

# Executive Summary

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It has been a little over 1 year that I have been serving as an executive editor of *SPE Journal*. It has been a great experience and I am delighted for the privilege to serve the SPE Membership in this manner. I thank Randy Seright of the New Mexico Institute of Mining and Technology, Vladimir Alvarado of the University of Wyoming, and Knut-Andreas Lie of SINTEF ICT/NTNU for their excellent work as past executive editors and welcome Luis Ayala of Pennsylvania State University and Reza Fassihi of BHP Billiton as new executive editors.

This issue of *SPE Journal* contains 30 peer-reviewed papers. They are organized in five categories, although there is some overlap among a few of the papers, which cover many research topics, including drilling and completions, production and operations, geomechanics, rate and pressure transient analysis, and naturally fractured and oil-sands reservoirs. A brief description of papers in each category is presented next.

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**Drilling and Completions.** There are 12 papers in this category. Research topics include annulus hole-cleaning issues, evolution of mud-weight windows, rate of penetration (ROP), use of distributed-acoustic-sensing (DAS) and distributed-temperature-sensing (DTS) technologies, drill cuttings in horizontal wells, completion fluids, expandable profile liners, casing cement consolidation, wellbore curvature, thermal/mechanical interaction, and net present value (NPV) of well-drilling sequence.

1. Rehman et al. present the results of an experimental study that might prove of significant value for studying annulus hole-cleaning issues in the drilling industry. The authors conclude that electrical resistance tomography (ERT) and a high-speed camera provide real-time tomographic images for quantitative visualization of multiphase flow in the annulus. Comparison with actual photographs of the flow conditions in a drilling annulus indicates that ERT might have a wide potential application.

2. Liu et al. apply a dual-porosity/permeability porochemoelectroelasticity theory to predict the time evolution of mud-weight windows, while calculating stresses and pore pressure around an inclined wellbore drilled in a fractured shale formation. The effects of natural-fracture geometric and spatial distributions coupled with the chemical activity are considered in the wellbore-stability analysis. The method proposed in this paper can be used as a back-analysis tool for estimating the fracture-matrix permeability from field operational data.

3. Vromen et al.'s research indicates that dynamic analysis using a drillstring model shows that an increase in drilling efficiency and higher ROP can be obtained with the use of an antistall tool. Field results show that the antistall tool increases the ROP of drilling systems when compared with ROP in offset wells drilled without this tool. Their drillstring model, including the antistall tool, describes the coupled axial/torsional dynamics in the form of delay differential equations.

4. Raab et al. use fiber-optic DAS for monitoring well-integrity in real-time and DTS technology to monitor the cement placement. This is important because properly cemented casing strings are a key requirement for maintaining well integrity and guaranteeing optimal operation and safe provision of hydrocarbon and geothermal resources from the pay zone to surface facilities. The potential use of DAS and DTS technology in downhole evaluations would extend the portfolio to monitor and evaluate cement-integrity changes qualitatively and in real time without the necessity of executing costly well-intervention programs throughout the well's life cycle.

5. Song et al. propose a model for estimating a comprehensive sliding-friction coefficient (CSFC). During microhole-horizontal-well drilling, cuttings deposit easily at the bottom of the wellbore because of gravity and nonrotation of the pipe. The pipe sliding on the cuttings bed causes extremely serious friction between the pipe and cuttings bed, which is estimated with the CSFC. This is important because friction is a significant limiting factor on the extended length of the microhole horizontal wellbore.

6. Liu et al. present case studies indicating that cuttings can be considerably accelerated by 20 to 30 m/s through the throat, which provides a good effective speed for the cuttings. Increasing the inlet speed also improves the crushing efficiency. The inclination of the target at near 65 shows good results. This paper proposes to introduce the jet comminuting technique for drilling operations. The authors anticipate that their findings could help in guiding drilling engineering design in the future.

7. Jia et al. address the feasibility for potassium-based phosphate brines to serve as high-density solid-free well-completion fluids in high-pressure/high-temperature (HP/HT) low-permeability formations. Oil and gas reservoirs in deep-sea environments worldwide are often located in HP/HT low-permeability environments. Challenges are faced for well drilling and completion in these HP/HT reservoirs. In this paper, novel potassium-based phosphate well-completion fluids were developed. The phosphate brine shows favorable compatibility with the formation water. The biological toxicity-determination result reveals that it is only slightly toxic and is environmentally acceptable. The cost of phosphate brine is approximately 44 to 66% less than that of conventional cesium formate, bromine brine, and zinc brine.

8. Zhao et al. discuss the application of an expandable profile liner (EPL) for leakage plugging in a directional section of deep and ultradeep wells. The research is at the prototype stage. The paper uses the finite-element software Abaqus (2014) for optimizing the section of nominal diameter 5 7/8-in. (149.2-mm) EPL that can meet the plugging and strength requirements. The internal-pressure-limit test, crushing test, overall string-sealing experiment, and mechanical shaping experiment are performed, and the optimal welding procedure is developed.

9. Huang et al. show that wellbore stresses caused by cement consolidation will be underestimated when the coupling effects are neglected. The most vulnerable positions for wellbore failure are on different cylinder elements under different wellbore stages. Wellbore properties, short-term stresses, and formation creep greatly affect wellbore mechanical behaviors. Therefore, they develop a new model that provides an important basis for wellbore-failure prediction and optimal design.

10. Huang and Gao examine, and recommend considering, the combined effects of wellbore curvature, connector, and friction force on tubular buckling behavior. They indicate that the wellbore curvature affects equivalent tubular-string weight, the connector affects potential energy, and friction force leads to dissipative energy in the buckling-initiation process. Critical helical-buckling loads are most likely underestimated if the combined effects are not considered.

11. Han et al. present development of a generic thermal/mechanical interaction model that predicts the penetration rate and mechanical damage around perforation tunnels that resulted from the laser perforation of rock samples. The temperature propagation, thermal expansion, and thermal/mechanical interaction were modeled by coupling heat conduction in solid media with the elastic/plastic constitutive mechanical response rocks. The model was used to parametrically investigate the effects of material properties, stress ratio, and laser-beam characteristics on the penetration rate and mechanical damage.

12. Wang and Oliver explain the use of learned heuristics for efficient optimization of a well-drilling sequence. This is important because, when preparing a field-development plan, the forecast and NPV of the development can be sensitive to the order in which the wells are drilled. The authors explain the formulation of a sequential decision problem to find the optimal or near optimal drilling schedule in a decision tree that most likely will generate the highest NPV.

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**Production and Operations.** There are 11 papers in this category, with research topics covering biological treatment of oilfield produced water (PW), effect on hydraulic fracturing of alternating low and high stress layers, acidizing of carbonates, sand control, scale prediction, liquid holdup in inclined pipes, gas/liquid flow in pipelines, separators and cylindrical cyclones, and carbon dioxide (CO<sub>2</sub> corrosion).

1. Lusnier et al. present a comprehensive review of biological treatments of oilfield PW. Crude-oil extraction leads to the production of water (PW), whose flow rate increases along with the time of operation, up to more than 20 times the flow rate of crude oil. PW is often considered toxic because of its complex composition. At the moment, only dispersed hydrocarbons are targeted by water regulation. However, as regulations are becoming more stringent, they are also targeting dissolved compounds and/or the whole effluent toxicity. Consequently, PW treatments have to be more efficient, also allowing for high reliability of installations and high compactness (offshore processes).

2. Fu et al. investigated the apparent toughness anisotropy induced by “roughness” of in-situ stress. This is an important mechanism that hinders vertical growth of hydraulic fractures and its simplified modeling. A particular problem is the alternating low and high stress among rock layers. The authors found that a hydraulic fracture propagates horizontally in low-stress layers ahead of neighboring high-stress layers and developed a simple relationship between the apparent differential rock toughness and characteristics of the stress roughness that induce equivalent overall fracture shapes. This relationship enables existing hydraulic-fracture models to represent

the effects of rough in-situ stress on fracture growth without directly representing the fine-resolution rough-stress profiles.

3. Wan et al. performed geochemical modeling of wormhole propagation in carbonate acidizing considering mineralogy heterogeneity. In the paper, a two-scale continuum model is implemented in UTCOMP, a 3D compositional reservoir simulator, coupled with IPhreeqc, a generalized code of PHREEQC, as a module. The simulation model is validated through comparison with an analytical solution, and is permitted to investigate the effects of mineral compositions on acidizing efficiency and the wormhole-propagation process. It was found that mineralogy heterogeneity is a key factor that affects acidizing efficiency and the dissolution structure. This finding permits carbonate-acidizing optimization.

4. Gavrielatos et al. present experimental observations, during oil-production operations, regarding the formation of oil/water emulsions stabilized by nanoparticles and surfactants. Similarities and differences between the two types of emulsions are discussed on the basis of acquired separation profiles, as well as respective fluid interfacial properties. A state-of-the-art portable dispersion-characterization rig was used to run the experiments, and a surveillance camera was deployed to monitor the emulsion separation kinetics. Furthermore, a literature model was used to predict separation profiles for the oil/water dispersions and was evaluated by comparing the predictions with the acquired experimental data.

5. Shaffee et al. performed a numerical investigation of sand-screen performance in the presence of adhesive effects for enhanced sand control. They found that an increase in particle adhesion reduced the amount of solid in the liquid filtrate that passes through the opening of a wire-wrapped screen, and that a solid pack of particle agglomerates was formed over the screen with time. An important application of these findings is the design and optimization of sand-control processes for a hydrocarbon well with excessive sand production, which is a major challenge in the oil and gas industry.

6. Kan et al. present the approach and limitations of recent advances in scale prediction, which can be challenging because the predictions from different models often differ significantly at extreme conditions. Furthermore, there is a great need to accurately interpret the partitioning of water ( $H_2O$ ),  $CO_2$ , and hydrogen sulfide ( $H_2S$ ) between different phases. This paper summarizes current developments in the equation-of-state and Pitzer models to accurately model the partitioning of  $H_2O$ ,  $CO_2$ , and  $H_2S$  in hydrocarbon/aqueous phases and the aqueous ion activities at ultrahigh-temperature, ultrahigh-pressure, and mixed-electrolytes conditions.

7. Rodrigues et al. address pressure effects, pressure gradient, flow pattern, and liquid holdup on low-liquid-loading oil/gas flow in slightly upward inclined pipes. Results were compared to available predictive models. The experiments were carried out at three system pressures (1.48, 2.17, and 2.86 MPa) in a 0.155-m-inside diameter pipe inclined at  $2^\circ$  from the horizontal. Three flow patterns were observed: pseudo-slug, stratified, and annular. A relation between the measured interfacial roughness and the interfacial friction factor is proposed, and the results agree with the existing measurements.

8. Meziou et al. discuss the use of reduced-order thermal fluid dynamic modeling of two-phase gas/liquid flow in pipelines. Specifically, a two-phase-flow thermal model is coupled with a two-phase-flow hydraulics model to estimate the gas and liquid properties at each pressure and temperature condition. The proposed thermal model estimates the heat-transfer coefficient for different flow patterns observed in two-phase flow.

9. Moncayo et al. discuss modeling foam breakup in batch separators and cylindrical cyclones. Models are developed for foam breakup in a batch separator, as well as inlet-cyclone and gas/liquid-cylindrical-cyclone (GLCC) compact separators, by improving the Saint-Jalmes et al. (2000) "1-g" foam-batch-separator model. The modified batch-separator model shows a better performance with respect to experimental data than does the original model. The extended model accurately predicts experimental foam-breakup data for both the inlet-cyclone and the GLCC compact separators.

10. Vargas et al. present a paper dealing with  $CO_2$ -induced corrosion of carbon steel X65 exposed to nitrite aqueous solutions. Their results demonstrate the following: The corrosivity of nitrite strongly depends on the pH level; nitrite increases corrosion at pH of approximately 5 and is relatively benign at pH of approximately 7; nitrite reduces to ammonium (thermodynamically stable in acid solutions), whereas vanadium(III) delays the formation of ammonium; inhibited corrosion tests indicate that nitrite reduces the performance of the studied commercial corrosion inhibitors.

11. Tang et al. discuss weak bedding planes (BPs) that exist in many tight oil formations and shale-gas formations and might strongly affect fracture-height growth during hydraulic-fracturing treatment. Few of the hydraulic-fracture-propagation models developed for unconventional reservoirs are capable of quantitatively estimating the fracture-

height containment or predicting the fracture geometry under the influence of multiple BPs. In this paper, we introduce a coupled 3D hydraulic-fracture-propagation model considering the effects of BPs.

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**Geomechanics.** In reality, geomechanics applies in all topics discussed in this issue of *SPE Journal*, but the two papers presented in this category deal specifically with geomechanics—one with new triaxial-testing equipment and the other discussing a slipping fault resulting from reservoir depletion.

1. Cuello Jimenez et al. describe a methodology comprising HP/HT in-situ-triaxial-testing apparatus for the measurement of sealant mechanical properties (i.e., compressive strength, Young's modulus, and tensile strength) under simulated downhole conditions. The equipment can be used to perform both curing and testing using the same apparatus, thus eliminating depressurization and cooling of test specimens. Additionally, at minimum, three samples can be tested sequentially for statistical analysis and uncertainty mitigation, along with performing real-time monitoring of total HP/HT shrinkage/expansion. The testing apparatus is rated to 30,000 psi for axial loading; 20,000 psi for confining loading; and 400°F.

2. Zhao et al. discuss a method for evaluating the potential for fault-sliding stemming from reservoir depletion. This is an important issue faced by the oil and gas industry. Traditional views suggest that with reservoir depletion, only normal faults can be activated. This paper, however, discusses the possibility of fault-sliding-potential for different reverse or strike-slip faults, either sealing or nonsealing. The results show that all faults might be reactivated with reservoir depletion. However, the sliding risk is higher with sealing faults.

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**Rate and Pressure Transient Analysis.** The two papers in this category include a coupled thermal-reservoir analytical model, and methods for calculating distance of investigation (DOI).

1. Galvao et al. present a coupled transient wellbore/reservoir-thermal analytical model, which consists of a combined reservoir/casing/tubing system. The analytical model considers flow of a slightly compressible, single-phase fluid in a homogeneous infinite-acting reservoir system and provides temperature-transient data for drawdown and buildup tests at any gauge location along the wellbore. The model accounts for Joule-Thomson, adiabatic-fluid-expansion, conduction, and convection effects. The solutions assume moderate- to high-permeability reservoirs and do not consider skin effects in the formation. The authors claim that their model provides more accurate transient-temperature-flow profiles along the wellbore in comparison with current analytical models in the literature.

2. Yuan et al. present methods for calculating DOI considering pressure-dependency of rock and fluid properties and continuous/discontinuous spatial variation of reservoir properties. The methods are verified using a series of fine-grid numerical simulations. The methods provide an analytical approach to directly estimate the spatial heterogeneity from the production history of field cases. The authors propose a production-data-analysis workflow to analytically characterize reservoir heterogeneity and fracture properties.

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**Naturally Fractured and Oil-Sands Reservoirs.** The three papers in this category cover research associated with stress-dependent petrophysical properties and gel treatments in naturally fractured reservoirs, as well as recovery of low-temperature bitumen from oil-sands reservoirs.

1. Civan proposes a methodology for correlating stress-dependent petrophysical properties of naturally fractured or induced-fractured reservoir formations by means of a matrix/fracture dual-compressibility treatment. The author claims that his method represents the thermal effect better than the frequently used Arrhenius (1889) equation and Vogel-Tammann-Fulcher equation (Vogel 1921; Fulcher 1925; Tammann and Hesse 1926).

2. Wang et al. investigated a CO<sub>2</sub>-responsive preformed particle gel for conformance control of CO<sub>2</sub> flooding in naturally fractured reservoirs. Gel treatment is an important technique to solve early CO<sub>2</sub> breakthrough and excess-CO<sub>2</sub>-production problems caused by the low viscosity and low density of CO<sub>2</sub>, as well as the heterogeneity of reservoirs with fractures or fracture-like channels. This paper reports on gels that increase their volume after reacting with CO<sub>2</sub> (termed CO<sub>2</sub>-responsive gel) for the conformance control of CO<sub>2</sub> flooding.

3. Abdelfatah et al. discuss the use of ionic liquids (ILs) for recovery of low-temperature bitumen from oil-sands reservoirs. The authors claim that recovery from oil sands is possible at low temperatures by means of a process analogous to solution mining with the design of the proper ILs, in contrast to viscosity-reduction processes achieved by thermal methods. This work establishes the basis for developing a new class of in-situ recovery processes with high recovery efficiencies and low environmental impact.

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