Formulas and Calculations for Drilling Operations

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...An elegant Euler's formula wrapped with imaginary and real numbers resulting in nothing depicts the relationship between the Creator and human intellect...

$$e^{i\pi} + 1 = 0$$

To

Cynthia, Nishanth and Sharon

Preface

This book is an introductory exposition for drilling engineers, students, lecturers, teachers, software programmers, testers, and researchers. The intent is to provide basic equations and formulas with the calculations for downhole drilling. This book may be a tutorial guide for students, to lecturers and teachers it may be a solution manual, and drilling engineers may find that it is a source for solving problems. Software programmers and testers may use it as a guide as they code, unit test, and validate their implementation, and researchers may use it as a source for further development. Of course, it is very difficult to cover all the aspects and areas of drilling, but this book aims to provide an introduction to exploring the vastness and complexity of drilling engineering. The readers are advised to refer to the books in the bibliography for more details regarding underlying theory. This book is a companion to my other books, *Drilling Engineering, Downhole Drilling Tools, Advanced Drilling Engineering,* and the upcoming *Applied Drilling Engineering Optimization.*

I am grateful to the contributors, the publisher, Phil Carmical, and copyeditor Brittyne Jackson and Mohana Sundaram from Exeter Premedia Services. Also, I thank Dr.João Carlos Plácido and Dr.Dali Gao for helping in formulating some problems. I thank them for their invaluable help. A work of this magnitude with many equations and numbers is bound to have errors even though painstaking efforts have been taken. Needless to say, I request that the readers send errors and comments in effort towards the improvement of this book.

Houston, Texas

Contents

1

Basic Calculations

This chapter focuses on different basic calculations such as buoyancy, weight, tension, etc.

1.1 Capacities

Capacities of the pipe, annular capacity, and annular volume can be calculated using the following equations.

The linear capacity of the pipe is

$$C_i = \frac{A_i}{808.5}\,\text{bbl/ft}, \tag{1.1}$$

where A_i is a cross-sectional area of the inside pipe in square inches and equals $0.7854 \times D_i^2$, and D_i is the inside diameter of the pipe in inches.

Volume capacity is

$$V = C_i \times L\ \text{bbl}, \tag{1.2}$$

where L = the length of the pipe, ft.

Annular linear capacity against the pipe is

$$C_o = \frac{A_o}{808.5} \text{ bbl/ft,} \tag{1.3}$$

where A_o, a cross-sectional area of the annulus in square inches, is

$$0.7854 \times \left(D_h^2 - D_o^2\right), \tag{1.4}$$

D_o = the outside side diameter of the pipe, in., and D_h = the diameter of the hole or the inside diameter of the casing against the pipe, in.

Annular volume capacity is

$$V = C_o \times L \text{ bbl.} \tag{1.5}$$

1.2 Displacement

1.2.1 Displacement of the Pipe Based on the Thickness of the Pipe

Open-ended displacement volume of the pipe is

$$V_o = \frac{0.7854\left(D_o^2 - D_i^2\right)}{808.5} \text{ bbl/ft.} \tag{1.6}$$

$$\text{Displacement volume} = V_o \times L \text{ bbl.} \tag{1.7}$$

Close-ended displacement volume of the pipe is

$$V_c = \frac{0.7854\left(D_o^2\right)}{808.5} \text{ bbl/ft.} \tag{1.8}$$

$$\text{Displacement volume} = V_c \times L \text{ bbl.} \tag{1.9}$$

Problem 1.1

Calculate the drill pipe capacity, open-end displacement, closed end displacement, annular volume, and total volume for the following condition: 5,000 feet of 5″ drill pipe with an inside diameter of 4.276″ inside a hole of 8½″.

Solution:

Linear capacity of pipe, using equation 1.1, is

$$C_i = \frac{A_i}{808.5} = \frac{0.7854 \times D_i^2}{808.5} = \frac{0.7854 \times 4.276^2}{808.5} = 0.017762 \text{ bbl/ft.}$$

Pipe volume capacity = 0.017762 × 5000 = 88.81 bbl.
Open-end displacement of pipe, using equation 1.6, is

$$V_o = \frac{0.7854\left(D_o^2 - D_i^2\right)}{808.5} = \frac{0.7854\left(5^2 - 4.276^2\right)}{808.5} = 0.006524 \text{ bbl/ft.}$$

Close-end displacement of pipe, using equation 1.8 is

$$V_c = \frac{0.7854\left(D_o^2\right)}{808.5} = \frac{0.7854\left(5^2\right)}{808.5} = 0.024286 \text{ bbl/ft.}$$

Annular volume, using equation 1.5 is

$$V = C_o \times L = \frac{A_o}{808.5} \times L = \frac{0.7854}{808.5} \times \left(D_h^2 - D_o^2\right) \times L$$

$$= \frac{0.7854}{808.5} \times \left(8.5^2 - 5^2\right) \times 5000 = 229.5 \text{ bbl.}$$

Total volume = Pipe volume + Annular volume = 88.81 + 229.50 = 318.31 bbl.

1.3 Buoyancy, Buoyed Weight, and Buoyancy Factor (BF)

The calculations are based on one fluid.