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CASING HEAD INTEGRITY CASE STUDY: DRJ-3 UNPLANNED WELL PLUG & ABANDONMENT

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ABSTRACT

As one main component of geothermal production operation, well integrity is an important issue to be taken care of. Parts of it are casing integrity and casing head integrity. Both are supposed to be closely monitored through routine inspection since there is no method to calculate lifetime of a wellbore. What we can do is make prediction based on monitoring data. Casing integrity is under constant threat from its completion process, completion fluid, formation fluid, formation pressure and temperature, and surface soil movement (i.e. land slide). All of those affect condition of the casing. Examples of methods applied to monitor casing condition are ring gauge and caliper log. These surveys give us qualitative and quantitative data on changing casing condition.

In the upper part of casing, casing head is not only under constant threats from same hazards that are harmful to casing integrity, but also taking external hit from corrosion due to its contact with air and humidity. DRJ-3 case was a great example of how casing head integrity was weakened and finally damaged by erosion from inside and corrosion from outside. Even when casing head thickness was measured regularly, DRJ-3 casing head failure occurred several months earlier than prediction – where prediction was made based only on DRJ-3 casing head thickness data.

DRJ-3 was one of Darajat injection wells, which active as injector since November 16, 1994. Injection wells have important role in injection management, where every geothermal producer has to comply with Government of Indonesia regulation concerning Environment Management and Protection (UU Nomor 32 tahun 2009 tentang Perlindungan dan Pengelolaan Lingkungan Hidup), where anything produced from earth should be injected back into earth instead of dumped to surface. As to comply with that need, DRJ-3 should be plugged and abandoned because casing head leak was observed on this well since November 2011. Initially, DRJ-3 casing head failure was predicted to occur on June 2012. Immediate action to prevent condensate spill from DRJ-3 had been done by performing casing head repair by installing casing collar - which was installed surrounding the leaking casing head section. The well was successfully and safely plugged and abandoned on May 9, 2012.

Based on experience of DRJ-3 casing head failure where it occurred 8 months earlier, it indicates that there was something missing/inaccurate concerning failure prediction based on casing head thickness data. Applying more appropriate/thorough calculation method, it is expected that casing head failure prediction could be more precise to avoid environment damage and unplanned well plug and abandonment.

DRJ-3 WELL HISTORY

DRJ-3 was an active injector in Darajat, dedicated for Darajat Unit-I condensate injection, injecting at 25 liter per second of average injection rate at -0.6 barg of wellhead pressure. The well was drilled on 1978 and had underwent several workovers ever since which includes 7” casing tie back in 1988, wireline fishing job in 1997, 13-3/8” casing sleeve repair in 2006, 4-1/2” casing tie back in 2008, and 4-1/2” equal tee replacement and split collar installation in 2011.

All casing tie back works, equal tee replacement and split collar installation were related to well integrity problems of DRJ-3. Factors such as casing corrosion and erosion are addressed as main problems acknowledged in DRJ-3.

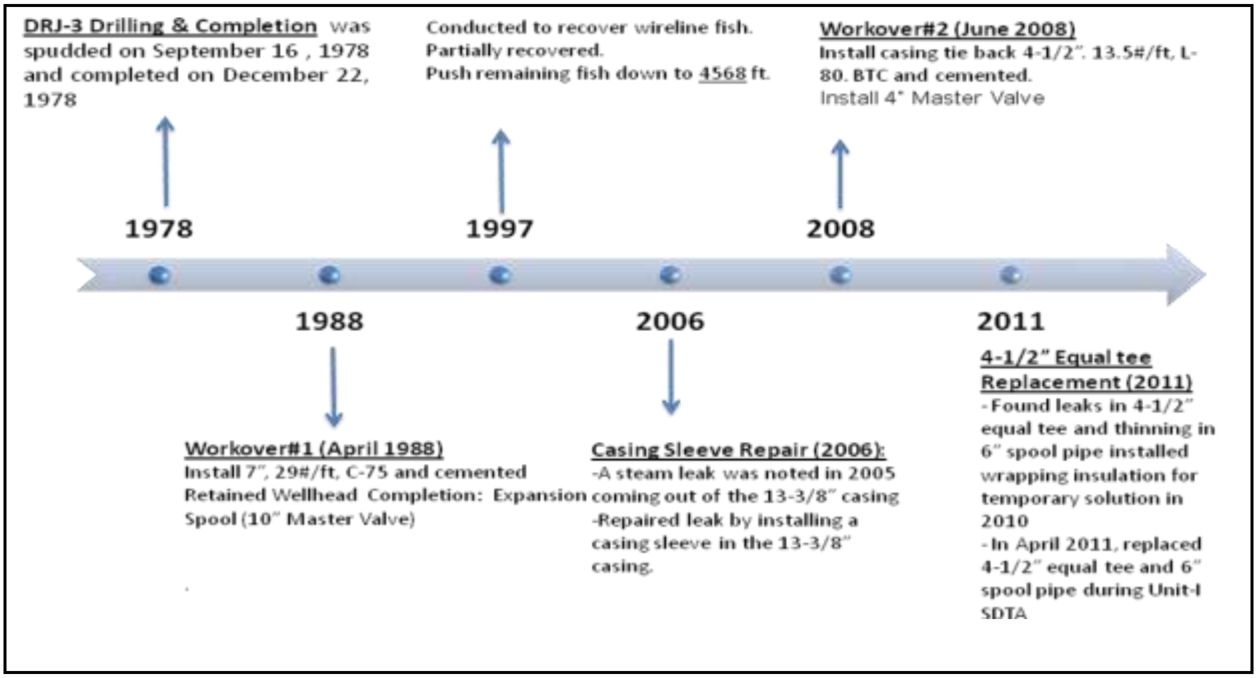

Figure 1: DRJ-3 workover history

Figure 2: DRJ-3 before plugged and abandoned

Latest event concerning this issue was casing head leaking, where a hole was observed at DRJ-3 casing head in November 2011. Immediate action to prevent condensate spill from DRJ-3 had been done by performing casing head repair by installing casing collar - which was installed surrounding the leaking casing head section. A casing head support was also installed to prevent wellhead collapse.

Nonetheless, these were only momentary prevention. Once the well builds up, there will be no guarantee that the split collar would not break due to casing and casing head expansion. Should this occur, then the wellhead would collapse and DRJ-3 would blow out. Therefore, the team proposes to plug & abandon this well to permanently solve the problem.

Below are conditions that support decision to plug and abandon DRJ-3:

1. A leak was observed at DRJ-3 casing head in November 2011. Split collar installed at casing head is not a permanent solution. Should the well build up, casing head & well head will collapse due to casing expansion
2. DRJ-3 casing has been tied back to smaller casing sizes, from originally 9-5/8” casing to 7” in April 1988 and to 4-1/2” casing in June 2008. Further casing tie back to smaller casing size is possible (e.g. from 4-1/2” to 2-3/8” casing), nonetheless that would disable any logging survey planned to monitor casing condition (the available technology to run smallest caliper is for 4-1/2” casing size). In addition, tie back to a smaller casing size will only worsen casing thinning due to erosion (as injecting fluid inside smaller casing diameter will result in higher fluid velocity - which means higher erosion. Should the smaller casing leak in the future, it would be more difficult to plug and abandon the well

Prior to plug and abandon DRJ-3, a back-up injector should be available to accommodate Darajat Unit-I condensate injection. DRJ-31, which is located in Pad-3, is planned to be switched to an injector. PT. PGE (PT. Pertamina Geothermal Energy) and EBTKE (Energi Baru Terbarukan dan Konservasi Energi) had approved the DRJ-3 and DRJ-S5 Plug and Abandon Program and demanding CGI (Chevron Geothermal Indonesia) to proceed with the plan according to technical guidelines available concerning well plug and abandonment technique. Later on DRJ-31 was killed before the start of DRJ-3 plug and abandonment program, and was injected as a substitute to DRJ-3 for Darajat Unit-1 injector. Thus DRJ-3 plug and abandonment program was successfully completed without creating any disturbances on Darajat Unit-1 electricity generation.

DRJ-3 ON WELL RELIABILITY OPTIMIZATION

The purpose of the Well Reliability and Optimization Process (WRO) is to provide a consistent approach and minimum standards for optimizing and improving the reliability of production and injection wells in order to maximize value. Inside the process, a critical well assessment is established. This takes into account the likelihood of well failure to occur and its consequence of failure. Combining the two will result in each production/injection well criticality rating.

The process is also applied to DRJ-3, which was Darajat Unit-1 injector. It was a critical well considering that a sudden failure of this well will stop Darajat Unit-1 electricity generation for some time until another back-up injector is ready. Below is the criticality rating of DRJ-3 from the likelihood & consequence of well failure:

Table 1: DRJ-3 critical well assessment

Well Name	Likelihood of Failure									Type of well failure	Most Likelihood Well Failure Rating (Compound)
	Well Head						Casing Condition				
	Well Head Condition Remaining Life (yrs)	Thickness Likelyhood Index	Well Head Condition - Master Valve	Master Valve Likelyhood Index	[illegible]	Most likely type of repair from WH repair	Casing Likelyhood Index	Casing Condition Likelyhood	Most likely type of repair from most likely type of failure		
DRJ-3	5.66	1		3	5	Minimum allowable MAT exposed casing	1	Casing Wear	Work over casing hole	Casing Wear	1

Well Name	Consequence of Failure																	Consequence/Impact Rating
	Health Environment Safety and Public Image							Regulatory Impact		Reservoir Impact		Business Impact						
	Health	Rating	Environment	Rating	[illegible]	Rating	HES Rating	Regulatory Impact	Regulatory Rating	Reservoir Impact	Reservoir Impact Rating	Estimated WH Repair Cost ($MM)	Estimated Casing Repair Cost ($MM)	Total Estimated Repair Cost ($MM)	Rating [illegible]	Prod. [illegible] Rating	Business Impact Rating	
DRJ-3	Localized reversible damage	4	Limited exposure of contaminants	4	Limited exposure of contaminants [illegible]	4	4	Immediate notification	1	Impacting Reservoir Performance	3	0.01	2.5	2.51	1	2	2	2

The likelihood of failure considers wellhead condition and casing condition. Included in wellhead condition are wellhead condition remaining life, thickness likelihood index, and wellhead condition (master valve). Taking the lowest score out of three we get wellhead likelihood index. In DRJ-3 case, wellhead/casing head thickness condition is most critical item (rated 1) compared to master valve condition (rated 3). Therefore, rating 1 is taken as wellhead likelihood index of DRJ-3. The DRJ-3 wellhead condition remaining life was estimated to be 0.68 years (8 months) left.

As for casing condition assessment, DRJ-3 casing is rated 2 due to casing wear. Combining wellhead condition and casing condition, DRJ-3 well failure compound rating is 1 as wellhead condition is more critical compared to casing condition.

In the other hand, consequence of failure rating taking into account Health, Environment, and Safety (HES) and public image compound, regulatory impact, reservoir impact, and business impact. Health compound is rated four due to its localized reversible damage risk. Environment compound is rated 4 for its limited exposure of contaminants. Public image is also rated 4. Thus, HES compound rating is 4.

Regulatory rating is 2 since it needs immediate notification of local regulatory agency concerning well condition. DRJ-3 belongs to Pertamina Geothermal Energy, thus any work planned for this well should be informed to shareholder (PGE). Later on PGE and CGI should notify Energi Baru Terbarukan dan Konservasi Energi (EBTKE) concerning work program planned on DRJ-3.

DRJ-3 is rated 3 for its reservoir impact. DRJ-3 was an infield injector. Condensate injection through DRJ-3 affect reservoir performance in a way that it results in cooling effect in the middle of reservoir, yet in the other hand it also provides mass influx into reservoir which later on is important in sustaining reservoir steam availability.

Business impact compound consists of total repair cost (wellhead repair and casing repair cost) which are summarized into COI rating (cost classification), and production-injection rating. In this case, DRJ-3 casing repair cost is estimated at $ 2.51 MM, equal to COI rating 3 ($ 1MM - $ 5MM). Production-injection rating takes into account the mass produced/injected through the well. DRJ-3 at 22 kg/s of injection rate is classified at rating 2 (21 - 28 kg/s). The minimum between COI rating and production-injection rating is taken as business impact rating (in this case, it is 2).

Consequence/impact rating is the lowest rating among HES rating, regulatory rating, reservoir index rating, and business impact rating. For DRJ-3 case, it scores 2 for its regulatory rating and business impact rating.

As last step, likelihood of failure and consequence of failure are combined in critical well assessment metric. Likelihood of failure (rating 1) and consequence of failure (rating 2) results in well criticality rating 2 (highest criticality rating is 1, lowest is 9).

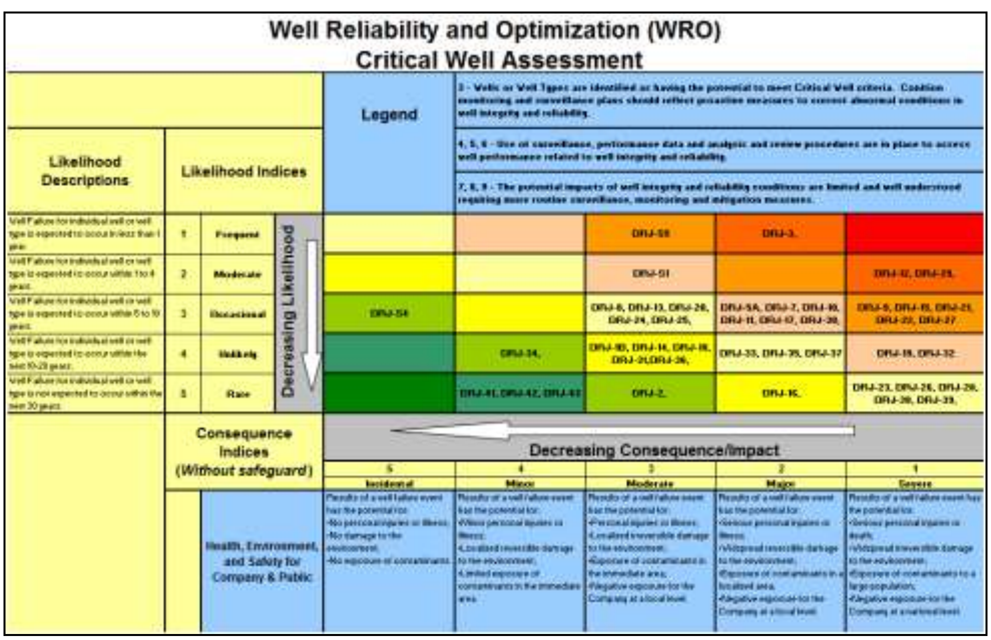

Figure 3: DRJ-3 Critical Well Assessment rating

DRJ-3 CASING HEAD CONDITION MONITORING

As per WRO guideline, a method is required to monitor wellbore condition (casing and wellhead) of production/injection wells. Methods used are ring gauge, caliper, and downhole video (casing condition monitoring); casing head thickness monitoring and master valve condition check (wellhead condition monitoring).

Casing head thickness monitoring of Darajat wells is performed utilizing periodic (Ultrasonic Thickness Gauge) UTG measurement. The measurement is conducted on production, injection, and monitoring wells annually. The gauge measures sound travel time from transducer to get through and traverse the material along its thickness to the end part, and then get back to the transducer.

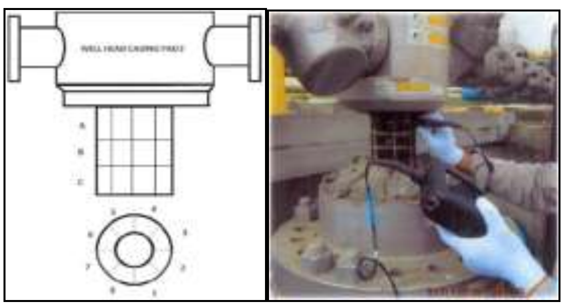

Figure 4: DRJ-3 casing head thickness measurement

As shown in Figure 4 above, DRJ-3 casing head is divided into several sections, horizontally into 3 rows (A, B, C), and vertically into 8 columns (1 – 8). UTG is used to measure thickness of each 24 points. The result is shown in Table 2 below (measurement unit is mm):

Table 2: DRJ-3 casing head thickness measurement 2012

IDENT	POINT OF MEASUREMENT						THK
	A		B		C		MIN
1	2.12	2.50	2.31	2.82	2.28	3.33	**2.12**
2	2.60	2.28	3.58	3.36	2.21	2.40	**2.21**
3	2.67	2.45	2.37	2.41	2.60	2.90	**2.37**
4	2.11	2.05	2.58	2.20	3.08	2.78	**2.05**
5	2.58	2.47	2.26	2.17	2.78	2.12	**2.12**
6	2.09	2.14	3.46	2.12	2.14	2.10	**2.09**
7	2.90	3.80	2.10	2.05	2.27	2.12	**2.05**
8	2.09	2.82	2.09	2.19	2.81	2.39	**2.09**

Every point is measured for minimum and maximum value, thus in the end there are 48 data points of casing head thickness of 1 well. Among all, the lowest value for DRJ-3 casing head thickness is 2.05 mm. This number is taken as representative of DRJ-3 casing head thickness since casing head failure (if it occurs), it will strike at weakest point, which is minimum thickness at A4.

DRJ-3 MAXIMUM ALLOWABLE WELLHEAD PRESSURE CALCULATION

Casing head thickness measured annually is one input for calculating maximum allowable pressure at which the casing head will not fail. Others input are estimated shut in wellhead pressure, saturation temperature at estimated shut in wellhead pressure, casing yield point, and casing outside diameter. The formula used to calculate maximum allowable wellhead pressure is shown in Equation 1 below:

$$WHP_{max} = \frac{2 \; x \; YP_{eff} \; x \; T_{csg}}{14.5 \; x \; 1.5 \; x \; OD_{csg}} \qquad (1)$$

Where

WHP_{max} = maximum allowable wellhead pressure (bar)
YP_{eff} = effective yield point (psi)
T_{csg} = casing wall thickness (in)
OD_{csg} = casing outside diameter (in)

Effective yield point is calculated as follow:

$$YP_{eff} = YP \; x \; T_{DF} \qquad (2)$$

Where

YP_{eff} = effective yield point (psi)
YP = yield point (psi)
T_{DF} = temperature degradation factor

Yield point here depends on casing grade/type, while temperature degradation factor is calculated from saturation temperature of estimated shut in pressure through the following equation:

$$T_{DF} = -0.0005 \; x \; T_{sat} + 1.0275 \qquad (3)$$

Where

T_{DF} = temperature degradation factor
T_{sat} = saturation temperature of estimated shut in pressure (°F)

Following all equations above, the DRJ-3 maximum allowable wellhead pressure is then converted into minimum allowable thickness, shown in Figure 5 below:

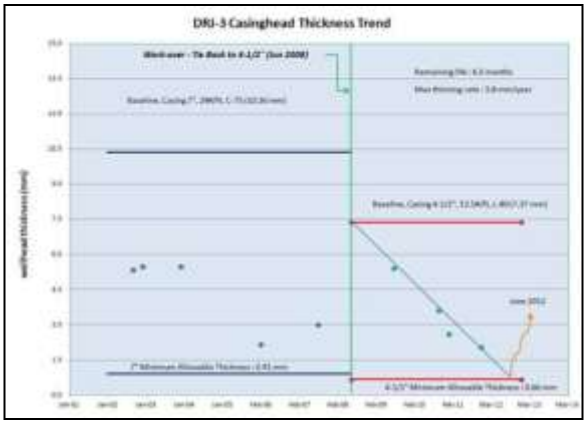

Figure 5: DRJ-3 minimum allowable thickness

As shown in Figure 5 above, there is a change of baseline in 2008 due to well workover of 4-1/2" casing tie back. Since the casing size is decreasing, hence the strength of the casing (i.e. minimum allowable thickness) is also decreasing from 0.91 mm for 7" casing to 0.66 mm for 4-1/2" casing. Also shown in figure, extrapolation of last four casing head thickness measurement suggests that the casing head failure would likely to occur in June 2012 when the casing head thickness is predicted to be less than 0.66 mm (using maximum thinning rate of 3.8 mm/year).

However, DRJ-3 casing head thickness occurred in November 2011, which is 7 months earlier than predicted failure. Internal and external factors might be the cause of accelerating failure. Some internal factors could be error in casing head thickness data acquisition and flaw in failure prediction method. Adding some safety factor might improve the prediction, for example in estimating shut in pressure and in calculating effective yield point. External factors could be some major physical event impacting the strength of casing head that leads to accelerating casing head failure (e.g. improper casing head support installation process). It adds external force working on the casing head that initially was not taken into account during the failure prediction calculation. Physical event like this could greatly reduce casing head strength.

REFERENCES

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