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Experimental study on a feasibility of using electromagnetic wave cylindrical cavity sensor to monitor the percentage of water fraction in a two phase system

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ABSTRACT

This study proposed a microwave sensor system to monitor single and two phase flow systems. The microwave sensing technology in this study utilises the resonant frequencies that occur in a cylindrical cavity and monitor the changes in the permittivity of the measured phases to differentiate between the volume fractions of air, water and oil. The sensor system used two port configuration S_{21} (acted as transmitter and receiver) to detect the fluids inside the pipe. In principle, the strong polarity of water molecules results in higher permittivity in comparison to other materials. A tiny change of water fraction will cause a significant frequency shift. Electromagnetic waves in the range of 5–5.7 GHz have been used to analyse a two phase air-water and oil-water stratified flow in a pipeline. The results demonstrated the potential of a microwave sensing technique to be used for the two phase systems monitoring. A significant shift in the frequency and change in the amplitude clearly shows the percentage fraction change of water in the pipe. The temperature study of water also demonstrated the independence of microwave analysis technique to the temperature change. This is accounted to overlapping modes negating the affect. Statistical analysis of the amplitude data for two phase systems shows a linear relationship of the change in water percentage to the amplitude. The electromagnetic wave cavity sensor successfully detected the change in the water fraction inside the pipe between 0 and 100%. The results show that the technique can be developed further to reduce the anomalies in the existing microwave sensor.

1. Introduction

During the oil extraction, water and gas are produced as by-products. To maximise the production of oil from a reservoir, water and gas are often injected into the well. Water is used to maintain the pressure whereas the gas is used to reduce the viscosity of the oil. To enhance the production and optimise the process it is crucial to monitor the output of the mixture of water, oil and gas. The monitoring also helps to improve the operational and transportation management [1]. Water naturally occurs in the stratum and the percentage of water often increases with the production life of a well [2]. The water fraction also increases as the well is flooded with water. Many wells are still considered to be economic if the percentage of water in the liquid phase is more than 90% [3]. It is, therefore, important to consider the presence of water when predicting and designing a method to monitor flow behaviour in both pipelines and wells. In recent years, a numbers of studies have been published on water/oil/gas flow in pipes [4–7].

Conventionally, single phase monitoring techniques are utilised to measure the flow rates of well fluids by separating the mixture. The drawback is the time needed, which can take up to several hours, to obtain the flow rate of each well because each phase has to be separated before measuring it. The complexity of this technique increases when it comes down to monitoring up to 10 or more wells in the oil field which could be substantially time consuming and inconvenient. In addition, the oil-water-gas separators are expensive and maintenance-intensive [8].

One alternative to replace the water-oil-gas separators is the utilisation of Multiphase Flow (MPF) meters. It is acknowledged that MPF meters could bring benefits to the oil and gas industry in terms of layout of production facilities, reservoir management, regular monitoring, production allocation and well testing [9]. Ideally

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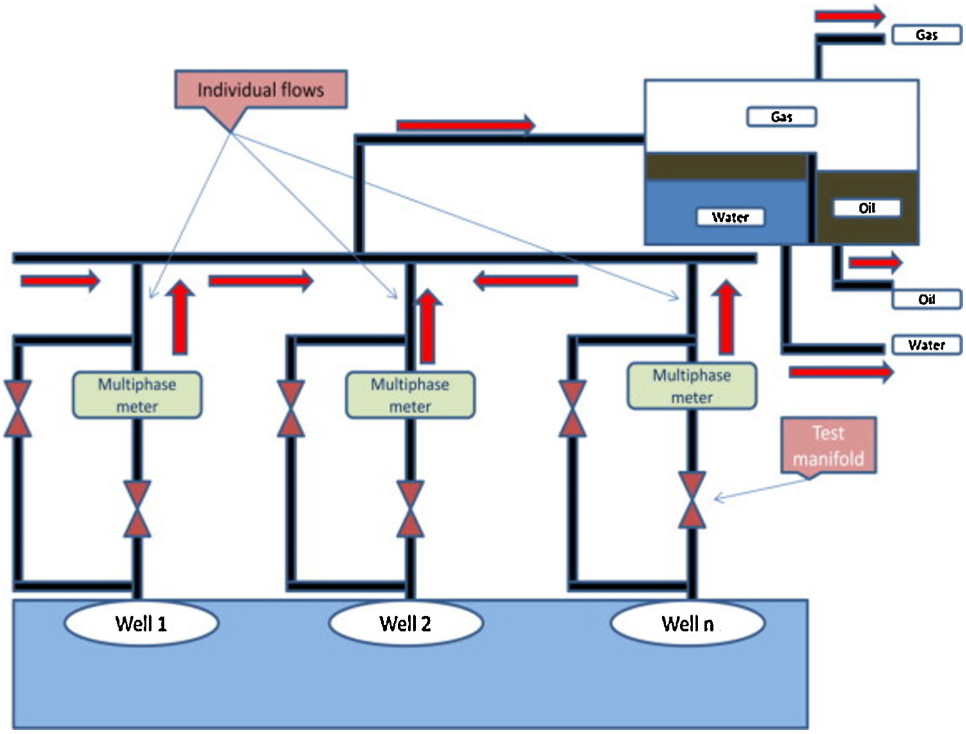

Fig. 1. Schematic diagram of the implementation of multiphase flow meters in the adjacent wells to monitor the flow [11].

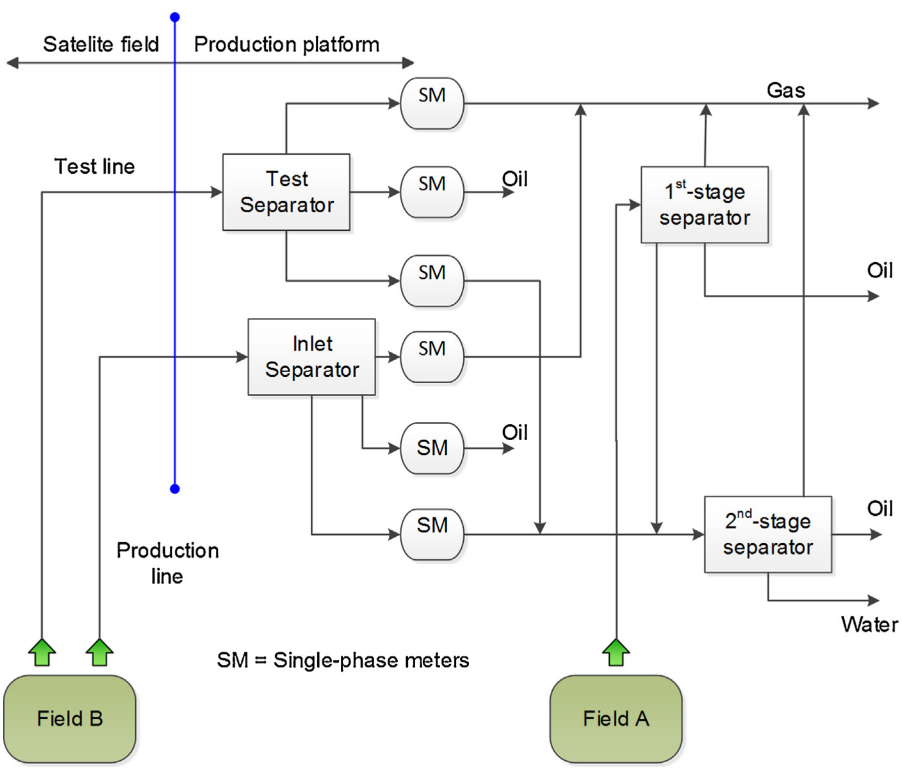

Fig. 2. Conventional Multiphase flow measurement utilising phase separators [12].

multiphase flow meter should be accurate, reliable, non-intrusive, compact and capable of measuring the flow rates continuously to within 5–10% of error [10]. Fig. 1 shows the implementation of MPF meters in an offshore oil and gas production that involves several adjacent wells. The data captured during the production of these wells can help in estimating the performance of each individual well. The data gathered can also be used to locate a production anomaly, for instance, a gas or water breakthrough in the production well [11]. Conventional MPFs that employ phase separators create a complicated network of pipelines that occupy valuable space on the platform. Figs. 2 and 3 show the single phase meter involving phase separators and an online multiphase flow mea-