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Innovative Approach for Determining Downhole Flow Rates from Stationary Flowmeter Measurements

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Abstract

Production Logging measures the downhole flow properties under dynamic conditions to understand the fluid flow behavior in a well, quantify layer wise and phase wise flow rate measurements and also to diagnose wellbore problems at times. The downhole measurements help in making some crucial decisions for gain in oil production or reduction in water cut on the basis of production logging results. One of the critical inputs to achieve these results is fluid velocity obtained from flowmeter (spinner) measurements. Downhole fluid velocity obtained from flowmeter when multiplied by phase hold-up and internal diameter of casing yields flow rates. The priori and essential requirements for accurate flow rate measurement is stabilization of wellbore pressure within certain acceptable limits. Consistent and stable flowmeter measurements enable the accurate fluid velocity estimation.

Many a times, various external factors like surface compressor application, gas injection for lifting the fluid column especially in low pressures and water loaded wells result in instability of the wellbore.When a well is opened to produce under such circumstances, enormous variations in flowing bottom hole pressure (FBHP) during the flow period are observed.These pressure fluctuations could be irregular or periodic depending upon the flow regime established affected by aforementioned factors. In such cases, in-situ spinner calibration and its subsequent fluid velocity estimation stands invalid. In general, it is observed that the spinner response is very sensitive to any flowing pressure variations.

An innovative methodology of determining downhole flow rates have been developed for periodic pressure fluctuations where flowmeter passes could not yield accurate results. Flowing Stations, in which Pressure and Spinner data is acquired, while keeping tool stationary for a pre specified time - is used for fluid velocity computations. Acquired pressure and spinner data is plotted on time scale and one complete pressure cycle is identified, equivalent to which, flowmeter response is captured. Subsequently, fluid velocity at current station is computed by using average spinner value, which in turn provides one of the inputs for flow rate calculations. Assumptions of flowmeter slopes and thresholds are made, based on the theoretical specifications and previous experience from the same type of fluids and overall PVT of the fluids in the formation.

Case studies of two wells of ABC field are presented, where due to cyclic fluctuations of FBHP; flowing spinner passes were severely affected and could not be used for flowrates determination. In the absence of stable spinner data, flow rates were determined using data from Stationary Flowmeter Stations and the obtained rates matched well with reported Surface Test Data - confirming the efficacy of the Technique.

Introduction

Field description

The ABC field is one of the major oil fields of Bombay offshore basin, located in western offshore India. It is about 45km S-W off the Mumbai city and was discovered in January 1987 by the Oil and Natural Gas Corporation (ONGC), India **(Figure-1**). The ABC field is a heterogeneous limestone

reservoir of Middle to late Eocene age with a lack of well-defined layering, variation in lithofacies . Bassein limestone is the only hydrocarbon bearing section.

Hydrocarbons are confined to the A and B zones of Bassein limestone. The upper zone, Zone A, is about 40 meters thick, while the lower zone, Zone B, has an average thickness of 550 meters. The two are separated by shale zone. Zone A is gas bearing in the upper part, whereas the upper interval (~70 meters) of Zone B (Upper B) is the main producer of oil and gas **(Figure-2)**.

The production from the field started in the year 1990. It had earlier been predicted that the field would produce with low water cut up to the year 2000. However, the water cut started increasing rapidly after few years of production. In addition to partial aquifer and gas drives, pressure is maintained in the field by water injection initiated in 1994.

In a heterogeneous reservoir, the nature of the reservoir may cause its flow behavior to change with time and proper field management becomes crucial in order to understand the changes. Therefore, considering the same, field management and timely monitoring the wellbore performance has been a key focus in western offshore India, where Cased hole production logging has been a mainstay for workover operations. Besides the usual operations production logging has been pivotal in determining various important parameters for understanding the wellbore and reservoir behavior.

Production Logging Measurements

Production logging is carried out to provide data in several key areas, principally well diagnostics, production monitoring, injection monitoring and well testing. Well diagnostics is the PL activity that often leads to well intervention to remedy a production problem. Mature reservoirs, often under waterflood to maintain reservoir pressure, are having increased water breakthrough, usually through high permeability layers. Shutting off water or gas or identification of non-performing zones for stimulation is becoming a key diagnostic activity. The production logging environment has driven the need to develop novel measurement and interpretation methods to provide the data for confident remedial intervention.

The traditional measurements such as pressure, temperature, density and spinner, in addition, new sensors such as local electrical probes for holdup, collocated with spinner and X-Y caliper, bring effective answers in complex flow regimes. The production logging provides the flow profiling thereby computing the total flow rates and of the individual phases at downhole conditions and the results can be validated when the computed rates (simulated at surface conditions) provide a good match with the actual surface production rates at the wellhead.

In order to achieve the accurate production rates the essential condition is stabilization of the wellbore. Under unstabilized condition the production logging data is uncertain and affected by the wellbore dynamics such that, it's not the true representative of the downhole conditions. There can be multiple reasons for the same such as surface compressor applications, gas injection for production enhancement etc. Therefore, under such scenario, an innovative technique of station measurements can be used and have been proved to be successful to accomplish the production logging objective of downhole rate quantification in the absence of interpretable data. Following sections describe case studies describing the production logging applications using stationary measurements in unfavorable environment, thereby giving the most fitting and accurate results to accomplish the objective.

Production logging in Gas Lift Wells

Field wise production logging has always been an excellent source to evaluate the openhole results and suggest some immediate workover to optimize the production. To ascertain the production performance, quantify the zone wise rates and identify the water producing zones production logging was planned. Wells were on Gas Lift application to enhance the production. The job was designed to record the log data deploying conventional production logging sensors along with advanced electrical probes to pinpoint the first water entry in order to execute immediate well intervention to reduce the water cut.

Wells A and B were chosen for production logging and monitoring the production response. An unusual and identical response of various sensors was observed in both the wells whereby an unconventional and innovative approach of interpretation by a proactive real time decision making was followed. Mentioned below are the case studies enumerating this methodology.

Well X

Well X is a deviated producer well with the Maximum deviation of 29 deg. This well was completed with 7" casing and 3-1/2" tubing and three open perforations. The objective of production logging was to evaluate the production profile and identify the water entry. To accomplish the objective, production log measurements were carried out both in flowing and shut-in condition. When the well was put on stabilization before flowing survey, a cyclic pressure fluctuation ranging 3 psi/hr from peak to trough was observed. Measurements were carried out under these unstable conditions.

The spinner, temperature and density data was affected due to wellbore turbulence, such that the accurate flow rate quantification could not be performed **(Figure-3)**. Keeping these facts under observation, multiple number of stationary measurements (while keeping tool stationary for a pre specified time) for the duration of 10 mins were recorded in both shut-in and flowing surveys.

Further, spinner and pressure data were plotted on time scale (time of the recorded station) and an average of complete cycle of spinner rps vs time was used to generate the velocity profile **(Figure-5)** equivalent to which, flowmeter response was captured. The in-situ spinner calibration was done in the sump area or below the perforation where the data is stabilized using the spinner data.

The velocity computation was done theoretically by the formula:

Fluid Velocity= (Spinner rps/Slope)-Cable Speed + Threshold

Once the station velocity was calculated **(Table-1)**, it was used as the input to quantify phase wise flow rates in generic way which was found matching with surface test rates, thus validating the results. The similar technique was used for other data measurements such as density etc. and a successful interpreted results were established. **(Figure-4)**

Well Y

Well Y is a deviated producer well with the Maximum deviation of 36.5 deg. This well was completed with 7" casing and 3-1/2" tubing and four open perforations. With the similar logging objectives as in Well X, the well was stabilized before the commencement of the survey whereby similar unstable wellbore conditions were observed with pressure fluctuation range of 5psi/hr. Spinner, temperature and density measurements were affected. (**Figure-6)**.

20 mins long stations were recorded in both shut-in and flowing surveys. In this case the duration of recording the stations was increased in order to get a pronounced cyclic response for better interpretation so as to avoid any loss of data. Therefore, the average of the spinner rps for velocity calculations **(Table-2)** can be done with better accuracy **(Figure-8)**.

Flowrate quantification was possible with this innovative technique and objective of the production logging was met successfully **(Figure-7).**

Conclusions

- The pressure fluctuations due to the gas lift application created the turbulence in the well or an unstable flow regime was established that resulted to inconsistencies in the production logging measurements.
- Stationary measurement i.e sensor response vs time at a particular depth proved to be successful in such situations and validated by the application in two scenarios.
- The logging pass data was also important and irreplaceable by the stationary measurements as stable pass data in the sump or below the perforation is required for in-situ calibration for slope and threshold values for velocity calculations and in turn for downhole flow rate computation.
- Long and multiple stations accounted for complete cyclic response of pressure vs time or spinner Vs time data. This aided in the accurate averaging of spinner rps response.
- Un-optimized gas lift conditions for well deliverability were suspected as the reason of existing cyclic pressure fluctuations.

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Figures

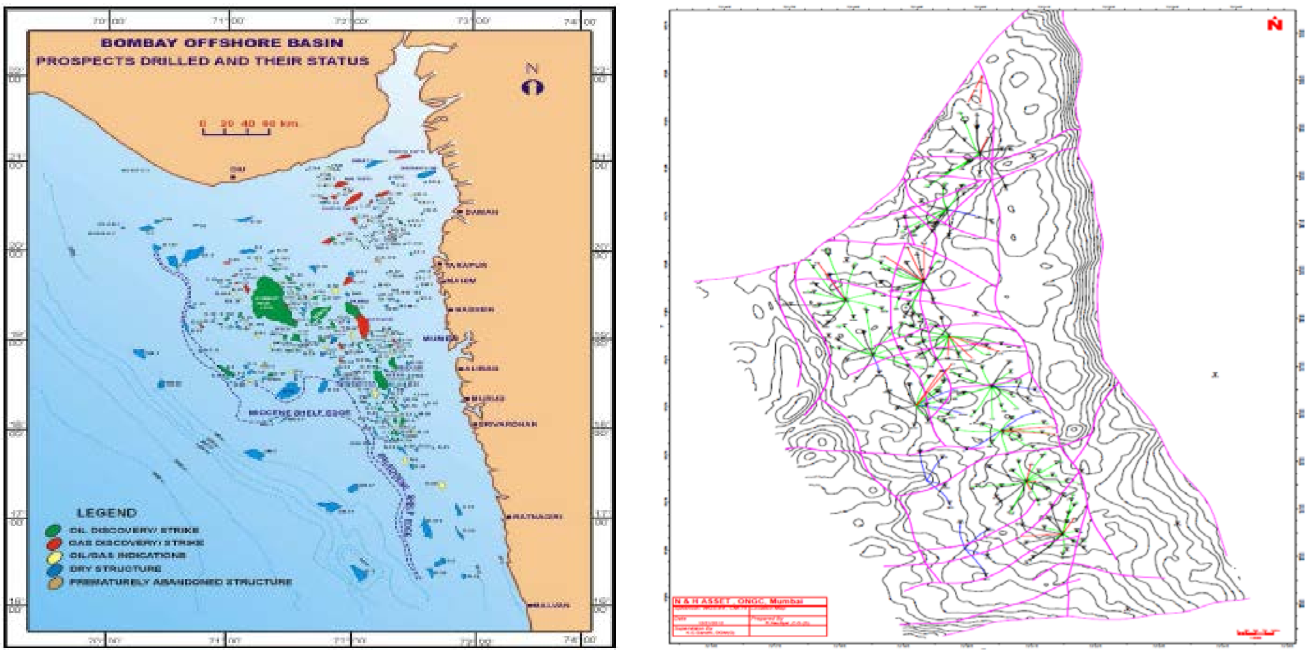


Fig 1: Western Offshore India and ABC field.

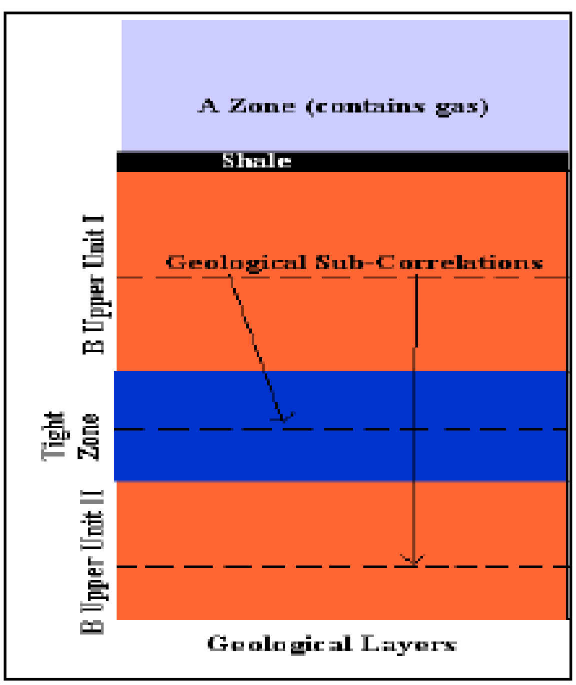


Fig 2: ABC field zone classification

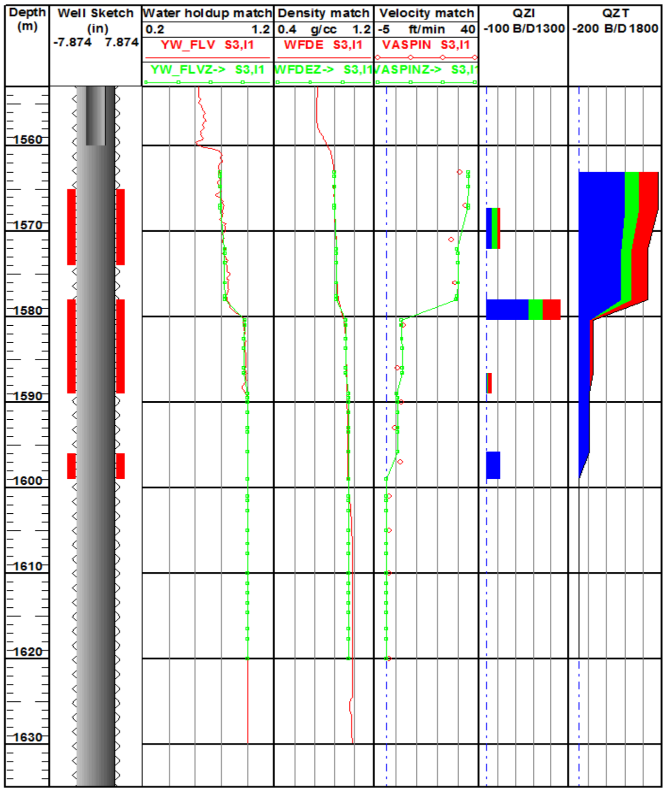


Fig 3: Well-X: Production logging raw data measurement.

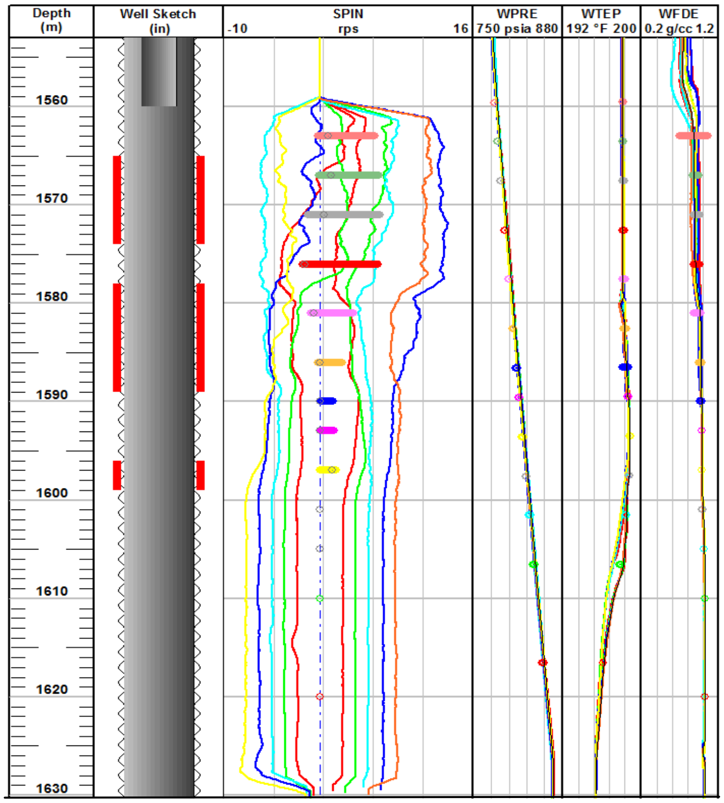


Fig4: Well-X: Rate quantification using stations data

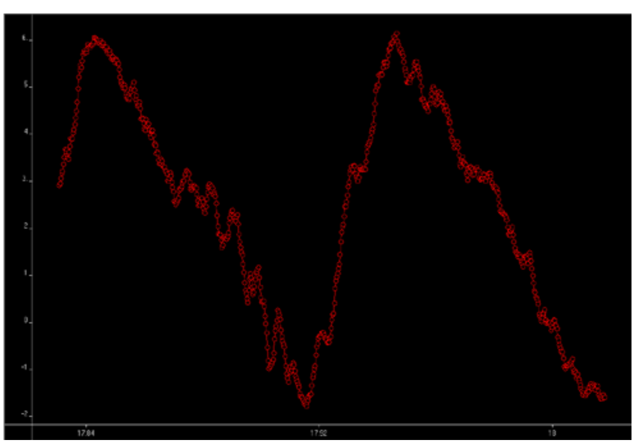
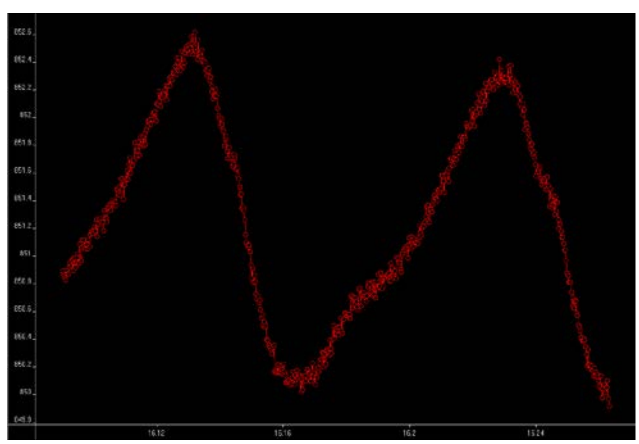
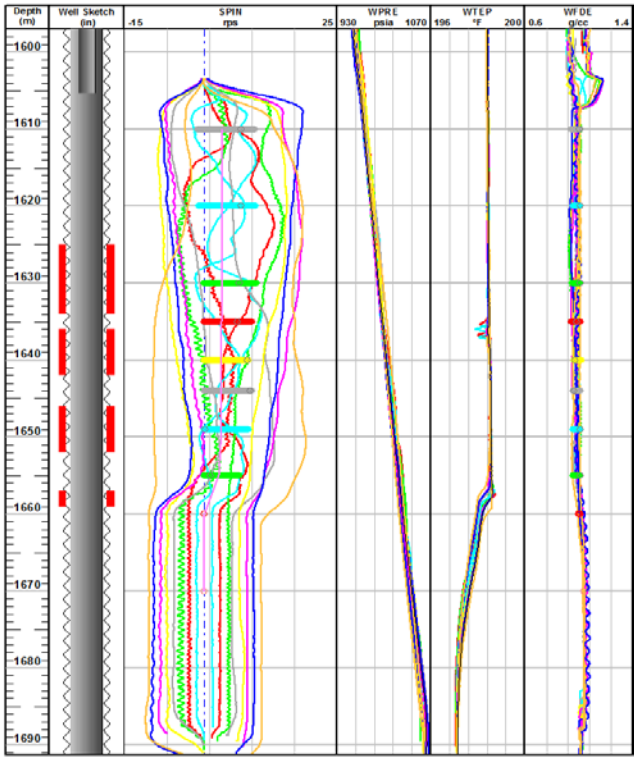


Fig5: Stationary measurement: Spinner Vs Time



Stationary measurement: Pressure Vs Time



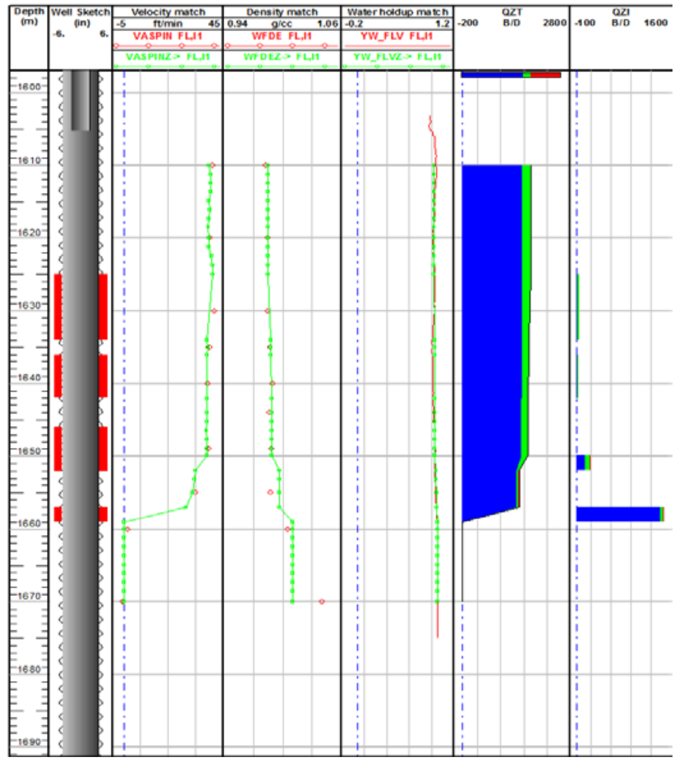
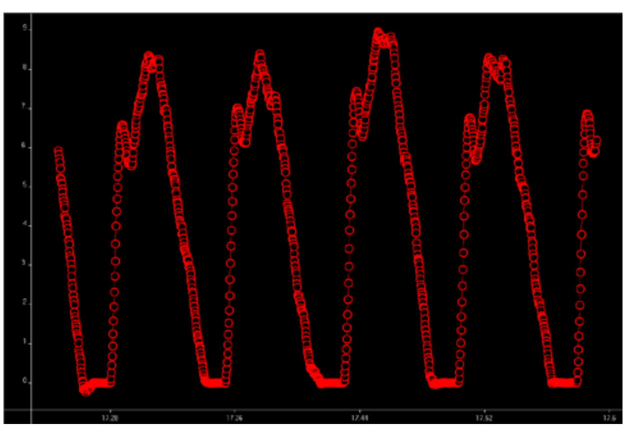


Fig 6: Well-Y: Production logging raw data measurement. Fig7:Well-Y: Rate quantification using stations data



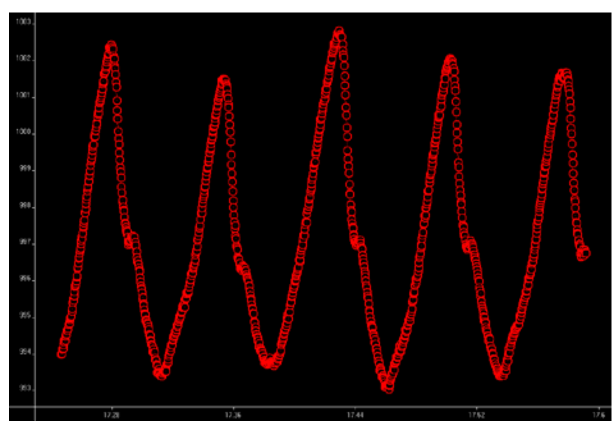


Fig 8: Stationary measurement: Spinner Vs Time Stationary measurement: Pressure Vs Time

Tables

Table-1

Depth (m)	Spinner RPS (Average of the cyclic response)	Computed Velocity (ft/min)
1610	40.9	3.44
01620	40	3.36
1630	38.8	3.24
1635	38.8	3.24
1640	38	3.16
1649	37.7	3.13
1655	32.3	2.62
1660	5.2	0.019
1670	0	0

Table-2

Depth (m)	Spinner RPS (Average of the cyclic response)	Computed Velocity (ft/min)
1567	2.78	34
1576	2.35	29.55
1581	0.22	7.33
1590	0.15	6.55
1597	0.09	5.98
1600	0	1.17
1610	0	1.18
1620	0	1.18

*Average of the cyclic response was done by identifying the complete cycles from the pressure response of the recorded station at each depth.

* Slope and Threshold obtained from calibration using recorded passes data or theoretical values can also be used.