The Impact of Regular Well Testing on the Accuracy of Allocation Calculations

Mahdi Sadri, Seyed M. Shariatipour, and Masoud Ahmadinia
Fluid and Complex Systems Research Centre, Coventry University, UK

Abstract

Although the interest in using multi-phase flow meters in the oil and gas industry has recently increased, there remain some oil and gas fields in which the flow rate of their individual wells is measured by occasional well tests. In such fields, the commingled production streams from all the wells are transferred to the separation unit and the total production rates are subsequently measured by single phase flow meters. As a consequence, although continuous flow measurement data of the total production is available for the whole field, the production data of the individual wells within it is intermittent. In the absence of measured data between two well tests, well flow rates are estimated by allocation factors which are calculated based on the well test data. While allocation factors are normally assumed to be constant between two consequent well tests, fluctuations in the well production typically change values over time. Long time intervals between well tests can therefore create large uncertainties in the allocation results. In this research, the effect of increasing the regularity of well tests on the uncertainty in the allocation process has been studied. Fluctuations in the production of three actual wells have been statistically analysed and quantified using their relative standard deviation. The same fluctuations have then been applied to the production streams of a simulated oil field with 36 wells to generate three different cases. Allocation and hydrocarbon accounting calculations have subsequently been undertaken for one to four well tests conducted per month. The pattern of fluctuations has been generated using a Matlab code. Each calculation has been repeated 100 times with different patterns and the results have been subsequently averaged and reported. The results show that increasing the regularity of flow tests can considerably reduce the allocation error. The most significant reductions were observed when the number of flow tests was increased from one to two per month. In this case, the average allocation error of the three investigated cases was reduced by 0.43%, 0.45%, and 1.11% which is equivalent to an $18.2M (Million), 18.9M, and $46.6M decrease, respectively, in the cost of allocation uncertainty for the three cases based on hydrocarbon accounting calculations. The results of the case studies suggest that the cost of allocation uncertainty can be reduced by $27.1M, $29M, and $80.1M, respectively, for the three cases if well tests are undertaken weekly instead of monthly.

Keywords: *Allocation calculations, well test, flow measurement, hydrocarbon accounting, uncertainty*

Introduction

More than 11% of people in England live in fuel poverty according to the UK Department for Business, Energy, and Industrial Strategy [1] and the Office of Gas and Electricity Markets [2]. In other words 2.55 million households in England cannot afford to keep their houses warm during the winter. The statistics in some other areas of the world show even worse situations as a result of the high price of energy and poor economies. Since the oil and gas industry is still the main supplier of energy across the world, although political and conflict influences can affect hydrocarbon prices, any method that can increase the efficiency of the production processes in this industry can reduce the price of energy and ameliorate fuel poverty.

Uncertainty in the oil and gas production data is one of the sources that create additional costs for oil and gas operators. These costs inevitably increase the price of oil and gas or decrease the income of the operating companies. This uncertainty can be large in cases where the production of different wells is commingled and not monitored individually using multi-phase flow meters (MPFM). In these cases the total flow rate is transferred to a separation unit where the flows of oil, gas and water are measured using single phase flow meters. In addition to the total production flow rate, however, the flow rate of individual wells are also necessary for reservoir management purposes and hydrocarbon accounting. Therefore, it is common in the industry to undertake occasional well tests (flow tests) on individual wells using test separators. In a well test, the production flow rate of the well is monitored for a short period of time (it can be from a few hours to a day). The test is normally repeated over fixed time intervals (e.g. a month). The data gathered during the test is typically used in addition to total production data of the entire field (at the output of the separation unit) to calculate ‘allocation factors’. These allocation factors are employed in a process (which is called ‘allocation’ or ‘back allocation’) to calculate the contribution of each well in the total production. The values of the allocation factors are updated when new well tests are undertaken. Although the allocation exercise provides estimations of the flow rates of the wells, the calculated values normally incorporate uncertainties, especially when there is a considerable time interval between two consecutive well tests. The source of these uncertainties is the assumption that allocation factors remain the same over the time between two consecutive well tests. Fluctuations in production, water cut, or gas to oil ratio in addition to any other factors in the reservoir, well, or production facilities, can change well flow rates over time. These fluctuations can cause the actual value of the allocation factors to be diverge from the estimated values. The uncertainties in allocation calculations ultimately affect hydrocarbon accounting and reservoir management and can be costly for oil and gas producers.

A number of publications on allocation uncertainties can be found in the literature. Cramer, Schotanus, Ibrahim and Colbeck [3] employed a data-driven modelling application for allocation purposes which provides a virtual three-phase meter for all wells. They reported that daily allocation using the application was more accurate than a discontinuous allocation based on periodic flow tests. Stockton and Allan [4] described potential pitfalls in typical allocation uncertainty calculations and explained how to avoid them. Kaiser [5] compared two methods for estimating the production of single wells based on decline curves and allocation techniques. The author reported that the decline curve procedure results in a better understanding of individual well behaviour and estimated ultimate recovery but has a higher calculation requirement. Pobitzer, Skålvik and Bjørk [6] presented a framework that optimises metering uncertainty in allocation setups based on a cost-benefit perspective. Acuna [7] used pressure and temperature data in a production modelling practice to estimate the real time production flow rate of all wells in an actual field. The author reported that the approach reduced the allocation errors to less than 10% for all the investigated production streams. In addition to the aforementioned studies that have focused on allocation uncertainties, there are also other publications that have addressed the effect of allocation (or flow measurement) uncertainties on reservoir management or hydrocarbon accounting [8-10].

In this research the effect of decreasing the time interval between well tests on the accuracy of the allocation calculations has been studied. In the following section the methodology and the results of the research have been presented and discussed.

Methodology, Results, and Discussion

The fluctuations in the production data of three oil wells have been statistically analysed in this research. The Relative Standard Deviation (RSD) of the available production data has been calculated to quantify the magnitude of the flow fluctuation for each well. The obtained RSD values have subsequently been used to generate similar fluctuations in the production data of a simulated oil field with 36 wells, and therefore three data sets have been created (Case A, B, and C). The data sets have subsequently been used in allocation calculations [4, 11] to investigate the effect of increasing the number of flow tests per month (TPM) on reducing the uncertainty of estimated production data of individual wells in each case. Reducing the aforementioned uncertainty is important since it can increase costs for the operating oil and gas companies. The effect of the uncertainty is clearer when different wells in the same field are owned by different companies. In such a case, any error in allocation calculations may result in allocating the produced oil of a company (and therefore its equivalent revenue) to another one. Hydrocarbon accounting calculations have therefore been undertaken to show the effect of increasing the number of TPMs on reducing the total cost of allocation uncertainty for the investigated cases.

Figure 1 shows the average absolute allocation errors for individual wells in three cases as a function of their RSDs when just one flow test per month is performed.

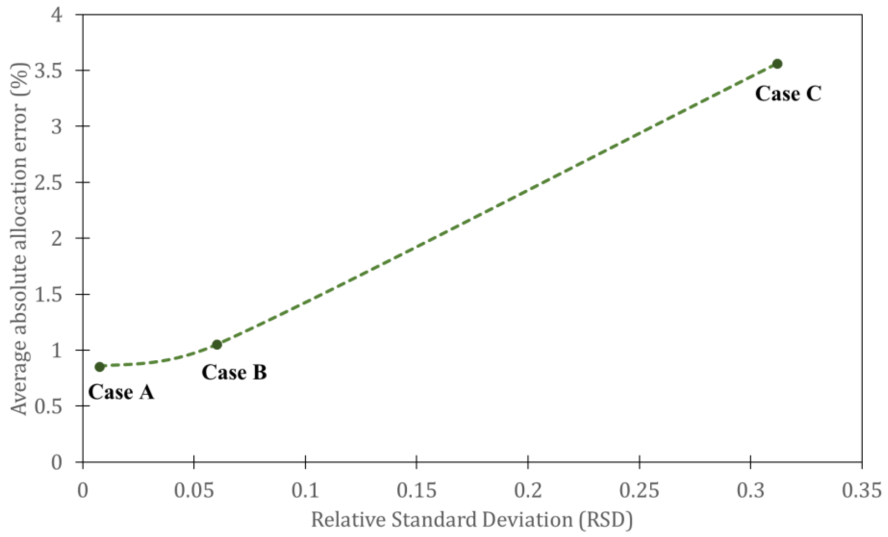

Figure 1: Average absolute allocation error as a function of relative standard deviation for Cases A, B, and C when just one flow test per month is performed: larger fluctuations (or equivalently larger RSDs) result in larger allocation errors

Case A has the smallest RSD (smallest fluctuations) and Case C has the largest (largest fluctuations). Larger fluctuations (or equivalently greater RSDs) create larger allocation errors, as shown in Figure 1. While the error is seen to be less than 1% for Case A, it has risen to more than 3.5% in Case C. Such an error can potentially cause companies to lose a considerable proportion of their revenue. Table 1 shows the equivalent amount of oil which has been allocated to a wrong well in all three cases when just one flow test per month has been performed. The total cost of the wrong allocation has also been calculated and reported considering the value of 60 US dollars per oil barrel at the time of writing.

Table 1: Allocation error and its yearly cost for Cases A, B, and C when one flow test per month is performed

Case	Length of production (days)	Total oil production (million STB)	Average total oil allocated to wrong wells (thousand STB)	The yearly cost of the wrong allocation (million US$)	Allocation error (%)
Case A	365	70.40	598.37	35.90	0.85%
Case B	365	70.07	735.73	44.14	1.05%
Case C	365	69.63	2492.58	149.55	3.58%

The total annual cost of allocation varies from 36 million US dollars for Case A to 150 million US dollars for Case C. The results, therefore, show that the annual financial cost of allocation errors can be considerable, even for small allocation error values.

In the next step of the research, the number of flow tests per month was increased from 1 to 2, 3, and then 4, respectively. Allocation calculations were undertaken for each number of tests per month in each case and the average errors obtained. Figure 2 shows the average absolute error for all the cases as a function of the number of flow tests per month.

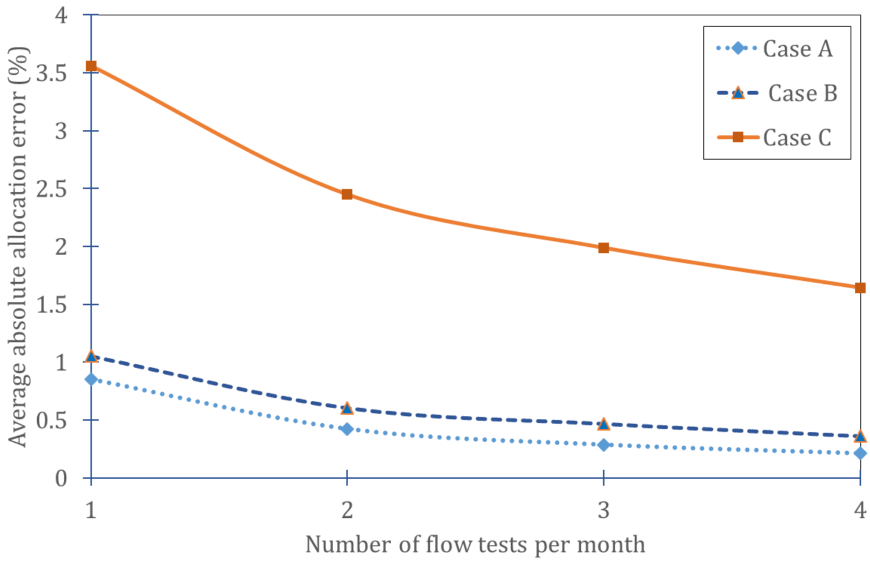

Figure 2: Average absolute errors as a function of the number of flow tests per month for Cases A, B, and C

In all cases the average allocation error is seen to decrease when the number of flow tests per month increases. Therefore, as Figure 2 suggests, increasing the regularity of flow tests can mitigate the uncertainty in the estimated production data of individual wells. The results of hydrocarbon accounting calculations for increasing the number of flow tests per month have been presented in Table 2.

Table 2: Hydrocarbon accounting results

Case	Reduction in the total yearly cost of allocation error as a function of increasing the number of flow tests per month (million dollars)		
	1TPM to 2TPMs	1TPM to 3TPMs	1TPM to 4TPMs
Case A	18.2	24.0	27.1
Case B	18.9	24.5	29.0
Case C	46.5	65.7	80.1

Table 2 shows that the cost of allocation errors can considerably be reduced by increasing the regularity of performing flow tests. The largest cost reductions occur when regularity of the tests increases from monthly to weekly (1 TPM to 4 TPM). In such a case the reductions in the yearly costs of allocation error for Cases A, B, and C are 27M, 29M, and 80M US dollars, respectively.

The results of the research are sensitive to different characteristics of the defined cases since this research has been a case study. The research, however, shows how data analysis can be used as a powerful means of reducing the cost of oil production and play an important role in providing more affordable energy to end users. The key is to undertake the same statistical data analysis for any specific oil field and decide on the optimum number of flow tests per month which is practically possible and at the same time minimises the cost of production.

Conclusions

The effect of increasing the regularity of flow tests on allocation errors and decreasing oil production costs was studied in this research using a statistical data analysis technique. The results show that increasing the number of flow tests per month can mitigate allocation uncertainties and significantly reduce their associated production costs. For the three investigated cases, the reduction in allocation errors caused a 27M, 28M, and 80M US dollars reduction in the yearly cost of production when the regularity of undertaking the flow tests changed from monthly to weekly (four times per month). The reduction in the cost of oil production can eventually lead to providing more affordable energy to the market and can play an important role in decreasing fuel poverty.

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