RESERVOIR SOLUTIONS

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The industry debate on how to best forecast oil and gas production from tight formations has intensified recently, as evaluators pore over a growing cache of historical well data. Various supportable claims have questioned how unconventional petroleum reserves are estimated, what indicators are key parameters, including reservoir pressures and fluid properties, and whether industry is overestimating oil and gas volumes in these low-permeability reservoirs.

"Several recent claims have been made that the 'sky is falling' in Permian Basin tight oil reservoirs," said **John Lee**, a petroleum engineering professor at Texas A&M University. "Logical rebuttal has been offered by some, but skepticism remains."

Over the last decade, no one has contributed more to the body of knowledge in reserves evaluations than Lee. He discussed various recent claims at the Ryder Scott reserves conference on Sept. 13 in his presentation, "Death by Bubble Point: Fact or Fantasy."

Flow regime trumps GOR

Lee borrowed his title from a premise of petrophysicist **Scott Lapierre**, founder of Houston-based Shale Specialists LLC. Lee said that Lapierre's observation is that oil production rate begins to decline rapidly just when the gas-oil ratio (GOR) begins to increase.

"Scott's diagnosis is that higher-than-expected GORs plus lower (oil) production rates develop as the reservoir pressure drops below bubble point, thus 'bubble point death,'" said Lee.

Oil is the prize. When a well goes to gas, its economic life may be over.

"Investors are faced with a new concern – what are the long-term implications of increasing GORs and how should they affect valuations," he wrote. "It's no secret that traditional forecasting methods are flawed and a new approach is warranted to better understand the true, long-term potential of shale."

Lapierre's solution is what he calls bubble-point decline-curve analysis. His technique is described at https://www.linkedin.com/pulse/bubble-point-death-pxd-oil-mix-challenge-part-2-scott-lapierre/.

"Not everyone agrees with Scott, of course," said Lee. *Please see Permian Basin on page 2*

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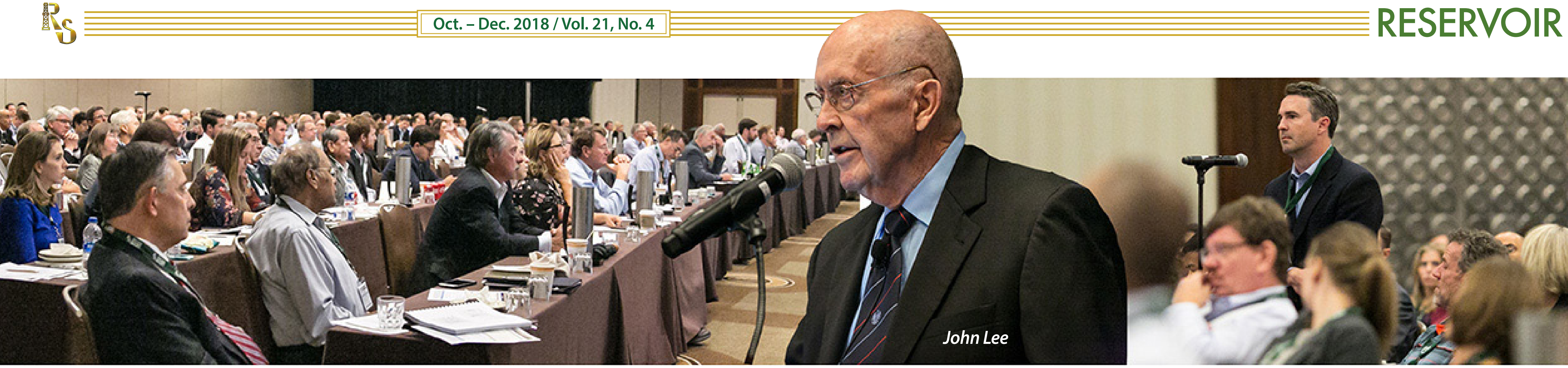


John Lee

Permian Basin – Cont. from page 1

C. Clarkson et al, in SPE Paper 178665, "An Approximate Semianalytical Multiphase Forecasting Method for Multifractured Tight Light-Oil Wells with Complex Fracture Geometry," makes a case that a change in the flow regime is the "cause of death." When transient linear flow ends, GOR increases and flow rate decreases. Flow dynamics are the real cause of accelerated oil production decline and GOR is a symptom. The study observed that below bubble point, the GOR remains constant until transient linear flow ends.

"The point is it depends on certain reservoir and completion properties and not just on the fluid and its bubble point. The situation is more complex than that," said Lee.

In transient linear flow, the fluid is draining into the fractures from the matrix in a multiple-fractured horizontal well until interference among the fractures occurs. At that point, oil rate drops and the transient linear-flow trend ceases. Reservoir permeability, length of time to fracture interference and fracture spacing determine the duration of transient linear flow, Lee explained.

Boundary-influenced flow is a "tweener"

This year, the Wood McKenzie research firm found that after five years of production, horizontal wells in the Wolfcamp deep basin experienced annual decline rates of about 14 percent. Industry has been applying 5-to7-percent terminal declines seen in older vertical wells. Higher decline rates decrease EURs (estimated ultimate recoveries) but have less effect on the five-year NPVs (net present values) because industry practice is to discount them 10 percent per year. Wood McKenzie said that the near-term effect on Permian reserves is relatively minimal, but by 2040, the firm says almost 800,000 BOPD of production will be at risk.

Lee questioned whether the wells in the study are really in terminal decline or somewhere between that and linear flow. He termed this sometimes lengthy interlude in flow dynamics "boundary influenced."

Lee added that industry may be prone to miscalculating reserves if it applies the theoretical Wattenbarger type curve to Permian Basin production. That model assumed short-duration, boundary-influenced, single-phase gas flow whereas the volatile, liquids-rich areas of the Permian experience multiphase flow.

Lee researched the Wood McKenzie claim further by analyzing it in a compositional model in a student-assisted simulation study. On a logarithmic scale, the results showed, boundary-influenced flow lasts two log cycles — a factor of more than 10 in duration.

"The effects of the boundaries are beginning to be observed. True boundary-dominated (BD) flow occurs later," said Lee. "There's just no evidence presented in the Wood McKenzie study that a well will stay on that decline for the remaining life. The evidence suggests we may be somewhere in the middle of transition and the final decline may be quite a few years into the future."

Three years ago, Lee also worked on a more rigorous compositional modeling study with one of his students that focused on fluid behavior in nano-pores. Under simulated conditions, the bubble point was depressed, GORs were compressed and relative permeability curves for gas and oil became less favorable to gas. Lee said that the key "takeaway" of that study was a very long-duration, boundary-influenced transition region. The study — published in SPE Paper 175137 in 2015 — was written by **M. Khoshghadam** et al.

Location, variation matter

Lee said, "I don't think we want to make the claim that 'one size fits all.' What kind of behavior we get when we go through bubble point (pressure) and what happens after that depend on fluid composition which varies with location."

He showed a map, published by Ground Truth Consulting LLC, indicating heterogeneity of oil production and GORs in several counties throughout the Midland Basin in the Permian. Ground Truth specializes in oilfield analytics.

Lee showed another slide by the consultant showing GORs and oil rates of four different wells in the Midland Basin. Two wells exhibited death by bubble point, two did not.

"This suggests perhaps we should minimize intuitive interpretations and proceed with a systematic, principles-based analysis," said Lee.

Physics-based models

"Back to science" is a rallying cry for evaluators who want to develop predictive geologic, reservoir-simulation and fracture-propagation models to help industry optimize field development in tight plays. To that end, the Berg-Hughes Center for Petroleum and Sedimentary Systems at Texas A&M and Core Labs plan to conduct a Delaware Basin study.

The objectives of that study are as follows:

- Develop physics-based models to predict rate and GOR and provide basis for decline curve and rate-transient analysis.
- Develop models to forecast rate and GOR as functions of time, cumulative production and other geoscience and engineering parameters.
- Determine geological controls (source, thermal history, maturity and pore size/type) on GOR and fluid composition of the reservoir using experimental and basin modeling tools.
- Infer controls and uncertainty in forecasted rates, GOR and fluid composition using data analytics.
- Predict recovery factors and how they vary regionally.

"Some organizations may lack time and resources to study the claims seriously. The joint project may assist many to reach logical, defensible conclusions," said Lee.

***Editor's Note**: Industry has been searching for answers to reliably forecast production from unconventional oil and gas reservoirs for more than a decade.*

*In 2008, **C.L. Kupchenko** et al wrote a seminal paper, "Tight Gas Production Performance Using Decline Curves," for SPE in 2008. The authors stated that "if decline analysis is performed using … transient production data, the main assumption of boundary-dominated flow (BDF) is violated and inaccurate forecasts may result."*

*A few months later in 2008, **D. Ilk** et al wrote another SPE paper, "Exponential vs. Hyperbolic Decline in Tight Gas Sands: Understanding the Origin and Implications for Reserve Estimates Using Arps' Decline Curves." It suggested that "using the hyperbolic relation by itself may not be appropriate for reserves extrapolations in tight gas reservoirs," so the Power Law method was proposed.*

That method is not designed for use with limited data. Lee said the Power Law is not easy to use, and requires fitting four parameters. Also, the final decline rate is somewhat arbitrary and difficult to determine. Since then, other methods have been proposed.

***He Zhang**, senior petroleum engineer at Ryder Scott, released the Extended Exponential Decline Curve Analysis (EEDCA) method in a 2015 SPE Paper, "An Empirical Extended Exponential Decline Curve for Shale Reservoirs." EEDC provides similar results to other DCA techniques, but is simpler and requires less effort. EEDCA is able to match early and late time well performance without any requirement to switch decline models for shale producers.*

A sunset silhouettes a pump jack in the Permian Basin. Is oil extraction there soon-to-be a sunset industry? Those analyzing flow regimes say no.


Marc Folladori

By the numbers, No. 1 issue of SEC comment letters: Reasons for changes in oil and gas reserves not specific enough

In September, **Marc Folladori**, then senior counsel at Haynes & Boone LLP, told the audience at the Ryder Scott reserves conference that the topic receiving the most comment letters from the U.S. Securities and Exchange Commission was treatment of annual changes in net quantities of total proved reserves as required by FASB ASC 932-235-50-5.

"The staff criticized many companies for their unsatisfactory explanations of reasons for annual changes in total reserves and PUDs," he said. "Where there were significant changes in categories — such as extensions, discoveries and revisions — the staff often asked for separate identification and quantification of each factor that contributed to significant changes."

Folladori annually tracks and documents SEC comment letters to oil and gas companies. For the most part, he said that SEC comments during 2017-2018 were similar to those issued the previous period.

The five-year rule for booking proved undeveloped reserves (PUDs) continued to be the subject of a good number of comments. SEC definitions require that undrilled locations can be classified as having PUDs if the company's adopted development plan indicates those locations are scheduled to be drilled within five years of their initial disclosure as PUDs.

Folladori said that in cases where a relatively large component of a company's PUDs were associated with drilled-but-uncompleted (DUC) wells, the SEC staff interpreted the "scheduled to be drilled" language to mean that wells to be drilled on those locations must be completed, and the PUDs related to those locations must be converted to developed status within five years.

The SEC also indicated in comment letters that if a company wasn't annually on track to develop its PUDS in five years or made limited progress in PUD conversions, the agency asked the company to provide support that it would meet its adopted development plan.

If the company was holding undeveloped acreage assigned to leases scheduled to expire in the near term, then SEC staff asked for explanation of the total PUDs assigned to those leases and the company's plan to extend expiration dates.

The SEC staff often inquired whether calculations of standardized measures took into account cash outflows for estimated asset retirement obligations.

FASB (Financial Accounting Standards Board) guidance requires separate disclosure of natural gas liquids (NGLs) reserves if the NGL quantities are significant, said Folladori.

"It appears that the SEC staff often construes 'significant' in this regard to mean the NGL reserves quantities equal or exceed 10 percent of a company's total proved reserves," remarked Folladori.

His and other conference presentations are posted on the Ryder Scott website at www.ryderscott.com/presentations/.

U.S. industry has bright outlook for prices and RBL

The latest survey from Haynes and Boone law firm offers a promising outlook for U.S. oil and gas producers seeking to maintain or increase their reserves-based lending (RBL) lines of bank credit.

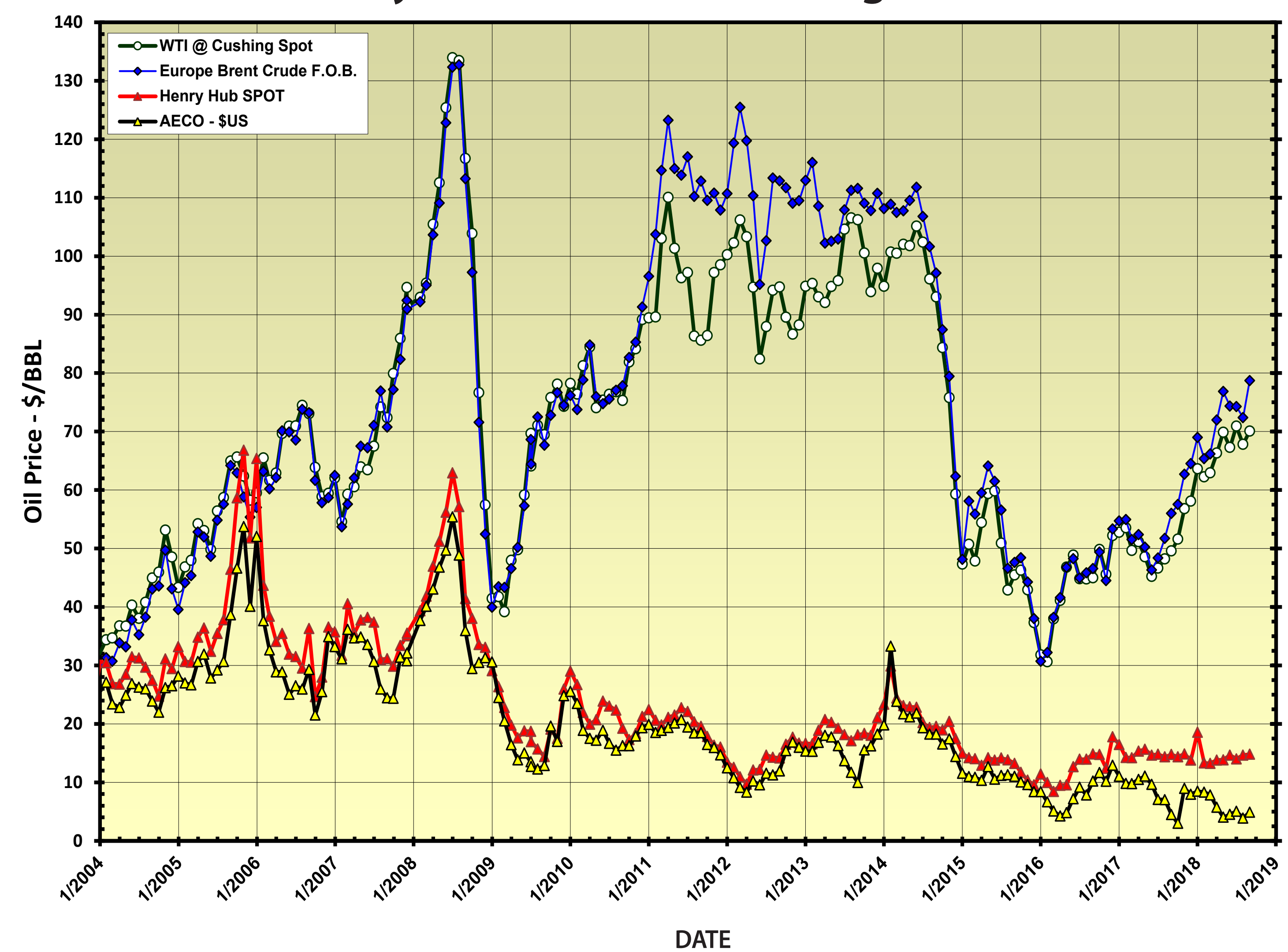
More than 78 percent of the 123 respondents expected borrowing bases to increase. Furthermore, 36 percent expect borrowing bases to increase by 20 percent or greater, which is consistent with the prior survey in April. Haynes & Boone polled producers, oilfield services companies, energy lenders, private equity firms and other industry participants and released the survey Sept. 26.

It can be accessed through a link in the press release at http://www.haynesboone.com/Press%20Releases/2018-fall-energy-roundup. Banks assess their loans twice a year to determine how much credit will be available based on the collateral values of oil and gas properties. Borrowing bases shift based on bank projections of estimated future oil and gas prices.

Other key findings from the survey were as follows:

- Strong oil prices are leading borrowers to hedge oil prices. Two-thirds of respondents indicate that borrowers have locked in prices for the majority of their 2019 production.
- Producers are expected to use cash flow from operations, bank debt, and private equity as their primary sources of capital in 2019.
- Midstream capacity constraint was, by far, the most frequently cited concern by respondents, outranking concerns related to services costs and commodity price volatility.

Price history of benchmark oil and gas in U.S. dollars



Published, monthly-average, cash market prices for WTI crude at Cushing (NYMEX), Brent crude and Henry Hub and AECO gas.

Dan Olds

No major changes in 2017 SPE-PRMS, economic limits calculated differently

The new 2017 Society of Petroleum Engineers Petroleum Resources Management System was rolled out in July, and as expected, SPE and its sister societies made no major changes, said **Dan Olds**, managing senior vice president. Olds is a member of the SPE Oil and Gas Reserves Committee. He presented the new guidelines at the Ryder Scott reserves conference in Houston in September.

"The SPE goal was to limit changes to areas requiring clarification and focus on key principles," said Olds. "There was extensive rewording in many sections of PRMS, but no material change from 2007."

One of the so-called key principles is using economic limits (EL) to estimate petroleum reserves. EL is part of the very definition of reserves.

SPE changed the way to calculate EL. In 2007, SPE termed EL as "the production rate beyond which the net operating cash flows from a project, which may be an individual well, lease, or entire field, are negative, a point in time that defines the project's economic life."

New SPE guidelines state that an EL is reached when the project's production rate reaches maximum cumulative net cash flow before consideration of ADR (abandonment, decommissioning and restoration).

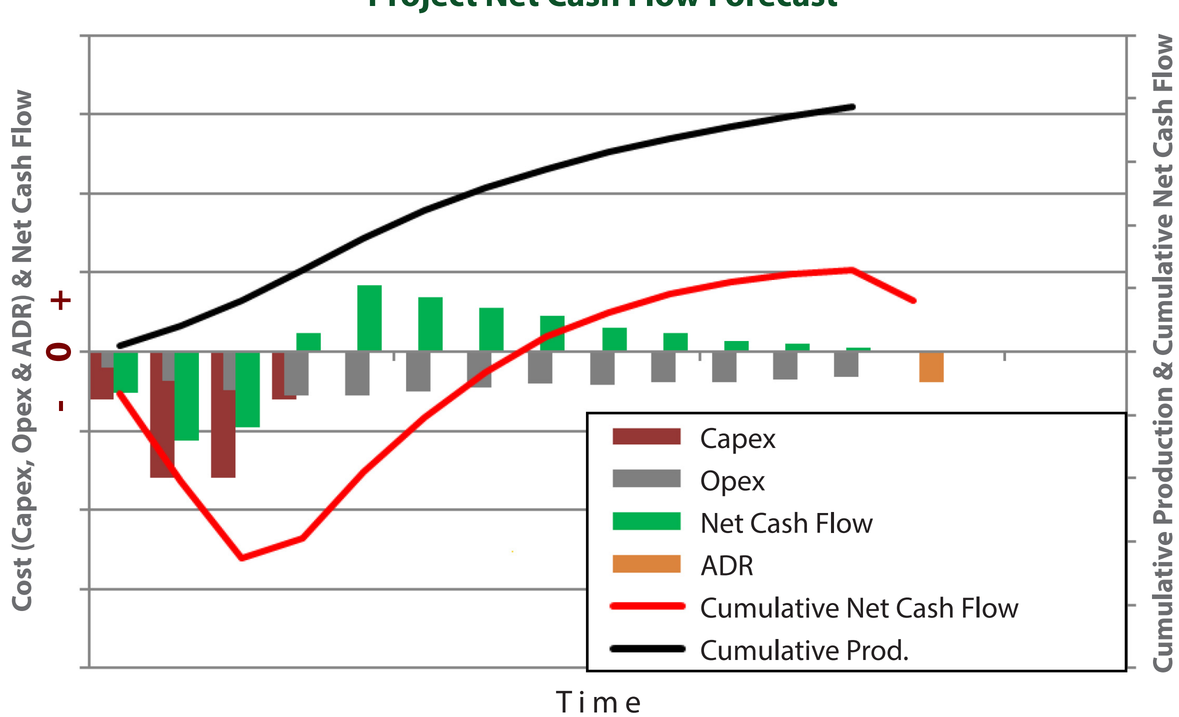
Why the change by SPE? To accommodate "periods of development capital spending, low product prices, or major operational problems, provided that the longer-term cumulative net cash flow forecast determined from the effective date becomes positive." New SPE guidelines also state that "these periods of negative cash flow (NCF) will qualify as reserves if the following positive periods more than offset the negative."

In practice, E&P companies, including public companies, were already qualifying production as reserves during temporary cashflow dips and in line with the intent of the 2007 SPE-PRMS to accommodate that.

"We see many times that an investment in a producing property results in a negative cash flow for a short period, but we expect it to go back positive and more than pay for the investment. Spending capital to install a waterflood may result in a negative NCF. However, when the project kicks in, the producer expects to get money back plus more," said Olds.

Under new SPE-PRMS guidelines, the economic limit is reached when the project's production rate reaches maximum cumulative net cash flow before consideration of ADR.

Project Net Cash Flow Forecast



Industry practice, SEC interpretation differ on how economic limits are handled

Producers' reserves booking practices using economic limits have always been consistent with industry guidelines. The new SPE-PRMS hasn't changed this. It states that "periods of negative cash flow (NCF) will qualify as reserves if the following positive periods more than offset the negative."

The U.S. Securities and Exchange Commission does not address the economic limit in its modernized rules, which are now almost a decade old. However, the agency has argued that once a project initially hits negative net cash flow, its economic life is over and the EL cutoff for proved reserves should be applied.

The SPE reconciliation process is somewhat at odds on this. The new PRMS states that "production must be economic to be considered reserves. … However, once produced, such quantities can be shown in the reconciliation process for production and revenue accounting as a positive technical revision to reserves."

SPE guidelines and SEC regulations don't have to agree, but both are used by oil and gas companies, stock markets and bankers. All factors being equal, consistency between the two simplifies internal and external bookings. Most public companies estimate 2P reserves under PRMS guidelines for business cases and 1P reserves for government-regulated external reporting.

If U.S. regulators switched their bright-line test for ELs to give more leeway to producers, that would be welcomed by industry. On the other hand, the SEC has a mission to protect investors and falling net cash flows are a red flag, not only for regulators but for all stake holders — especially cash flows that fail to climb out of the red for extended periods.

"The revision of the PRMS during 2018 may prompt the SEC to consider amendments to its oil and gas reserves disclosure rules, but this appears to be unlikely in the immediate future," said **Marc Folladori**, a Houston attorney who tracks the SEC reserves disclosure interpretations.

How temporary is temporary?

The new SPE-PRMS states that "periods of negative cash flow will qualify as reserves if the following positive periods more than offset the negative," including periods of "low product prices." Qualifying production with negative cash flows as reserves during temporary periods of low product prices can be iffy. How temporary is temporary?

The most recent lower-for-longer price period illustrates the problem. Short-term forecasts of oil and gas prices proved to be biased to the high side.

Ultimately, evaluators will have to use judgement and reasonably escalated price decks to help mitigate the effects of lower temporary prices on reserves forecasted over the field life.

SPE-PRMS glossary bolsters requirements for qualified reserves evaluators, auditors

A 16-page glossary in the new 2017 SPE-PRMS guidelines includes high-level definitions, including those for a qualified reserves auditor and evaluator. An auditor has to have at least 10 years' practical experience instead of the five required under the earlier SPE-PRMS — a 100 percent increase in years of experience. Evaluators need five years' experience, up from three in 2007.

The 2007 SPE-PRMS did not address those qualifications. However, SPE defined those terms in its guide on reserves audits, "Standards Pertaining to the Estimating and Auditing of Oil and Gas Reserves Information" in 2007.

"New standards are expected to be released shortly to conform to changes in the glossary," said **Dan Olds**.

A higher minimum for years of practice could raise the bar for hiring third-party experts to estimate reserves to file with regulatory agencies outside North America that accept SPE-PRMS guidelines.

Reserves can receive boost as learning curve grows

Producers now have an argument for boosting future net cash flows and reserves based on a concept of the manufacturing-progress function, which is more commonly called a "learning curve." The new SPE-PRMS states, "The learning curve is characterized by a decrease in time and/or costs, usually in the early stages of a project when processes are being optimized. …As the project matures, further improvements in time or cost savings are typically less substantial."

More than four years ago, Ryder Scott documented the learning-curve effect in a database analysis of the Wolfcamp horizontal-drilling play in the Permian Basin. The firm generated correlations between recoveries and several variables, including lateral lengths, frac intervals, number of frac stages, frac pressure, pounds of proppant, etc.

Ultimately, the database showed that the strongest correlations were between recovery levels and operator, taking into account varying drilling-and-completion approaches.

"That logically addresses the cumulative knowledge and operational practices of each operator," the Ryder Scott project manager said.

At that time, Wood Mackenzie also discovered a clear-cut relationship among well locations, recovery levels, operators and their D&C techniques. The research firm found that locations were not as strong of a predictor of recovery levels as the length of time operators were active in the Permian and how concentrated they were in that area.

SPE has recognized as stated in the 2017 PRMS, "In oil and gas developments with high well counts and a continuous program of activity (multi-year), the use of a learning curve within a resources evaluation may be justified to predict improvements in the time taken to carry out the activity, the cost to do so, or both."

Analytics platform used for analyzing value of asset sales package with properties in four areas of Canada

Marketed Canadian properties were in Bow River, Castle Mountain, Lake Louise and Prince areas

Ryder Scott's approach to identifying value using an analytics platform was presented by **Jean Liu Halfe**, vice president – project coordinator, at the company's Calgary reserves conference earlier this year.

Spreadsheet applications have always been effective tools for petroleum engineers. However, increasingly, the oil and gas industry is turning to other more sophisticated analytics programs.

Ryder Scott has integrated data science and analytics technologies into its work flow through the use of Tibco Spotfire. It is one of several data analytics tools on the market that include Tableau, Qlikview, Cognos and Microsoft Power BI.

Liu Halfe showed the power of using Spotfire. "Using this tool, I was able to quickly, efficiently and cost effectively analyze the value of an asset block for sale and identify which areas held the key to future growth," she said.

Traditionally, to value an asset sales package, for example, a reserves evaluator uses the seller's database, several public data sources and aggregated project data. "Handling multiple data sets in multiple formats to synthesize useful information is often a struggle," said Liu Halfe. "Indeed, just the information volume in the seller's database can be challenging to assess."

She demonstrated how a reserves evaluation engineer using Spotfire's visualization and analytics abilities can tease out key technical-performance outcomes on new plays from public databases.

"Production history from public data sources is important, because a seller's reserves database may not capture all production and injection data," she said. "Using publicly available information in concert with detailed information in a proprietary reserves database can reveal materially new knowledge for a client."

Ryder Scott constructed a Spotfire template that assists in workflow creation and has built-in ability and flexibility for project customization and quicker turnarounds. Liu Halfe showed production histories and projections in those templates. Her presentation is at ryderscott.com/presentations.

"These templates were constructed to exclude misleading production and injection information for a given reservoir," said Liu Halfe.

Output included graphs that married relevant historical production and injection information to forecast information for data streams, such as total well counts, daily oil and gas rates and average daily BOEs per well. Liu Halfe grouped wells into Bow River, Castle Mountain, Lake Louise and Prince asset packages in Canada.

"Another strength of the application is the ease in controlling the wells used in constructing a type curve. When you build a type curve you don't include everything," said Liu Halfe.

She built the type curves taking into account downtime, and reduced the data to a group of horizontal oil producers only – no injectors were included. Liu Halfe then parsed it out to the production curves.

"I was able to see my horizontal well time to boundary-dominated flow and terminal decline rate in a quick look," Liu Halfe said.

Compared to a more traditional, time-intensive spreadsheet analysis, the analytics program reduced the work time to six hours — from receipt of the reserves database and well list to the program's output comprising a high-level overview of the asset package and an analysis of material assets, the latter a key focus area, she said.

Liu Halfe also discussed quick audits of proved developed producing and undeveloped locations. She pointed out that data analytics applications do not replace geologists and engineers.

"The application is not a be-all, end-all. It's just a tool to help us," she said.

"Using this tool, I was able to quickly, efficiently and cost effectively analyze the value of an asset block for sale and identify which areas held the key to future growth,"

Jean Liu Halfe

Five engineers, two geoscientists join RS


Mark A. Nieberding

Five engineers and two geoscientists joined Ryder Scott in the third and fourth quarters of this year. **Mark A. Nieberding** joined Ryder Scott as a senior petroleum engineer. He has more than 33 years of international experience in reservoir engineering and economic evaluations, which includes estimating petroleum reserves under U.S. SEC rules and SPE-PRMS guidelines.

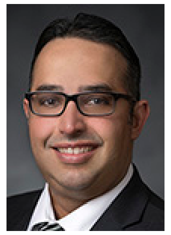
Most recently, Nieberding was a reserves planning engineer at BP Plc in the Lower 48 (U.S. states) for six years. He conducted onshore field development planning and optimization, evaluated risk categories, estimated reserves and resources volumes, analyzed capital-expenditure metrics and audited financial analysis of assets.

Before that, Nieberding was a reserves manager at Exco Resources Inc. during 2009–2012. He estimated reserves and resources and coordinated third-party auditors and reserves consultants. Nieberding ensured Sarbanes-Oxley compliance and conducted evaluations for bank loans and internal reviews.

During 2001–2009, Nieberding was a vice president at DeGolyer and MacNaughton consulting firm. He categorized, forecasted and estimated reserves and resources volumes and evaluated acquisition opportunities throughout Europe, Russia and Asia. Nieberding also taught classes on SPE-PRMS guidelines and SEC rules on reserves and resources.

He was a senior petroleum engineer at Gaffney, Cline and Associates during 1997–2001. Nieberding has BS and MS degrees in petroleum engineering from the University of Tulsa and an MBA degree from the University of Texas at Dallas.

He is a registered professional engineer in Colorado and Texas, and is a member of SPE and SPEE.


Inty Cerezo

Inty Cerezo joined Ryder Scott as a senior petroleum geoscientist. He is an expert in geo-modeling, geophysics, quantitative interpretation, workflow development and project management. Before that, Cerezo was a software technologies analyst at Schlumberger Ltd. for two years with expertise in the company's geology and modeling software platform. He was a decision-maker for implementing seismic well-tie technologies and was involved with the new quantitative rock physics and inversion interpretation capabilities.

In 2012, Cerezo was a G&G team lead at Schlumberger Information Solutions. He managed techniques, tools, processes and practices within geology and geophysics. He also conducted planning, scheduling and designing of projects and assigned work to team members.

During 2009–2012, Cerezo was a senior geo-modeler at Schlumberger, analyzing workflows in seismic interpretation and geo-modeling. He optimized and implemented new procedures and processes for information management and trained and supported field engineers and a data management team.

Cerezo also was a senior geoscientist and workflow consultant at Schlumberger in Trinidad and Tobago starting in 2005. He was involved with seismic interpretation, petrophysics, geo-modeling, log interpetation and software implementation.

Cerezo started his career with PDVSA-Intevep in 2000 as a petrophysicist and became an operations geologist in 2001. He has a geological engineering degree from the Universidad de Oriente in Venezuela.


Cecilia P. Flores

Cecilia P. Flores joined Ryder Scott as a senior petroleum engineer. She has more than 16 years of experience in multidisciplinary projects to support and help optimize exploitation plans. Previously, Flores was a consultant at the Halliburton Consulting & Project Management Division in the mature fields group supporting global operations.

During 2011–2014, she was a senior reservoir engineer for PB Energy Storage Services Inc. responsible for developing strategies for storage operations in depleted reservoirs through numerical modeling. Before that, Flores evaluated fractured, horizontal gas wells in the Haynesville shale play as a reservoir simulation engineer at Object Reservoir Inc.

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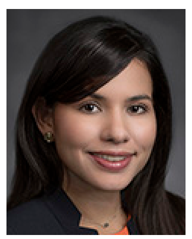
Five Engineers – Cont. from page 9

Flores began her career in 1997 as a reservoir engineer at PDVSA Intevep where she worked for six years in the numerical simulation group. She performed classical reservoir analysis of fields in Venezuela by analyzing production performance and conducting material-balance and decline-curve analyses to estimate reserves.

Flores then worked at Schlumberger Abingdon Technology Center as a simulation tester before enrolling in a graduate engineering program at Texas A&M University. After graduation, she returned to Schlumberger Ltd. as a production engineer in customer support where she solved technical issues involving mapping, plotting and estimating reserves.

Flores was also a graduate research assistant at Texas A&M. She has a BS degree from the Universidad de Oriente, Venezuela, and an MS degree from the Texas A&M, both in petroleum engineering. Flores is a member of SPE.



Mariella Infante

Mariella Infante joined Ryder Scott as a senior petroleum engineer in the reservoir simulation group. She has 12 years of experience in basic and advanced reservoir simulation, reservoir optimization, assisted history matching, reserves forecasting, optimal field development and planning.

Her work focused on 20 oil and gas fields in various countries and regions, including Venezuela, Trinidad and Tobago, Mexico, Brazil, Argentina, Colombia, U.S., Canada, U.K., Norway, West Africa and Western Siberia.

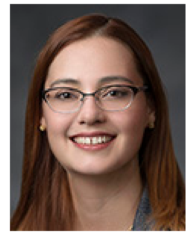
Infante worked at Schlumberger Ltd. for eight years beginning in 2006 when she was a reservoir engineer providing reservoir simulation consulting services and software support to PDVSA and joint-venture companies. In 2009, she transferred to the U.K. as a product analyst and later became a reservoir engineer in technical services.

During 2011–2013, Infante was a senior reservoir optimization engineer and provided expert guidance on reservoir optimization and characterization to Schlumberger clients in the Americas. As a technical sales engineer, she recommended advanced reservoir characterization workflows to clients, and developed and executed marketing and sales strategies for reservoir simulation services in North America.

She also worked at Southwestern Energy Co. where she conducted studies on Fayetteville and Marcellus shale areas. Before joining Ryder Scott, she was a senior reservoir engineer and conducted oil and gas reserves evaluations and economic determinations for U.S. and international projects at Miller and Lents Ltd.

Infante has a BS degree in petroleum engineering from Universidad Central de Venezuela.

Sara K. Tirado joined Ryder Scott as a senior petroleum geophysicist. She has more than 14 years of geophysics experience, including involvement in reservoir characterization, AVO analysis and trending, well time-to-depth ties, fluid substitution and generation of 1D and 2D synthetics. In addition, she conducted structural and stratigraphic seismic interpretation and mapping, prospect generation and maturation, seismic-attribute generation and analysis, seismic time processing, post-migration data conditioning, well planning and monitoring and well-level geophysical lookbacks.



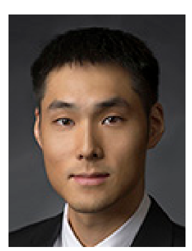
Sara K. Tirado

Before joining Ryder Scott, Tirado worked at Lumina Geophysical LLC as a principal geophysicist and manager of training and software support during 2016–2018. As part of her responsibilities, she designed and facilitated a training course on the company's software product and incorporated quantitative seismic interpretations into reservoir characterization workflows.

Tirado started her career as a geophysicist at Chevron Corp. where she worked for 12 years. Her most recent position there was senior petroleum geophysicist. Tirado examined prospect maturation in Australia and served on the post-drill exploration review team during 2012–2016. She also helped develop and interpret the first broadband seismic survey of the Carnarvon basin and passed high-grade regional leads to maturation teams. During that time, Tirado tied more than 100 wells to preferred seismic volumes. She also was a senior geophysics mentor.

During 2009–2012, she performed pre-stack depth migration and conducted data analysis and workflow parameterization for improved noise attenuation and imaging. Tirado also was a technical geophysicist in the far western and far eastern shelves in the Gulf of Mexico for five years starting in 2004.

She has a BS degree in exploration geophysics and an MS degree in geophysics, both from the University of Oklahoma. Tirado is a member of the AAPG and SEG.



Jonathan Lee

Jonathan Lee joined Ryder Scott as a senior petroleum engineer. He worked at three international oil companies (IOCs) over nine years, acquiring a wide range of experience, including serving on multi-disciplinary teams to evaluate and report portfolio-level reserves.

Lee also evaluated large-scale, deepwater field development projects and conducted waterflood studies. He performed fluid and pressure analysis, material balance, transient analysis, nodal analysis and reservoir simulation. Lee also examined reporting issues under U.S. SEC interpretations and SPE-PRMS guidelines to ensure compliance and consistent internal standards, respectively.

Before joining Ryder Scott, he was a senior economist at Shell Oil Co. Lee provided robust economic evaluations and decision analysis for major GOM deepwater projects involving infill production/injection wells and subsea tiebacks of new fields. During 2014–2017, he was reserves coordinator for Shell's upstream Americas division, ensuring delivery of SEC-compliant reserves for a wide range of assets, including unconventionals and deepwater fields. Lee also mentored staff on issues involving internal controls, audits and reserves reporting.

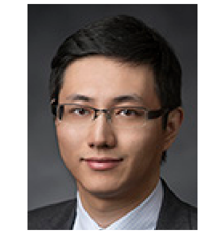
During 2011–2014, he was the reservoir engineer assigned to Shell's multidisciplinary development team for deepwater areas in Brazil. Lee performed reservoir simulation modeling to forecast production and ultimate oil-recovery distributions under different field development scenarios.

He started his career at BHP Billiton Petroleum as a reservoir engineer for the deepwater GOM in 2010. Lee evaluated 1P and 2P reserves under SEC rules using various reservoir engineering techniques.

He has a BS degree in petroleum engineering from the University at Texas at Austin and is an SPE member.

Xiaoyang (Jeremy) Xia joined Ryder Scott as a petroleum engineer. He has experience in reservoir management, field development planning and petroleum economics.

Most recently he was an associate analyst, reservoir engineer at Quantum Reservoir Impact (QRI Group) during 2015–2018. Xia worked with Pemex subsurface development teams to perform integrated reservoir studies, review business plans and evaluate key well performance and upside potential.



Xiaoyang Xia

Before that, he was a graduate research assistant at Texas A&M University starting in 2012. During that time, Xia implemented a new automatic history-match method that improved quality and speed.

He has a BS degree in chemical and biomolecular engineering from Nanyang Technological University in Singapore and an MS degree in petroleum engineering from Texas A&M. Xia is an SPE member.

Rietz named 2018 UH distinguished engineering alumnus

Dean Rietz, president, was named a 2018 University of Houston (UH) distinguished engineering alumnus earlier this year at the university's Engineering Alumni Association annual gala, which celebrated the professional achievements and contributions of Cullen College of Engineering alumni, faculty and students. Ryder Scott was a supporting sponsor of the event.

Dean Rietz addresses the audience at the annual gala of the University of Houston Engineering Alumni Association, June 7. He received a distinguished engineering alumni award for his professional achievements and contributions to the UH Cullen College of Engineering. Rietz is an adjunct professor in the graduate petroleum engineering program at UH.

Rietz has conducted reservoir simulation studies of oil and gas fields throughout the world. He has been involved with all facets of simulation such as initial model design and conceptualization, model construction, history matching, calibration and final project documentation.

Rietz headed up the formation of the Ryder Scott reservoir simulation group in 1998 when the firm recognized that the demand for those services was growing. In 2001, he and a colleague wrote a seminal SPE paper on reserves evaluations and the application of simulation, "The Adaptation of Reservoir Simulation Models for Use in Reserves Certification under Regulatory Guidelines or Reserves Definitions," (SPE 71430). The published work broke ground and was the first of four SPE papers written by Rietz and Ryder Scott co-authors.

Reservoir simulation is widely regarded as the most technically sophisticated, advanced reservoir engineering sub-discipline in the industry. However powerful, the technique is also poorly understood and suffers from misuse by those with insufficient hands-on knowledge.

Rietz was able to bridge that shortfall through teaching, presenting and mentoring. He designed his presentations to clear up misconceptions, establish the basics and delve into advanced issues.

In 2001, UH reached out to Rietz to put together a school on reservoir simulation for petroleum engineers and teach a graduate class. "I've been teaching a master's level course in petroleum engineering ever since then," said Rietz, an adjunct professor at UH.

He became further involved with UH in its drive to establish a new Bachelor of Science degree in petroleum engineering. He and **Ron Harrell**, chairman emeritus, became founding members of the UH Petroleum Engineering Advisory Board (PEAB) in 2002. PEAB and industry and community leaders began a campaign to get support for an undergraduate petroleum engineering program.

"The growing industry shortage of petroleum engineers is a result of increasing industry demand, retirements of our 'mature' engineering force and the limited capacity of the petroleum engineering universities in the U.S," stated a letter of support from Ryder Scott. "We strongly support this new program and urge the University administration to approve its formation.

Rietz and others at Ryder Scott formed Ryder Scott Company Friends of UH Petroleum Engineering, and have contributed more than $50,000 to help support the petroleum engineering program and provide student scholarships. Rietz and Harrell also made monetary contributions as members of PEAB.

The undergraduate program was approved by the Texas Higher Education Coordinating Board in 2009.

Petroleum engineering suits Rietz just fine. "I've always been a tinkerer in terms of trying to figure out how things work and so I always thought engineering was the way to go for me," he said. "But I also like the idea of being out in the elements, being outside. Petroleum engineering is probably one of the

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few disciplines where you can be outside, if you want, and you can travel the world as part of your job."

Ryder Scott conducts worldwide studies, which requires international travel at a sometimes torrid pace. However, nothing compares to the international travel schedule of Rietz when he was a 2016-2017 SPE Distinguished Lecturer. His year-long commitment consisted of 45 travel segments, with stops and overnight stays in more than 30 cities and 16 countries throughout the world.

"My participation in Engineering Week, on PEAB and as an adjunct professor is really my way of giving back. I think the UH award is recognition of what I've been doing," said Rietz.

***Ron Harrell** (left), chairman emeritus at Ryder Scott, and **Dean Rietz** at the annual gala of the University of Houston Engineering Alumni Association, June 7. Rietz received a distinguished engineering alumni award.*

Publisher's Statement

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Reservoir Solutions

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