.

This chapter has taken the calculation skills you learned in the first section and shown you how to apply them for a number of different volume calculations.

There are other volume calculations that have not been covered in this chapter, such as those needed when running casing for instance. Now you understand how volumes work you will pick these up pretty quickly when you need to.

The next chapter will introduce you to pressure calculations.

There will be some new terms but there will be some familiar ones also.

Have a break before starting the next chapter - don’t wait too long though.

No mud loggers were hurt in the making of this chapter.

NOTES

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