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on

MULTI PHASE PRODUCTION

Edited by
A. Wilson

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Multi Phase Production

Edited by Professor A Wilson

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FOREWORD

Although the term Multiphase Production has figured in discussions concerning hydrocarbon production for many years, much still remains to be understood. Today it is less of a black art than it was twenty years ago, but it should be remembered that one aspect, hydrate formation, was defined at the turn of the century. Today, ninety years on, major projects to better understand this one phenomenon within multiphase production are being carried out with participation by almost all major oil companies as well as many universities and research associations.

The state of the art of multiphase production changes continually, and in Europe and North America more than one hundred related projects are underway. The availability of powerful computer models has helped considerably to better understand the results obtained from research work but the total cost of investment for these tools is very high. Funding is an ongoing problem.

Governments world-wide are taking a greater interest in this form of production. For them, it offers, in the future, lower investment costs and operating costs, whilst simplifying the very costly conventional installations that are needed to produce hydrocarbons, particularly from deep water offshore reservoirs. Oil companies also see these techniques as a considerable help in boosting production world-wide, whilst avoiding high costs in a market that has reduced earnings, in constant dollar terms, against an increasingly difficult exploration background. Thus, Government and industry funding is increasingly important in progressing this area of long term development.

The Community of European Countries has also appreciated the importance of understanding correctly, and in depth, the various phenomena associated with multiphase production. Hence, through their various commercial and technical aid schemes they have invested heavily in a wide variety of relevant projects to everyone's benefit.

This, the 6th International Conference organised by the British Hydromechanics Research Group Limited, with sponsorship from the Institut Français du Pétrole, the University of Tulsa and the Tulsa University Fluid Flow Projects, provides a forum to examine recent progress in this most important subject. Activities such as slug flow analysis, flow modelling, multiphase metering and boosting, are all examined in depth and will lead to a further improvement in the overall level of knowledge. The conference papers and discussion will reveal the many areas still in need of detailed evaluation and understanding.

May I, on behalf of the Technical Advisory Committee, wish you all welcome to Cannes and hope that all of you will benefit from the wide range of excellent papers that are being presented.

Professor Alan Wilson
Chairman
Technical Advisory Committee

6th International Conference on
MULTI PHASE PRODUCTION
Cannes, France : 16-18 June 1993

OPENING ADDRESS

Mr Chairman, Ladies and Gentlemen,

It is a great pleasure to open this 6th Conference on Multiphase Production. It is also difficult to introduce such a large subject!

So let me start with words you have probably already heard a hundred times, but which will nevertheless be useful to keep in mind during these few days to stir up our discussions.

Oil industry is facing new challenges. New exploration areas are limited, production from major fields is on the decrease and companies are forced to extensively explore their "own garden" around their existing facilities. Consequently, the size of discoveries is generally smaller. At the same time, new technical challenges have come up : high pressure, high temperature, reservoir fluids in critical state, deep water...

Taking all these elements into consideration and in order to cash in on these discoveries or existing portfolios under the current rather depressed economic conditions, governments and oil companies have to stimulate innovation and promote cheaper production concepts.

Naturally Petroleum Engineering should be on the first line. Petroleum Engineering aims to maximize recovery from the reservoir and at the same time to optimize the use of its proper downhole energy. This requires to look at it from a global perspective so as to overstep the present-day limits of flow conditions in, let's say, the reservoir, the well or the pipeline system.

From the reservoir to export facilities, we handle a multiphase product which behaves acording to thermodynamic laws. Multiphase production is therefore the essence of Petroleum Engineering. More specifically, it applies to the simultaneous handling of significant proportions of gas, oil, water and sometimes solids. And this is a challenge in itself...

First it is a challenging domain for **modelling**. We must remember that Bernouilli introduced hydrodynamics more than two centuries ago. Reynolds wrote down his unforgettable number in the middle of the 19th century and we have all played with it...

We have started from an empirical approach. During the fifties, data became available from test facilities and from field production. The idea was to extrapolate from these laws that describe one-phase fluid. Multiphase fluids were considered as mixtures of homogeneous components. Attention was focused on slippage effects and the frist flow pattern maps were constructed.

The first mechanistic models for slug flow and flow pattern prediction appeared in the '70 s.

In the early '80 s the personal computer phenomenon spread extensively and with it, the use of software to evaluate pressure drops. But all this was based on beloved old-time correlations and extensive use of existing models and correlations that were far from being perfect.

To improve prediction accuracy it was necessary to have a better knowledge of basic physical mechanisms... New sensors and instrumentation asociated with computer hardware and software helped obtain a better data acquisition and thereby a better understanding of these phenomena.

Nodal analysis was also introduced and engineers were able to optimize, for instance, the operation of gas-lift supply networks.

New equations and experimental data are continuously introduced into flow models. Steady state two-phase flow models were first developed, then commonly used.

Recently, transient configurations have been evaluated. Operational events, as shutting down or opening a well, changing the outlet pressure, are now simulated with a fair degree of reliability, which is to be further improved.

Careful observation of transient conditions in the North East Frigg pipeline in Norway, for instance, revealed a change in the composition of the liquid hold-up with time, as condensate was replaced by water in the course of time. The effects thereof can be dramatic, especially causing hydrate formation or impairing corrosion inhibition. This confirmed the need to further improve our knowledge of three-phase flows. For this reason, first attempts at three-phase flow simulation are now being made.

As far as multiphase technology is concerned considerable progress has been made too.

To minimize back pressure effects on the formation, engineers imagined to implement subsea separators. Test programs have been recently performed in Europe and US. It can be concluded that conventional subsea separation is technically feasible but not yet sufficiently reliable.

On the other hand, engineers worked on downhole pumping.

A lot of efforts were made to increase the gas void fraction acceptance at the downhole pump suction. The hydraulic cells of pumps were modified so as to handle increasing quantities of gas. Such pumps could even be installed downstream the well choke... The Poséidon concept was born. It had moved from the bottom to the surface.

Different pumping systems were studied. Screw pumps proved to be feasible while promising results were obtained for reciprocating pumps.

On the metering side, the 88 IMPEL study has led to an impressive list of theoretical concepts which could be used to build multiphase meters. Some of them have been selected and some others are now being tested in laboratories or through field test loops.

Let me say a few words about **physico-chemistry** in multiphase transportation. There are two main areas of concern today. Different from a thermodynamic point of view, they are nevertheless similar in terms of operational consequences. I am talking of hydrates and high pour point or waxy crudes.

For a while, it has been thought that hydrate plugging could be prevented by using conventional methods such as alcohol inhibition or thermal isolation to keep the flow system away from the thermodynamic hydrate area. But new production conditions constrain such methods in certain economic and environmental limits. New methods for hydrate inhibition are being developed in laboratories. Though their field of application may not be universal, they can however be complementary.

In the field of high pour point or waxy crudes, much progress has been made, too. Crudes, regarded as non producible 10 years ago, are now flowing through pipelines at temperature below their pour point.

This rapid overview of the last decades shows how knowledge and technology have progressed in the multiphase domain.

If we look back at the list of contents of the first multiphase production conference which took place in Coventry in April '83 under the official mane of "The International Conference on the Physical Modelling of Multiphase Flow" and if we compare it with the present-day Conference in Cannes, ten years later, we can measure the whole progress that has been made since then. The '83 Conference was mainly dedicated to multiphase flow modelling and the '91 Conference included reports on multiphase technology and on operational experiences.

Even if we do not see yet many pages about the physico-chemistry phenomena, we must keep in mind that more challenging developments will require a more global approach from operators which will have to face them.

Mr Chairman, Ladies and Gentlemen, I am sure this 6th Multiphase Production Conference will contribute to the promotion of new ideas and new applications, and I thank you for your kind attention.

M. Jacques Duquesne
Directeur Délégué aux
Techniques Industrielles
Elf Aquitaine, Pau, France

CONTENTS

6th International Conference on
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FLOW MODELLING

A MECHANISTIC MODEL FOR THE FLOW PHENOMENA IN JET-LIFTING AND DISPLACEMENT OF WELL FLUIDS WITH COILED TUBING AND NITROGEN

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ABSTRACT

Surgence induction and displacement of well fluids with coiled tubing and nitrogen is a very common technique in the oil industry. Although effective, it is also a quite expensive operation. Bianco (1990) developed a full mechanistic and comprehensive model to predict fluid rates and recovery in order to minimize costs related to this operation. Laboratory experiments were carried out to supply reliable data regarding the validation of these model. A reasonable agreement between the lab data and the numerical scheme was observed. It was also verified that the frictional pressure drops plays a very important role in both predicted fluid recovery and total pressure gradients. Moreover, the authors verified that the gradients due to accelerational effects must not be neglected.

NOMENCLATURE

A_{an}	Cross sectional area of the coil tubing-production tubing annulus
A_c	Cross sectional area of the production tubing, internal
A_g	Area occupied by gas in the annulus cross section
A_i	Area of the orifice in the ending nozzle of the coiled tubing
A_L	Area occupied by liquid in the annulus cross section
A_T	Cross sectional area of the coiled tubing
d	Distance between the centres of the coiled tubing and production tbg.
D_C	Internal diameter of the production tubing
$D_{e,fl}$	External diameter of the coiled tubing (O.D.)
$D_{i,fl}$	Internal diameter of the coiled tubing (I.D.)
D_{eq}	Equivalent diameter of the annular section
f_{an}	Fanning friction factor for annular geometries
f_T	Fanning friction factor for tubular geometries
g	Acceleration of gravity
L	Length of the annular section
L_e	Length of production tubing below the ending nozzle of the coil tubing.
L_S	Length of prod. tbg. below the static level of fluid
$\dot{M}_L$	Mass flow rate of the liquid phase
$\dot{M}_G$	Mass flow rate of the gas phase
P_{atm}	Atmospheric pressure
P_i	Pressure at the coiled tubing outlet