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What's New in Reservoir Fluid Sampling

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1. Introduction

Obtaining valid reservoir fluid samples is fundamental to the value of phase behaviour studies and research projects. Each reservoir contains a different mixture of hydrocarbons, and these must be sampled and maintained at high pressures, commonly up to 10,000 psi (700 atmospheres), until they can be subjected to special Pressure-Volume-Temperature (PVT) procedures in the laboratory, or used in other areas such as core flooding work.

Phase behaviour data are vital for reservoir simulation, tubular goods specification, plant design and of course safety, so poor samples lead to higher risks and possible financial penalties. For example, an oil sample which has lost some of its dissolved gas would have increased viscosity, and could lead to a reservoir appearing to be uneconomic to produce. A gas-condensate fluid which has lost some of its heavy hydrocarbons could lead to inadequate facilities to handle liquid production. Incorrect sampling can result in fluids that show no sign of wax or asphaltene deposits, and problems may only be identified when full-scale production starts.

2. Industry Developments

Over the last ten years R&D work around the world has led to major changes in fluid sampling technology. Surface sampling has seen a move away from the use of mercury as displacing fluid, which is a hazard for personnel and the environment, and an increase in the use of piston sample cylinders. Now, computer acquisition and control technology is normally used for recording vital sampling data and in some cases in controlling the sampling process itself.

Even more significant innovation has occurred in the field of downhole sampling, both for cased hole applications and in open hole situations. Advanced tools have been developed to monitor the quality of fluid being sampled, to perform bubble point checks downhole, to maintain the sample above reservoir pressure during retrieval, and to preserve low

concentrations of reactive components. Formation test tools can collect samples at several precise depths, and contribute to knowledge of compositional gradients, a common feature in Saudi Arabian reservoirs.

In non-conventional sampling technology, some development work has been carried out in the use of coiled tubing to reduce the drawdown while sampling in gas condensate wells, but this approach requires special small scale separation systems to achieve the necessary accuracy in flow rate measurements, and does not appear to have been commercialised. Isokinetic sampling techniques, which involve withdrawing a small sample stream using a probe facing into the main production flow while maintaining identical velocity, have been extended from the flowline to separator gas outlets. Here, a new approach determines the quantity of liquid carry-over in the gas stream from different fluid samples taken with the probe facing upstream and downstream. Implementation of the technique has remained fairly limited though, with the majority of the industry concentrating on achieving optimum sizing and control of separators to minimise carry-over.

Recent work within the Hydrocarbon Phase Behaviour Unit (HPBU) at Saudi Aramco's R&D Centre has involved: research studies on bottom hole sampling (BHS) techniques; development work involving improved sampling methodology; on-site sampling and analysis projects; work on industry standards documentation; and evaluation of quality issues relating to formation test samples.

3. Research studies on BHS techniques

State-of-the-art BHS technology now involves so-called single phase or monohasic samplers in which the sample is collected in a downhole tool by the controlled movement of a piston, triggered either by a clock or an electric signal from the surface. Then, once the sampler is locked closed, a charge of high pressure nitrogen is released inside the sampler to pressurise the hydraulic oil. This nitrogen buffer will then maintain oil samples well above bubble point pressure despite the cooling that occurs while they are retrieved from the well. A diagram of a single phase sampler (SPS) is shown in Figure 1. This sampler is especially useful to Saudi Aramco in fields where potential asphaltene precipitation problems are being studied, because asphaltene deposition usually occurs as sample pressure decreases towards the bubble point.

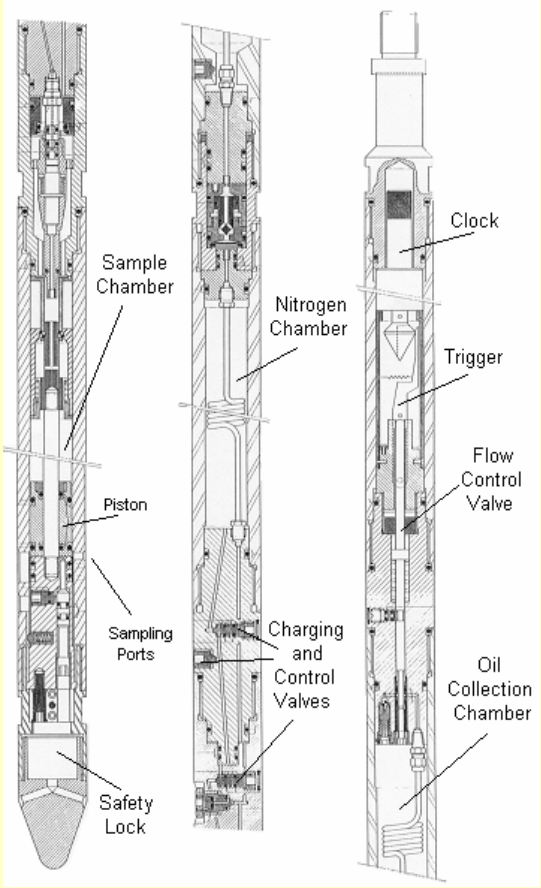

Figure 1. Single Phase Sampler (SPS) Drawing

Work is also underway involving various commercial sampler designs and prototypes to investigate the down hole sampling of gas condensate reservoirs both for high quality PVT studies, and for improved accuracy of hydrogen sulphide (H_2S) measurements. This project may well change industry practice in gas condensate reservoir fluid sampling. Figure 2 shows laboratory testing of a new down hole sampler underway.

Figure 2. Laboratory Testing of a New Down Hole Sampler

4. Development work involving improved sampling methodology

In line with all major oil and service companies, changes have been made to Saudi Aramco field sampling operations which are now totally free of mercury. This has necessitated a major investment in piston sample bottles, and in changes in handling and maintenance procedures.

Increasing work involving on-site low-level H_2S measurements has benefited from the use of a gas monitor designed for personal protection. The special application of this instrument has recently been written up as Saudi Aramco Laboratory Analytical Method (SALAM) 320-14.

One problem that occurs throughout the petroleum industry relates to the quantity of gas sample required for laboratory recombination. In most cases, duplicate samples provide an adequate amount of gas, but when samples are collected from separators or Gas Oil Separation Plants (GOSPs) operating at low pressure, a greater volume of gas will be required and this may be overlooked on-site, leading to insufficient sample to perform laboratory studies. The chart in Figure 3 has therefore been created to solve this problem and allow easy estimation, at the well site, of the gas sample volume that must be collected as a function of separator pressure, gas oil ratio, and volume of oil sample.

5. On-site sampling and analysis projects

On-site measurements may not fall into the category of sampling that most engineers envisage, but this is a critical area in which reactive or trace constituents may be lost or changed during shipment to the laboratory, so measurements must be made on-site on a representative sample or sample stream. This area highlights the fact that the sampling process does not just concern itself with collecting representative fluid from the sample point. It also involves arranging for representative fluid to be flowing where the sample is collected, or for the sample point to be chosen where the best fluid sample can be obtained. Since many on-site tests for H_2S and carbon dioxide (CO_2) in Khuff gases involve clean-up tests without a separator, guidelines have also been developed both for site managers and sampling personnel to ensure maximum sample quality is achieved in these circumstances.

This work has shown that no single method for sampling and measuring H_2S can be relied on in all situations, and an approach using two independent

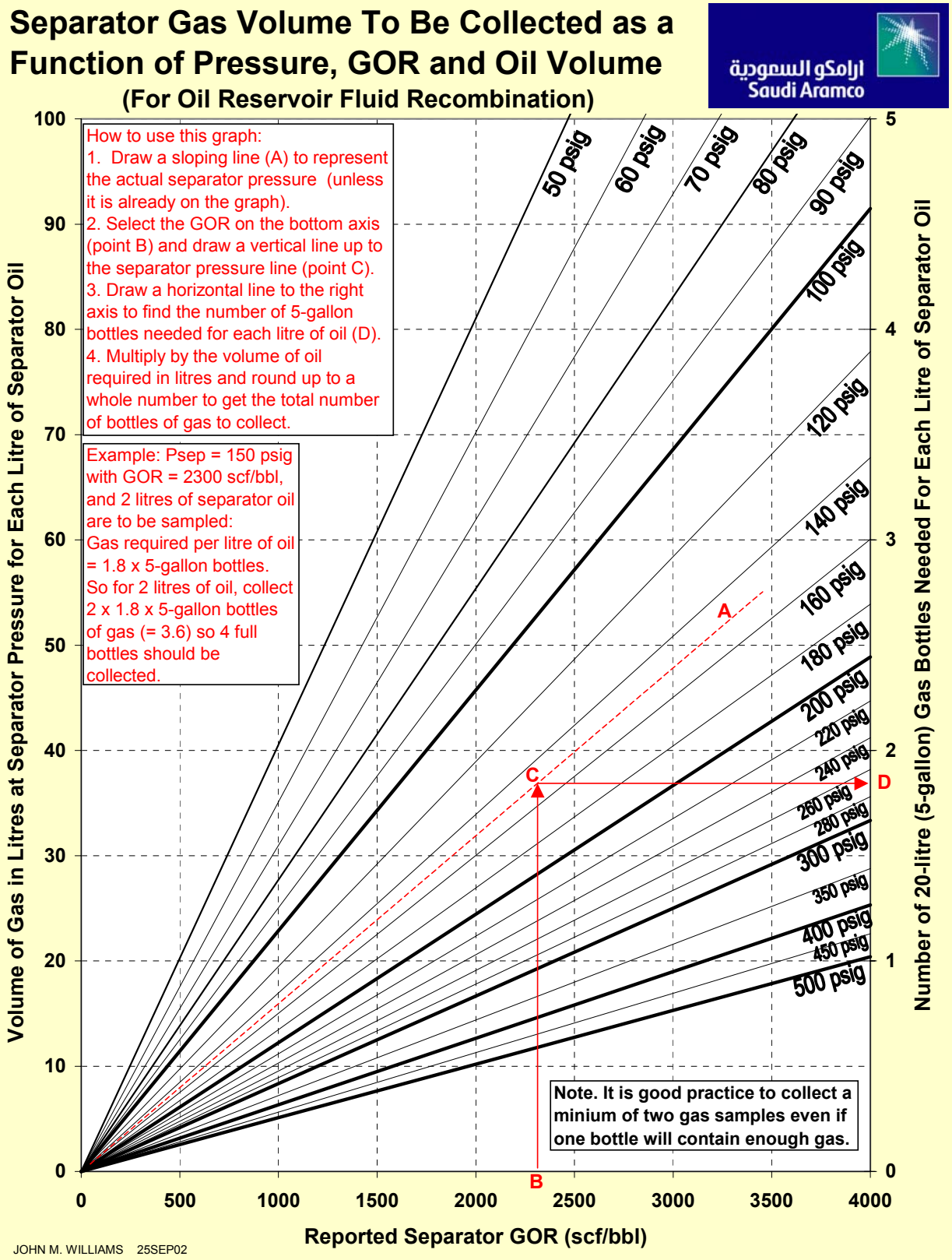

Figure 3. Separator Gas Volume Calculation Chart

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6. Work on industry standards documentation

The HPBU has been involved in the development of new and updated industry documentation and standards, notably the American Petroleum Institute's Recommended Practice 44, "Sampling Petroleum Reservoir Fluids". This was originally published in 1966, and the second edition, Figure 4, has been published this month. Pressure of work on specialists throughout the industry has made voluntary projects of this nature a major challenge to accomplish - the effort to update RP 44 has been ongoing since the early 1990s. The new edition covers the use of piston bottles resulting from the move away from mercury, and introduces the new generation of formation test tool sampling capabilities.

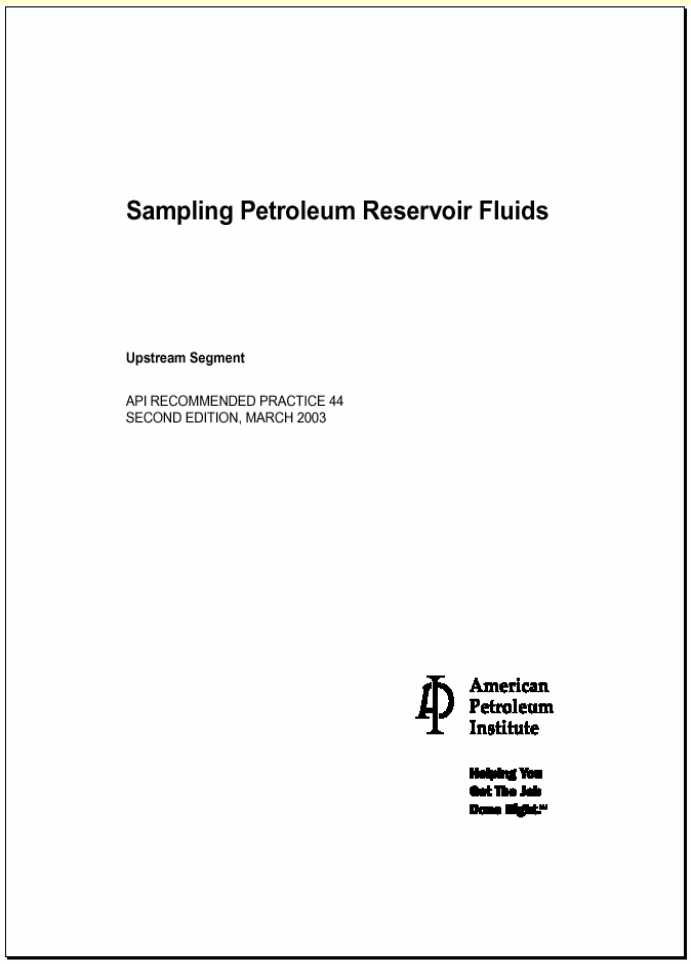

Figure 4. The New API RP-44

Saudi Aramco employees can access API standards via the Technical Information Centre as follows:

- http://tic/
- Click on "Engineering Resource Centre" (under Information Sources)
- Enter your Internet User Name and Password
- Complete the Sub-Account Login using the user **n**ame and password that appear in a separate TIC window
- Click on "Specs & Standards" (under Standards Applications)
- Then use the search window to find the document required.

For example, using "RP 44" as the document number and "API" as the organization locates both the new version of RP 44, together with the First Edition, which is being maintained by API as an historic reference (primarily to all the sampling methods using mercury). Electronic copies of most of the API documents can be downloaded from this site.

7. Evaluation of quality issues relating to formation test samples

New technology brings new challenges, and the latest generation of formation tools have often been found to provide fluid samples of variable quality. Although recent tool developments offer improved quality indications downhole, and better control of the sampling operation, the condition of the near-wellbore region after drilling is also a major factor in sample quality, and work is on-going with drilling and reservoir evaluation personnel to improve this aspect of the operation.

For the present, HPBU recommends the following guidelines for improving the quality of formation test samples:

(1) planning must optimise the match between tool capability and sampling and analysis needs,

(2) sample sizes collected should be compatible with storage containers so that individual samples can be transferred in their entirety,

(3) sample chambers containing mixing devices are to be preferred as they facilitate sample homogenisation prior to transfer,

(4) where possible duplicate samples should be taken from each depth sampled,

(5) to determine depth gradients, samples should be collected from at least three different depths spanning the reservoir interval,

(6) when available, fluid quality monitors should be used to evaluate clean-up of the fluid entering the tool,

(7) fluid sampling rate should be adjusted where possible to minimize pressure drawdown unless down-hole bubble point measurement or estimation are available which allow higher sampling rates to be used with confidence,

(8) if oil base mud (OBM) was used in drilling, collect a sample of the mud that has most recently been used,

(9) if OBM was used in drilling, contact the laboratory that will analyse the samples to establish what samples are needed - for some correction techniques samples are required from the same depth with different levels of filtrate contamination,

(10) use of the formation tester pump to compress collected samples (sometimes referred to as "over-pressuring") may help reduce the effects of cooling, but should not be used if final pressures are to be used as a measure of sample quality. If phase segregation on cooling must be avoided, single-phase sample chambers should be selected,

(11) if fluid pump out into the well is not possible, for example for safety reasons (H_2S, low over balance etc.), large sample chambers should be used at the start of sampling to serve as "dump" chambers, allowing better quality samples to be collected afterwards,

(12) the depth and sampling time must be recorded together with the serial number of each chamber,

(13) if possible, avoid using OBM when drilling, or switch to water base mud for probable hydrocarbon-bearing intervals.

As is evident from these guidelines, wells drilled with OBM are particularly problematic for formation test tool sample quality, and many R&D centres

worldwide are working on correction techniques. Figures 5 and 6 demonstrate the sort of contamination that can occur, and because the base oil is miscible with reservoir oil, it is impossible to remove this contamination from samples.

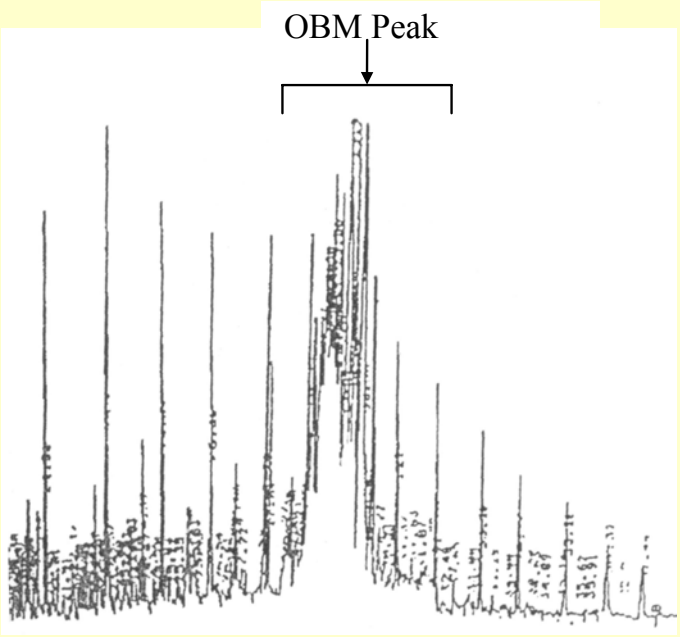

Figure 5. Chromatogram Showing Broad OBM Peak

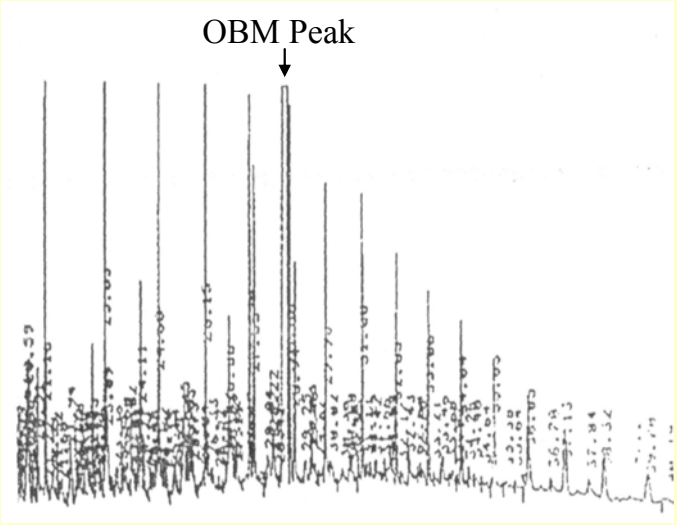

Figure 6. Chromatogram Showing Narrow OBM Peak

Fortunately very little use of oil-base drilling muds has been made by Saudi Aramco, but this article may help to keep in mind the added complications that must be resolved if the situation changes in the future. Many companies are forced to use such muds in order to manage drilling costs in water sensitive formations, and the added expense of handling contaminated samples, and the risk associated with poorer quality data must be used to evaluate the overall economic balance.

8. Fluid sampling in the future

Optimising cost in all petroleum industry activities continues to have a major effect on sampling operations with competition between production testing and formation test tool operations leading to widespread industry acceptance of lower quality fluid samples from the latter. A key challenge now is to get better quality FTT samples not simply by advanced tool capability, but by better planning and preparation for the test. Increasing efforts to obtain reservoir information from short well clean-ups is also putting pressure on fluid sampling operations, but in some cases such as on-site measurements, this change in emphasis may provide opportunities for measurements that would otherwise not be available.

Multiphase metering is likely to have an increasing impact on sampling operations, because the accuracy of flow rates is seen to be improving, and the economic benefits of avoiding the use of separators will be major. However, even with significant development of special sampling approaches, such as isokinetic sampling, it seems unlikely that the same quality of samples will be available as with traditional methods.

Among the major developments in the last 10 to 15 years, is the progress towards the worldwide elimination of the use of mercury in fluid sampling operations, producing significant improvements in personnel safety and environmental protection. Efforts continue to achieve better management of sampling programmes and cost-efficient sample storage, despite the difficult challenge of trying to assign monetary values to fluid samples and the measurements made on them.

Specific technical developments that can be anticipated are a greater use of automatic surface sampling systems, introduction of equipment better designed to preserve reactive samples such as fluids containing H_2S, an increase in gas condensate BHS, and greater use of heated downhole samplers especially for sampling waxy fluids.

With the tremendous pace of development of new down hole tools and functionality, there is a need for speedy updating of industry standard documentation, to allow broad dissemination of new sampling knowledge and practices, yet it is clear this is not a role readily filled by traditional standards organizations such as the American Petroleum Institute. Recent advances are readily available through organizations such as the Society of Petroleum Engineers, which offers a much better prospect of developing peer-reviewed standards updates, and a more international approach.

We hope that this article has been informative. If there is any topic that is of interest, or that you would like us to address in future issues, please contact the Well Testing Unit in Dhahran.

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