Challenges on using subsea wet gas meters for gas and condensate allocation between the wells at Sleipner Vest Field

Tarun Grover, Statoil; Knut Kr Meisingset, Statoil; Oystein Tesaker, Statoil; Siv Kari Lien, Statoil; Solfrid Loken Tonstad*;Terje Kristian Wilberg, Statoil

Abstract

Sleipner Vest field constitutes two different reservoirs, Sleipner Beta and Alfa Nord. Sleipner Beta field is drained by platform wells while Alfa Nord wells are subsea tie-back to the processing platform. The field is operated by Statoil. This paper highlights the problems related to using subsea wet gas meters for gas and condensate allocation between the wells at Sleipner Vest Field.

The objectives of this study were to identify the sources of wrong gas/condensate allocation on Sleipner Vest field and to suggest a robust solution to reallocate gas/condensate correctly.

A thorough investigation was done on production data from Sleipner Beta and Alfa Nord fields. It was identified that inability and hence failure to update PVT in wet-gas meters were the source of wrong gas/condensate allocation. To correctly reallocate gas/condensate, gas-condensate ratio (GCR) was reconstructed by using the wet gas meter raw hydrocarbon mass rates and then using post processing of reservoir simulation results and the compositional data from the processing platform. The reconstructed GCR was then applied to all wells in Sleipner Vest field to obtain correct gas and condensate rates from the wells.

The GCR reconstruction algorithm proved to be robust and was easily incorporated into production database. The reallocated gas and condensate volumes were then used to update the field specific simulation models.

This paper quantifies the importance of regular PVT updates in Wet-gas meters when they are used in allocation calculation routines. Further we show that GCR reconstruction algorithm can be used as an alternative when PVT update is not possible in wet-gas meters in a gas-condensate field.

1. Introduction

Sleipner Vest field is located offshore Norway. The field produces from two different reservoirs, Sleipner Beta and Alfa Nord. The fluid in both reservoirs is gas-condensate, but with different PVT characteristics such as GCR. The production strategy in Sleipner Vest field is pressure depletion. Wells drilled in Sleipner Beta are platform wells, with wellheads located on Sleipner B platform. Sleipner B platform is the Normally Non Manned Platform (NNM) and all the wells can be remotely routed to the test-separator to measure the gas, water and condensate streams from each well periodically. Alfa Nord reservoir is produced as a subsea tie back to Sleipner T (see Figure 1) without any test-separator options.

**Formerly with Statoil ASA*

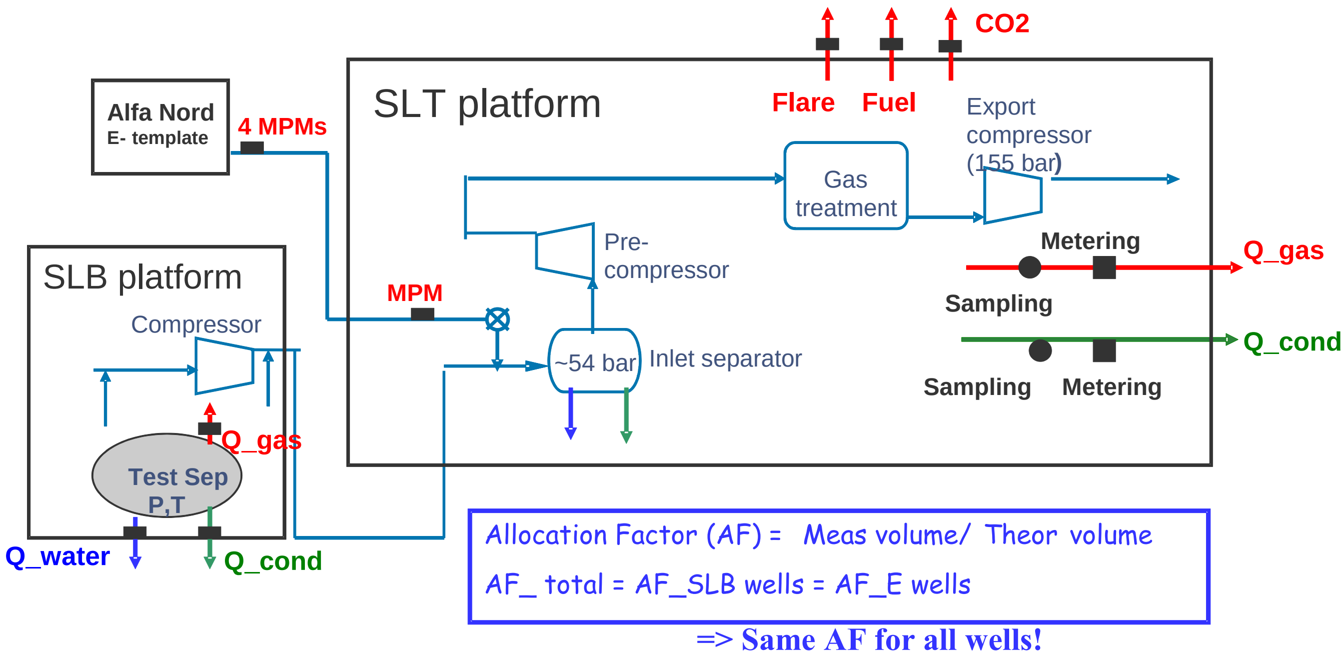

Figure 1 – Production routes and measurements of various streams in Sleipner Vest Field.

1.1. Allocation methodology

Sleipner T (SLT) platform is the processing platform where CO_2 is stripped off from the feed gas from SLB platform and Alfa Nord subsea template. Also, fuel and flare is taken out from the SLT platform and is measured. The gas and unstable condensate exported from SLT platform are measured through fiscal metering and a monthly average compositional analysis is done on export gas and export condensate.

The gas and condensate volumes are then back allocated to the wells on SLB and Alfa Nord. The allocation factor for whole Sleipner Vest field is defined as a ratio of measured volume to the sum of theoretical volumes from the wells. AF should be close to 1 for a system where the allocation system is correctly set-up combined with good the measurements from test-separator and Wet-gas meters.

$$AF = \frac{V_{measured}}{\sum_{wells} V_{theoretical}}$$

For wells producing towards the SLB platform, the gas and condensate rates are measured by routing the wells to the test-separator. The measured gas and condensate rates from the test-separator are then fed into a PVT algorithm inside the production database. The algorithm takes into account the process description on SLT platform in addition to the gas and condensate measured from test-separator and then performs a mathematical iteration which results in a process corrected gas-condensate ratio (GCR).

For Alfa Nord wells, since there is no access to test-separator, the gas and condensate rates measured directly by the subsea wet gas meters are used as theoretical rates. This means that PVT algorithm built inside the wet-gas meters (based on initial fluid composition of Alfa Nord wells) is supposed to calculate correct process corrected GCR.

2. Allocation problems

It was clear that the theoretical gas and condensate rates calculated in Alfa Nord wet-gas meters might be source of error if the fluid compositions inside the wet-gas meters was not updated regularly. A meeting was organized by the wet-gas meter vendor and it was found out that the fluid composition in the wet-gas meters was not updated at all after initial installation. The reason stated was the inability to have communication access with the subsea wet-gas meters.

In addition to subsea wet-gas meters, during the start-up of the Alfa Nord field, a topside wet-gas meter was installed on the SLT platform. However, after a brief period of operation, the top side wet-gas meter had malfunction in V-cone installed in the meter. Since then, the top-side meter has not been in operation.

When looking at GCR output for Alfa Nord wells, it was found out that the development of GCR with time, which has been used in allocation, has been steady with time (Figure 2). The GCR for a typical gas-condensate reservoir does not follow this trend because the produced gas will become leaner due to dropping of heavy-ends of fluid in the reservoir during pressure depletion. Therefore, according to the allocation system, the allocated gas volumes were underestimated and allocated condensate volumes were overestimated compared to the actual values.

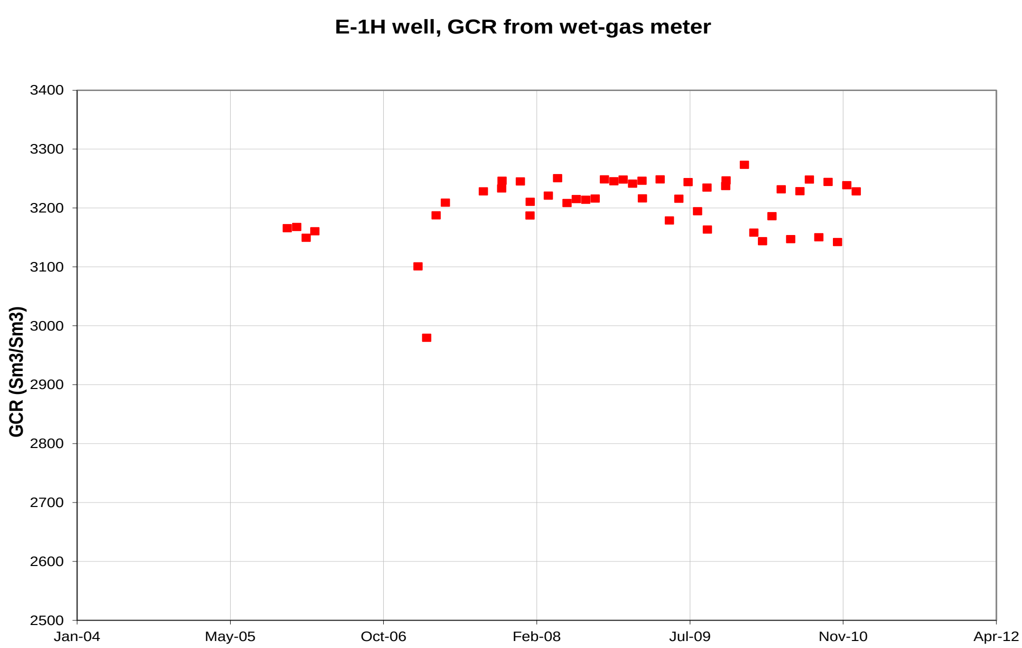

Figure 2 – GCR output from WGM in the one of the Alfa Nord wells (E-1H)

3. Development and implementation of new allocation routine

Since the source of wrong allocation was identified, a simple method for correct allocation was worked out. Instead of using theoretical gas and condensate rates from the wet-gas meters, it was decided to calculate the theoretical gas and condensate rates from wet-gas meters outside of production database system.

3.1. Use of total hydrocarbon (HC) mass rates:

The first step was to use the hydrocarbon mass rates from the wet-gas meters. It was concluded by study done by the wet-gas meter vendor that the hydrocarbon mass rates are reliable measurements from the meter at the line (subsea) conditions. The hydrocarbon mass rates output from the wet-gas meter depend on the Gas-volume fraction (GVF), Condensate-volume fraction (CVF) and Water-volume fraction (WVF). The source of error in the theoretical rates from wet-gas meter, as stated before in section 2, was the PVT package inside the wet-gas meter because the fluid composition was not updated regularly.

3.2. Conversion of total HC mass rates to gas and condensate splits:

The PVT experts in Statoil were consulted on a methodology to split the total HC mass rate to gas and condensate. The split into gas and condensate at process conditions was possible to be calculated using the initial fluid compositions from each reservoir, monthly gas and condensate compositional analysis of export gas and condensate streams from SLT platform and the history matched black-oil reservoir simulation model.

Since the intrinsic permeability in the Sleipner Vest reservoirs has been estimated to be good, it was assumed that the Constant Volume depletion (CVD) experiments represent the depletion of a gas condensate reservoir. Simulation of CVD was used to define a relationship between the reservoir pressure, GCR and well-stream composition, making it possible to estimate the composition of production streams in a ‘black-oil’ reservoir simulator.

The separation of the production streams into export gas and condensate (i.e. re-constructed GCR) was then calculated on the basis of monthly compositional analysis of export gas and condensate streams on SLT platform.

Table 1 gives an example of this calculation based on the above described method.

3.3. Implementation of new allocation routine

Once the split of total HC mass into gas and condensate was done, the new method was easily and robustly applied in the production database. A retroactive re-allocation was performed using the re-constructed GCR for Alfa Nord wells. Figure 3 illustrates the GCR before and after the application of new methodology.

Table 1 – Illustration of re-construction of GCR for month of October 2004

Component	Export gas			Condensate	Component split factor	
	Mol.weight	Composition		Composition	Gas	Condensate
	(mol%)	(mol%)	(wt%)	(wt%)		
Nitrogen	28.013	0.766	1.113	0.00	1.000000	0.000000
CO_2 *	44.01	2.929	6.690	0.46	0.978016	0.021984
Methane	16.043	84.237	70.138	0.53	0.997482	0.002518
Ethane	30.07	8.490	13.249	4.41	0.899931	0.100069
Propane	44.097	2.898	6.632	14.6	0.576220	0.423780
i-Butane	58.124	0.231	0.698	4.58	0.313307	0.686693
n-Butane	58.124	0.324	0.978	8.86	0.248326	0.751674
i-Pentane	72.151	0.048	0.181	4.13	0.116151	0.883849
n-Pentane	72.151	0.038	0.144	4.37	0.089687	0.910313
C6 fraction **	90 **	0.038	0.177	6.58	0.074617	0.925383
C7 fraction				8.78	0.000000	1.000000
C8 fraction				10.93	0.000000	1.000000
C9 fraction				6.89	0.000000	1.000000
C10+ fraction				24.88	0.000000	1.000000
Total mass (tons)			490807	163961		

*: 71.64 tons of CO_2 was removed from the gas stream on Sleipner T
**: C6+ fraction for gas (C6 fraction for condensate)

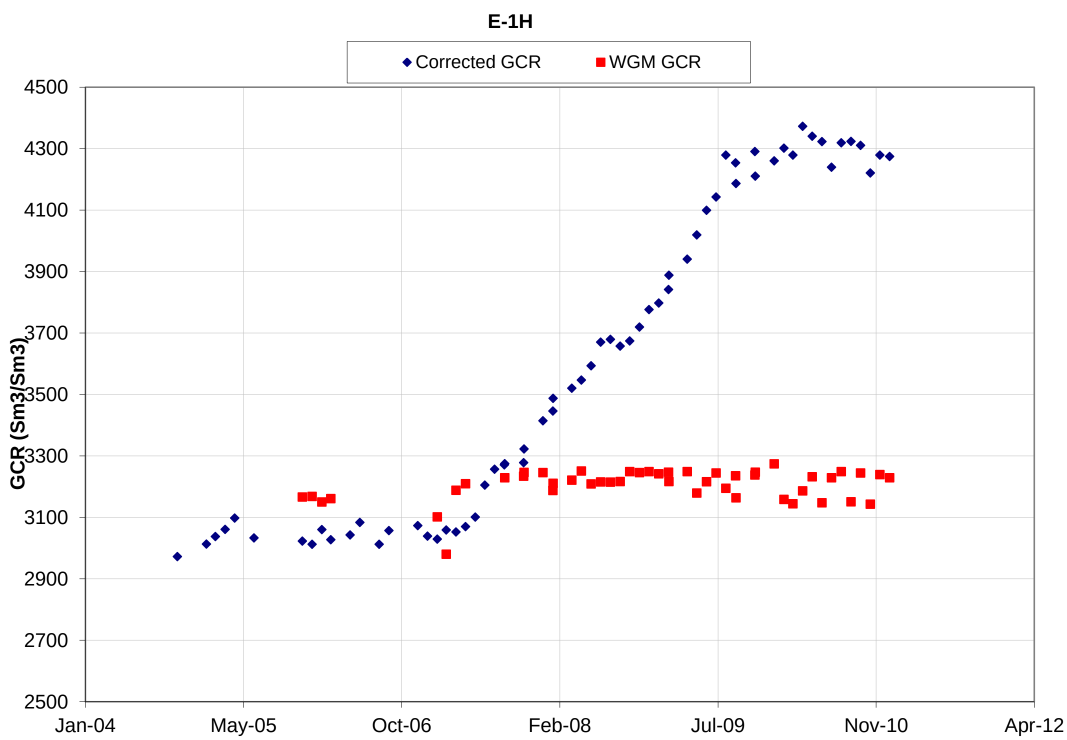

Figure 3 – GCR development for one of the Alfa Nord wells (before and after implementing correction)

4. Results and Discussion

Figures 4 and 5 show the theoretical gas volumes and theoretical condensate volumes, respectively from well E-1H (Alfa Nord well) before and after implementing the new allocation routine. The %age difference between correct and incorrect theoretical condensate production has been much more than that of the gas production. As mentioned before, the original allocation routine was underpredicting theoretical gas production and overpredicting condensate production.

With implementation of new allocation method, the allocation factor for gas and condensate at Sleipner Vest improved (especially with respect to condensate, see figures 6 and 7). The AF for condensate improved to acceptable error of ±5%. This shows that new allocation routine was able to normalize the individual well production better to the overall fiscal metered and measured volumes from the SLT platform.

The availability of compositional analysis of export gas and the condensate from SLT platform and the relatively simple production drainage for Sleipner Vest reservoir (pressure depletion) combined with the good reservoir quality sands of Sleipner Vest and Alfa Nord reservoir helped to develop an alternative allocation methodology to correctly find theoretical well rates.

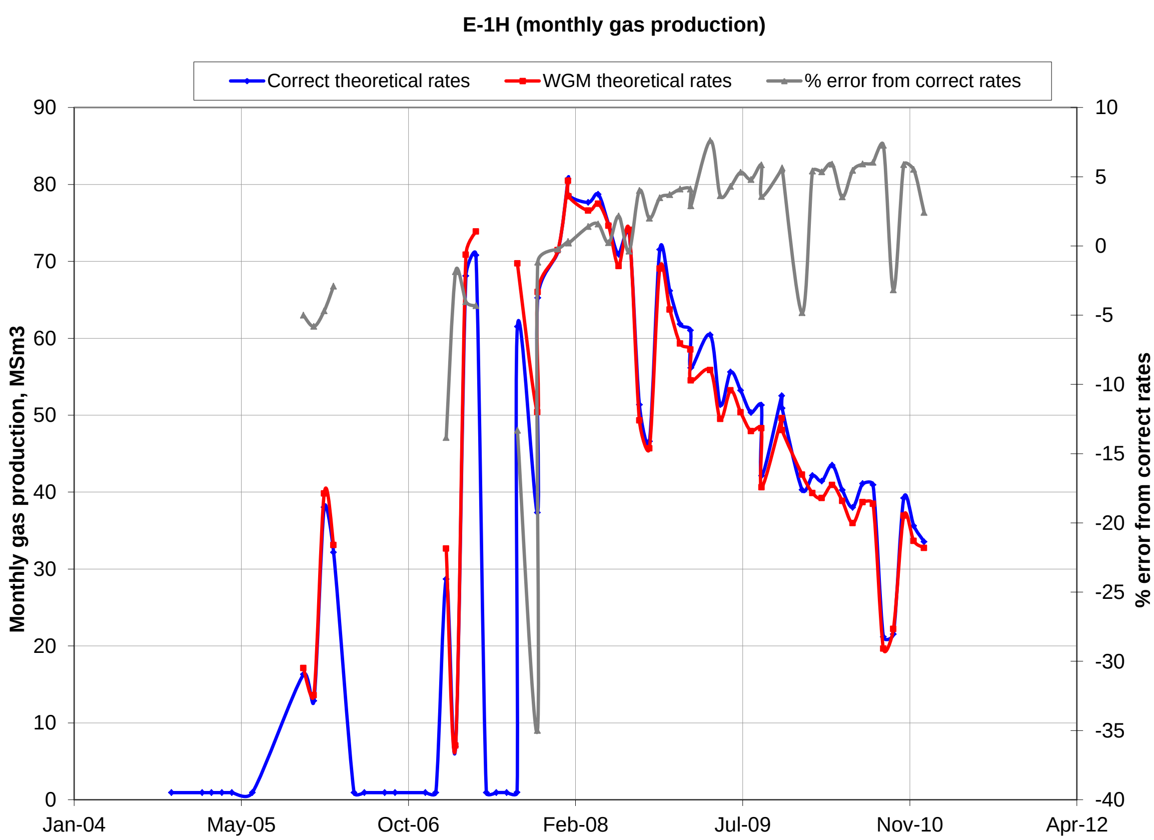

Figure 4 - Theoretical gas production from well E-1H before and after implementing the new allocation routine

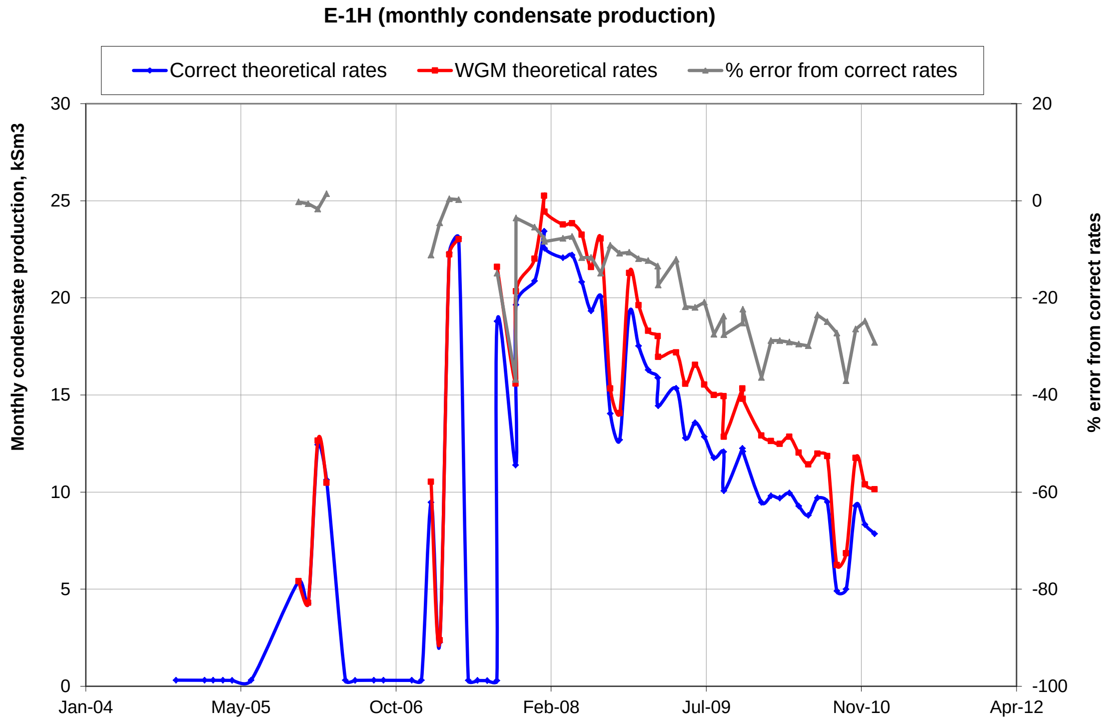

Figure 5 - Theoretical condensate production from well E-1H before and after implementing the new allocation routine

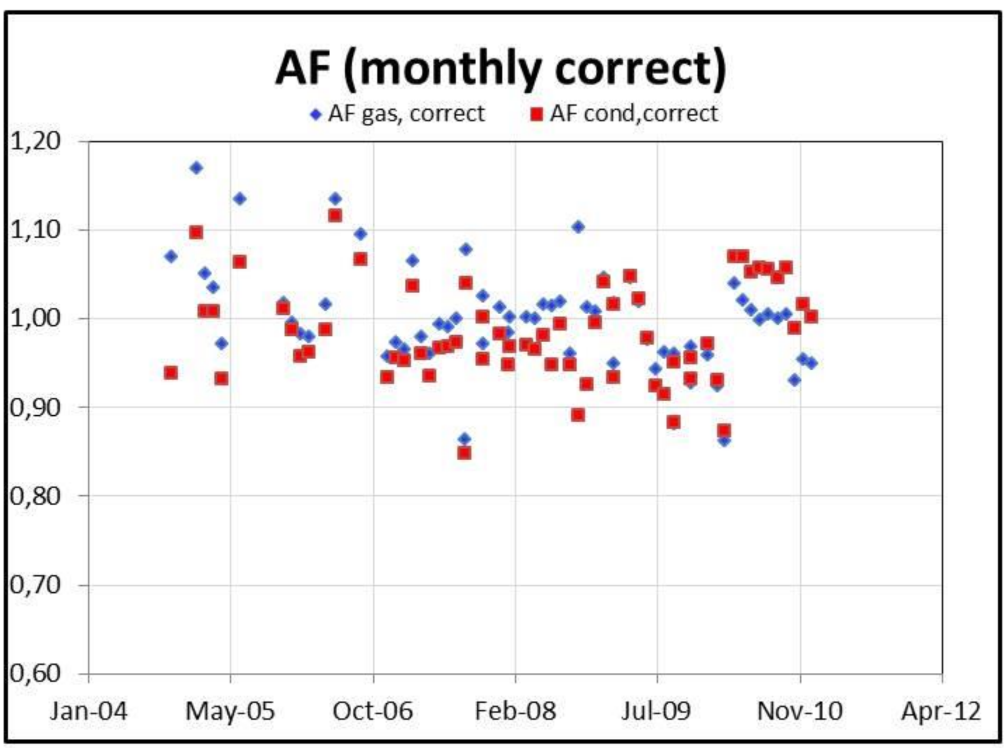

Figure 6 – Allocation factor (AF) for gas and condensate with new allocation routine

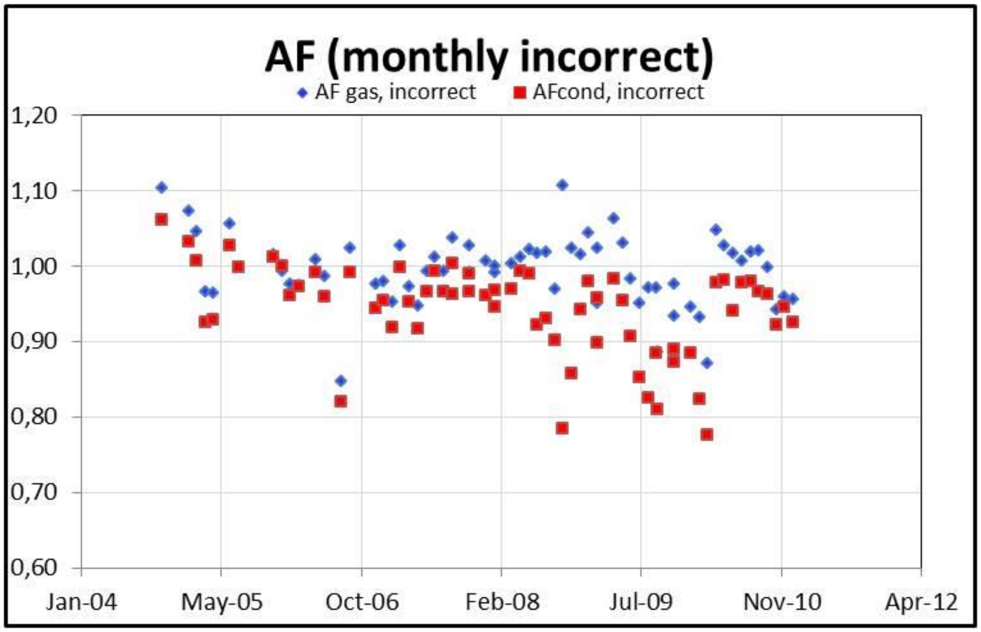

Figure 7 – Allocation factor (AF) for gas and condensate with old allocation routine

5. Conclusions

A relatively simple allocation methodology was developed to overcome the issue of poor allocation at Sleipner Vest Field. It is shown that it is extremely important to update the fluid compositions regularly in the wet-gas meters wherever they are used for allocation purposes. Our method described here can be used fairly easily by any operator if the conditions (i.e reservoir, processing and measurements) are similar to that described in this paper, if they face the difficulty of getting access to wet-gas meter for PVT updating. **The method is robust enough to be implemented in any production allocation engine.**

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