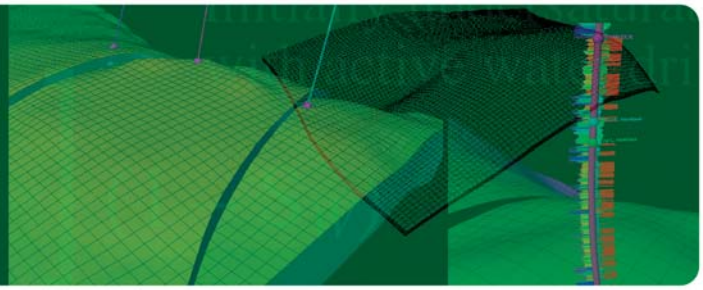
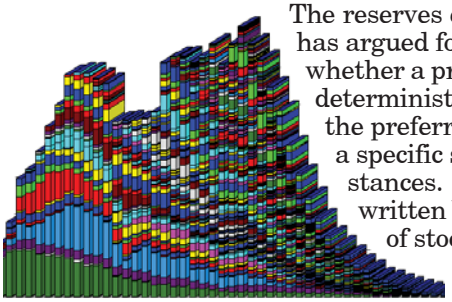
RESERVOIR SOLUTIONS



A quarterly publication of Ryder Scott Petroleum Consultants | March–May 2007/Vol. 10, No. 1

Industry in age-old debate on probabilistic vs. deterministic



The reserves evaluation sector has argued for 30 years as to whether a probabilistic or deterministic approach is the preferred method given a specific set of circumstances. Technical papers written by early adopters of stochastic methods for evaluations in the mid 1970s sparked the debate.

Most evaluators in the industry take the middle road and subscribe to both views. When the property is mature and the range of uncertainty is low, then an evaluator uses performance analysis and deterministic methods. At earlier stages when uncertainty is high, probabilistic methods are useful, especially when the properties are material to the company or evaluated entity.

Those charged with finalizing jointly sanctioned industry guidelines have had to consider a variety of recommendations, including one on probabilistic vs. deterministic. A subcommittee of the Society of Petroleum Engineers Oil and Gas Reserves Committee summarized and analyzed feedback from 60 respondents submitted during a comment period ending Feb. 1 and made a first set of revisions to the guidelines Feb. 9. After considerable debate, other revisions followed and at press time, the draft was still in flux.

Representatives of SPE, American Association of Petroleum Geologists, Society of Petroleum Evaluation Engineers and the World Petroleum Council were hammering out the final draft of new 2007 reserves guidelines for submission to the respective society boards, including the SPE board of directors, which meets March 23.

At the heart of the debate was draft language stating that best practice is to use a combination of both probabilistic and deterministic methods. Committee members also discussed issues in risking

Please see Debate on Page 8

Inside Reservoir Solutions newsletter

Credit Suisse says companies booking "new era" year-end PUDs

A Feb. 21 research report from analysts at Credit Suisse in New York stated that U.S. E&P companies are booking "new era," lower-quality proved undeveloped reserves for year-end 2006. CS cites industry's transition from higher-risk exploration to low-risk, high-cost, onshore unconventional gas reservoirs as a factor.

"PUD locations are being booked simply in conjunction with 'on-trend' acreage acquisitions, often with no wells having yet been drilled and without specific capital budget allocations," the report stated. "This acreage-driven booking process poses obvious questions regarding reserve quality."

The analysts noted that rising PUD ratios have been a familiar trend over the past eight years and are poised to increase an average of 35 percent, up from 30 percent the prior year and 23 percent in 1995. "Rising PUD ratios in 2006 will make F&D (finding-and-development) costs understated given the needed future development costs," they said.

The report noted a difference in the new PUDs vs. PUDs attributed to international and deepwater E&P projects requiring several years of capital for planned drilling in the short term, one to two years. "The economic characteristics of these newer PUDs are not well-defined and appear less certain," the analysts stated.

As a result, CS recommended looking at reserves valuations on a PUD-adjusted basis.

Consultant use for year-end work surges to all-time high

The use of consultants to audit or evaluate year-end reserves surged to an all time high a year ago, according to a recently published John S. Herold survey of annual reports. In their year-end 2005 10-K filings, more than 9 out of every 10 producers that identified sources of petroleum reserves estimates cited independent engineering consultants vs. internal engineers.

Each year, the Herold survey tracks and categorizes companies reporting to the U.S. Securities and Exchange Commission, including U.S.-listed companies outside North America. The survey, compiled from public information, cites the accounting auditor and reserves consultant for each public company.

The 92-percent figure for consultant use is a 10-percent jump from the prior year and broke the previous record of 86 percent three years ago.

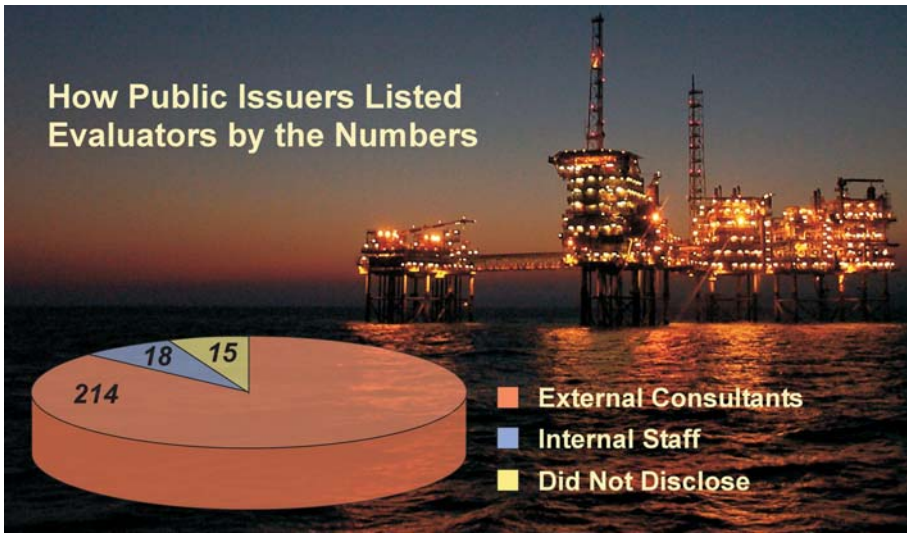
Founded in 1948, John S. Herold, a Norwalk, CT-based independent research firm, provides subscription-based financial, operational and capital-markets data on the energy industry.

The latest compilation is aggregated from 247 companies, a healthy increase from the 187 listed the year before. The survey tracked 404 companies five years ago but since then consolidation has thinned the pool.

Ryder Scott retained its top position as the most listed independent consultant of record for preparing SEC-case year-end reserves reports. The firm was listed in 45 annual reports, followed by 39, 32, 20 and 14 listings for consultants two through five, respectfully. The prior year, Ryder Scott was listed by 37 companies.

In the 2005 annual reports published in 2006, 232 of the 247 companies indicated they used either independent or internal engineers. The remaining 15 companies or 6 percent of the total did not release that information.

The 94 percent that disclosed reserves preparation sources is 2



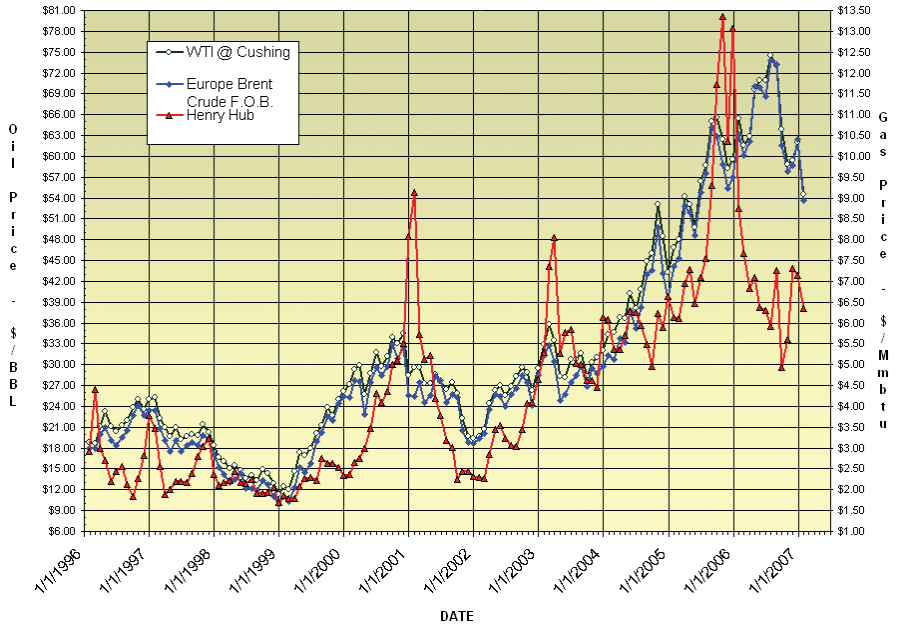
Publisher's Statement

Reservoir Solutions newsletter is published quarterly by Ryder Scott Company LP. Established in 1937, the reservoir evaluation consulting firm performs hundreds of studies a year. Ryder Scott multidisciplinary studies incorporate geophysics, petrophysics, geology, petroleum engineering, reservoir simulation and economics. With 115 employees, including 72 engineers and geoscientists, Ryder Scott has the capability to complete the largest, most complex reservoir-evaluation projects in a timely manner.

Reservoir Solutions
Editor: Mike Wysatta
Business Development Manager

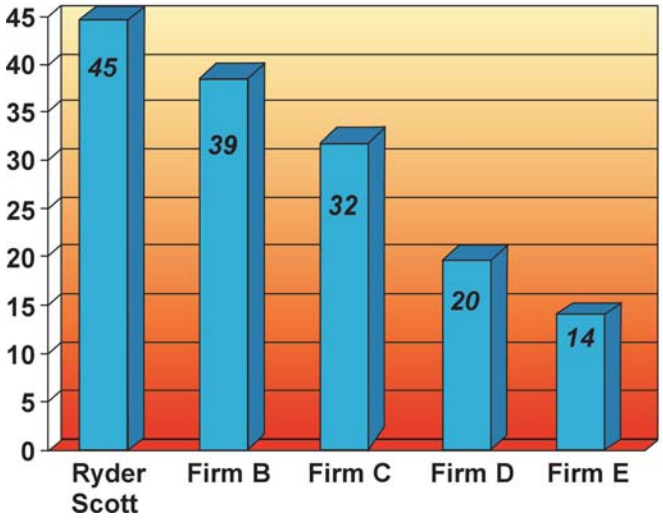
Ryder Scott Company LP
1100 Louisiana, Suite 3800
Houston, Texas 77002-5218
Phone: 713-651-9191; Fax: 713-651-0849
Denver, Colorado; Phone: 303-623-9147
Calgary, AB, Canada; Phone: 403-262-2799
E-mail: info@ryderscott.com

Price history of benchmark oil and Henry Hub gas



The historical price chart shows published, monthly-average, cash market prices for WTI crude at Cushing (NYMEX), Brent crude and Henry Hub gas.

10-K Listings for Top 5 Consultants



percent lower than the previous year. However, overall, the high percentage of disclosures indicates a continuation of transparency in reporting, especially when compared to the 18 percent that did not disclose 9 years ago.

Of those disclosing companies, 214 used engineering firms (92 percent) and 18 indicated internal preparation of year-end reports.

The five most-listed consultants collectively were used by more companies in 2005/2006, garnering 150 citations compared to 115 the prior year. That 30 percent annual increase in listings for the major consultants plus 10 percent overall annual increase quantify what industry already knows—that demand for third-party reserves-certification services is at an all-time high.

At the same time, the survey indicated that year-end reserves work in North America is spread among 47 small and large U.S. and Canadian shops compared to 46 the prior year. Increased demand for services from a fixed number of established consultants has at least one result—heavier work loads, which is supported by anecdotal evidence.

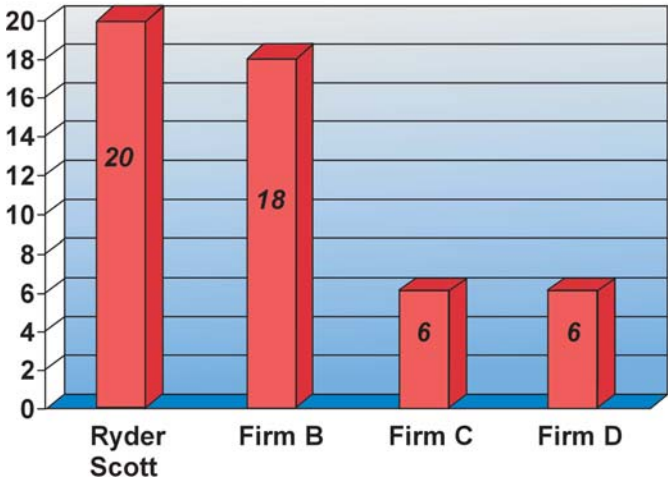
The big-company trend in using third parties to audit corporate-wide year-end reserves appears to be on the increase. The latest figures show that six of the 10 largest U.S.-registered oil and gas companies used independent consultants, the highest on record and an increase of two from the prior year.

A ranking by company size was based on the latest "OGJ200," which is an *Oil & Gas Journal* list of the largest publicly traded U.S. oil and gas producers sorted from largest to smallest by total assets. Ryder Scott was listed by four of the 10 largest companies, with no other consultant getting more than one listing.

Also, 43 of the 50 largest companies referred to outside consultants in their annual reports, an increase of eight from the previous year and the highest on record. By contrast, only 14 of the 50 largest companies cited outside consultants in their 1998 annual reports.

Ryder Scott was listed by 20 of the 50 largest companies, an increase of six from the prior year. The

Consultant Listings in 10-Ks of 50 Largest E&P Companies



second most numerous listings within the top 50 was 18 followed by two consultants with six a piece. Ryder Scott had 13 listings from the 30 largest companies followed by nine listings and five listings for two other consultants.

Since Ryder Scott has been following the survey for the past 11 years, the firm has consistently led the rest of the field as measured by the number of listed client companies and the size of those companies.

As the best available marketplace barometer, the Herold survey indicates that Ryder Scott is used more often overall and more often by large companies than any other consulting firm for preparing year-end reserve estimates in accordance with SEC guidelines.

For more information on Herold services, including its widely used annual reserves replacement cost analysis, please contact John Cannon at jcannon@herold.com or go to www.herold.com.

Editor's Note: Ryder Scott has followed the survey beginning with 1994 annual reports. At that time, Arthur Andersen compiled and published the data. Historical comparisons in this article are limited to an 11-year retrospective.

Ryder Scott start in 1937 detailed by first employee

Don May, back row, second from left, and former president John F. Buckwalter, row above front row, second from right, appear in photo of undetermined vintage.

Ryder Scott is celebrating its 70th anniversary this year. The firm incorporated in 1937 in Bradford, PA, as the first laboratory in the world devoted to solving oilfield waterflood problems.

However, much more recently, an improbable reunion enabled Ryder Scott to discover that an engineer's mistake ironically led directly to startup operations in 1936, a year before incorporation. In 2000, former Ryder Scott engineer **Donald T. May**, then 89 years old, revealed his mistake cutting well cores and the role it played in the firm's early history. He died four years later, but not before sharing his recollections, which formed the basis for an article in the September 2000 *Reservoir Solutions* newsletter.

In 2001, Don May (left) tells Jim Bryner, director of the Penn-Brad museum, about the microscope that he donated.

May had discovered a company history on the Ryder Scott Web site stating that founders **Harry M. Ryder** and **David Scott Jr.** originated chip-coring analysis, a technique developed by May. The history made no reference to May, who was hired by Scott in 1935 as the first employee.

To set the record straight, May wrote a letter to **Ron Harrell**, then CEO at Ryder Scott, narrating the genesis of the coring technique. That started a dialogue leading to an interview over two days with May close to his home in Muleshoe, TX.

Chip-coring analysis, a selective shot method for open-hole completions developed by Ryder and a modified five-spot well pattern were responsible for the uncanny success of Ryder Scott-engineered waterfloods in the Bradford field in the mid 1930s.

At that time, Ryder Scott was a producing company and so successful that other Bradford operators began asking for technical assistance. "Oil was only a couple of dollars a barrel, so Ryder and Scott figured that they could be more profitable as consultants rather than as producers," said May.

The firm continued to implement the best techniques under total engineering control to slow the production decline in the Bradford area during the 1940s. Ryder Scott used selective plugging in zones of water inflow. The firm recommended improvements in core acquisition, logging, completion practices, injection waters and pressures, well spacing and oilfield equipment.

With the Bradford area's inevitable decline in the 1950s, Ryder Scott moved to Wichita Falls, TX, to design successful secondary recovery projects. May relocated and worked there until he retired in 1967, the year Ryder Scott acquired Robert W. Harrison & Co. and moved to Houston.

A silk purse from a sow's ear

May's story begins in 1936 on a Bradford lease at a Ryder Scott cable-tool drill site. To cut away cores for lab analysis, the company used a Baker core barrel designed to hold a six-foot stack of biscuit-shaped formation pieces. May should have taken a stack of biscuits at every foot interval of the core but instead took only one. After coring 60 feet of the formation, May delivered the samples to a lab but was told that he did not have enough biscuits for a complete

analysis.

"I thought I might lose my job for not taking proper samples," said May. "Then, as I walked down the hall with the one sand biscuit in my hand, an idea came to me."

He walked into Ryder's office and told him about the mistake. May said, "While standing in front of Mr. Ryder with the biscuit, I said, 'Mr. Ryder, I believe a procedure can be found wherein all measurements can be made on this one piece of sand.' Mr. Ryder got a big smile and said, 'Don, get with it.' This made me feel like jumping to the ceiling."

May immediately changed the lab setup to begin his research. In less than a year, he figured out how to completely analyze a piece of sand the size of the end of one's little finger. Chip coring used with cable-tool drilling enabled a complete analysis to be made on a single plug of sand, providing engineers with accurate data to do their jobs.

As a result, oil recoveries were increased several fold by proper engineering of the Bradford water floods. Ryder Scott sold its oil properties by 1937 and became a consulting firm with about 40 employees almost overnight.

Ryder Scott moved to this Wichita Falls, TX, office in the 1950s. Employees from Bradford, PA, who relocated to the city complained of 100-degree heat and scorpions.

May's revelations in 2000 helped fill in some missing pieces of the early chronologies. Ryder Scott had visually identified cofounder Scott from a boxed-up stack of archived historical photos, but not Ryder. At the interview, May pointed to Ryder in a couple of photos. In that instant, if even through mere photos, the company was reunited with its primary founder after decades of estrangement.

May provided insights into the characters of Ryder, Scott and other early Ryder Scott personnel, including John F. Buckwalter, who was president from 1956 to 1972. May also discussed major Ryder Scott projects. His remarks were transcribed and have become part of the firm's corporate history.

Modern era for Ryder Scott, led by Cruce, began in 1967

Ray Cruce guided the evolution of Ryder Scott beginning in the late 1960s as it intensified its business focus on independent petroleum reserves estimations. In 1967, the firm moved from Wichita Falls, TX, to Houston after acquiring Robert W. Harrison & Co. Cruce had joined the firm from Harrison in 1966 as a partner. The "marriage" of Ryder Scott and Harrison, a consulting company known for advanced skills in reservoir evaluation, provided the right balance of skills.

Ray Cruce (sitting), former CEO, reviews company agenda in the mid 1970s with (from left) Charles Milner, a former president; William Fickert, a former senior vice president, and Harry Gaston, a former president. See Gaston's obituary on Page 8.

Cruce's background was primarily in reserves estimations. He sensed greater opportunities for that type of work, so he began contacting financial institutions after becoming chairman of the board and president in 1972.

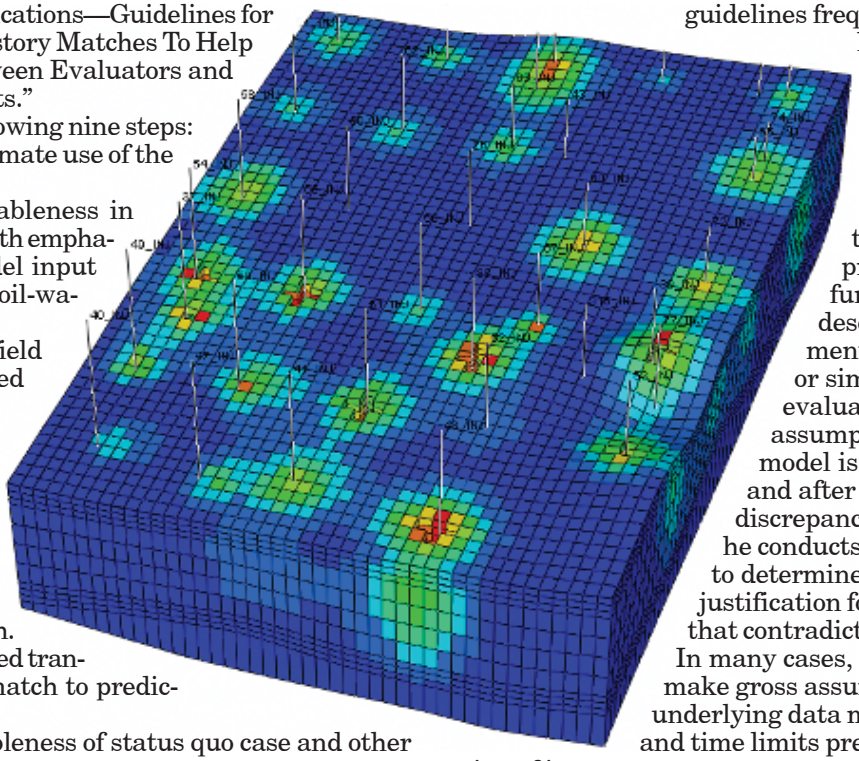
New York investment bankers and commercial lenders, keen on reducing risks in reserves-based lending, listened to Cruce, whose personality and credibility helped open doors. They became convinced that third-party certification was the best method of establishing a reasonable value for petroleum properties used as collateral.

Reservoir evaluations became the mainstay of the firm as bankers recommended to their clients that they obtain reports from reputable consultants as prerequisites for loan considerations. Ryder Scott's name became a standard on most bankers' lists of qualified evaluators. Cruce retired in 2000 and died in 2003.

Evaluating reservoir simulation history matches—Part 1

A reservoir simulation model can be a powerful tool to assist in estimating and booking petroleum reserves, but with conditions. "According to the SEC (U.S. Securities and Exchange Commission), proved reserves can be derived from a model only if it features a good history match," said **Dean Rietz**, managing senior vice president at Ryder Scott and manager of the reservoir simulation group. "Of course, in addition to reviewing the history match, the evaluator has to examine the geological model and how it was constructed among other tasks."

Rietz and **Adnan Usmani**, petroleum engineer, outlined a systematic review of the history match in their SPE paper No. 96410, "Reservoir Simulation and Reserves Classifications—Guidelines for Reviewing Model History Matches To Help Bridge the Gap Between Evaluators and Simulation Specialists."



They cite the following nine steps:
1. Determine the ultimate use of the model results.
2. Check for reasonableness in model construction with emphasis on pertinent model input parameters, such as oil-water contact.
3. Assess quality of field pressure and produced volume match.
4. Assess quality of local (well) pressure and saturation match, as warranted.
5. Look for reasonableness in modifications to achieve match.
6. Review the simulated transition from history match to prediction mode.
7. Evaluate reasonableness of status quo case and other forecast cases.
8. Assess overall quality and validity of model.
9. Use results as analogy to actual field.

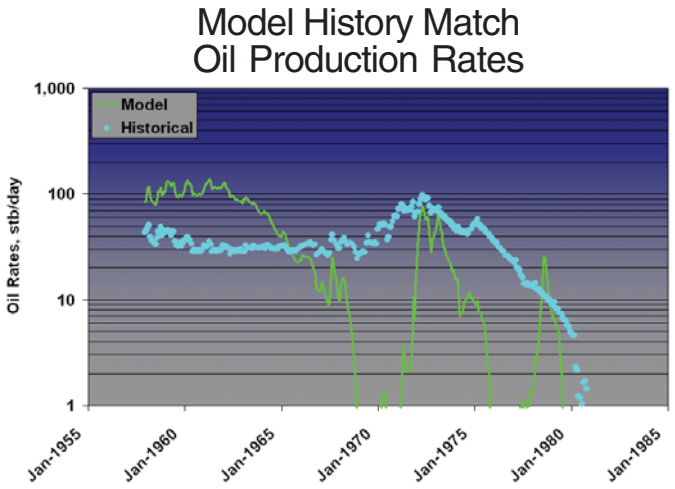
Generally, longer-duration history matches yield more reliable modeling results than shorter-duration ones. However, this is not always the case. "The model with less history may be more reliable if constructed to higher standards and history matched with more reasonable assumptions," said Rietz.

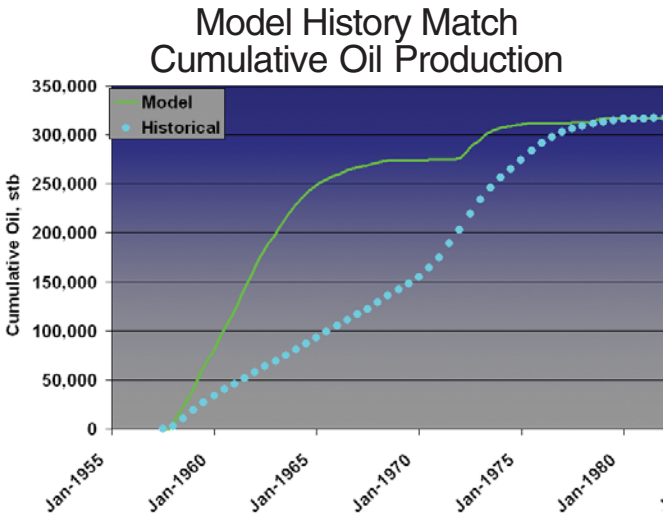
Summaries for steps 1 to 4 are as follows. Steps 5 to 9 will be published in the June article, Part 2.

1 **To avoid overkill, determine the ultimate use of the reservoir model**—If the producer needs field-deliverability estimates to quickly make a sanctioning decision or rough estimates for initial sizing of field-facility requirements, then a field-wide match generally will suffice rather than individual well matches. If, however, the producer is using the reservoir model to help certify reserves or conduct development well planning or completion optimization, then a more detailed history match may be warranted.

2 **Check for reasonableness in model construction**—First, the evaluator examines the rational behind the building of the model. This involves assessing data available during model construction and whether the modeler used that information appropriately. The evaluator investigates discrepancies between mapped structural and stratigraphic features and those incorporated into the model. He questions whether reasonable assumptions for reservoir description were made in cases where data is unavailable or sparse, especially if the model is used to assess reserves. Reserves guidelines frequently place strict limitations on geological features, such as contacts, reservoir thickness, etc. The review also focuses on whether model assumptions in regard to fluid and rock properties, saturation functions and well descriptions and placements are consistent with or similar to field data. The evaluator considers these assumptions and the way the model is constructed before and after a history match. If a discrepancy is discovered, then he conducts an additional review to determine if there is sufficient justification for model assumptions that contradict observed field data. In many cases, the evaluator must make gross assumptions because underlying data may not be available and time limits preclude detailed checking of input parameters.

3 **Assess quality of field pressure and produced volume match**—After model construction is validated, the evaluator begins appraising the quality of the history match by reviewing the overall pressure and material-balance match. The model should have global reservoir pressures that are reasonably matched throughout the history-match period. General fluctuation and errors are inherent in those pressure measurements, which are point measurements representing field-wide values. So there are no clear-cut tolerances to determine good- or poor-quality matches. The evaluator checks to see if observed pressures fluctuate above and below model-calculated average regional pressures. In general, if the calculated pressures are within five percent, for example, at all times, then the pressure match is very good. The exception to that would be very large fields with limited depletion.
Next, the evaluator examines the field-wide phase





Cumulative volumes may match at the end of the history match (right-side graph) even though the rate profile (above) is radically different. These are at the pre-history-match stage.

match. One phase is usually specified. So the evaluator compares model-calculated rates and cumulative volumes of the non-specified phases — i.e., water and gas for a typical oil reservoir — to historically observed values.

Rates and cumulative volumes of the primary hydrocarbon phase—which is oil for oil reservoirs and gas for gas reservoirs—should be within a close tolerance, such as two to three percent of historical, particularly for reserves purposes. This match should be observed throughout the history-match period.

Cumulative volumes may match at the end of the history match, even though the rate profile before that point is radically different, as shown in the two graphs above at the pre-history-match stage. In those cases, a difference in historical-rate profiles may lead to significant divergence between simulated and actual rate streams. So simply achieving correct cumulative volumes for each phase by the end of the history match does not, in itself, constitute a good history match.

The combination of a good pressure and phase-volume matches will ensure that overall field material balance is reasonable and that the model has approximated field- rather than well-by-well performance.

Assess quality of local (well) pressure and saturation match—Next, the evaluator "digs deeper" and examines individual well history-match results to find out if shut-in pressures and produced phase volumes are reasonably matched. Rarely will all wells in a model have good matches.

The criteria to determine a "quality" match are the same as previously discussed for field-wide evaluations—the evaluator looks for overall field-wide quality in the well matches. If the evaluator observes a poor match in a well surrounded by a few good wells, then he discounts the poorer-matched well. Models cannot capture all heterogeneities or geological features, especially with limited data, time and budgets.

The evaluator also reviews the well's rate and pressure data to investigate whether poor-quality measurements, rather than a poorly constructed and matched model, are causing an overall lack of quality.

When local groups of wells indicate a similar, poorly matched response, then that suggests that the modeler may not have fully understood the reservoir dynamics in that area and did not properly model the reservoir. When the evaluator observes general or regional mismatches, he will seek an explanation by the engineer who conducted the history match and will review work notes and model documentation.

Editor's Note: This article is a revised excerpt from SPE paper No. 96410. To order the full paper, go to spe.org. Rietz will conduct a two-day short course, "Reservoir Simulation for Practical Decision Making," May 9 and 10, in Houston, for the SPE Gulf Coast section. He will also participate in a SPE-GCS forum on May 11. For more information, go to spegcs.org.

Upcoming Events

March 26—SPE workshop on reserves, Muscat, Oman; Ron Harrell, retired CEO, to present. For details, send a request via e-mail to shyde@spe.org.

April 1-3—SPE-HEES, Dallas, TX. Ryder Scott Booth 131. Presentation on reserves evaluator training; Paper by Harrell, Dan Olds, vice president, et al. Go to spe.org.

April 3—AAPG annual meeting, Long Beach, CA. Presentations by Harrell and John Hodgin, president, on reserves and resources classifications. Go to aapg.org.

April 30—OTC, Houston. Presentation by Hodgin on reserves and world petroleum supply. Go to otcnet.org.

May 4—Ryder Scott Reserves Conference (OTC week), DoubleTree Hotel, downtown Houston. Agenda TBA. For more information, send an e-mail to mike_wysatta@ryderscott.com.

May 9-11—SPE-GCS forum/workshop on reservoir simulation. See details in Editor's Note above.

June 13-14—SPE EUROPEC, London. Short course on reserves presented by Hodgin and Bob Wagner, former senior vice president. Go to spe.org for details.

Petroleum engineer joins Ryder Scott

Robinson

Rick Robinson recently joined Ryder Scott as a petroleum engineer. Before that, he was a senior project reservoir engineer at Exxon Mobil Production Co. where he evaluated development opportunities and performed reserves and economic analyses.

Robinson assessed reserves in the Hugoton embayment and Anadarko basin using volumetric analysis, reservoir modeling and decline-curve and rate-transient analyses. He has experience with shallow carbonate reservoirs in Hugoton, deeper gas and condensate fluvial systems in Texas and Oklahoma and various south Texas properties. He has a BS degree in chemical engineering from Brigham Young University.

Gaston

Harry Gaston, president emeritus at Ryder Scott, died Nov. 25 in Austin, TX, after a battle with cancer. He began working at Ryder Scott in 1967 and retired in 1998 as president.

Gaston was an early promoter of the use of computers to do engineering work in the 1960s when the industry used slide rules and punch cards. He managed the development of Ryder Scott's first cash-flow computer program, which provided many levels of summary and became a standard.

Gaston began his oil and gas career in 1954 when he joined Atlantic Refining Co. as a petroleum engineer. He was briefly with Continental Oil Co. as a petroleum engineer before he joined Robert W. Harrison & Co. in 1958. That firm later merged with Ryder Scott in 1967.

Debate—Cont. from Page 1

deterministic estimates with low, most likely and high cases. Subcommittee members said that the unapproved draft was a work in progress and that after receiving more feedback, they planned to make content revisions, additions and deletions throughout the document as well as specifically with language relating to best practices.

The SPE subcommittee was also reviewing another recommendation that the forecast case be the base case for estimating oil and gas reserves. Most evaluators use the constant case as a base and perform a sensitivity analysis using forecast prices and costs.

Several regulatory agencies outside the U.S. defer to the SPE guidelines, so establishing a standardized measure would be difficult if the sometimes highly variable internal forecasts were used in the base case. Canadian regulators, which require both constant and forecast pricing and cost assumptions, have solved that problem to some degree.

The Alberta Securities Commission requires that public issuers submit the details of their forecast assumptions. The commission then compares those forecasts to ones from consultants and bankers. Those third-party forecasts are aggregated, averaged and published for review by regulators and other subscribers to that information.

Susan Mitchell coordinated the Ryder Scott toy drive last Christmas for a Children's Protective Services gift program.

Ryder Scott Co. LP
1100 Louisiana, Suite 3800
Houston, Texas 77002-5218
Phone: 713-651-9191; Fax: 713-651-0849
Denver, Colorado; Phone: 303-623-9147
Calgary, AB, Canada; Phone: 403-262-2799
E-mail: info@ryderscott.com
Web site: www.ryderscott.com

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