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Field experience of well testing using multiphase Coriolis metering

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ABSTRACT

A previously described Net Oil & Gas Skid (Henry et al., 2013) [1] combines a multiphase Coriolis mass flow meter with a water cut meter to generate on-line estimates of oil, water and gas flow rates, with an update rate of one second. This system has received approval from GOST, the Russian standards agency, for use in upstream oil and gas applications. The NOG system has been applied to well testing, where the output of an individual well is measured, typically over several hours. The conventional equipment used for this task is a test separator; however, a separator only provides the totalised flows of oil, water and gas over the test period. By contrast, the NOG system is able to provide time series of each flow rate, thus allowing more detailed characterisations of well behaviour. This paper draws on the results of several hundred well tests carried out in Russia to illustrate the different types of well behaviour observable using the Net Oil & Gas Skid.

1. Introduction

It is a surprising fact, to those unfamiliar with the upstream oil and gas industry, that it remains impractical to monitor the output of every well on a continuous basis. Most wells produce mixtures of oil, water and gas, and in some cases additional components such as sand. Simultaneous three-phase (oil/water/gas) metering is technically difficult and current solutions remain expensive. Falcone et al. [2] provide a book-length treatment of three-phase flow metering technologies, while Thorn et al. [3] give an article-length summary of the main commercial technologies, their development, and their applications in the petroleum industry. A further barrier to more widespread adoption of several of the current multiphase technologies is their use of radioactive materials, which, in the current climate of heightened security concerns, significantly raises the cost of ownership. Accordingly, a widely used means of assessing the production of each well is by well testing [4].

In well testing, the production streams from several wells (typically 6–20) are piped to a test station (Fig. 1, right), where a single three-phase flow metering system is provided. While this can be any type of three-phase metering technology, commonly a separator system is used. Here, a storage vessel of sufficient capacity is used to hold the incoming production stream to enable at least the gas to separate from the liquid; in more elaborate designs separation of the oil and water also takes place. The gas and liquid streams are metered independently as they emerge from the separator. A key aspect of any separator operation is that it acts as an integrator: instantaneous flow behaviour of the production stream is lost, while the flow profiles of the gas and liquid outputs are a function of the control scheme. Typically, level and/or pressure controls are used to trigger short batches of gas and liquid expulsion. Accordingly, measurements recorded from a separator-based well test consist only of totalised flows for gas, oil and water over the test period (typically several hours) as effectively all well flow profile information is lost through the operation of the separator..

With only a single three-phase measurement system at each test station, it is only possible to measure the output of each well (or a combination of wells) on an occasional basis. A common arrangement is for each well to be tested for a twenty four hour period once per month. The production of a well for the entire month is then estimated from the results of its one day test period. Furthermore, as discussed above, when a separator is used for well testing, only the totalised flows are provided, and so it is not in general possible to identify which wells have stable flows and which have irregular flow profiles.

If it were possible to provide detailed flow time series this could be valuable in determining a more optimal schedule of well testing: for example wells with stable flows could be monitored less frequently. Additionally, flow time series may enable the identification of well behaviour features that can be valuable in reservoir management. For example, the effect of changes in extraction arrangements (e.g. pumping strategy) may be observed in the real-time production of the affected well or wells. Finally, flow time profiles may assist in identifying poorly executed well tests, for example where a substantial and unexpected step change in well behaviour is observed during the course of the test, so that the results of a poor test could be discounted and a new test rescheduled.

The authors have developed, together with their industrial partners,

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Fig. 1. (Right) conventional well test station, including separator. Note piping to handle multiple well production streams. (left) Mobile trailer carrying NOG system. Note piping extended from well test station, enabling NOG system to perform well tests.

a new commercial three-phase flow metering system, called the Net Oil & Gas skid (NOG). This system is based on combining a multiphase Coriolis mass flow meter with a water cut meter, along with pressure and temperature measurements, and has been described in detail in [1]. Having received GOST certification for use in upstream oil and gas applications in Russia, a number of systems have been applied to well testing in field trials. At the time of writing, several hundred well tests have been carried out. The results of many of these have been made available to the authors, and permission has been obtained to present anonymised data in this paper to illustrate the wide range of flow profiles that have been observed, in order to demonstrate the benefits of providing relatively high frequency (1 s update) time series of oil well production. Similar benefits may be provided by other multiphase technologies with comparable update rates.

The paper is arranged as follows. Section 2 provides an overview of the NOG technology and describes its application in field trials. Section 3 gives examples of stable flow profiles, and explains how the limited flow profile graphs provided in this paper are derived from the complete reports generated by the commercial system. Section 4 illustrates the disruption caused to flow profile time series when a separator is used. Sections 5–7 describe classes of well test profile identified among the hundreds of examples collected thus far. These include cycling, slugging and erratic profiles, with further examples where it is possible that the well test has not been executed properly.

2. Net Oil & Gas Skid

A detailed description of the Net Oil & Gas skid (NOG), including its construction, functionality and performance in formal laboratory trials, is given in [1]. A brief summary is provided here. Fig. 2 shows the design. The instrumentation consists of a Coriolis mass flow meter, a water cut meter, and pressure and temperature sensors. A central computing and communication unit regularly polls each of the instruments and calculates a set of measurements, including the instanta-

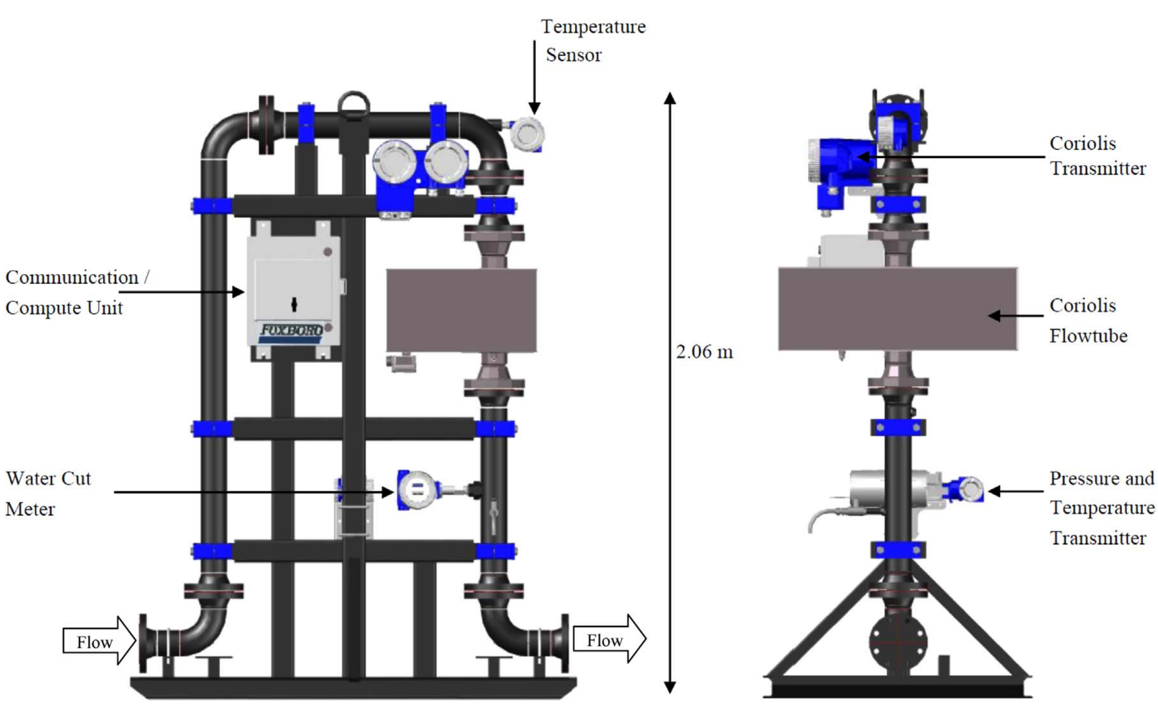

Fig. 2. Net Oil & Gas Skid Design.