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).