Oil Well Testing Handbook

Amanat U. Chaudhry

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Foreword

Although elements of oil well testing methods have been practical almost since oil reservoirs were first recognized, the concept of oil well testing techniques took form only within the past three decades. Many individual monographs and at least one manual on the subject have been published in the open literature, and it is probable that proprietary presentations of oil well testing concepts are to be found within the internal libraries of some oil-producing companies. In the present volume, the author presents a treatment of the subject to be published in book form.

The roots of oil well testing are to be found in reservoir engineering taken in its broadest sense as the technology that deals with the well/reservoir behavior through the measuring and analysis of drill-stem tests, flow, and transient pressure responses in unfractured and fractured gas wells. The concepts related to oil well test data acquisition and interpretation are presented from a practical viewpoint. These concepts are emphasized throughout the book by means of examples and field case studies.

In *Oil Well Testing Handbook*, the author has presented a comprehensive study of the measuring and analysis of flow and transient pressure responses in oil wells. The basic principles are reviewed, and the applicability and limitations of the various testing techniques are critically discussed and illustrated with actual field examples. The material is presented in a form that will allow engineers directly involved in well behavior, pressure build-up, and flow testing to re-educate themselves in the subject. At the same time, with its up-to-data review of the literature and extensive bibliography, the book will serve as a useful guide and reference to engineers directly engaged in well pressure behavior work. The author has accomplished the intended objectives of the book in a thorough and excellent manner.

The author has illustrated field application examples and field case studies to describe the type of wells and reservoir behavior encountered in modern production practice. The source, nature, and precision of the data and studies on which the calculations and analysis are based are discussed subordinately. Numerous exercises are provided to develop an understanding of the principles and limitations of applied oil well testing methods.

The book is essential and important to engineers concerned with evaluating well/reservoir systems and the pressure performance of oil wells. The author has extensive experience in this field and is most qualified to treat the subject. It is a timely addition to the literature of petroleum technology.

Dilip Borthaker
Head of Gas Engineering Department
Gulf Indonesia Resources

Preface

The major purpose of writing this book is to provide a practical reference source for knowledge regarding state-of-the-art oil well testing technology. The book presents the use of oil well testing techniques and analysis methods for the evaluation of well conditions and reservoir characteristics. All techniques and data described in this book are "field-tested" and are published here for the first time. For example, this book contains new tables and comparisons of the various methods of well test analysis. Most of these techniques and applications are clearly illustrated in worked examples of the actual field data. Several actual field example calculations and field case studies are included for illustration purposes.

This text is a must for reservoir engineers, simulation engineers, practicing petroleum engineers and professional geologists, geophysicists, and technical managers and helps engineering professors better acquaint their students with "real-life" solution problems. This instructive text includes practical worked examples that the readers should find easy to understand and reproduce.

Fundamental concepts related to well test data acquisition and interpretation are presented from a practical viewpoint. Furthermore, a brief summary of the advances in this area is presented. Emphasis is given to the most common interpretation methods used at present. The main emphasis is on practical solutions and field application. More than 129 field examples are presented to illustrate effective oil well testing practices, most analysis techniques and their applications.

Many solutions, which are presented, are based upon author's experience dealing with various well testing techniques and interpretation around the world. I am very thankful to the many companies with whom I had the opportunity to work in well test analysis for many years.

A properly designed, executed, and analyzed well test can provide information about formation permeability, reservoir initial or average pressure, sand-face condition (well damage or stimulation), volume of drainage area, boundary and discontinuities, reservoir heterogeneity, distance or extension of the fracture induced, validation of geological model, and system identification (type of reservoir and mathematical model).

Further, it is important to determine the ability of a formation to produce reservoir fluids and underlying reason for a well's productivity. These data, when combined with hydrocarbon, production data, and laboratory data on fluid and rock properties, afford the means to estimate the original hydrocarbon in-place and the recovery that may be expected from the reservoir under various modes of exploitation. In addition, well test data and IPR well performance equations, combined with production data, help to design, analyze, and optimize total well production system or production optimization.

The rigorous discussions, practical examples, and easy-to-read manner make this a valuable addition to every petroleum professional's library. Our colleagues' discussions and their suggestions were very valuable in making this book useful to a practicing engineer. Most users of this book will find it logically organized and readily applicable to many well testing problem solutions and field application.

One additional note should be made concerning this book. The author has inserted many personal opinions, evaluations, analysis, recommendations, conclusions, etc. He is often criticized for doing this without specifically stating that these are personal thoughts. If the reader does not find a reference or logical proof of a particular statement, he can safely assume that it is a personal opinion based on the author's experience and knowledge of the subject.

Suggestions of many readers were evaluated in preparing this book. Any further comment and suggestion for improvement of the book will be gratefully appreciated. Please feel free to contact me directly.

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Mr. Dilip Borthakur* has reviewed the material presented in this book. He has spent hundreds of hours reading, checking, and critically commenting on all aspects of the material and its presentation. There is no doubt that the book is a much better volume that it would have been without his aid.

The technical typing as well as figures and tables have been largely the work of Ms. Faiza Azam who is a graduate student in Physics and Mathematical Methods at Allama Iqbal Open University, Islamabad, Pakistan. Her highly accurate work has added substantially to this book.

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Chapter 1

Introduction

1.1 Role of Oil Well Tests and Information in Petroleum Industry

Oil well test analysis is a branch of reservoir engineering. Information obtained from flow and pressure transient tests about in situ reservoir conditions are important to determining the productive capacity of a reservoir. Pressure transient analysis also yields estimates of the average reservoir pressure. The reservoir engineer must have sufficient information about the condition and characteristics of reservoir/well to adequately analyze reservoir performance and to forecast future production under various modes of operation. The production engineer must know the condition of production and injection wells to persuade the best possible performance from the reservoir.

Pressures are the most valuable and useful data in reservoir engineering. Directly or indirectly, they enter into all phases of reservoir engineering calculations. Therefore accurate determination of reservoir parameters is very important. In general, oil well test analysis is conducted to meet the following objectives:

- To evaluate well condition and reservoir characterization;
- To obtain reservoir parameters for reservoir description;
- To determine whether all the drilled length of oil well is also a producing zone;
- To estimate skin factor or drilling- and completion-related damage to an oil well. Based upon the magnitude of the damage, a decision regarding well stimulation can be made.

1.2 History of Oil Well Testing and Uses of Oil Well Tests

Two monographs[1,3] and numerous additional oil well test analysis technical papers have been published. Those papers have extended the scope of oil well test analysis, publicized many new problems, provided

solutions for previously unsolved problems, and changed the approach to some phases of oil well test analysis. Thus, it is appropriate to provide an updated handbook dealing with advances in oil well test analysis in a manner that presents an up-to-date treatment of the state of the art. This book presents popular pressure transient test analysis techniques and estimates of the range of applicability. More than 100 actual field examples illustrate most analysis techniques. Figure 1–1 shows uses of well tests.

1.3 Oil Well Test Data Acquisition, Analysis, and Management

Throughout the life of an oil well, from exploration to abandonment, a sufficient amount of well test data are collected to describe well condition and behavior. It should be emphasized that the multidisciplinary professionals need to work as an integrated team to develop and implement the well test data management program.

Efficient Oil Well Test Analysis Programs

Initial bottom-hole pressure measurements should be made, preferably at each well and at selected "Key Oil Wells" periodically. Key oil wells represent 25% of the total wells[2]. Reference 2 has also found that it is beneficial to measure pressure in all wells at least every 2–3 years to aid in calibrating reservoir models. It is essential to establish the specification of what and how much well test data need to be gathered, and the procedure and frequency to be followed. A logical, methodical, and sequential well test data acquisition and analysis program is shown in Figure 1–2.

1.4 Selecting Oil Wells for Optimum Stimulation Treatment

The key to determining whether or not a well is a good candidate for stimulation treatment is diagnosing the well to find the cause for its low productivity. Buildup, drawdown, or drill-stem tests, core analyses offset well data, and other information can be used to accomplish this. After diagnosis, the optimum well stimulation treatment, either small or massive hydraulic

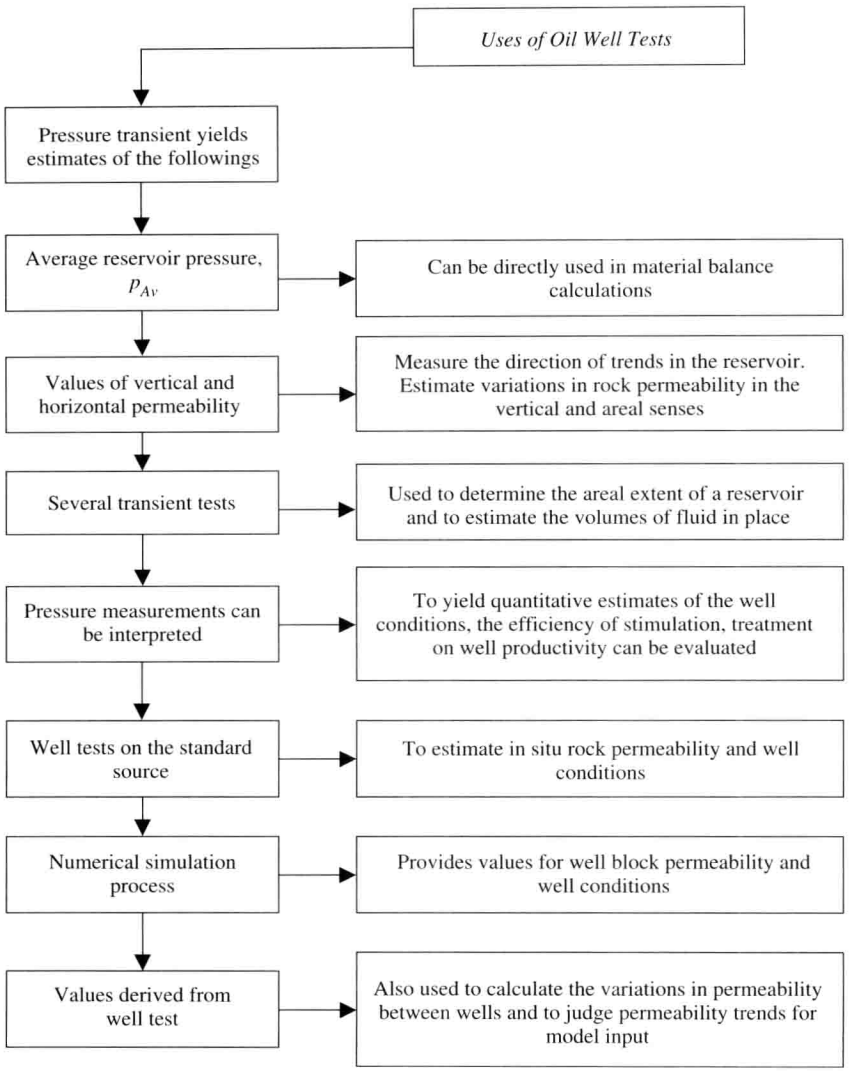

Figure 1–1. Various reservoir parameters and their uses.

fracturing, can be designed for the well. Figure 1–3 shows several sets of calculations designed to evaluate well/reservoir behavior, and to evaluate reservoir parameters, quality, and stimulation efforts to optimize completion methods for enhancing hydrocarbon oil recovery and maximizing profitability.