Rheology and Hydraulics of Oil-well Fluids

API RECOMMENDED PRACTICE 13D
SIXTH EDITION, MAY 2010

AMERICAN PETROLEUM INSTITUTE

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Upstream Segment

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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, and their application to drilling operations.

1.2 The target audience for this RP covers both the office and wellsite engineer. The complexity of the equations used is such that a competent engineer can use a simple spreadsheet program to conduct the analyses. Given that the equations used herein are constrained by the spreadsheet limitation, more advanced numerical solutions containing multiple subroutines and macros are not offered. This limitation does not mean 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. Drilling fluid hydraulics pertains to both laminar and turbulent flow regimes. The methods for the calculations used herein take into account the effects of temperature and pressure on the rheology and density of the drilling fluid.

1.4 For this RP, rheology is the study of flow characteristics of a drilling fluid and how these characteristics affect movement of the fluid. Specific measurements are made on a fluid to determine rheological parameters under a variety of conditions. From this information the circulating system can be designed or evaluated regarding how it will accomplish certain desired objectives.

1.5 The purpose for updating the existing RP, last published in May 2003, is to make the work more applicable to the complex wells that are now commonly drilled. These include: High-Temperature/High-Pressure (HTHP), Extended-Reach Drilling (ERD), and High-Angle Wells (HAW). Drilling fluid rheology is important in the following determinations:

a) calculating frictional pressure losses in pipes and annuli,

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

c) determining flow regimes in the annulus,

d) estimating hole-cleaning efficiency,

e) estimating swab/surge pressures,

f) optimizing the drilling fluid circulating system for improved drilling efficiency.

1.6 The discussion of rheology in this RP is limited to single-phase liquid flow. Some commonly used concepts pertinent to rheology and flow are presented. Mathematical models relating shear stress to shear rate and formulas for estimating pressure losses, equivalent circulating densities and hole cleaning are included.

1.7 The conventional U.S. Customary (USC) unit system is used in this RP.

1.8 Conversion factors and examples are included for all calculations so that USC units can be readily converted to SI units.

Where units are not specified, as in the development of equations, any consistent system of units may be used.

1.9 The concepts of viscosity, shear stress, and shear rate are very important in understanding the flow characteristics of a fluid. The measurement of these properties allows a mathematical description of circulating fluid flow. The rheological properties of a drilling fluid directly affect its flow characteristics and all hydraulic calculations. They must be controlled for the fluid to perform its various functions.

1.10 This revised document includes some example calculations to illustrate how the equations contained within the document can be used to model a hypothetical well. Due to space constraints, it has not been possible to include a step-by-step procedure for every case. However, the final results should serve as a benchmark if the user wishes to replicate the 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/ISO 10414-1, *Recommended Practice Standard Procedure for Field Testing Water-based Drilling Fluids*

API Recommended Practice 13B-2/ISO 10414-2, *Recommended Practice Standard Procedure for Field Testing Oil-based Drilling Fluids*

API Recommended Practice 13D:2003, *Recommended Practice on the Rheology and Hydraulics of Oil-well Drilling Fluids*

API Recommended Practice 13M/ISO 13503-1, *Recommended Practice for the Measurement of Viscous Properties of Completion Fluids*

3 Terms, definitions, symbols and abbreviations

Symbol	Definition	Standard Units	Conversion Multiplier	SI Units
A	Numerator in Blasius form of friction-factor equation	dimensionless	-	dimensionless
A	Surface area	in^2	6.4516E+02	mm^2
a_1	Density correction coefficient for pressure	lb_m/gal	1.1983E+02	kg/m^3
a_2	Density correction coefficient for temperature	lb_m/gal/ºF	2.1569E+02	kg/m^3/ºC
A_b	Bit cross-sectional area	in^2	6.4516E+02	mm^2
a_p	Pipe acceleration	ft/s^2	3.048E-01	m/s^2
B	Exponent in Blasius form of friction-factor equation	dimensionless	-	dimensionless
b_1	Density correction coefficient for pressure	lb_m/gal/psi	1.7379E-02	kg/m^3/(Pa)
b_2	Density correction coefficient for temperature	lb_m/gal/psi/ºF	3.1283E-02	kg/m^3/(Pa) /ºC
B	Expansibility of the conduit			
B_a	Well geometry correction factor	dimensionless	-	dimensionless
B_x	Viscometer geometry correction factor	dimensionless	-	dimensionless
c_1	Density correction coefficient for pressure	lb_m/gal/psi^2	2.5206E-06	$kg/m^3/(Pa)^2$
c_2	Density correction coefficient for temperature	lb_m/gal/psi^2/ºF	4.5370E-06	$kg/m^3/(Pa)^2$/ºC
c_a	In-situ cuttings volume concentration	decimal fraction	-	decimal fraction
$CaCl_2$	$CaCl_2$ concentration	wt%	-	wt%
CCI	Carrying Capacity Index	-	-	-
C_{dt}	Proportionality constant for downhole tool pressure loss	-	-	-