

Challenges and Mitigation Strategies for High Gas Situation during Drilling in Sapi Field

Muhammad Aditya Firman Wahyudi*, Febro Adira Putra, Ramadhana Aristya, and Andang Kustamsi

PERTAMINA HULU KALIMANTAN TIMUR

* Email: mk.muhammad.wahyudi2@mitrakerja.pertamina.com

Abstract. This paper discusses the challenges and mitigation strategies for dealing with high gas situations during Sapi development well drilling operations on Pertamina Hulu Kalimantan Timur. Sapi's drilling campaign began in December 2021, with three re-drill and four new wells. Historically, the highest record of gas encountered during drilling is 4,500 U TG and 1,000 U BG without a kick sign. The Sapi-13RD1 is used as the benchmark for the high gas situation in Sapi area during this campaign. This well encountered a high gas situation while displacing the well with mud from 12 ppg MW to 12.4 ppg at 13148 ft, BG reading increased from 180 U to 400 U. This situation induces confusion among operation and also drilling program design against material stock and drilling time efficiency despite the limitation of drilling cost.. As a result, new strategies for dealing with this situation were developed. Offset well studies show that increasing MW has been shown to reduce BG Gas in some cases, but not necessarily peak gas encountered during drilling. The SAPI-1 well was drilled to TD with a maximum of 14.5 ppg MW but still encountered up to 3000 U of connection gas. Despite maintaining adequate mud overbalance (max pore pressure SAPI-13 is 8.7 ppg from MDT log), we still encountered high gas content during drilling. Following a thorough analysis of pore pressure-related events, the drilling history of all offset wells, and responding from the drilling operation side by ensuring safe drilling, the high gas reading is not related to pore pressure close to mud weight. The decision flowchart for high gas situations during drilling was made by increasing the cut off of BG gas to 400U prior to increasing MW and setting a cut off TG 2500 U to close annular and circ gas out. This decision flowchart was used for the remaining six wells in this campaign, giving the drilling team the confidence to accept the high gas reading while maintaining safe operation in the Sapi area. This decision record is developed to give clear guidelines when encountering high gas situation during drilling to ensure that the well can be safely drilled – maintaining well control at all times - without compromising other factors when we decide to increase the MW to specific value (risk of differential sticking, losses, ballooning, cement slurry weight strategy, etc)

Keyword(s): background gas, mud weight, pore pressure, total gas, high gas, well control.

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1 Introduction

In a coastal swamp area in East Kalimantan, Pertamina Hulu Kalimantan Timur produced the remaining reserves of 104 BCF and the gas reservoir zone's production by adding 4 new wells and 3 re-drill wells in the Sapi Drilling Campaign 2021 shown in **Figure 1**. Based on a previous drilling campaign, Sapi wells



have been drilled with various MWs ranging from 10 – 14.5 ppg when entering “overpressure” zones below ~10,300’ TVDSS. And the MW was increased due to the increasing trend of BG (Background Gas) or sudden peak of TG (Total Gas / Peak Gas) which sometimes can reach 3000 – 4500 U.

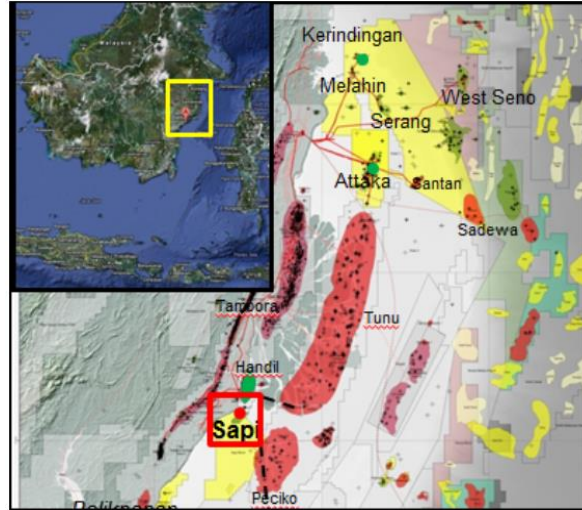


Figure 1. Sapi location map on the south side of Handil Field and north-west side of Peciko Field

The gas recorded by the data logging unit during drilling at Sapi is quite high when compared to wells in other fields at PHKT. The gas that comes from the formation that comes out when the mud circulation (drilling) is in progress is called liberated gas. Liberated gas is then divided into two, namely background gas (BG) and total gas (TG) which refers to gas coming out of reservoir rocks with large related permeability (eg.: sandstones and permeable limestones as well as diagenetic limestones). An illustration showing the terms BG and TG is shown in **Figure 2**.

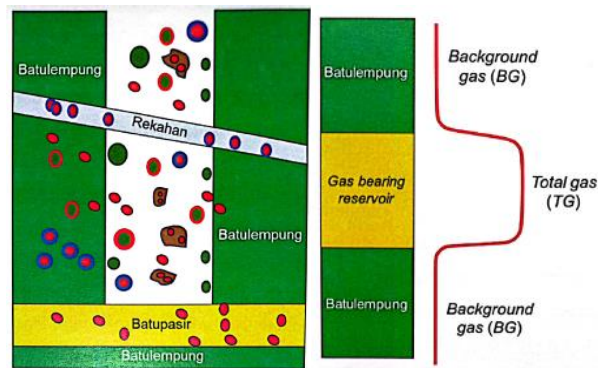


Figure 2. Gas While Drilling: Gas Source (Left), BG and TG term (Right) [2]

Deviations from the background gas trend likely indicate changes in porosity, permeability, or drilling conditions, any of which may require further investigation. Formation intervals that contain hydrocarbons or act as source rock will have a higher gas content when compared to other intervals so that formation and





cutting gas need to be distinguished from gas flowing into the wellbore and recorded in the logging data unit [1].

2 Sapi High Gas Situation Challenges

Sapi-13RD1, first well in this campaign, encountered a high gas reading situation (10-25 BG with maximum gas 148 U) while drilling 5 ft of 6-1/8" hole section new formation using mud with 10 ppg MW was increased from 12 ppg to 12.4 ppg at 13148 ft but BG reading still increase from 180 U to 400 U as shown in **Figure 3**. While looking at the MDT data, all the wells in Sapi has max PP less than 9.2 ppg and the pressure point in Sapi-13RD1 range between 4.2 ppg – 9.2 ppg.

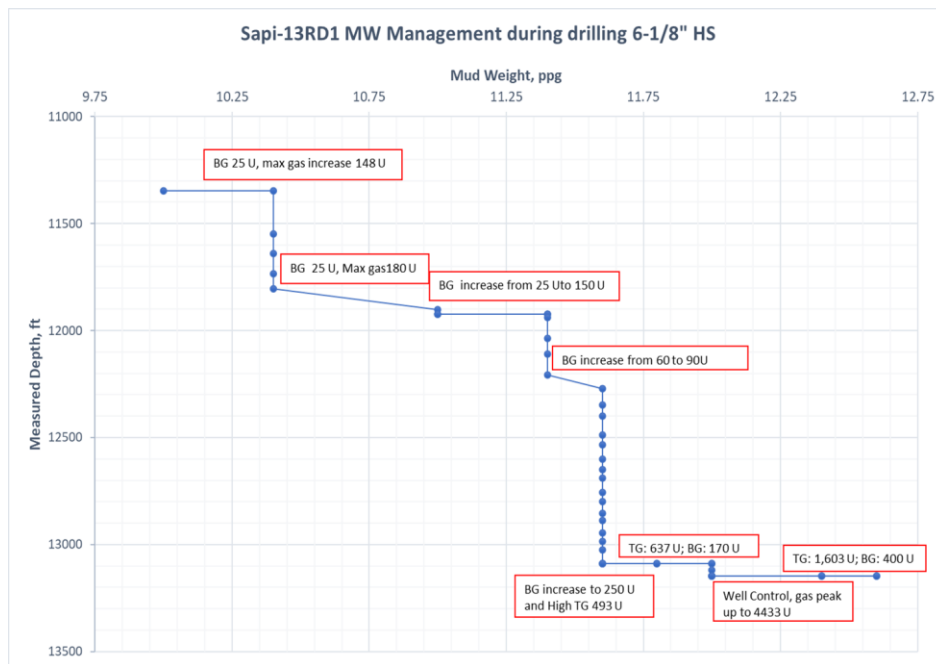


Figure 3. Sapi-13RD1 Mud Weight Management during drilling 6-1/8" Hole Section

From this experience, Sapi-13RD1 is used as the benchmark for the high gas situation in the Sapi area added with a drilling summary on some offset wells that represent the analysis of high gas situations that occurred on Sapi field drilling operations, shown in **Table 1 and Figure 4**. As seen on Sapi-1 drilling, the well was drilled to TD with maximum 14.5 ppg MW but still encountered up to 3000 U of connection gas. Also, Sapi-4RD2 which is the closest well with Sapi-13RD1 was drilled with MW 10.8 ppg, BG 407 Unit, TG 3346 Unit at TD. This phenomenon indicates that an increase in MW is still not proven to reduce BG in some cases and not necessarily reduce peak gas encountered during drilling. Some wells has been pulled out with BG 500U and TG 3300U without having well control issues.



Table 1. Offset Well Review

Well	Date	Drilling Records
Sapi-1	20 Apr 2000	<ul style="list-style-type: none"> Start drilling w/ 11.7 ppg MW from 10,916' TVD At 11,400' TVD increase MW to 12.7 ppg After having several connection gas up to 991U ABG, BG 60U, at 11,675' TVD increase MW to 14 ppg Increase MW to 14.3 ppg at 11,840' TVD after having 138U ABG connection gas, BG 65U. Increase MW to 14.5 ppg at 12,020' TVD after having 2930U ABG connection gas, BG 95U. TD well at 12,126' MD/ 12,099' TVD POOH BHA Run MDT, result max PP = 8.7 ppg <p style="text-align: right;">Run completion</p>
Sapi-6	29 Des 2007	<ul style="list-style-type: none"> Start drilling w/ 14.5 ppg MW (ECD 16.4 ppg) from 10,600' TVD TD at 13,180' MD / 11,664' TVD, max gas 52U Run RDT, abort after 5 pressure point due to sticking problem. Run 3-1/2" tubing to 3000' MD, displace well w/ 12 ppg MW. Run tubing to bottom, displace well to 12.3 ppg MW. Max gas 1423U during circulation
SAPI-4RD2	10 Oct 2010	<ul style="list-style-type: none"> Start drilling w/ 10 ppg MW Raise MW to 10.5 ppg at 11,526' TVD due to sloughing shales and BG gas Increase MW to 10.8 ppg at 12,062 due to high BG gas TD well w/ 10.8 ppg MW (ECD 12.3 ppg) at 12,231' TVD. Flow check, static. First SIT BG 550 Unit, TG 29 Unit, ABG 2372 Unit. Second SIT BG 407 Unit, TG 3346 Unit, ABG 2836 Unit. POOH BHA to surface TIH 3-1/2" tubing, circulate at bottom, max gas 3245U, last gas reading 230U. No losses during cementing
Sapi-13	30 Jan 2014	<ul style="list-style-type: none"> Start drilling w/ 10.5 ppg MW Observed first connection gas at 12,100' TVD, CG 3540U, BG 190U. Con't drilling w/ 10.5 ppg MW Observed connection gas until TD (3391U, 3200U, 1755U), BG 200U At TD increase MW to 10.8 ppg for trip margin. SIT BG 180U, TG 1720U, ABG 1540U. Flow check static. POOH BHA to surface TIH 3-1/2" tubing, circulate at bottom, max gas 4874U. Con't circulation, gas drop to 900U and con't circulation until stabilize. No losses during cementing

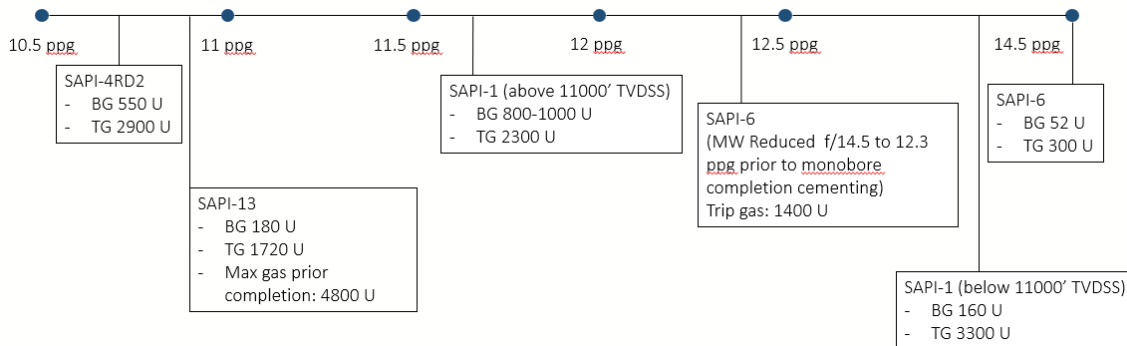


Figure 4. MW recap from Sapi Well Drilled



According to the predrill PP-FG (Sapi-5RD1) from the Subsurface team, maximum pressure at 120 series is ~11.2 ppg, shown in **Figure 5**. Also, the latest Sapi-17 PTFA result showed the max PP at 6-1/8" HS (11119 TVDSS) is 8.71 ppge..

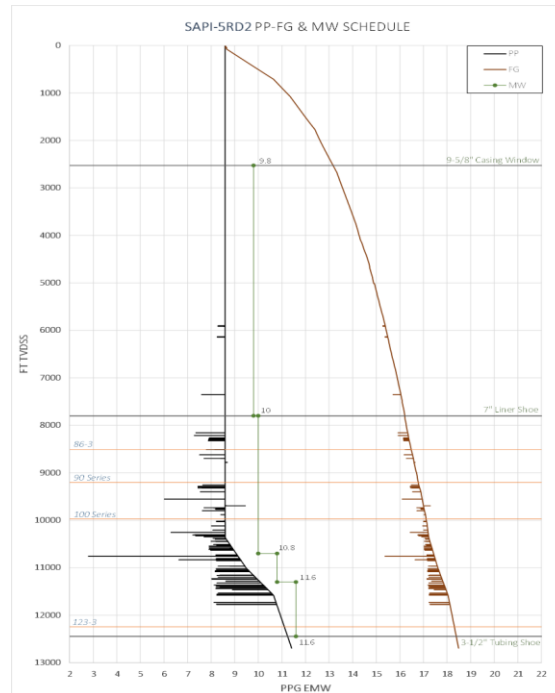


Figure 5. PP-FG Prognosis (Sapi-5RD1 Case)

3 Sapi High Gas Handling

Following a thorough analysis of pore pressure-related events, the drilling history of all offset wells, and responding from the drilling operation side by ensuring safe drilling, some improvement that can be done, shown in **Figure 6**:

- Increase the cut off of BG gas to 400U prior to increase MW. Do not use ABG as a cut off point.
- If there is high gas value > 2500 units, close annular and circulate with fully open choke until gas reading going down. Open BOP, flow check and continue drilling.
- As a precaution, close monitoring of BG figure increment must be taken by DSM whenever the BG number is higher than 250U.
- BG cut off for MW increase & TG cut off for circulation via choke will also be applied for SIT results.
- If there is any doubt during drilling, perform a flow check.
- Regroup and assess with team in town regarding the TKI/TKO, kick tolerance recalculation, material balance for mud adjustment, gas remover equipment and spacer-cementing displacement.

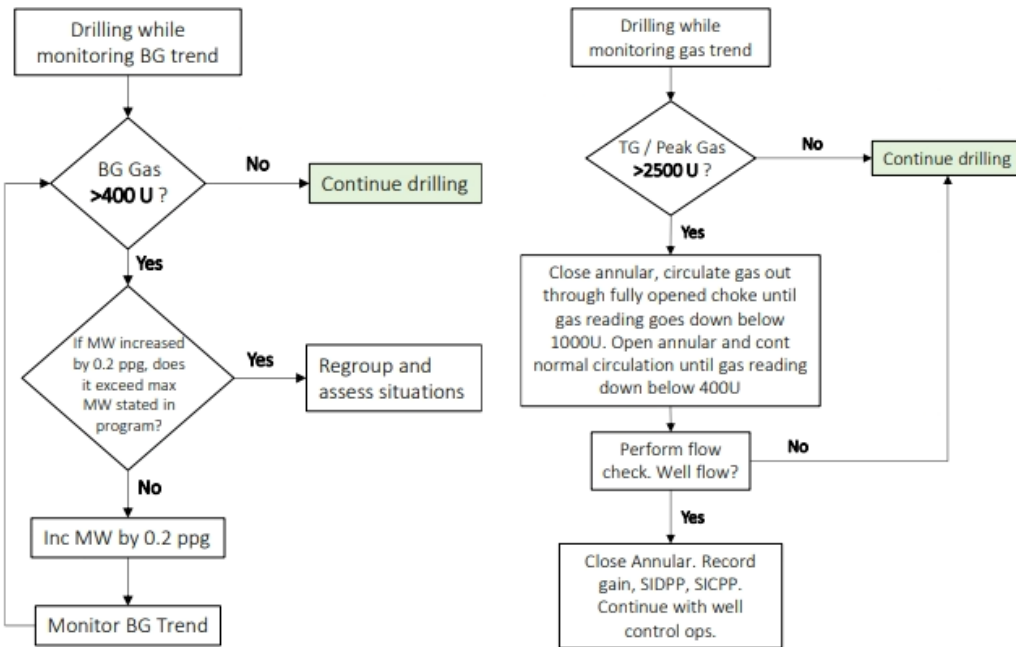


Figure 6. Decision flowchart for high gas situation during drilling towards BG gas (left) and TG (right)

4 Result and Discussion

4.1 Evaluation and Lessons Learned

a. The calculation of the background gas and total gas margin is carried out to determine the total concentration and background gas levels that will be recorded and enter the borehole, Gas cut mud from hydrocarbon formations or source rock formations can be distinguished against the background gas recorded in the logging data unit.

c. Gas recorded (BG, ABG, TG) while drilling in Sapi field insignificantly affected by ramp up pressure from formation, proven by records of MDT test for all Sapi wells indicate the maximum PP of 9.16 ppg at 12813 mMD. The high gas readings could be due to the gas diffusion from the reservoir into the borehole that occur very slowly even in overbalance condition and the gas dissolve into the synthetic oil base mud. Some gas still reenter the circulation into the borehole and thus it gets accumulated.

c. The gas saturation of each field is different, so it is necessary to make adjustments to the work reference in terms of planning and operation (Figure 7)

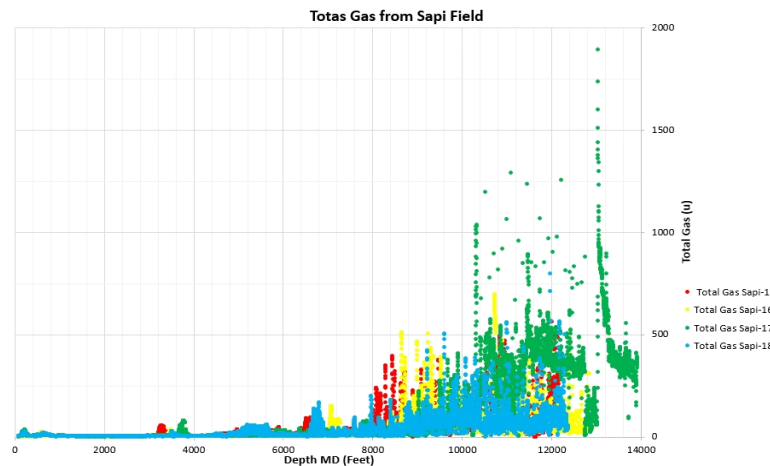


Figure 7. Typical total gas recorded in the Sapi field drilling campaign

4.2 Opportunity

- a. Mapping of total gas and background gas needs to be done in the entire field and gas saturation modeling can be done both in 2D and 3D modeling.
- b. Study on the diffusion of gas using the filter cake prepared using our oil based drilling fluid. After the diffusion coefficient is determined, flux of gas into the borehole can be estimated.
- c. Ensure safe operation to deal from Sapi high gas issues with MW increment assess with team in town regarding the TKI/TKO, kick tolerance recalculation, material balance for mud adjustment, gas remover equipment and spacer-cementing displacement.

Acknowledgments

The authors wish to express their gratitude to PT Pertamina Hulu Kalimantan Timur for the permission to publish this paper. Special thanks are extended to project team members for the full commitment and supports.

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