Risk Factors in Reservoir Simulation

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Sources Of Data

Petro-physical Data

- **Water saturation may be estimated from log analysis, capillary pressure data, or analysis of cores taken using oil-base mud.**
- **Measurement and interpretation of capillary pressure data are important.**
- **Porosity may be determined from core and/or log analysis.**
- **In situations where data are not available, reference may be made to tabulations of reservoir data published by the Society of Petroleum Engineers.**

Fluid Data

- **The fluid data are needed for the design of any EOR Project.**
- **These data are obtained from laboratory analysis of fluid samples representative of the reservoir.**

Analysis of Data

Raw data from field and laboratory sources should be analyzed carefully and cross-checked for consistency before being used for engineering calculations.

Statistical Analysis

- **Porosity in both sandstones and carbonates tends to exhibit a normal distribution.**
- **Permeability tends to exhibit a log-normal distribution (the logarithm of the permeability's tends to be normally distributed).**

- **Determination of the statistical distribution of porosity and permeability is key to the characterization of the reservoir.**

- **Statistical analysis may reveal the presence of more than one type of depositional unit in the reservoir.**

- **Average water saturation is one of the parameters needed for volumetric calculations of oil and gas initially in place.**

- **If there is not a significant oil-water transition zone, the average water saturation in the reservoir may be approximately equal to the irreducible water saturation.**

Adjustment/Correlation of Data

Petro-physical and fluid data from all sources should be compared and cross-checked for consistency.

Core depths seldom agree with wire-line log depths, and appropriate adjustments must be made before direct comparison.

A core-gamma log usually facilitates correlation between core depths and log depths.

Well Test and PVT Data

- **If recombination samples have been taken for PVT analysis, the initial GORs determined from well tests are in reasonable agreement with those determined from laboratory flash liberation tests.**

- **If there is reasonable agreement, the laboratory formation volume factor at initial reservoir pressure, and the corresponding GOR, should be adjusted to compensate for separator conditions in the field.**

- **The test data used in these correlations to estimate initial formation volume factor should indicate a bubble-point pressure equal to, or less than, initial reservoir pressure.**

- **When material balance or reservoir simulation calculations are made, the PVT data always should be smoothed using the Y functions.**

Reservoir Conditions

The PVT analysis should represent fluid properties at reservoir temperature and initial reservoir pressure.

Pressure

Accurate determination of initial reservoir pressure is critical in many EOR processes.

Subnormal initial pressure might be indicative of partial drainage from other wells or reservoirs producing from the same formation and may establish a need for early pressure maintenance.

Temperature

- **Accurate determination of reservoir temperature is important if laboratory PVT data are to be measured under reservoir conditions.**

- **Accurate reservoir temperature is necessary for the phase behavior calculations.**

- **Reservoir temperature and initial pressure estimated using correlations should be considered preliminary and not a substitute for actual measurements.**

Geological Aspects

Types of Traps

- **The degree of uncertainty in a an EOR process is influenced more by the:**

- degree of geologic complexity of the reservoir

- amount and quality of geophysical and subsurface geologic data.

- **Three broad categories of reservoirs may be identified:**

  (1) those controlled by structure, (2) those controlled by stratigraphy, and (3) those controlled by a combination of structure and stratigraphy.

The *Santa Fe Springs Field* in California and the *Abqaiq Pool* in Saudi Arabia are examples of simple structural traps. At the other extreme are stratigraphically complex reservoirs on highly folded and faulted structures.

The *Painter Reservoir Field* in the U.S. western over thrust belt and the *Maloosa Field* in Italy are examples of complex structural traps that pose substantial difficulties in estimating reserves.

It is very important throughout the life of a reservoir that the engineers involved in EOR become familiar with the geologic setting in which the reserves occur and the possible geologic complications associated with that setting.

Reservoir geology impacts all phases of reservoir management, including drilling and completion techniques, well testing, drainage areas, well and reservoir performance, reserve estimates, and improved recovery techniques.

- If a water-flood is being considered, net pay typically includes only those intervals considered “floodable.”
- The methods used to define floodable intervals are subjective and may exclude intervals that could contribute to recovery by imbibition.
- Depending on the purpose, methods for determining net pay also depend on the type of core, log, and well-test information available and on the lithology of the reservoir.

Reservoir Limits

- **Reservoir limits include fluid contacts (i.e., gas-oil, oil-water, gas-water, faults, porosity or permeability pinchouts and unconformities and other truncations (e.g., diapiric salt or shale).**

- **It is difficult to determine these limits within acceptable confidence levels early in the drilling and production stages of reservoir life.**

- **The quality of reservoir rock observed in the commercial wells around the periphery**

- **The depositional environment of the reservoir rock**

- **The distance to the nearest dry hole**

- **The apparent rate of thinning of reservoir rock**

- **The minimum thickness of reservoir rock needed to support a commercial well.**

Capillary Transition Zones

- **Significant transition zones may be expected in heavy-oil reservoirs, or in any oil reservoir with low permeability.**

- **Gas-oil and gas-water transition zones are negligibly small.**

- **Depending on the reservoir drive mechanism, some of the oil in the transition zone may be commercially recoverable.**

- **In heavy-oil reservoirs, a significant portion of the oil initially in place may be in the oil-water transition zone.**

- **On low-relief structures, the entire reservoir may be in the oil-water transition zone, and it might not be possible to make a water-free completion, even at the crest of the structure.**

- **It has been noted that the “best” capillary pressure curve to use for saturation calculations is from a rock sample that has arithmetic-average porosity and median permeability.**

- **The vertical distribution of reservoir rock above the 100% water level may be determined using a vertical distribution curve.**

Reservoir Heterogeneity

Reservoir heterogeneity **refers to the non-uniform spatial distribution of a reservoir's physical and chemical properties**

During the last 20 years or so, there has been increasing recognition that reservoir heterogeneity has a major influence on the recovery of oil and gas from subsurface reservoirs.

Several developments have contributed to a growing knowledge of reservoir heterogeneity:

- **increasing infill drilling of major waterfloods in the United States, especially of the carbonate waterfloods in the Permian Basin of West Texas-New Mexico.**

- **development of better downhole logging devices (both open-and cased-hole), and of better interpretation techniques**

- **advances in geophysical technology and interpretation techniques, including seismic stratigraphy.**

- **rapid advances in computer technology that have enhanced capabilities for geophysical processing, log analysis, and reservoir simulation.**

- **development and application of enhanced recovery processes, which have supported research on reservoir characterization.**
- **use of multidisciplinary “teams” for coordinated geophysical, geologic, and engineering studies of developing fields.**
- **Two examples of favorable heterogeneities are thin, low-permeability layers and natural fractures.**
- **Shale stringers or thin, low-permeability layers near the bottom of a hydrocarbon column underlain by water may retard bottom water coning.**
- **Shale stringers or low-permeability layers near a gas-oil contact may retard gas coning.**

Natural fractures may be either favorable or unfavorable, depending on reservoir drive mechanism.

- **Without natural fractures, many low permeability oil and gas reservoirs would be noncommercial (example: the Austin Chalk trends in Texas).**
- **Natural fractures may cause major problems in waterflooding.**
- **<u>Heterogeneities cause two general types of problems</u>: they make it difficult to characterize and monitor reservoir performance of, and they tend to cause non-uniform recovery of oil and gas.**

- **Characterization of a reservoir involves determining the spatial distribution of porosity, oil and gas saturation, oil and gas properties, permeability, relative permeability, net and gross thickness, fractures, dip, rock texture and mineralogy, and other physical/chemical properties relevant to commercial oil and gas recovery.**

- **Adequate characterization almost always requires ongoing monitoring of dynamic data (e.g., individual well bottom hole pressure, well performance, and fluid saturations).**

- **Monitoring reservoir performance involves observation of spatial and temporal changes in pressure, fluid saturation, and fluid phase as the reservoir is produced (i.e. the periodic procurement of dynamic reservoir data).**