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Pipe Stuck Causes Analysis and Preventive Actions in Geothermal Drilling Well Awi Field Gunung Salak Based on Previous Drilling Problems

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ABSTRACT

The stuck pipe incident occured four times in three wells located on pad AWI-9. The three wells that experienced the stuck pipe were occurred first at AWI well 9-3, then twice at AWI well 9-5 and finally at AWI well 9-7. The first stuck pipe incident occurred at AWI 9-3 at the depth of 4,248 ftMD or 1,294 meters. There is a change in elemental anomalies or mud properties, an increase in the chloride property from the presence of brine in the wellbore as well as the increase of torques as a result of the accumulation of cuttings around the drill pipe assembly which resulted in sloughing or formation collapse. The next stuck pipe incident came from the AWI 9-5 well which occurred at the depth of 3,478 ftMD or 1,060 meters and at 4,667 ftMD or 1,422 meters. The background of the stuck pipe in this well can be seen from the collapse of the Paleosoil formation, the decrease in pump rate due to damage of the mud pump and the absence of air use when drilling in a loss circulation circumstances. This latter hindrance also led to the stuck pipe incident in the AWI 9-7 well at a depth of 6,266 ftMD or 1,910 meters. The overall occurrence of stuck pipes in thethree wells above can be overcome and the drill pipe series can be released through working pipe efforts, maximizingthe use of air and conducting well heat-ups. The methodology used in this thesis is a study of sub-surface and surface data during and before the occurrence of the stuck pipe incident. The data are log data in the form of daily drilling report, drill cutting or cutting data, drilling parameters and periodic reports of drilling mud per well. From the analysis of the data above, it was found that preventive measures were taken to prevent the same thing from re-occuring. The form of adding a mud additives that function as a reduction or prevention of fluid loss so that the loss circulation conditions can be prevented and brine and formations that have sloughing properties as the cause of collapse will not enter the hole, maintaining the weight of the mud and viscosity so that the mud cake maintained and the hole wall remains strong and the importance of hole cleaning during the drilling process; this includes the time before the connection process or removing the pipe circuit and the importance of using air in geothermal drilling which has a loss circulation character.

Keywords: drilling; geothermal; hole problem; pipe stuck.

I. INTRODUCTION

In the development of geothermal energy, drilling is one of the main activities carried out for exploration and production development in a fully developed field. In the drilling operation of a well, many problems may occur due to natural conditions and mechanical error factors. One of the problems that occurred during the operation is the pipe stuck. In a geothermal drilling well, pipe stuck is occurred when the pipe, such as drill pipe and casing, in the borehole, cannot be pulled out without exceeding the planned workload. Drilling operation is generated from 35-50% of the total project cost, the occurrence of a pipe stuck would make the unproductive or non-productive time (NPT) and can raise the average drilling cost by more than 15%. Therefore, it is important to manage the drilling cost and keep them low, so that the occurrence of a pipe stuck should be avoided as much as possible.

The drilling operations are not always as smooth-running as expected. Occasionally, there are problems that interfere with drilling operations and are very detrimental. In detail, the losses include losses in time, equipment, and drilling operating costs.

A pipe stuck means pipes that cannot be moved in the borehole (cannot be rotated or pulled) and occasionally the pipes can be rotated yet it cannot be pulled. As a result of stuck pipe, drilling operations are hampered and additional costs are increased to overcome the pipe stuck and the rig rental costs must be borne.

Pipe stuck located in AWI in Gunung Salak, especially, in AWI 9 pad occurred in AWI 9-3, AWI 9-3, and AWI 9-7 well. This occurrence of pipe stuck causes a high operation cost, considering the cost to replace the stuck pipe if the pipe cannot be removed will be very expensive.

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This paper contains incidents of pipe stuck in wells located in one of the wellpads in Gunung Salak geothermal field, Sukabumi, West Java, namely AWI 9 wellpad. The other things that would be covered by this paper are the analysis of pipe stuck based on well data, factors that can cause the pipe stuck such as mud aspects, drilling parameters, borehole stability, type of formation and lithology including prevention and control for mitigating the occurrence of pipe stuck in the future.

II. METHODS

The methodology used in this paper is the study of sub-surface and surface data at or before the occurrence of pipe stuck. The data are as follows:

- Log data in the form of Daily Drilling Report, mud log, and tour sheet.
- Cutting data in the form of lithology, rock type, and classification of formation.
- Drilling parameters in the form of well depth (feet), borehole diameter (inch), ROP, RPM (rotation per minute), WOB, GPM (gallons per minute), SPP (standpipe pressure), SCFM, and TQ (torque).
- Drilling fluid parameters in the form of mud weight, viscosity, PV, YP, GS, MBT, API fluid loss, and pH.

From the data above, it would result in a reliable study of the supporting drilling equipment, drilling fluid, and drilling parameters including the role of air in geothermal drilling to formation lithology so that it would produce the cause, the preventive actions, and the control of pipe stuck incident during drilling.

III. RESULTS AND DISCUSSION

At the beginning of commercial operation in 1994, brine was injected in the hottest part of the upflow zone of the reservoir at AWI 9 and at the southern edge of the field at AWI 10. The general belief at the time was that the limited brine produced from a 110 MWe plant would not significantly damage the high-temperature reservoir. In 1998, the increase of the plant capacity increased brine production to an average injection rate of 12,000 kilo-lb/hour (130,600 tons/hour). Chemical and thermal breakthroughs were observed in the main production area and, as a result, infield injection has been minimized by transferring condensate and brine injection to the edges and outside of field production areas. The injection wells in pad AWI 9 are AWI 9-2, 9-3, 9-4, 9-5, and AWI 9-6.

To maintain the 377 Mwe power plant, the field has been developed through regular drilling of production wells. The latest production well drilling campaign was in 2021. The production wells in pad AWI 9 are AWI 9-1, 9-7, 9-8, 9-9, and the last one in 2021 is AWI 9-10.

The AWI 9-3 well that was drilled in 1993, has a depth of 8,096 ftMD or 2,467.7 meters. The first occurrence of pipe stuck at AWI 9-3 well occurred at depth of 4,248 ftMD. The first analysis from daily data of drilling fluid indicates a change in the mud anomaly.

DATE	IN/ OUT	TIME hrs	DEPTH m	HOLE SIZE in	F L Deg C	MUD WT ppg	VIS sec	PV	YP	GELS 10 sec	GELS 10 min	FILTRATE API ml	CK /32	HTHP ml	CK /32	Deg F	RETORT SOL %	H2O %	OIL %	SND %	MBC ppb	pH	PM	Pf	Mf	Cl xK mg/L	TOT HARD mg/l	XS LIME ppb	KCl WT %	PHPA ppb	REMARKS/TREATMENT
21NOV	IN	1045	2015	17.5	N/A	8.80	44	16	8	3	15	15.6	1	N/A			3.5	96.5		TR	18	12.2	3.10	0.50	0.92	300	100	0.7			P/U BHA;RIH
	IN	2200	2057	17.5	144	8.65	41	10	10	8	30	14.6	1	N/A			2.4	97.6		TR	18	12.4	5.80	0.36	0.66	300	60	1.4			DRLG;LOT=13.5 EMW
22NOV	OUT	1000	2168	17.5	144	8.70	42	10	12	8	30	12.8	1	N/A			2.8	97.2		0.3	18	13.0	3.40	0.32	0.52	300	60	0.8			DRILLING
	IN	2100	2351	17.5	140	8.70	71	17	13	14	65	14.4	1	N/A			2.8	97.2		0.3	20	12.4	3.20	0.30	0.90	300	56	0.8			DRLG CO2 POSS
23NOV	OUT	1000	2536	17.5	148	8.80	42	12	13	21	48	16.0	2	N/A			3.5	96.5		0.3	23	12.7	2.50	0.44	0.74	300	24	0.5			DRLG
	IN	2200	2701	17.5	140	8.60	44	10	12	6	26	12.6	1	N/A			2.0	98.0		TR	15	12.8	3.80	0.50	0.80	300	60	0.9			PLC @ 2600
24NOV	OUT	1000	2877	17.5	140	8.65	38	10	9	2	7	14.0	1	N/A			2.4	97.6		0.2	15	13.2	4.90	1.10	1.40	300	20	1.0			DRLG WITH PLC
	OUT	2200	3056	17.5	148	8.80	38	15	10	3	10	9.8	1	N/A			3.5	96.5		0.3	13	13.4	10.00	1.18	1.60	300	24	2.3			CHANGE TO L-LIME
25NOV	OUT	1000	3189	17.5	148	8.90	36	9	7	1	2	10.4	1	N/A			4.3	95.7		0.3	13	13.4	11.10	1.30	1.70	300	88	2.5			DRLG WITH PLC
	OUT	2100	3290	17.5	140	8.90	36	7	10	3	5	10.0	1	N/A			4.3	95.7		0.3	13	13.5	11.00	1.70	2.20	300	140	2.4			PLC AVG=37.8 BPH
26NOV	IN	1000	3384	17.5	N/A	9.00	36	10	8	2	3	10.4	1	N/A			5.0	95.0		0.3	15	13.5	9.50	1.20	1.60	300	128	2.2			POOH-BIT CHANGE
	OUT	2100	3407	17.5	140	8.90	39	12	8	2	3	12.8	1	N/A			4.3	95.7		0.3	15	13.5	9.50	1.54	1.90	300	240	2.1			PLC AVG=24.4 BPH
27NOV	OUT	1030	3560	17.5	148	9.00	36	9	6	1	2	12.4	1	N/A			5.0	95.0		0.3	15	13.4	8.50	1.20	1.60	300	168	1.9			DRILLING
	OUT	2200	3686	17.5	148	8.90	35	7	7	1	4	13.4	1	38.0	4	250	4.3	95.7		0.3	15	13.3	9.20	1.36	1.70	300	180	2.0			PLC AVG=14BPH
28NOV	IN	0930	3805	17.5	N/A	9.10	37	11	8	2	5	12.0	1	40.0	4	250	5.8	94.2		TR	15	13.3	10.70	1.70	2.30	300	220	2.4			POOH X/O BHA
	OUT	2230	3813	17.5	152	8.90	38	13	5	1	5	12.4	1	40.0	4	250	4.3	95.7		0.3	15	13.4	9.10	1.38	1.80	300	240	2.0			DRLG PLC=13.9BPH
29NOV				17.5														100.0										0.0			DRILLING
				17.5														100.0										0.0			TLC @ 3918
30NOV				17.5														100.0										0.0			CEMENT PLUG
				17.5														100.0										0.0			DRLG AIR INJ=1200 CF
01DEC	OUT	1000	4182	17.5	160	8.80	35	9	6	1	4	9.7	1	38.0	4	250	3.5	96.5		TR	18	13.5	9.30	1.40	1.75	900	220	2.1			PLC: STUCK
	IN	2200	4254	17.5	160	8.85	37	10	8	2	5	9.2	1	36.0	4	250	3.7	96.3		0.2	15	13.3	10.20	1.40	1.70	900	280	2.3			HI VIS EACH CONN.
02DEC	OUT	900	4340	17.5	148	8.70	36	13	11	2	5	8.2	1				2.8	97.3		0.3	15	13.8	9.50	1.40	1.80	900	220	2.1			DRLG WITH PLC

Figure 1. Mud Properties

Figure 1 shows the change in mud property which is the chloride value from 300 mg/L to 900 mg/L at a depth of 3,813 ftMD to 4,182 ftMD. It indicates the presence of brine enters the system or hole. Brine can cause the collapse of formation that absorbs the existing formation so that the cutting is forced into the drill pipe, accumulated, and finally causing the pipe to be immobile and stuck. Another analysis of drilling fluid data is the decrease in API fluid loss as an implication of existing loss circulation and no impairing is made in the condition.

The next analysis is from the drilling parameters before the occurrence of pipe stuck.

Table 1. Drilling Parameters Before and After Pipe Stuck

Depth (ft.)	ROP (ft/hr)	WOB (Klbs)		RPM		GPM	SCFM	TORQUE (ft.lbf)
		Min.	Max.	Min.	Max.			
4115	8.1	30	50	180	270	950	1200	380
4269	7.3	30	50	180	270	950	1300	500

Table 1 shows an increase in torque caused by the accumulation of cutting around drill string that is caused by sloughing or formation collapse.

The effort to free the stuck pipe in the occurrence at AWI 9-3 well includes the working pipe process by attempting an overpull and injecting viscosity pill to ensure the hole is clean.

Preventive actions that must be taken to prevent similar incidents are to improve the mud cake, to add the mud additives that function as a reduction of prevention of fluid loss so that loss circulation can be prevented and brine as the cause of collapse would not enter the hole.

The second well that experienced a pipe stuck in pad AWI 9 is AWI 9-5 which experienced stuck pipe twice. The first incident occurred at a depth of 3,478 ftMD or 1,060 meters.

Table 2. Lithology in AWI 9-5 Well

Depth (ft.)		Lithology	Alteration	Comments
From	To			
3300	3500	Andesit Tuff	M-MI alt, Ch, 1, Ca, Qz, He, Py	Paleosoil at 3400 ft to 3420 ft, tight at 3470 ft

Table 2 shows the existence of a tight spot at a depth of 3,470 ft caused by the formation of the Paleosoill layer that collapsed resulted in the drill string was stuck due to the formation.

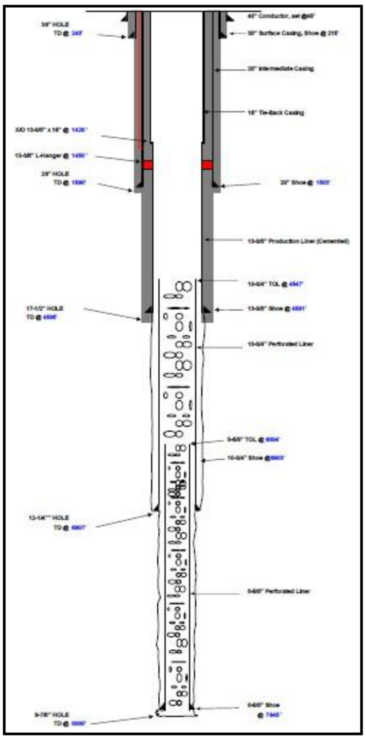

Figure 2. Well Schematic of AWI 9-5

Figure 2 shows a good response from the mud engineer by remaking the drilling fluid so that there is no decrease in mud properties such as YP, mud weight, and viscosity which helps suspension cutting to the surface. Frac seal pumping is also carried out to overcome circulation loss so that the permeability, as the cause of cutting is not well circulated to the surface, in the fracture zone could be reduced. Hence, the drilling fluid factor does not contribute to the occurrence of stuck pipe.

Table 3. Drilling Parameters Before and After Pipe Stuck

Depth (ft.)	WOB (Klbs)		RPM		GPM	SPP	SCFM	TORQUE (ft.lbf)
	Min.	Max.	Min.	Max.				
3360	30	45	120	240	962	2300	0	6700
3478	30	45	120	240	800	1800	600	7000

Table 3 shows a decrease in pump rate followed by a decrease in standpipe pressure. This is due to damage to the mud pump. Repair of the pump is carried out at the open hole causing the cutting above the drill string to drop to the part of the string that has a larger diameter which is the BHA assembly and causing a pack-off.

From the above analyses, it can be concluded that the first stuck pipe incident in the AWI 9-5 well was caused by the Paleosoil formation which causes the formation collapse and was exacerbated by pump repair when the drill string was in an open hole, causing a pack-off.

The pipe could be removed through the working pipe process by atempting an overpull and injecting 600 SCFM of air into the system to assist dispersing the pack-off and lift the cutting properly in a condition of lost circulation.

Preventive actions that must be taken to prevent similar incidents are to maintain the weight of the mud and viscosity so that the mud cake is maintained and the hole walls remain strong. The second is to pump *Hivis* or high-viscosity mud to lift the cuttings away from the BHA string.

If the damage occurred due to equipment reliability issues, the repair needs to be carried out at a safe depth such as in cased hole or on the surface. This is to prevent a pack-off that occurs in the open hole area.

The second incident of stuck pipe at AWI 9-5 well occurred at a depth of 4,667 ftMD or 1,422 meters.

Table 4. Loss Circulation Before and After Pipe Stuck

Depth (ft.)		Losses (bph)	SPM spm bph		Air Rates (scfm)	Loss Type	Remarks
From	To						
4595	4667	-68	2x80	1944	No air	PLC	drill w/mud, stuck pipe at 4667'
4667	4727	-60	2x70	1045	700	PLC	drill w/aerated mud, switch on air at 4667'

Table 4 shows a change of drilling parameter that is the absence of wind use at PLC of 68 BPH which only uses mud so that the cutting coult not be suspended to the surface properly in a condition of lost circulation.

Table 5. Mud Properties

Date (1996)	Depth (ft)	Wt (ppg)	FV (s/qt)	pV (cps)	yP (lb/100ft^2)	Filtration		Sol (%)	Water (%)	Oil (%)	Sand (%)	MBT (ppb)	pH	Pm	Pf	Mf	Chlor mG/L	Ca mG/L
						API	HTHP											
9-Jul	4595	8.8	36	6	6	12.2	NC	3.5	96.5	0	TR	12.5	11	2	0.65	1.35	2400	160
POOH: BUILT 860 BBLS FRESH MUD , GAINED APPROX. 150 BBLS W/ CIRC. W/ 1200 CFM AIR, LOSS RATE W/ 700 CFM APPROX. 350 BPH																		
10-Jul	4595	8.8	33	6	3	14	NC	3	97	0	0.1	12.5	11	2	0.7	1.4	1500	40
POOH: M/U 12.5" BIT RIH TAG PLUG @ 1515', WOC, BREAK CIRC. FILL UP HOLE W/ 250 BBLS, ATTEMPT TO DO PLUG, WOC, POOH 12.25" BIT																		
11-Jul	4667	8.8	47	15	15	8	35	3	97	0	0.1	12.5	11.5	2.5	1.5	2	1500	80
W/O STUCK: RIH TO 1501' W/CMT DIFFUSER. SET CMT PLUG, WOC, RIH W/ 17.5" TO 1317', WOC, CIRC. RIH TAG CMT @ 1349', WASH DOWN TO 1508'																		

Table 5 shows a good response from the mud engineer by remaking the drilling fluid so that there is no decrease in mud properties such as yP, mud weight, and viscosity which assists cutting suspension to the surface. Hence, the drilling fluid properties did not contribute to the occurrence of stuck pipe.

Table 6. Drilling Parameter Before and After Pipe Stuck

Depth (ft.)	ROP (ft/hr)	WOB (Klbs)		RPM		GPM	SPP	SCFM	TORQUE (ft.lbf)
		Min.	Max.	Min.	Max.				
4594	40	35	40	60	60	506	1760	0	1800
4727	41	35	40	60	60	614	1800	700	1850

Table 6 shows that there was no use of air from a depth of 4,595 ft even though at the time lost circulation was occurring. After the stuck pipe occurs, the wind air injected into the hole.

The effort to free the stuck pipe at a depth of 4,667 ftMD in the AWI 9-7 well is by injecting air into the hole which was not previously carried out even though the well is in PLC condition and jar down efforts have been carried out several times until the pipe string could be released.

Preventive actions that must be taken to prevent similar incidents is to ensure effective hole cleaning before making up pipe connections. This could be carried out by several things such as injecting *hivis* mud, circulating clean bottoms up, and making sure the cutting is clean by observing in the shale shaker. The next step is to use the air during a condition of lost circulation so that the cutting can be litfted effectively to the surface.

The last occurrence of stuck pipe in the pad AWI 9 in AWI 9-7 well occurred at a depth of 6,266 ftMD or 1,910 meters. This well was drilled in 2009 to a total depth of 9,500 ftMD.

Table 7. Formation Lithology

Depth (ft.)		Lithology	Alteration
From	To		
6240	6540	Andesite Lava	Chlorite - Silica - FeOx - Calcite - Illite - Epidote - Pyrite

Table 7 shows that the PLC condition occurred at a depth of 6,183 ftMD of 70 BPH. In the PLC condition, drilling is only carried out with mud, but without air injection which is able to lift the cutting properly in a condition of lost circulation.

Table 8. Mud Properties

Date	24-02-09	25-02-09
MD (ft)	6147	6817
TVD (ft)	5531	6071
Wt (ppg)	8.6	8.6
FV (s/qt)	43	44
pV (cos)	12	10
yP (lb/ 100ft2)	18	18
API FL (cc)	11.6	11.6
HTHP FL (cc)	32	32
Sol (%)	4	4
Water (%)	96	96
Sand (%)	1	0
MBT (ppb)	12.5	12.5
pH	11	11
Pm	1.2	1.2
Pf	0.4	0.4
Mf	0.6	0.6
Chlor mG/L	500	500
Ca mG/L	40	40

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Table 8 shows a good response from the mud engineer by remaking the drilling fluid which is resulted in no decrease ofmud properties such as YP, mud weight, viscosity, and API FL, and also a good mud concentration from the MBT value which is within the normal threshold: to keep the mud properties and build mud cake on the hole wall which helpsthe cutting suspension to the surface. Hence the drilling fluid factor does no contribute to the occurrence of stuck pipe.

Table 9. Drilling Parameter Before and After Pipe Stuck

Depth (ft.)	ROP (ft/hr)	WOB (Klbs)		RPM		GPM	SPP	SCFM	TORQUE
		Min.	Max.	Min.	Max.				(ft.lbf)
6147	18.89	27	34	276	202	862	2300	0	12599
7300	103	27	34	276	202	772	1515	2500	15823

Table 9 shows the reduction and even shutting down the air of 3 stands before pulling out the bit into the casing shoe. Shutting off the air contributes to the problem of not having sufficient mud flow before the drill pipe string is pulled to asafe depth inside the casing shoe.

The effort to free the stuck pipe at a depth of 6,266 ftMD in the AWI 9-7 well is by injecting air into the hole which wasnot previously carried out even though the well is in PLC condition and jar down efforts have been carried out several times including the heat-up well process or the process of letting the steam from the reservoir into the hole in order to soften/loosen the pack-off; these processes will result in the detachment of pipe string.

The preventive action that must be taken to prevent similar incidents is to use and maximize the air during loss circulation conditions so that cutting can be lifted effectively to the surface. In addition, in a condition of loss circulation, it is also necessary to consider using *hivis* mud more intensely so that the cuttings are more easily lifted to the surface.

Appropriate action has been taken in the event of a breakdown due to equipment reliability issues. Repairs are planned to be carried out at a safe depth such as in a cased hole or at the surface. This is to prevent pack-offs from occurring in the open hole area.

IV. CONCLUSION

1. The initial indication of the entry of brine (influx) into the system which could potentially cause the collapse or sloughing of formation or hole walls is from observing the Chloride element from the properties of the mud. With this indicator, preventive actions can be taken immediately, namely by forming a mud cake from the existing bentonite so that collapse holes can be minimized and prevent influx from entering the system.
2. Paleosoil formations have the same impact, namely collapse or sloughing. Any debris needs to be mitigated by building a strong mud wall. This can only be done by forming a mud cake which is made from the basic ingredientof mud, namely bentonite.
3. Several incidents of pipe stucks started from damage to drilling equipment or equipment reliability, so this needsto be taken seriously because it leads to pipe struck. When there is an equipment damage that interferes to drilling process such as damage to the top drive, mud pump and others; pull-out the drill string as far as possible to a minimum depth where there is a casing or called a cased-hole and not in an open-hole so that there is no cutting resulted from the formation that can cause pack-off.
4. The use of air in drilling or aerated drilling plays a major role in geothermal drilling. Air is required to lift the cutting to the surface or to make the cuttings enter the fractures pores when the drilling is in a loss circulation condition.
5. Some efforts in overcoming the stuck pipe could be done in the form of work pipes including the jar-up and jar-down processes. However, the method of heating up the well is worth considering. This process can be carried out when the pipe is pinched in the reservoir area by allowing hot reservoir steam to enter the hole so that within a certain time it can soften/loosen the pack-off around the drill pipe series so that the pipe can eventually be released.

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