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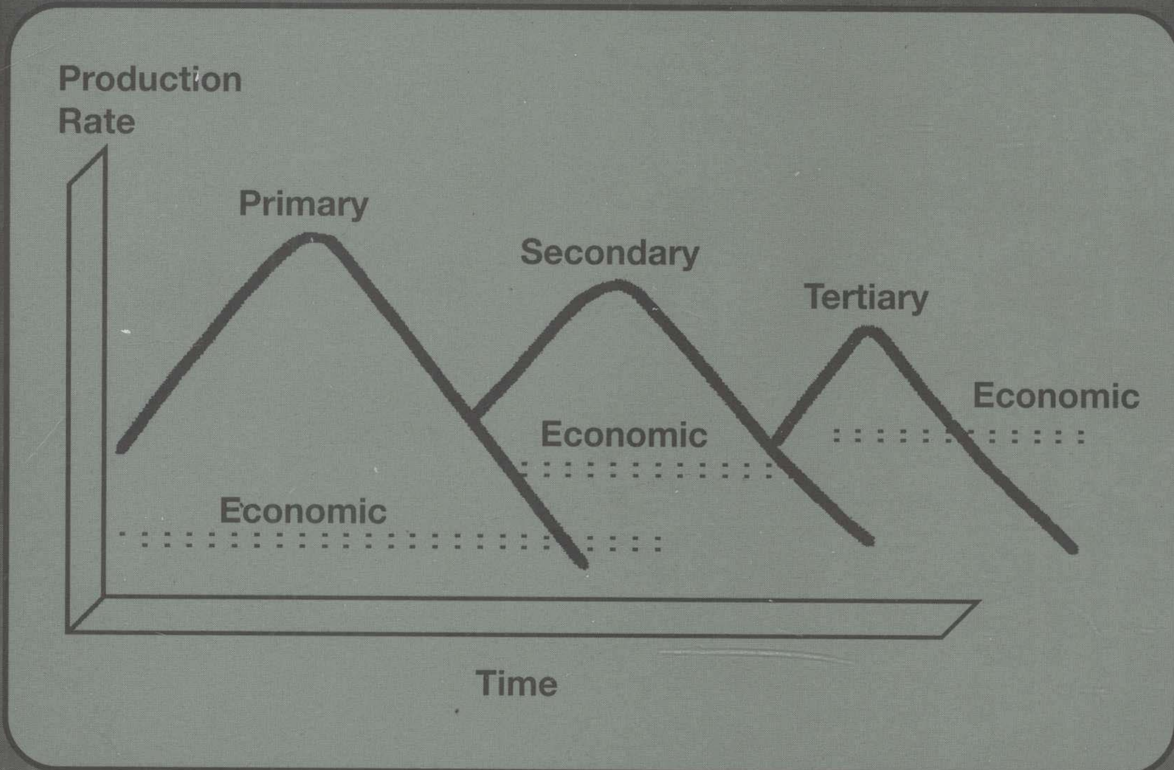
NO. 48 RESERVOIR MANAGEMENT



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FOREWORD

Petroleum reservoir management has generated significant industry interest in the last decade. However, the concept of reservoir management is not new. The industry has always managed its reservoirs in some form. In certain cases, special attention had been given to the study and operations of a particular reservoir to ensure long-term benefits to the producer. In other cases, reservoirs have been produced with little regard for long-term viability. Sometimes, reservoir management was a primary issue at some stage in the life of a reservoir only to become an afterthought as the reservoir aged or when a newer, larger reservoir was discovered. This dichotomy has led to a number of technical papers dealing with reservoir management and the application of technical principles to managing oil and gas reservoirs. As one paper in this Reprint Series volume points out, reservoir management is not a technology. Rather, it's a strategy for maximizing the value of a petroleum asset.

In this Reprint Series volume, we try to provide the reader with an overview of reservoir management. We carefully reviewed many papers to select those that can be used as background in developing a reservoir-management strategy. The papers span the technical aspects for use as background material during the E&P stages of petroleum reservoirs. The volume is divided into eight topical areas that relate to the various aspects of reservoir management: General Reservoir Management, Synergy and Integration, Reservoir Characterization and Geosciences, Reservoir Engineering and Modeling, Data Management and Surveillance, Production Operations and Facilities, Economics, and Reservoir-Management Applications. We selected the papers to demonstrate the integrated nature of these principles in successful management of oil and gas reservoirs.

A literature review suggests that there are varying conceptions of what reservoir management is and what it involves. The General Reservoir Management section of this reprint contains three papers that define reservoir management. These papers provide a complementary overview of reservoir management and what it encompasses. Each proposes that reservoir management is an integrated, continuous process requiring cooperation and teamwork between various disciplines to use the resources available to optimize field operations. The papers provide information on how to implement reservoir-management practices and briefly describe the technical aspects of reservoir management.

Synergy and integration required in modern reservoir management has been compared with the teamwork necessary in a well-coordinated basketball team. Synergism is an old industry concept that means the whole is greater than the sum of its parts. The Synergy and Integration section has three papers that emphasize the values of teamwork in terms of creating more opportunities for petroleum reservoirs and improving the productivity of interdisciplinary team members. The first paper stresses the sharing of skills and knowledge, and the second discusses close teamwork and coordination among various functions. The third paper presents a systems approach involving reservoir characterization and fluid behavior in the reservoir, creation and operation of wells, and surface facilities and processing of fluids.

Recent technological advancements in various geoscience and engineering methods, aided by high-powered computers and graphics, have created a more efficient and productive teamwork environment for corporate-asset teams. The objective of reservoir characterization is to improve reservoir management by providing accurate geologic-model input for reservoir-performance predictions. Application of three-dimensional (3D) -seismic technology has significantly improved our understanding of complex reservoir architecture while reducing the field-development costs. Geostatistical modeling integrates multidisciplinary data and generates a more realistic reservoir description with better representation on interwell heterogeneity. We selected three papers in the Reservoir Characterization and Geosciences section to highlight the method and synergistic work flow from reservoir geologic description, 3D-seismic integration, and stochastic reservoir modeling to minimize uncertainty in production forecasts.

The reservoir model is not just an engineering or a geoscience model; rather, it is an integrated model, prepared jointly by a multifunctional team, reflecting all pertinent reservoir data from seismic to simulation. The geologic model is derived by extending log and core data to the full reservoir with geophysics, mineralogy, depositional environment, diagenesis, geochemistry, and pressure-transient analysis. The definition of geologic units and their continuity and compartmentalization is an integral part of geostatistical, and ultimately reservoir-simulation, models. We chose three papers for the Reservoir Engineering and Modeling section. The first outlines the role of reservoir simulation in optimal reservoir management. The second presents real-life examples by use of interactive personal computer simulation to illustrate the method and benefit of applying minisimulation to the management of smaller reservoirs. The third paper describes the use of simple mathematical models for predicting reservoir behavior, with several example problems.

A well-formulated and integrated data-acquisition and -analysis program is fundamental to an efficient reservoir-management plan. To ensure technical success and to maximize economic value, an experienced multifunctional team should have the ongoing responsibilities of identifying, acquiring, assessing, and evaluating data for quality, representability, and consistency. We included two papers in the Data Management and Surveillance section. The first paper discusses data acquisition and analysis for efficient reservoir management, and the second documents waterflood surveillance techniques and their applications that use a reservoir-management team approach to maximize economic value from a reservoir.

Reservoir management not only includes reservoir processes and behavior but also surface operations. The most efficient plan may be created to develop and produce the reservoir fluids, but it will be incomplete if no attention has been paid to surface operations. Surface production facilities must be a part of the reservoir-management strategy. Production systems must be designed to optimize overall reservoir production rates and efficiency. The Production Operations and Facilities section provides two papers that address issues surrounding the integrated design of production facilities in large field applications. The first paper addresses the problem of multiple reservoirs sharing common surface facilities, while the second looks at consolidating production facilities of multiple operators after a reservoir has been unitized.

Reservoir management requires economic evaluation and analyses of the total asset and associated projects throughout the life of the reservoir. Making a sound business decision requires that a project be economically viable, i.e., that it will produce profits meeting or exceeding any economic yardsticks. We selected two papers in the Economics section to provide a rationale for reservoir-management economics and an approach to optimize reservoir management with linear programming in an offshore field. The first paper summarizes the economic aspects of reservoir management as two-fold: efficient use of available resources and maximization of asset value within the context of a company's strategy. The second paper describes an example involving the optimal redevelopment program and drilling schedule while maintaining operationally feasible product processing requirements, drilling-rig use, and well/platform relationships.

The Reservoir-Management Applications section contains three papers describing innovative reservoir management in a successful waterflood; reservoir-management practices used in several fields in Malaysia; and the evolution of reservoir management to meet ever-changing economic and technical challenges as a field has been produced by primary, secondary, and tertiary methods. All three papers emphasize the benefits of teamwork to identify opportunities and implement timely, innovative solutions for maximizing the economic value of petroleum assets.

Ganesh Thakur
Chairman

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An Approach to Reservoir Management

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SPE Members

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This paper was prepared for presentation at the 65th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers held in New Orleans, LA, September 23-26, 1990.

ABSTRACT

Many petroleum reservoirs are not developed and produced properly. This failure can be the result of poor reservoir operations management. An understanding of reservoir management and its elements is needed to effectively exploit petroleum reservoirs. This paper defines reservoir management and proposes a comprehensive, integrated approach to the management of reservoir operations.

The paper does not address the many technical details of reservoir management, nor does it give detailed recommendations for particular operations. It presents a method and approach to making these decisions for any reservoir. Its purpose is to communicate the importance of reservoir management and to present an approach for the development of a reservoir management plan.

INTRODUCTION

The petroleum industry has progressed from an early period of unrestrained production, through a period of maximum production regulated by government constraint into a period of declining production where companies plan to maximize profits based on the current management environment. The industry has now moved into a period of challenge. Industry must accept the challenge that a significant amount of oil and gas will remain unrecovered unless improvements are made in reservoir management practices.

Petroleum reservoir management is an area that has generated significant discussion within the industry in recent years as reserves have declined, prices have fluctuated and companies have begun to realize the necessity for comprehensive planning in reservoir development. A review of the literature suggests that there are varying conceptions of what reservoir management is and what it involves as evidenced by just a few references.[1-8] A thorough understanding of the petroleum reservoir management process is important to the proper development and exploitation of oil and gas reserves. This paper will define reservoir management, discuss its process and recommend the use of a written reservoir management plan.

References and figures at end of paper.

RESERVOIR MANAGEMENT

Petroleum reservoir management is the application of state-of-the-art technology to a known reservoir system within a given management environment. Reservoir management can be thought of as that set of operations and decisions by which a reservoir is identified, measured, produced, developed, monitored and evaluated from its discovery through depletion and final abandonment.[1] Figure 1 summarizes the concept of reservoir management. A reservoir is managed for a particular purpose and that purpose is accomplished within the management environment using the available tools and technology.

Elements of Reservoir Management

Reservoir management is not simply the creation of a depletion plan and/or a development plan but rather a comprehensive, integrated strategy for reservoir exploitation. Management is comprehensive in that it requires the three primary components of reservoir management; 1) knowledge about the entity being managed, 2) the management environment, and 3) the available technology. When these three components are integrated, decisions can be made and a strategy developed for achieving management goals. Without an understanding of these components, effective management cannot take place and a comprehensive strategy for achieving management goals will not be developed.

Reservoir Knowledge. Knowledge of the system being managed has several dimensions. First is the general nature of the system. A petroleum reservoir is an accumulation of hydrocarbons trapped within a single hydrodynamically-connected geological environment. This general knowledge includes an understanding of fluid movement, rock properties, phase behavior and other basic knowledge.

A second dimension of reservoir knowledge provides information about the macroscopic nature of the reservoir. This includes reservoir fluid content, size and variability; geologic province, formation and environment of deposition; type of rock, depth, pressure and similar general information. A third dimension provides detail on a microscopic level. This includes information such as reservoir morphology, porosity, fluid saturations, matrix content, capillary pressure relationships, relative permeability data, rock characteristics, pressure-volume-temperature relationships and other information concerning the internal variability of the reservoir.

A fourth dimension of reservoir knowledge is its history, the events which have taken place during the operation of the reservoir. Information of this type includes what wells have been drilled, how they were completed, what type of well stimulation has occurred, amounts of fluids removed or injected and any other data that pertains to the reservoir as it may have changed from its original condition.

Management Environment. The second component, the management environment, deals largely with social and economic factors. This environment may involve factors such as lease ownership, government conservation, safety and environmental regulations, market demand for petroleum products, availability of capital, equipment and personnel and the importance attached to reservoir management by a particular organization. To a certain degree, the management environment might be influenced by public attitudes and perceptions about the petroleum industry. Very often the management environment will place constraints upon the actions that may be taken in reservoir management, but the management environment may also provide options and opportunities for creative new initiatives.

Technology. The third component of reservoir management is the existence of technology through which management can be affected. Technology not only controls what may or may not be considered as a course of action but it can also control the extent of knowledge that may be gained about the reservoir. This includes all knowledge that may be generic to the behavior of reservoirs, knowledge that may be specific to an individual reservoir and knowledge that may be derived from other fields of technology.

Technological knowledge also includes the types of techniques and operations that may be used to study or be performed on a reservoir. Methods for acquiring data, monitoring techniques, diagnostic and analytical procedures, modeling techniques and any other concepts which pertain to the handling of reservoir data and its use for determining a condition, a reservoir process or a course of action are examples of this type of knowledge.

Integration and Communication

It is not enough just to know the entity being managed, to understand the technologies and their capabilities and to be free of constraining management factors. One must know how to integrate the components as decisions must be made in response to the desired objectives. The decision process itself must be analytical and must take into account and consideration the alternative courses of action that may be available. With the information that is available, the reservoir manager must make assessments and take action.

The process of petroleum reservoir management is dynamic, not static. Each component is constantly subject to change. Technology does not stand still. It is advanced as more is learned from each reservoir that is managed. The reservoir system is never known completely, but the knowledge becomes more perfect as the reservoir matures. In addition, the management environment is also subject to change. Thus the process of reservoir management is a changing process from discovery to abandonment.

Effective communication is essential to successful reservoir management. An open dialogue must take place within and between those groups concerned with finding and developing oil and gas reservoirs. To be effective, the disciplines must work as a team and integrate and share their knowledge. Thakur[2] recently advocated the team approach to reservoir management. The team approach allows the full benefit of available technology to be gained by an organization.

Industry must make an effort to move away from so quickly employing what has worked before. It must move toward examining and evaluating all alternatives from all viewpoints, then deciding on a course of action that will optimize the accomplishment of management objectives. The team approach encourages this overall evaluation of the reservoir system.

Yet the process cannot stop here. Reservoir management must be a continual process where plans are made based on available information and implemented. The results must be monitored to be sure objectives and goals are being met and as new information is obtained it must be evaluated and changes made to the plans as necessary.

Planning

Planning is fundamental to reservoir management. Many companies do a very good job of forecasting financial budgets, expenditures and revenues. They forecast production, estimate revenues and propose expenditures based on their projections. Yet many fail to plan. Planning is not merely forecasting. Planning is a comprehensive strategy for the accomplishment of management objectives and should be the basis for reservoir management.

Planning results from thinking about things that will happen in the future. The reservoir manager and reservoir management team must look at all the possible events that might occur, options and alternatives that may be implemented and evaluate the economic consequences of the various outcomes. Then they can plan to optimize the accomplishment of management objectives.

Corporate management must communicate to their reservoir managers the objectives of the company and how those objectives are to be measured. The reservoir managers and technical staff can then develop a plan to achieve those objectives. They must predict the possible events that might occur and evaluate all the options and alternatives that could be implemented. Then a final plan can be prepared which optimizes the corporate objectives. The plan is then implemented, monitored and changed as new information is obtained to continue meeting those objectives. This must be an ongoing process that ends only when the reservoir is abandoned.

THE RESERVOIR MANAGEMENT PROCESS

The process of petroleum reservoir management can be approached by considering the overall steps in any management activity. These steps include: 1) setting goals and objectives, 2) creating a plan of operations to achieve the goals and objectives, 3) monitoring and control of operations to achieve the quality intended, and 4) auditing to verify that goals and objectives have been achieved.[9]

Inherent in these statements are assumptions that the petroleum reservoir and its operations can be defined, that both can be quantified and measured, that techniques for performance evaluation are available, and that control of operations is technologically feasible. Reservoir management involves a full delineation of these assumptions and the limitations that apply to them for each reservoir managed.

Management Environment

Corporate management is responsible for communicating goals and objectives to their reservoir managers. Hellriegel[9] emphasizes the importance of corporate management setting organizational objectives. These objectives, when linked between the various organizational levels, act as an aid in planning and assist in evaluation and control of operations. They also help direct and motivate personnel. It is important that top corporate management clearly identify an objective for the reservoir manager. This objective needs to be singular and measurable. With this knowledge, managers can evaluate all possible options and outcomes and make decisions to optimize the objective.

A simple example will demonstrate the importance of a single objective. Consider the development of a volumetric dry gas reservoir which is homogeneous and isotropic with known areal extent and constant thickness. Gas prices are constant as well as operating, drilling and facility costs which are estimated on a per well basis. Due to rig availability, only one new well can be completed each month. Well spacing is unregulated. The only management decision in this example concerns the number of wells to be drilled. Figure 2 is a graph of two important economic measures, net present value and rate of return, shown as functions of wells drilled. Drilling 66 wells will maximize net present value while rate of return can be maximized with six wells.

This example shows how the optimal reservoir management policy is affected by the decision criterion. It is upper management's duty to choose an appropriate criterion and make the choice known to those involved with reservoir management activities.

Technical Elements

What may be considered the technical aspects of reservoir management include the creation of a plan, monitoring of the plan and evaluation of the results. Just as none of the three components of reservoir management is independent of the other, none of these elements stand alone. Each is interrelated with the others and all information must be integrated for effective reservoir management.

The process of reservoir management includes: 1) reservoir description, 2) reservoir performance prediction, 3) evaluation of recovery methods, 4) economic analysis, 5) selection of alternative and plan development, 6) implementation, and 7) tracking and auditing.

Each of these are continual elements in the reservoir management process. Some may require more attention than others at specific times during the life of the reservoir, yet no one element is static.

Reservoir Description. Reservoir description is the interpretation of the microscopic and macroscopic spatial distributions of rock and fluid properties for a single reservoir unit. The description is required to establish the amount of petroleum in place, predict the amount that can be produced and plan development operations. The objective of reservoir description is to display the rock and fluid properties by maps and equations so that the reservoir can be divided into segments that have common physical characteristics and fluid volumes. The production history can then be simulated by mathematical methods and future performance can be forecasted. Figure 3 depicts the stages of reservoir description.

Reservoir description is composed of four primary aspects: 1) the primary properties of the rock, 2) the reservoir rock properties, 3) the properties of the fluids under reservoir conditions, and 4) the displacement characteristics from laboratory tests. Reservoir description makes use of a data base that is comprised of all available information on the reservoir: 1) the geological and geophysical data from logs, cuttings cores and seismic, 2) the reservoir rock properties measured in cores or from well tests, 3) the fluid properties based on samples of the produced fluids, and 4) the displacement characteristics from laboratory tests.

This information has to be integrated into a comprehensive reservoir description. The reservoir description must take all available data and merge it into a characteristic model of the reservoir. This model must be consistent with the available data and all discrepancies resolved or the model modified. Reservoir description is a continuous process which cannot be isolated from the geologic, geophysical and engineering studies that should be conducted during its preparation.

Reservoir description is one of the most important aspects of reservoir management. All decisions will be based mainly on this model as it is used in predicting performance and in evaluating development plans. It has to be constantly tested and modified to represent the reservoir as best as possible at a given point in time. If not, the results of reservoir operations may be less than satisfactory.

Reservoir Performance. The success of reservoir operations depend primarily on how the reservoir performs under the current method of operating that reservoir. If reservoir management is inadequate, operations might be disappointing; however, sound reservoir management should optimize the accomplishment of management objectives. Therefore, analyzing the past and current behavior of a reservoir as well as predicting its future behavior is an important aspect of reservoir management.

Once the reservoir description has been completed and a geological model hypothesized, reservoir performance should be predicted. At this stage, the data used in the reservoir description and the historical production and pressure data are used to predict future recoveries under various operating schemes. This step is critical to the development of a reservoir management plan because it allows the optimum operating scheme to be selected. This selection is based on predicting performance not for just one mode of operation, but for all the available and applicable modes of operation or combination of modes to optimize the management objective. The predicted performance allows the comparison of alternative operating scenarios and the selection of the optimum scheme of reservoir operations.

Recovery Methods. Another important aspect of reservoir management deals with the methods utilized to recover petroleum reserves. For reservoir fluids to flow and be produced, energy must be expended. This energy transformation is the basis for all recovery methods. Recovery methods may be divided into three classes: (1) natural energy sources, (2) external energy sources, and (3) combination energy sources

It is rare to find a reservoir that produces under only one form of energy. Consequently, the recovery mechanism for reservoir production may be very complex and involve several different energy sources. In general, however, one energy source may dominant and is considered the primary energy source. Though the primary energy source may change during the life of the reservoir, it is important to identify it as early as possible.

The main reason that the reservoir drive mechanism needs to be identified is to allow the early determination of reserves and to predict ultimate recovery. Each mechanism can have a substantial impact on the ultimate recovery, which can greatly affect economic evaluations. This knowledge allows good decisions to be made during reservoir development.

The ability to estimate reservoir performance and predict ultimate recovery can also affect the mode of operation for the reservoir. Performance predictions may indicate the need for an artificial energy source, or improved recovery method, to optimize the reservoir recovery.

If the need for an improved recovery method is indicated, the reservoir should be screened to determine which improved recovery methods are applicable. Once a method has a possible application to the reservoir, future performance must be predicted. This will allow an evaluation of additional recovery over primary under the various improved recovery methods being considered. This analysis must be done for each potential improved recovery technique that is applicable.

Any application of an improved recovery method requires a detailed reservoir description that incorporates both geological and engineering data. Each technique must be screened for applicability to a particular reservoir. Preliminary performance predictions and economic evaluations of all suitable processes should then be undertaken to determine the optimum process. Once a process is chosen as the optimum choice, detailed engineering and laboratory work must be performed to confirm the applicability of the method. In short, a great deal of engineering, geological and research effort must precede the field implementation of any improved recovery process to insure satisfactory results.

Economic Analysis. Generally, though not always, the objective in reservoir management is economic. Consequently, the economic objective must be clearly defined. After viable operating modes have been identified and the necessary performance predictions made, an economic analysis must be made. The preferred way of evaluating economic worth of the various operating scenarios is the risk adjusted-incremental approach. This approach assumes that all choices will be compared to the current operating policy and that each choice will involve some risk. Risk can be quantified by using one or more of the following approaches: 1) sensitivity analysis, 2) expected value (risk-adjusted) analysis, and 3) Monte Carlo simulation. Partly for reasons of simplicity, operators seem to prefer the expected value method.

The economic analyses will allow the selection of the mode of operation that will optimize the management objective.

Plan Development. Once the economic analysis has been completed, the mode of reservoir operation will be selected based on optimizing the management objective. During the development of the plan, great care should be given to what operations should be conducted, what type of data and information are required and how it should be acquired, and why the operations are to be conducted or the data and information required. It is important that everyone involved in the reservoir management process understand the objectives of the plan. This is why a written reservoir management plan is crucial to successful reservoir management. The written plan allows everyone to become familiar with the objectives and planned operations for the reservoir. The Reservoir Management Plan will be discussed in the next section.

Implementation. Once a reservoir management plan has been developed it must be implemented. The value of the plan is only recognized when it is put into operation. Though the field operations will more than likely be taking place during the development of the reservoir management plan, field operations also constitute the implementation of the plan. Through implementation all aspects of reservoir management are united to achieve the objectives of the plan. Here technology is applied to the reservoir to achieve management objectives. The proper execution of this part of the reservoir management process is critical to successful reservoir management. Without the implementation phase and careful observance of the plan, the reservoir management plan is useless.

Field operations should be conducted in accordance with the management plan. The reservoir management plan is the guideline to efficient reservoir management and operations must obey this guideline. Although implementation might suggest a last or final phase, it is a part of the continuous and ongoing process of reservoir management where reservoir knowledge is continuously being improved and the management plan updated.

Tracking and Auditing. One of the major items in understanding reservoir management is the need for tracking and auditing. The reservoir manager must realize that decisions made today will affect his decisions tomorrow. He may make a decision today that will severely limit his options tomorrow, or he may make a decision that yields options for creative thinking tomorrow. Planning and thinking about how one action affects others greatly improves reservoir management. Each aspect of operations from drilling the first well to abandonment of the last well is affected by operations and decisions preceding it and will affect the options available afterwards.

Consequently, reservoir management calls for constant surveillance of the reservoir. The primary purpose of which is to determine if reservoir operations are conforming to the management plan. This goes far beyond the typical economic concerns of measuring produced oil and gas volumes. Surveillance includes many things that may have varying applicability to different reservoirs. The reservoir management plan should spell these items out, how and when they should be performed, how analyzed and why. Talash[10] recently discussed the importance of surveillance to a typical waterflood project. Many of the comments are applicable to any type of reservoir operation.

Surveillance also includes reviewing how closely operations are following the reservoir management plan. The plan should be closely followed and, if warranted, updated to reflect changes. It should never be disregarded without an updated plan and only then to optimize reservoir management. It is important that day to day activities be tracked and overall operations by audited on a regular basis.

Another important aspect of tracking and auditing is records management. It is important that some system of records management be developed. The data should be organized in some manner which allows ease of use. It should be stored in a way that is readily accessible to all technical personnel involved in reservoir management. It is important that all information be available to everyone so that the entire reservoir operation might be reviewed. The collection of all records and data in a centralized records system can greatly enhance reservoir management.

THE RESERVOIR MANAGEMENT PLAN

A Reservoir Management Plan, in written form, will improve communications and allow all personnel, including drilling, production, geological, reservoir and field, to focus on a common goal. The size of the plan, amount of detail and frequency of revision will depend on the significance of the reservoir and the commitment of management to the planning process. A simple, carefully constructed reservoir management plan might suffice for the one well reservoir while a complex and complicated plan might be required for a large, multi-well reservoir. Though the approach to reservoir management should begin with the planning of the first exploratory well, reservoir management principles can be implemented at any time in a reservoir's life. The point is that every reservoir deserves sound reservoir management and a written plan is almost essential to assure sound reservoir management.

Structure

A useful Reservoir Management Plan should contain sections on objectives, constraints, geological setting, drilling and completion methods, reservoir description, production and injection information and references. It is important that the sections on drilling and completion methods, reservoir description and production and injection data contain information concerning past and present policy, reasons for the present policy, and methods used to track or monitor policy. Maps, production and injection rate curves, completion diagrams, type logs and surface facility diagrams are also very useful in these three sections.

Objective. This section is intended to establish the objective of the firm in operating and managing the reservoir. It can be stated simply as "Maximizing the Net Present Value of future cash flows discounted at 12% per year". It should also briefly mention the type of reservoir management plan being carried out. An example would be "conduct a five-spot waterflood on 40 acre spacing in reservoir A of field Z". The purpose of this section is to communicate the common purpose to all personnel involved in reservoir management.

Constraints. This section should clearly state any significant and realistic constraints under which the reservoir is managed. It is intended to make personnel aware of the environment in which reservoir management takes place. These constraints might include regulatory rules, environmental laws or lease obligations.

Geological Setting. This section should contain a discussion of the regional geology and the stratigraphy and structure of the reservoir interval or intervals being managed. The purpose is largely informative and should be written on a level to be understood by all personnel. Maps are useful in this section showing present and planned well locations.

Drilling and Completion Methods. Each of the various classes of wells, source, injection, disposal and producing, may have different drilling and completion programs. These programs should be described along with reasons why they are implemented. Diagrams are useful in this section to show, for instance, hole sizes and casing programs being used.

Reservoir Description. This section should contain a list of reservoir properties and parameters to be described along with tools and methods used.

In each case, the following information should be available: 1) parameter or property measured, 2) use of the parameter or property in managing the reservoir, 3) how the parameter or property is determined or measured, and 4) why a particular determination or measurement method was used.

Parameters can be grouped into several categories, especially those affecting project extent, fluids in place, flow properties of the rock with natural and introduced fluids and behavior of the reservoir under natural and induced mechanical and chemical changes.

Production and Injection Data. Although production and injection facilities are concentrated on the surface, far from the reservoir, they often have a profound effect on both reservoir behavior and economics. Optimal reservoir management practices must take full account of the effects that these facilities have on the economic objective.

This section should contain a detailed description, including maps and diagrams, of the installed facilities and those planned. Accompanying the facility description should be an explanation for the reason the various facilities were chosen.

References. A large number of special studies, such as simulation runs and core analyses, may have been made to support reservoir management decisions. Results of these studies, if they are in written form, may reside in various places including well files and company libraries. It is important that these studies be properly cited in the body of the Reservoir Management Plan with sufficient identification to locate them for future reference. Reference to past studies form an inventory of the body of basic knowledge of the reservoir. A properly documented reservoir management plan facilitates future research and improvements in the plan as the reservoir matures. References should include reference number, date, title, summary of contents, author and location of report.

SUMMARY

Reservoir operations are composed of many activities. These activities must be integrated within the framework of reservoir management. From this viewpoint several important observations are made.

1. Corporate management must communicate a single objective to the reservoir manager to allow the detailed planning required in reservoir management.

2. Reservoir management is a dynamic, integrated approach to reservoir operations that should continue for the life of the reservoir.

3. Reservoir operations are comprehensive. Each operation undertaken affects the entire reservoir. Consequently, the effects of a particular operation need to be quantified with respect to the accomplishment of management objectives.

4. A thorough reservoir description is essential to effective reservoir management. Development plans and performance predictions are based on the reservoir description. An incomplete or poor reservoir description can lead to less than satisfying results.

5. The geological and geophysical description are a critical element of the reservoir description. They can give valuable insight into the environment of deposition and yield information concerning the spatial distribution of reservoir rock properties and reservoir extent.

6. Uncertainty is a fact in reservoir operations: however, it can be quantified and analyzed. The proper handling of uncertainty can greatly improve reservoir management.

7. All viable alternatives need to be evaluated. This evaluation allows the optimal reservoir management plan be developed without being overly influenced by past experiences or biases.

8. Communication between the technical disciplines is required in reservoir management. The team approach to reservoir management can facilitate this communication.

9. A written Reservoir Management Plan is essential to successful reservoir management.

Reservoir management principles are closely related to geological, reservoir, drilling and production practices. In order to take maximum advantage of these principles it is necessary to closely coordinate geological, reservoir engineering, drilling engineering and production engineering practices. The present state of technology in the petroleum industry calls for all petroleum professionals to have an understanding of reservoir behavior and a willingness to share their individual expertise and experience with the other disciplines in order to optimize reservoir recovery and improve reservoir management.

The development of the optimum reservoir management plan results from sound geology and engineering, detailed planning, successful implementation and careful tracking and evaluation of operations. If we are to gain the maximum advantage of our oil and gas resources we must practice sound reservoir management.

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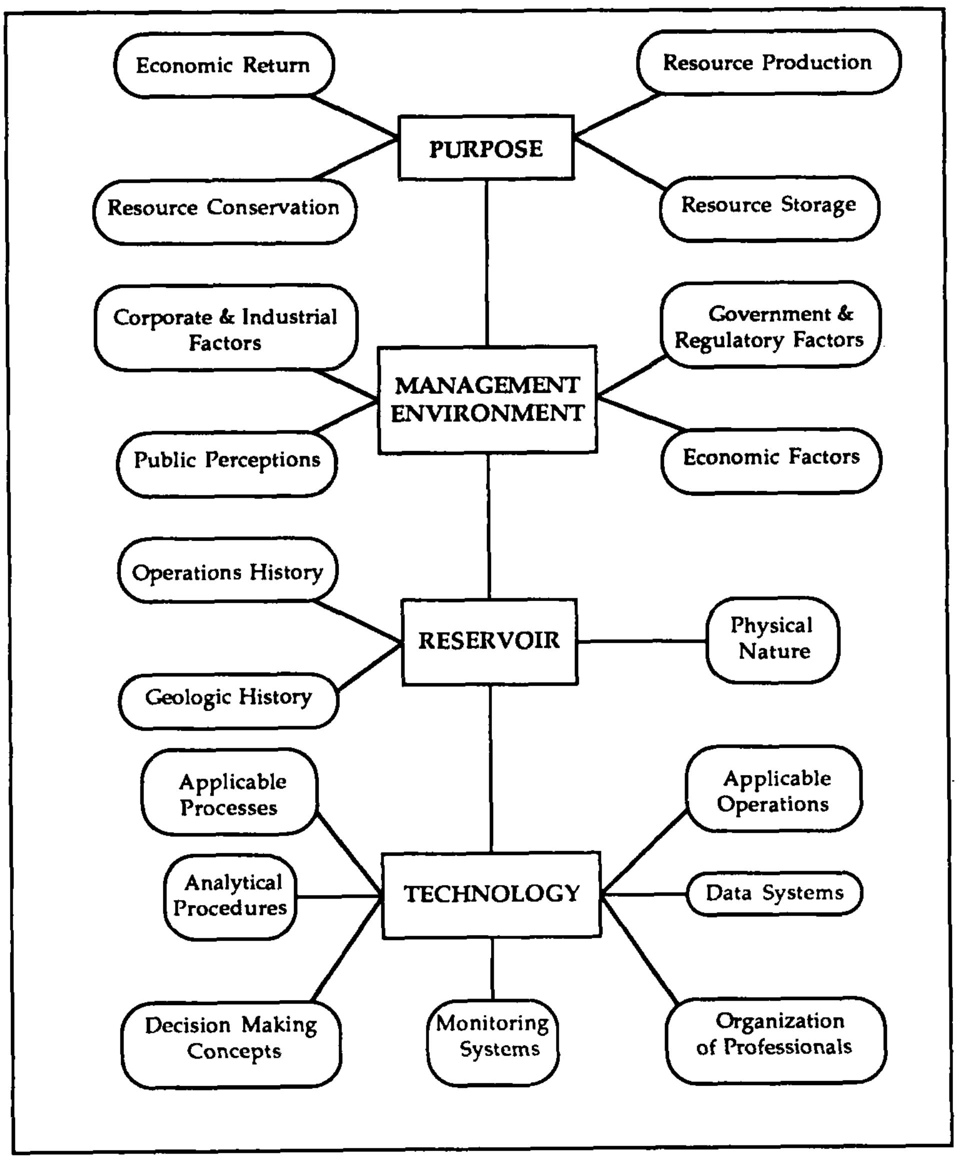

Fig 1. Components of Reservoir Management

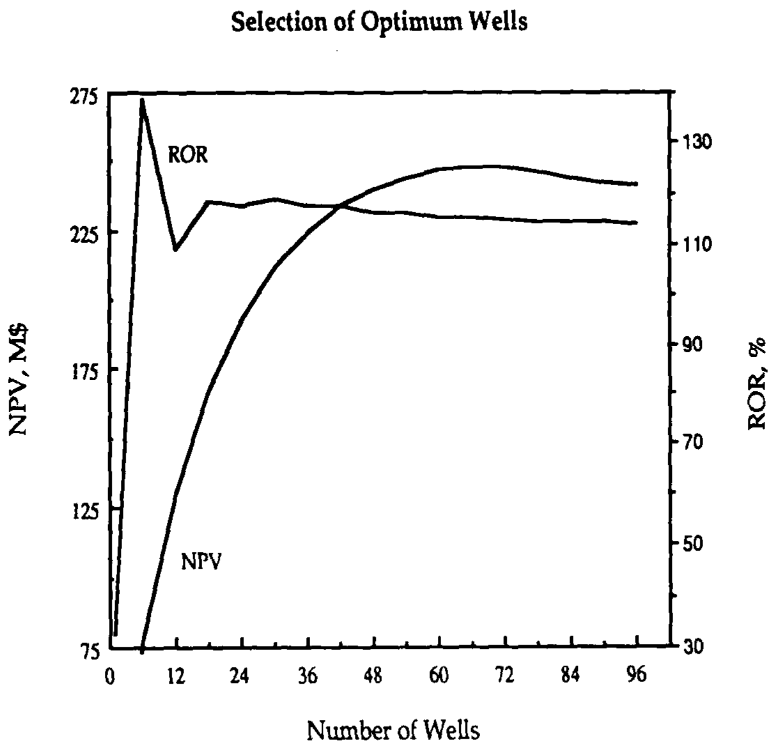

Fig 2. Comparison of Net Present Value and Rate of Return

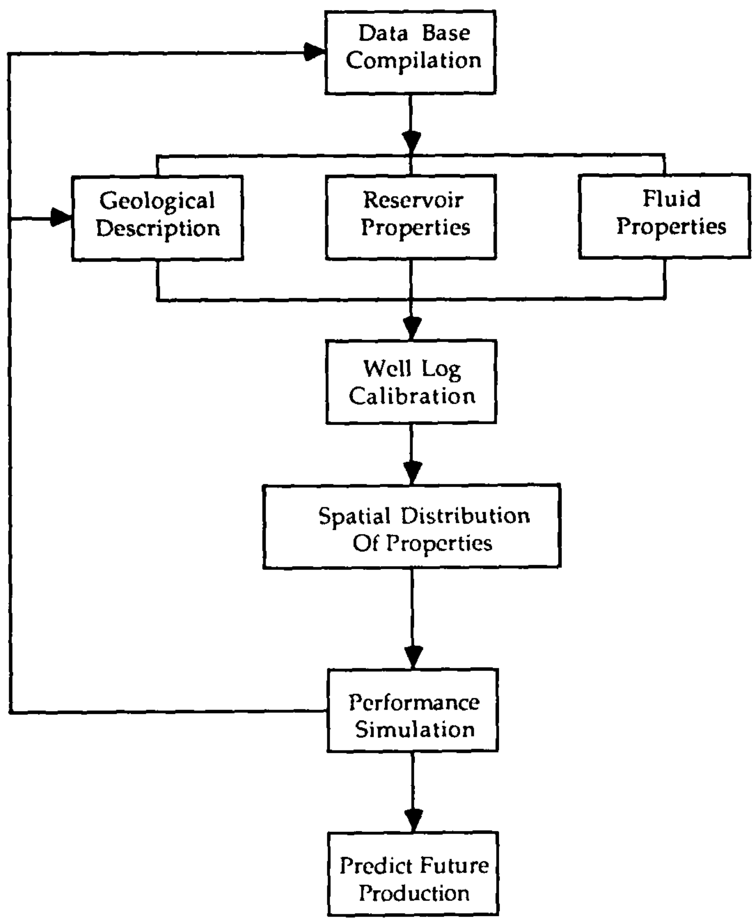

Fig 3. Stages of Reservoir Description

Integrated Reservoir Management

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Summary

The modern reservoir management process involves goal setting, planning, implementing, monitoring, evaluating, and revising plans. Setting a reservoir management strategy requires knowledge of the reservoir, technology, and an understanding of the business, political, and environmental climates. Formulating a comprehensive management plan involves depletion and development strategies, data acquisition and analyses, geological and numerical model studies, production and reserves forecasts, knowledge of facilities requirements, economic optimization, and management approval. Implementing the plan requires management support; field personnel commitment; and multidisciplinary, integrated teamwork. Project success depends on careful monitoring/surveillance and thorough ongoing evaluation of its performance. If the actual performance of the project does not agree with the expected performance, the original plan should be revised and the cycle (implementing, monitoring, and evaluating) reactivated.

This paper presents sound reservoir management concepts and methods including a team approach based on integration of geoscience and engineering professionals, tools, technology, and data.

Introduction

The newest industry buzz word, reservoir management, has received significant attention in recent years. Various panel, forum, seminar, and technical sessions[1-6] provided the framework for information sharing and exchanging ideas on many practical aspects of integrated, sound reservoir management. The needs to enhance recovery from the vast amount of remaining oil and gas in place around the world and to compete globally require better reservoir management practices.

A reservoir's life begins with exploration, which leads to discovery; reservoir delineation; field development; production by primary, secondary and tertiary means; and abandonment (**Fig. 1**). Sound reservoir management is the key to successful operation of the reservoir throughout its entire life. It is a continuous process, unlike how the baton is passed in traditional E&P organizations.

Historically, some form of reservoir management has been practiced only when a major expenditure is planned, such as original field development or waterflood installation. The reservoir management studies at these specific times were not integrated; i.e., different disciplines did their part separately. During the last 20 years, however, greater emphasis has been put on synergism between engineering and geosciences.[7-11] Halbouty[7] stated in 1977: "It is the duty and responsibility of industry managers to encourage full coordination of geologists, geophysicists, and petroleum engineers to advance petroleum exploration, development, and production." Despite the emphasis, progress in integration has been slow.

Many leading-edge technological advances have been achieved in geophysics, geology, petrophysics, production, and reservoir engineering. Mainframe supercomputers, more powerful personal computers, and workstations are providing ever-increasing computing power and more efficient database management systems. The technological advances and computer tools (i.e., 3D seismic surveys, cross-well seismology, horizontal wells, geostatistics, EOR processes, and facilities automation) can facilitate better reservoir management, enhancing economic recovery of hydrocarbons (**Fig. 2**). Even a small percent increase in recovery efficiency could amount to significant additional recovery and profit. These incentives and challenges should provide the motivation to practice sound reservoir management.

This paper provides management, engineers, geologists, geophysicists, and field operations staff a better understanding of the practical approach to reservoir management involving multidisciplinary, integrated team efforts.

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Reservoir Management Concepts

Sound reservoir management requires use of both human and technological resources for maximizing profits. Reservoirs have been managed every day for more than 100 years; the task of management is not in question. However, the quality of management is at stake. A number of windows of opportunity for improving reservoir management practices exist.

The Crisman Inst. for Petroleum Reservoir Management at Texas A&M U. published a manual for petroleum reservoir management proposing an integrated approach to reservoir management.[12] This manual, which is the first of its kind, tried to present from a nontechnical standpoint a thorough understanding of the various aspects of reservoir management.

The first treatment of integrated reservoir management in book form was recently published.[13] It focuses on reservoir management as a whole by integrating the technologies and activities of the many disciplines involved.

Haldorsen and Van Golf-Raacht[14] presented a philosophy of managing reservoirs from exploration to abandonment. The process of designing economically optimum field developments was discussed at great length, with emphasis on reservoir description and the interaction of disciplines.

The panel talks given by Wiggins and Startzman,[15] Journel,[16] Raza,[17] Thakur,[18] Stiles,[19] and Satter[20] provide in-depth discussions of many aspects of reservoir management.

Definition of Reservoir Management. A number of authors have defined reservoir management recently.[10,12,14,20,21] Basically, sound reservoir management practice relies on the use of available resources (human, technological, and financial) to maximize profits from a reservoir by optimizing recovery while minimizing capital investments and operating expenses (**Fig. 3**).

Reservoir management involves making certain choices: let it happen or make it happen. We can leave it to chance to generate some profit from a reservoir operation without ongoing deliberate planning, or we can enhance recovery and maximize profit from the same reservoir through sound management practices.

Reservoir Management Approach. ***Timing.*** The ideal time to start managing a reservoir is at discovery.[10] However, it is never too late to initiate a well-thought-out, coordinated reservoir management program. An early start not only provides better overall project planning, implementation, monitoring, and evaluation but also saves money in the long run, maximizing the profits.

Integration of Geoscience and Engineering. Synergy and team concepts are the essential elements for integration of geoscience and engineering. Integration involves people, technology, tools, and data (**Fig. 4**). Its success depends on the following.

1. An overall understanding of the reservoir management process, technology, and tools through integrated training[20] and integrated job assignments.
2. Openness, flexibility, communication, and coordination.
3. Working as a team.
4. Persistence.

It is becoming more recognized that reservoir management is not synonymous with reservoir engineering and/or reservoir geology. Success requires multidisciplinary, integrated team efforts. The players are everyone who has anything to do with the reservoir