Neftemer – A clamp-on multiphase meter for cost effective well monitoring

V. A. Kratirov, D. Gazin (Neftemer Ltd, Russia)
A. V. Kolonskih, (OOO Complex Resource)
A. W. Jamieson (Neftemer Ltd, UK)

INTRODUCTION

Neftemer Ltd has entered into an agreement with the Libyan Petroleum Institute to work together to improve well head flow measurements and information gathering in the Libyan oil industry. A key element in this activity will be the use of the Neftemer clamp-on, non-intrusive multiphase flow meter for assessing the characteristics of Libyan wells and for monitoring production.

Neftemer (the name means “oil meter”) is a multiphase meter which was conceived in the late 1970s, and whose development in the former Soviet Union and in the Russian Federation was in parallel but quite different to the development of multiphase meters in the West. There are no laboratory multiphase test loops in Russia, and assessing the performance and establishing the optimum design had to be done in the field using simple yet practical methods. The story of the development and testing of Neftemer was given in the paper, “Neftemer – a cost-effective multiphase meter for the 21st century”, presented at the 2006 North Sea Flow Measurement Workshop.

This paper deals with the use of Neftemer in normal production operations to improve well monitoring. Throughout the world it is not routine practice to monitor wells continuously. Well testing is usually done for a few hours each month using fixed or mobile test separators, or increasingly, mobile multiphase meter assemblies. Problem wells may receive more attention, but many wells receive far less attention. Key assumptions in well testing are that wells produce in a relatively stable manner during the period between tests, and that switching the well to the test separator does not significantly affect production. In many applications neither of these assumptions is valid. It has long been recognised that continuous well monitoring would represent significant progress in optimising well production. However, it has also been acknowledged that such a monitor must be sufficiently inexpensive to justify its installation on all of the producing wells in a field, and sufficiently accurate and reliable to give acceptable and useful information to operators.

MEASUREMENT OF MULTIPHASE FLOW

The Western oil industry began to take a serious interest in developing multiphase meters around 1980. The objective was to obtain the gas, oil, and water volume flowrates from wells at line conditions. (At present there is still a preference for volume rather than mass flowrates, but there are significant advantages in using mass rather than volume.) These are the measurements that are in principle obtainable from a test separator, the oldest type of multiphase meter, but it was recognised that continuous measurements would allow better control of wells, and the ideal would be to have one multiphase meter per well. Any multiphase meter can be fitted without much difficulty into one of the following four categories or a combination of them.

Compact separation systems

These devices perform a rough separation of the well flow into liquid and gas streams. These are then metered using meters that can tolerate small amounts of the other phase. The liquid must be further split up into oil and water. These systems are being applied worldwide, but are bulky and do not bring the full benefits of multiphase metering with them.

Phase fraction and velocity measurement

These meters attempt to identify the fractions of oil, water and gas and measure the phase velocities, which are not usually the same. Some manufacturers try to condition the flow so that the phase velocities are similar, and the differences in velocity are corrected using multiphase and slip models.

Tracers

Multiphase flow is measured by injecting at known rates tracers (e.g. fluorescent dyes) that mix with the individual phases. By analysing a sample of the multiphase fluid taken sufficiently far downstream of the injection point, and combining this with the injection rate, the individual flows can be determined. Currently tracers are only available for oil and water. The technique is particularly suited for wet gas measurement. Naturally occurring trace compound in crude oils can also be used as tracers to estimate production from different operators in a shared production system.

Pattern recognition

These systems are characterised by their use of simple sensors combined with complex signal processing. Potentially they offer the cheapest hardware combined with the highest metering performance. A major benefit from this approach will be targeting low cost solutions for specific applications.

A useful tool in explaining multiphase flow is the “Multiphase Triangle”, Fig. 1.

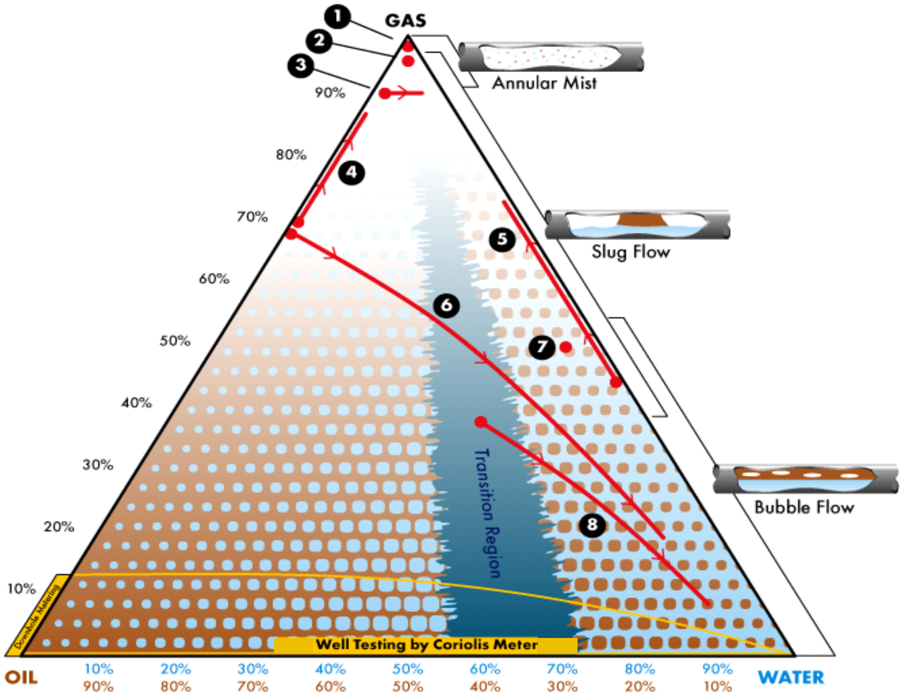

Fig. 1 Multiphase Composition Triangle

The vertices of the triangle represent single-phase gas, oil and water, while the sides represent two phase mixtures and any point within the triangle represents a unique three-phase mixture. The

transition region indicates where the liquid fraction changes from water-in-oil to oil-in-water. The ranges of common multiphase flow regimes, which are affected by temperature, pressure, viscosity and flowline orientation, are indicated at the side of the triangle. Several multiphase applications are shown, ranging from wet gas (1 and 2) to high water cut oil (8). Close to the oil-water axis are low GVF applications. When this diagram was prepared about ten years ago, there were large areas of the triangle for which there were no really suitable meters. Now most areas of the triangle can be tackled, with the need to improve accuracy. The major new challenge is heavy, high viscosity oil.
It is easy to use the triangle to show why multiphase metering is complex. If we have difficulty with the single phases, which are so obviously different from each other, we can expect measurement to be at least as difficult for any multiphase composition in the triangle. We have the added complication that the multiphase fluid composition from a well changes significantly with time. We are now at the stages where some generalities can be seen, but for most new applications each still has to be treated on its own merits.

NEFTEMER

Neftemer comprises two elements as shown in Figure 2 below: a Cs 137 661 kev gamma source housed in a holder unit (left) and a fast (250 Hz) gamma detection unit (right). These units are mounted diametrically opposite each other on a vertical pipe section containing a vertically upward multiphase flow.

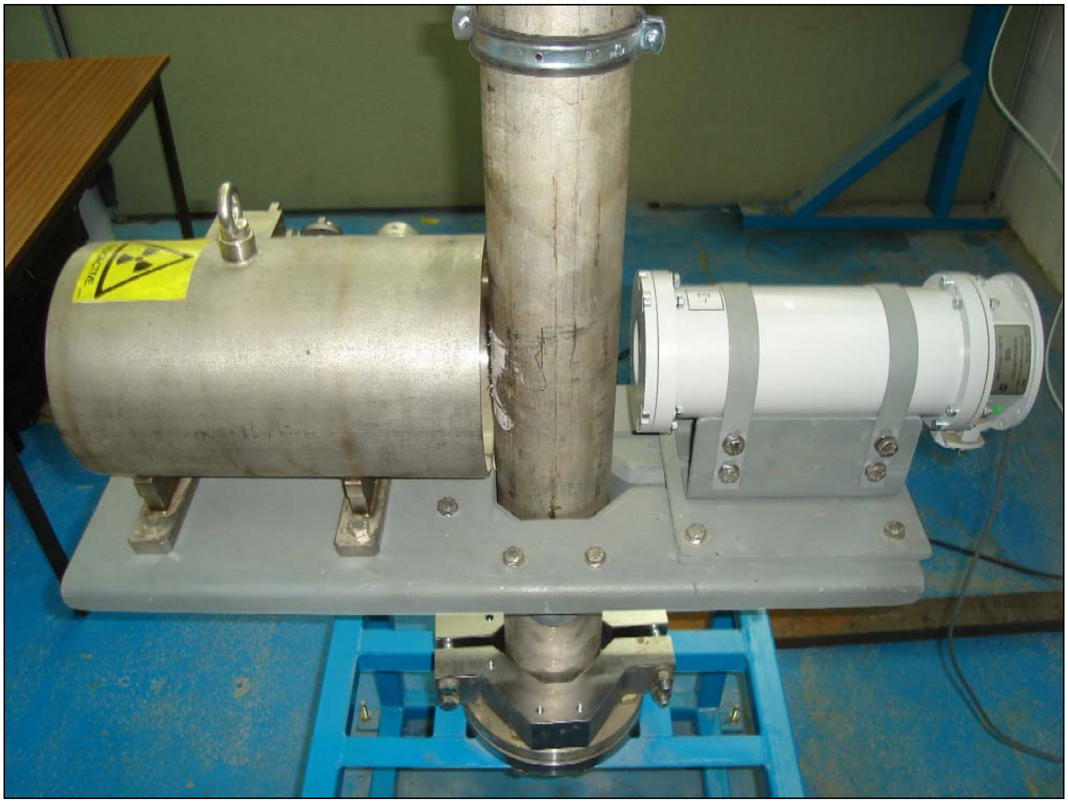

Figure 2 Neftemer comprising Gamma ray source in housing (left) and detector (right)

In terms of the categories given above, Neftemer is a combination of the “Phase fraction and velocity measurement” and “Pattern recognition” categories. The key to the operation of Neftemer is the determination of the velocities of the different sized gas bubbles in the “unseparated flow”, which is a Russian term for “multiphase flow”. Small bubbles are entrained in the liquid, so their velocity gives the velocity of the liquid. The average of the velocities for larger sized bubbles gives the gas velocity. Analysis of the pattern of gamma absorption fluctuations gives these velocities. Analysis of the direct 661 kev photons and the lower energy photons scattered by the pipewall and the multiphase fluid gives the oil and water fractions of the liquid.

Some 300 Neftemer detectors are deployed to monitor individual wells producing heavy oil in Arctic Russia, an application for which conventional well testing simply does not work. This is almost certainly the first time multiphase meters have been deployed on a large fraction of the wells in an oil field for production monitoring.

In the next three sections production plots illustrate different aspects of well monitoring.

- Stabilisation of a heavy oil well over several days from when it is opened.
- Switching different wells through a test section on which a Neftemer is mounted, showing how the meter can track the changes in production, and also give useful information on the fluid structure.
- How Neftemer responds to changes in downhole pump speed.
- How Neftemer tracks increases in production when light oil is injected in the well to dilute the heavy oil.

Three types of pumps are used in producing the oil, sucker rod pumps, downhole centrifugal pumps and downhole screw pumps. Sufficient plots have been made from different wells to allow assessment of what are the typical production plots for these different kinds of pumps, and it is clearly possible to see abnormal plots, allowing timely investigation of problems.

STABILISATION OF A HEAVY OIL WELL

Figure 3 shows how a heavy oil well stabilises during the three days after it is opened. In this figure the liquid flowrate and watercut came from Neftemer, but the gas data came from the DCS system. In these heavy oil wells the gas data is not considered to be of great importance.

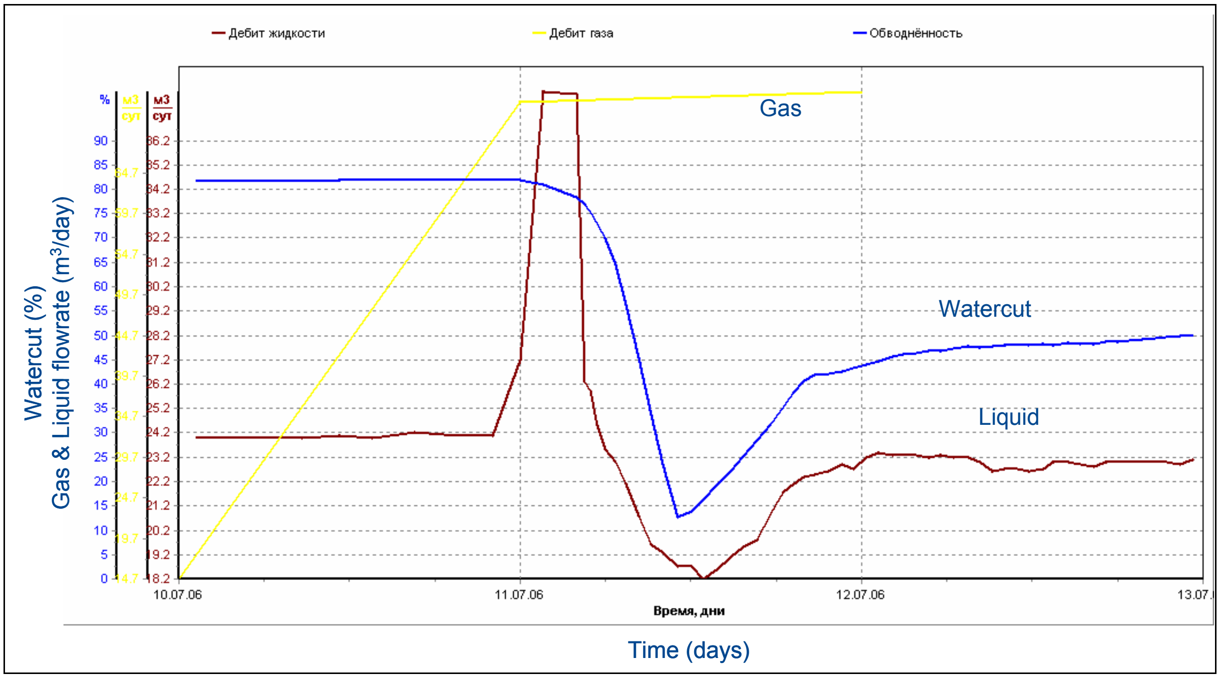

Figure 3 Stabilisation of a heavy oil well fitted with a downhole screw pump

For the first day after opening up the well, liquid production and watercut remain steady. Then over the next half day the liquid production increases rapidly, peaks, and declines to a very low value. During the same period the watercut declines to a low value. Over the next day and a half the liquid production increases and then stabilises, while the watercut increases rapidly at first and then more slowly. Such a plot cannot be made with conventional well testing equipment.

BASIC WELL PRODUCTION MONITORING

In this section we discuss straightforward tests performed on wells to demonstrate Neftemer's ability to follow changes in well flowrates. For these tests Neftemer was mounted on a spoolpiece to which different wells could be connected. In the three figures used to show this we only consider liquid flowrate against time. The flowrate is output as a vertical bar, at apparently irregular intervals.

In Neftemer, for flow calculation purposes the flow is split up into 2-second periods. In each period 500 measurements are made of gamma ray absorption, which is strongly related to the density of the multiphase fluid. (The Neftemer fast gamma ray detector scans at 250 Hz.) If in a 2-second period there are sufficient fluctuations in the gamma ray absorption by the multiphase fluid, Neftemer will calculate for that period the liquid and gas velocities, the watercut, the increments in mass for oil and water, and the increment in volume for the gas. If there are insufficient fluctuations in the 2-second period (in practice this occurs more than 50% of the time) no measurements are made; increments of mass of oil and water and volume of gas are made using the last good values for the liquid and gas velocities and the watercut. The incremental values are added up and a count is also kept of the number of periods in which measurements are actually made.

After Neftemer has been turned on and has stabilised, the first totalised values are output after there have been 1000 2-second periods in which measurements have been made. In practice this means that the minimum time before getting a first reading (the first bar on the graph) is approximately 35 minutes. Usually it will take an hour or longer. The subsequent readings or bars follow every 100 2-second periods in which measurements are made, using the previous 1000 2-second periods in which measurements have been made. This means that the minimum update time is about 3 minutes, but, as shall be seen, it is often much longer. Thus the bars display a running average of the liquid flowrate.

It is worth restating this assuming that measurements are being made in every 2-second cycle. When Neftemer is switched on, it takes some time for the detector to warm up and stabilise. After it starts to make measurements, it will output the first set of readings after a minimum of 2000 seconds, and thereafter it updates at a minimum time of 200 seconds.

Figure 4 shows the liquid flowrate for four different wells switched in turn through Neftemer. The first well has a relatively low production of about 27 m^3/day (160 bbl/day) and it is evident from the spacing of the bars that the flow pattern is changing over several hours from periods with few fluctuations to periods when there are many fluctuations. This will correspond in practice to periods when only water or gas is flowing, and periods when there is a mixture of oil, water and gas. The second well shows a completely different performance. Liquid production is much higher, about 100 m^3/day (600 bbl/day). The liquid flowrate is varying strongly, as the running average fluctuates ±15% about the mean. The flowrate is being updated very frequently, showing that the gamma ray absorption and therefore density is fluctuating rapidly.

The third well again shows a different performance. Liquid production is even higher but the updates occur only about every hour, implying that for every 2-second period with fluctuations there are 30 with insufficient fluctuations. The fourth well shows much lower production, but otherwise its characteristics are similar to the third well.

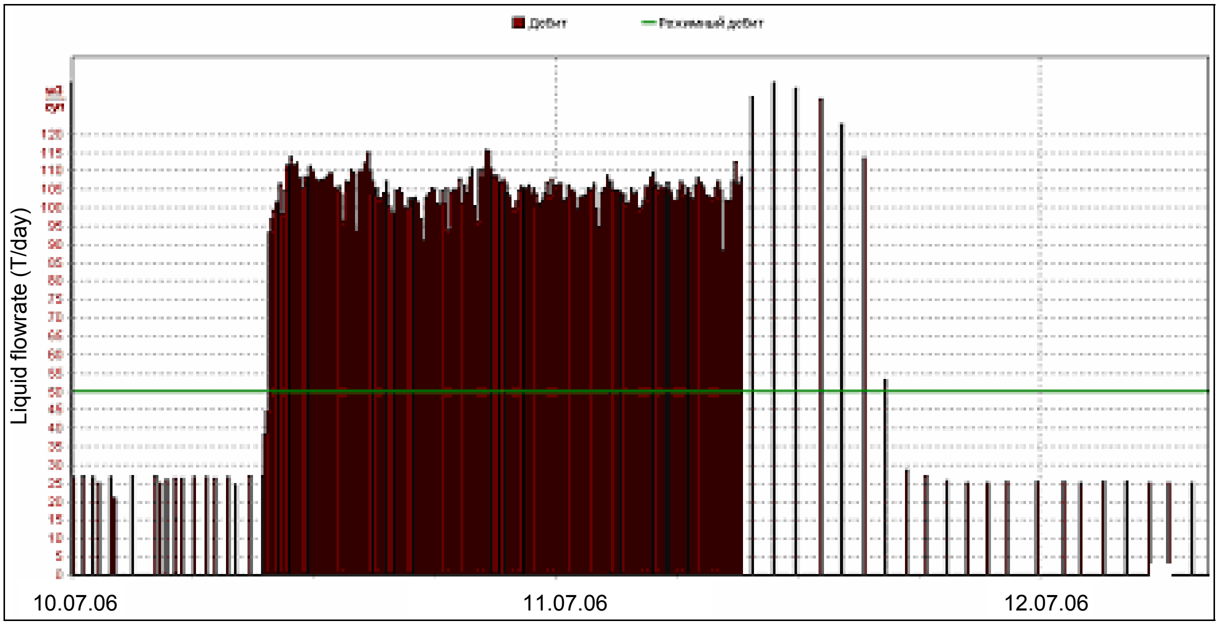

Figure 4 Four wells switched in turn through Neftemer

Figure 5 shows the effect of increasing the speed of a downhole screw pump by 20% from 1000 to 1200 rpm. The liquid flowrate increases in the same proportion. Note that the updates after the increase in pump speed occur more frequently and more regularly that those before.

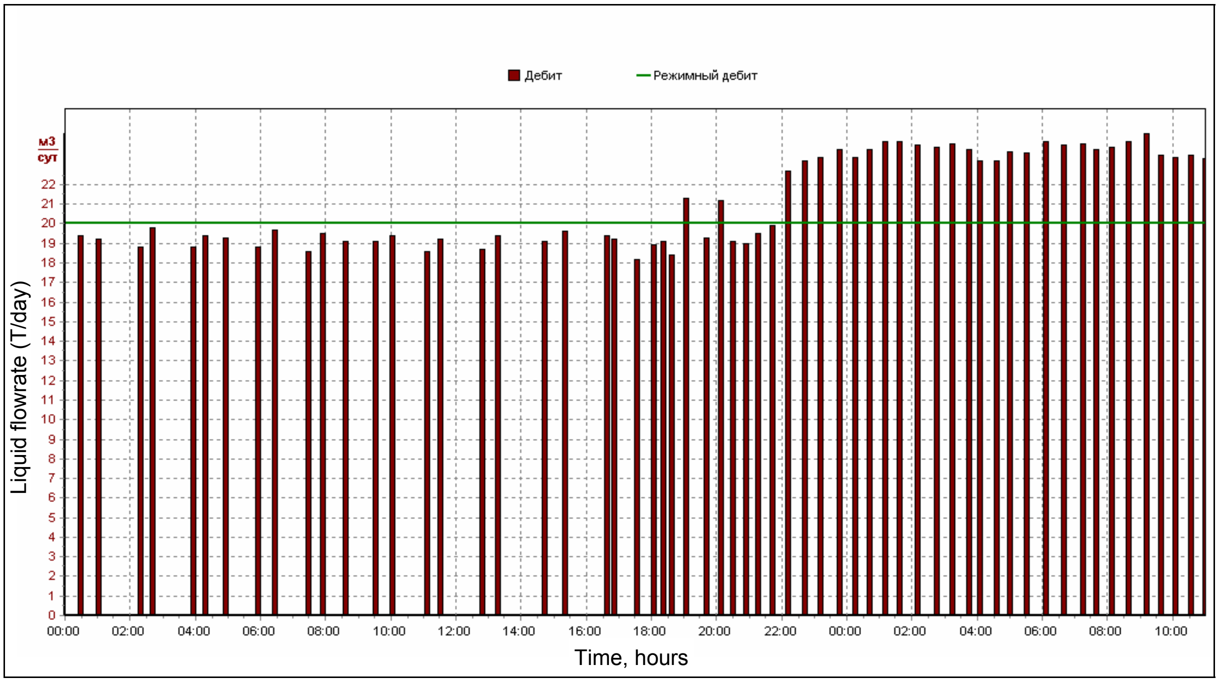

Figure 5 Production change on increasing speed of downhole screw pump

Figure 6 shows the effect of injecting a quantity of light oil into the well to reduce the viscosity of the mixture. It is evident that there is a dramatic increase in the production of liquid. Furthermore there are indications from the frequency of the updates that there are slow variations in the well characteristics.

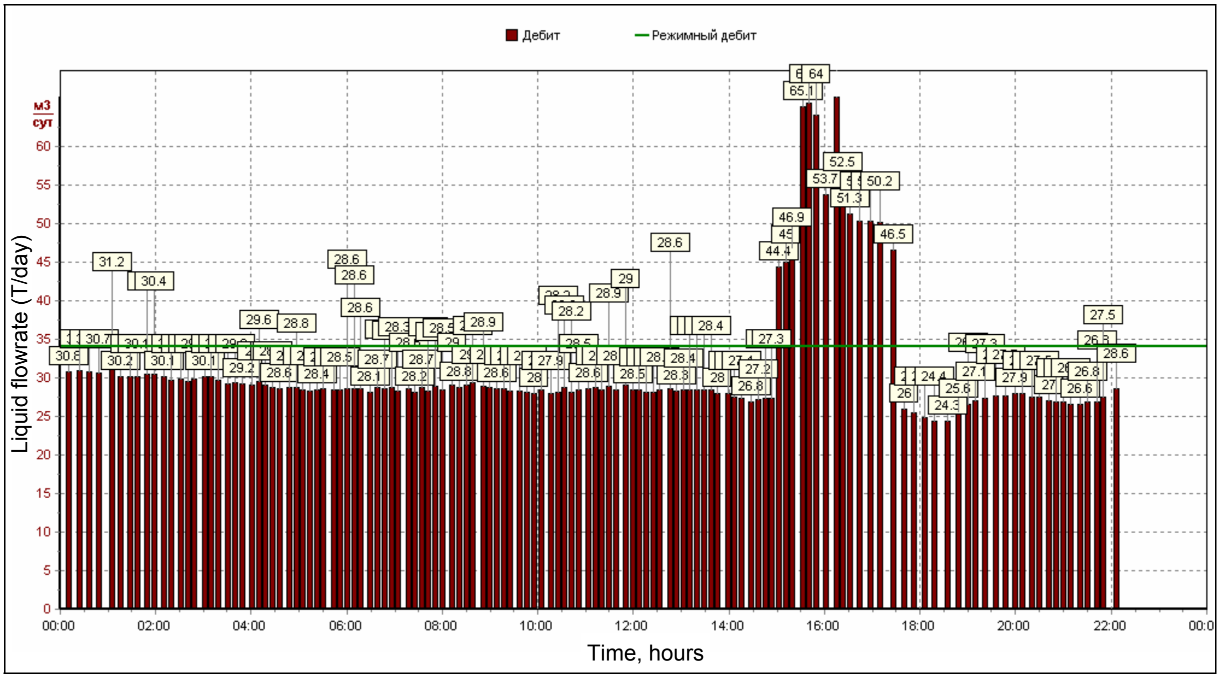

Figure 6 Production change on injecting light oil into well

This section has only discussed liquid production, but it is evident that the figures show that Neftemer can readily provide valuable information on well performance that cannot be obtained by conventional well testing.

WELL MONITORING FOR DIFFERENT PRODUCTION METHODS

In this section we discuss the different characteristics of wells produced with beam pumps, downhole centrifugal pumps and downhole screw pumps. In the figures the mass flowrate of liquid is given in tonnes/day, the volume of gas in m^3/day and the percentage watercut of the liquid. The figures have been chosen to illustrate typical examples of wells using the different production methods.

Figure 7 shows production using a beam pump. The liquid flowrate is steady, as one would expect when the downhole pump barrel is completely filled every pump cycle. The gas flowrate varies considerably, but this reflects a relatively small amount of gas in mass terms which breaks out of the liquid in the production tubing as the pressure decreases towards the surface. This results in an overall short-term surging flow characteristic at the surface. The watercut of the liquid is relatively steady.

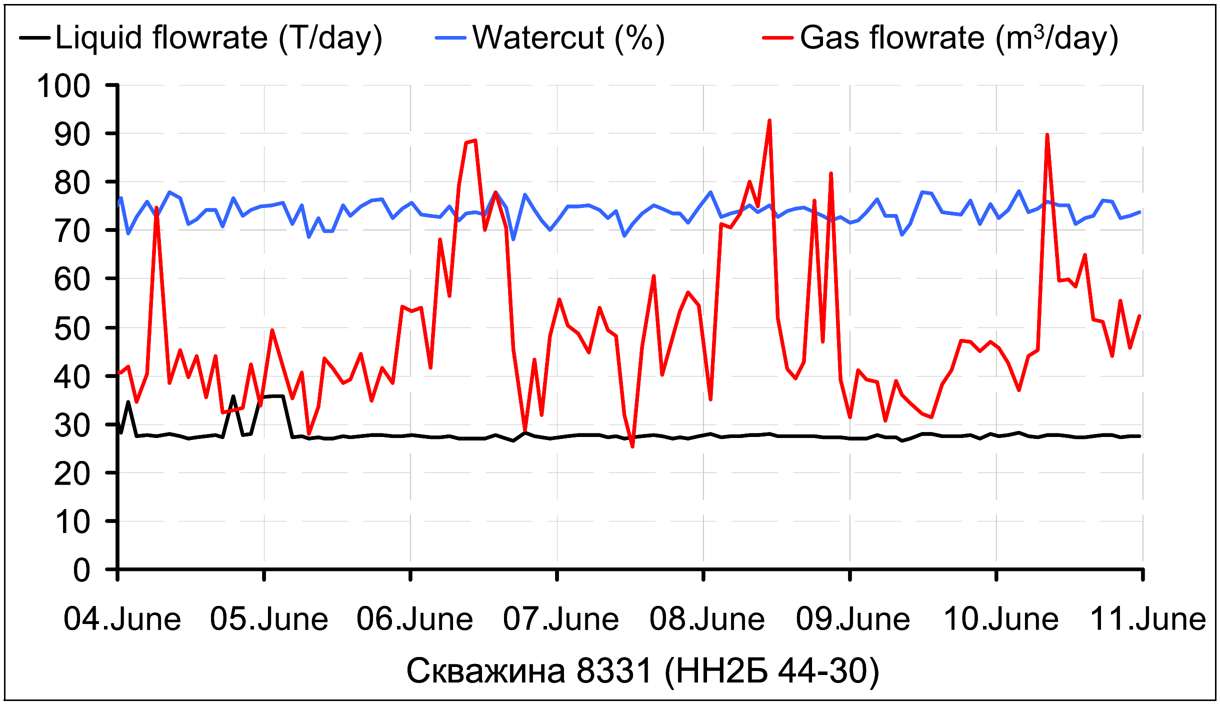

Figure 7 Production characteristics of well fitted with beam pump

Figure 8 shows the production characteristics of a well which has a downhole centrifugal pump. The liquid flowrate is much more variable than in the beam pumping case, as the production fluids do not come steadily to the inlet of the pump. As a consequence the working characteristics of the pump are continually changing. The gas flowrate is much more steady, probably reflecting the intense homogenisation of the multiphase fluid by the centrifugal pump. The watercut in this case is very steady. Overall, the working characteristics of a well fitted with a centrifugal pump are very complex.

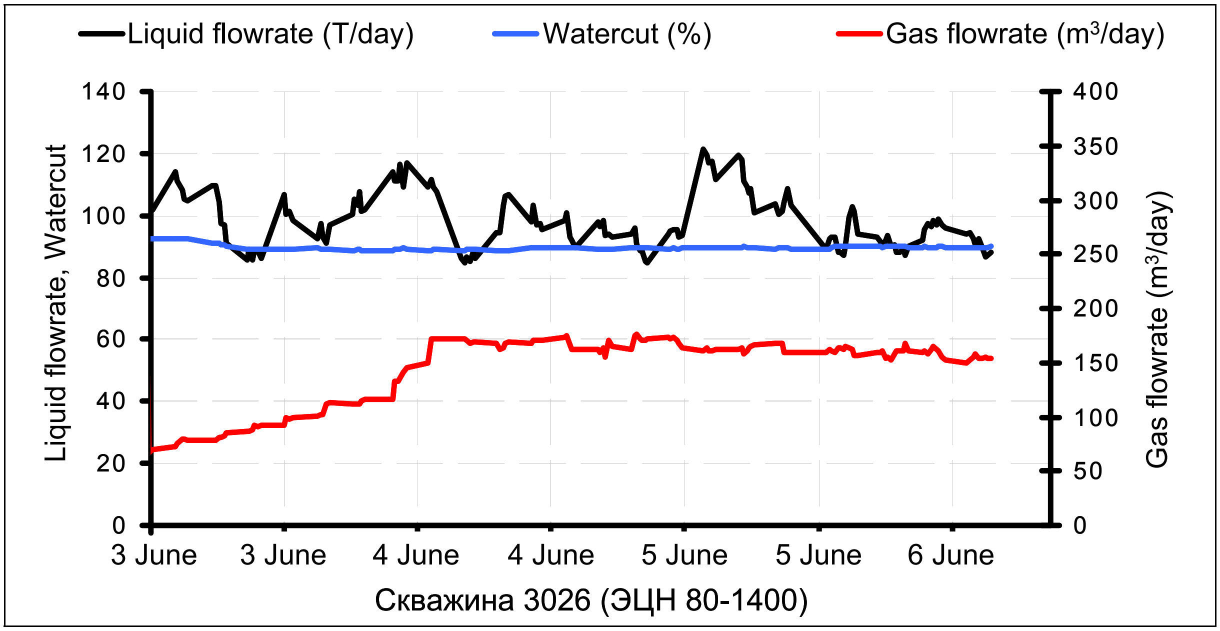

Figure 8 Production characteristics of well fitted with centrifugal pump

Figure 9 shows the production characteristics of a well which has a downhole screw pump. These appear to be somewhere between characteristics of the beam pump, which should mix the produced fluid least, and the centrifugal pump which should mix the produced fluids intensely. With the screw pump the liquid and gas flowrates vary smoothly and the watercut is steady.

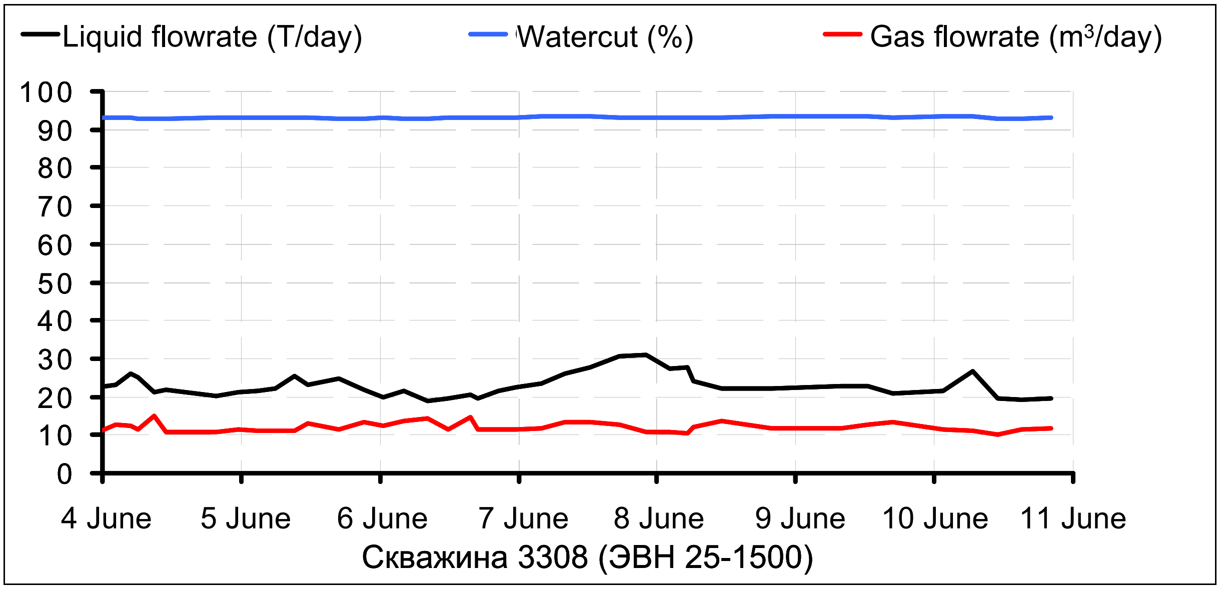

Figure 9 Production characteristics of well fitted with screw pump

As was stated earlier, these figures have been chosen to show typical behaviour. It is evident that such figures are invaluable for diagnosing faults in equipment and in optimising production. The simplicity of the data presented in the figures in the last two sections conceals the very significant technical challenges that have been overcome in order to provide this data in such a cost effective manner. This is the kind of data that is insisted on in any production process for monitoring single phase fluids. Up to now, such information could be obtained in the oil industry only at great expense, with specialised equipment, and in practice for limited periods of time. Now Neftemer can provide continuous well monitoring data cost effectively for a wide range of wells.

DISCUSSION

This paper has shown how Neftemer, an easily installed clamp on multiphase meter, can readily monitor heavy oil wells with widely varying production characteristics. It also shows the different production characteristics in wells using different types of pumps.

Such monitoring is virtually impossible to make with conventional well testing equipment. As Neftemer is clamp-on and non-intrusive it does not disturb the flow in the well and effectively gives operators completely new insights into the workings of their wells. At oil prices of, say $50/bbl, the cost of purchasing and installing a Neftemer on a well producing as low as 200 bbl/day of oil would be recovered in less than a year if use of the meter led to a production improvement of only 3%. In the case of a well producing 1000 bbl/day oil, for the same production improvement of 3%, the cost of the meter would be recovered in about 10 weeks.

Neftemer is currently deployed mostly on heavy oil wells. This was where it got its chance, as there were no other metering methods which could work satisfactorily. However, during its development it has been tested on lighter oils and a demonstration test was made on larger diameter flowlines carrying lighter oil. There is no reason why Neftemer should not work on many of Libya's wells, but extensive testing must be done. However, Libya has a wide range of oils and the aim of the LPI project with Neftemer Ltd is to find suitable methods for monitoring all types of well. One multiphase meter cannot address all of the applications, neither can one multiphase meter manufacturer supply the whole market. There are claims that multiphase metering is already a mature technology. We in Neftemer Ltd believe that we are still in the early phase of this technology.