Rheology and Hydraulics of Oil-well Drilling Fluids

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1 Scope

1.1 The objective of this recommended practice (RP) is to provide a basic understanding of and guidance about drilling fluid rheology and hydraulics to assist with drilling wells of various complexities, including high-temperature/high-pressure (HTHP), extended-reach drilling (ERD), and highly directional wells.

1.2 Office and wellsite engineers are the target audience for this document. The complexity of the equations provided is such that a competent engineer can use simple spreadsheet programs to conduct analyses. Given that the equations used herein are constrained by this spreadsheet limitation, more advanced numerical solutions containing multiple subroutines and macros are not offered. This limitation does not suggest that only the results given by the spreadsheet methods are valid engineering solutions.

1.3 Rheology is the study of the deformation and flow of matter. For this document, rheology is the study of the flow characteristics of drilling fluids and how these characteristics affect movement of the fluids. The discussion of rheology in this document is limited to single-phase liquid flow.

1.4 Rheological properties directly affect flow characteristics and hydraulic behavior. Properties must be controlled for drilling fluids to perform their various functions. Certain properties are measured at the wellsite for monitoring and treatment and in the laboratory for development of new additives and systems, formulation for specific applications, and diagnosis of special problems.

1.5 Measurement of rheological properties also makes possible mathematical descriptions of circulating fluid flow important for the following hydraulics-related determinations:

a) calculating frictional pressure losses in pipes and annuli,

b) determining equivalent circulating density (ECD) of the drilling fluid under downhole conditions,

c) determining flow regimes,

d) estimating hole-cleaning efficiency,

e) estimating swab/surge pressures, and

f) optimizing the drilling fluid circulating system to improve drilling efficiency.

1.6 The concepts of viscosity, shear stress, and shear rate are important in understanding the flow characteristics of fluids. Specific measurements are made on fluids to determine rheological parameters under a variety of conditions. From this information, the circulating system can be designed and evaluated to accomplish desired objectives.

1.7 Drilling fluid hydraulics involves hydrostatic pressures, frictional pressure losses, carrying capacity, swab/surge pressures, and equivalent static and circulating densities, among others. Mathematical models relating shear stress to shear rate and formulas for estimating drilling fluid hydraulics are included. Calculation methods used herein consider the effects of temperature and pressure on drilling fluid rheology and density.

1.8 The U.S. customary (USC) unit system is used in this RP. However, any consistent system of units may be used where so indicated, as in the development of equations in Section 4. The term “pressure” means “gauge pressure” unless otherwise noted.

NOTE The term “consistent units” refers to a set of units that does not require an extra conversion factor to complete a calculation. In consistent International System of units (SI unit), time is expressed in seconds (s), length in meters (m), mass in kilograms (kg), force in newtons (N), temperature in degrees Celsius (°C), and absolute temperature in kelvins (K).

In USC units , time is expressed in seconds (s), length in feet (ft), mass in pound mass (lbm), force in pound force (lbf), temperature in degrees Fahrenheit (°F), and absolute temperature in degrees Rankine (°R).

1.9 Factors included in Section 3, Table 2 permit conversions of USC units to SI units or SI units to USC units.

1.10 Annexes A through F contain example calculations to illustrate how equations contained within the document can be used to model a sample well. Step-by-step procedures are not included for every case; however, final results serve as benchmarks to replicate given cases.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 13B-1, *Recommended Practice for Field Testing Water-based Drilling Fluids*

API Recommended Practice 13B-2, *Recommended Practice for Field Testing Oil-based Drilling Fluids*

3 Acronyms, Abbreviations, Symbols, Definitions, and Units

Table 1—Acronyms and Abbreviations

Abbreviation	Definition
BHA	bottomhole assembly
BOP	blowout preventer
CCI	carrying capacity index
DIN	German Institute for Standardization
ECD	equivalent circulating density
EDD	equivalent dynamic density
EMW	equivalent mud weight
ERD	extended-reach drilling
ESD	equivalent static density
H-B	Herschel–Bulkley
HHP	hydraulic horsepower
HPO	hydraulic pump-off force
HSI	hydraulic horsepower per square inch
HTHP	high-temperature/high-pressure
ID	internal diameter
LCM	lost circulation material
LOT	leak-off test
LSYP	low shear rate yield point
MD	measured depth
MWD	measurement while drilling
OD	outside diameter
PDC	polycrystalline diamond compact (cutter)
PDM	positive-displacement motor