Green Well Westland

Second-opinion

to reports

HON-GT-01-S1 - Blockage investigation v1.4
Detailed design - HON-GT-01-S2 v1.2

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1 Introduction

GWW and AAB have requested Wellworks BV to conduct a second opinion on the report *HON-GT-01-S1 - Blockage investigation v1.4*, dated 26 March 2015 and report *Detailed design - HON-GT-01-S2 v1.2*, dated 25 March 2015. The first report describes the investigation process and possible causes of a blockage which occurred in the water producing well HON-GT-01-S1. The second report details the options for the well repair that should avoid reoccurrence of a similar kind of well failure.

The final reports were issued on Thursday, 26th of March 2015 to Wellworks BV although drafts were issued beforehand. The finalisation of the second opinion has been requested to be complete by Monday, 30th of March due to the tight schedule in preparation for the workover activities. This review is therefore limited to the information provided in before-mentioned reports and provides comments and suggestions to the observations, recommendations and conclusions as presented. The review is specific to well services and completion engineering, and does not cover geology and drilling engineering related issues.

This second opinion has been conducted fully independently.

2 General findings

Both the reports are well described and, in the opinion of reviewer, provide sufficient information to generate the conclusions as outlined in these reports. In general, the findings and observations as addressed in the reports are supported by reviewer.

Depending in the required production life of the well(s), recommendations and suggestions can be made to further improve the active life of the HON-GT-01-S2 well. Especially on the lower and permanent completion, all efforts should be taken to obtain the best system.

3 Report HON-GT-01-S1 - Blockage investigation v1.4

In this section, report *HON-GT-01-S2 - Blockage investigation v1.4* is being reviewed. The 'page' numbers and paragraph names are referring to the sections in this report. The 'quotes' are copied out of the report for easy reference and the 'notes' address comments, suggestions and/or questions applicable to that text.

Page 2 – Executive summary

Quotes: *Primary source of the blockage material is expected to be damage to the 4 ½" liner in the interval from 2470 to 2500 m, where a casing connection is likely eroded away due to high local flow velocities in combination with vortices as a result of the irregular internal surface of the BTC couplings.*

Notes [A]: The applicable pump rates certainly would have been turbulent and with solid particles being present, potentially could have eroded the BTC thread voids. An identical failure mechanism has been observed at the recovered tubing connections (see *2.1 – Retrieved Electric submersible pump (ESP)* and *3.1 – Clay analysis*) which certainly could be seen as a strong indicator of likewise failure mechanism for the liner. However, improper make up & running procedures and/or damages being present prior to running the liner may also have contributed, unless this is ruled out from observations or inspections at time of the lower completion installation process. According to reviewer, the depth of the damage to the 4-1/2" liner could also be at shallower depths. The lack of isolation behind the 4-1/2" liner would allow alternative routes for the clay particles to go.

Page 2 – Executive summary

Quotes: *In order to prevent problems as described above it is recommended to apply the following modifications in the well:*

- *Maximize ID of tubing to reduce flow velocity*
    - *o Increase OD as well to prevent reduction of wall thickness*
- *Use internal flush casing connections (premium connections)*
    - *o Remove uneven surfaces at casing collars*

Notes [B]: Increasing the size of the liner pipe and screen assemblies would further reduce fluid velocities which consequently would aid in lengthening the production life. The 6-1/8" open hole would safely allow for 5" base pipe and 5-1/2" screen assemblies. The suggested wall thickness increase are recommendable seen the potential continuously presence of solids during the production operations and premium connection are considered a must. Placement of the screen sections only across the Delft sandstone would reduce the risk of clay particles entering through the screen maze. If the mobility of clay particles is likely (geologist), annular isolation of the Rodenrijs clay stone from the Delft sandstone may be considered but only if this can be engineered without excessive running risk (small section of water swellable compound around liner pipe). In case any kind of future stimulation on the Delft sandstone is anticipated, ensure the well completion components and elastomers are suitable to cope with this. Reservoir stimulation experts could advise on potential future stimulation requirements.

Page 4 – Introduction

Quotes: *Starting September 2014 increasing quantities of clay were found in the surface filters. Up to that date the filters were only occasionally cleaned to remove the hydrocarbon film which aggregated on the filters. In the following months the quantities increased, until production was required to be ceased in November due to the persisting issues and an increase in required pump power.*

Notes [C]: It is advisable to maintain a continuous or frequent monitoring program on the well effluents and ESP performance. These trends will provide the first indications of down hole issues.

Page 6 – Retrieved Electric submersible pump (ESP)

Quotes: *In 2013 the 6 ⅝" production tubing was replaced after erosion-corrosion effects on the BTC couplings on the old tubing. The couplings showed small holes (see Figure 1). A study to the cause & solutions was performed by Technisches Büro Karl GOLLOB GmbH (1).*
The new tubing had internal flush BTC SC couplings installed. After pulling the ESP no damage on any part of the ESP was reported. No damage was observed on the connections in the string; connections were 'as new'.

Notes [D]: This is considered very valuable information, especially seen the occurrence of this erosion-corrosion on the larger sized tubing string (in comparison to the smaller sized liner). The fact that this phenomenon was observed on multiple couplings and the presence of BTC couplings on both the retrieved tubing string and the current liner string strengthens the presumption. The lack of damage on the tubing string with BTC SC couplings is certainly reassuring for any future approach.

Page 7 – Slickline operations (2)

Quotes: Several.

Notes [E]: The observations and conclusions of the slickline intervention runs as listed in this paragraph are clear and can be fully supported. The origin of the piece of rubber remains unclear, but since its origin is not from the liner hanger packer, this is not expected to play a role of significance in the cause of the blockage. Also, the several unidentified marks on the LIBs cannot be seen as critical in identifying the cause.

Page 7 – Slickline operations (2)

Quotes: Several.

Notes [F]: The condition of the 4-1/2" TOL appears to have some deformation in shape. Liner hanger packer integrity is important in any (future) installation. Good running practices, equipment selection, pressure testing and the availability of contingency tools are of importance. For all the installation and intervention operations, proper reporting of the sequence of events shall be made available and the activities shall be supervised by the client or his representative.

Page 12 – Coiled tubing operations (2)

Quotes: *An injection test was performed on the well with water. The pressure was building to 30 bar, after which the pump was stopped. Pressure was monitored for 30 mins during which it remained stable.*

Notes [G]: The pressure test graph shows excellent sealing capability of the blockage. Typically clay is capable of creating good seals due to the nature of its particles.

Page 12 – Coiled tubing operations (2)

Quotes: *During the milling operations the fluid returns from the well were monitored and found to be carrying similar solids particles (claystone) as found in the production filters before. Flowrates were however limited to 275 l/min, which would be insufficient to remove larger cuttings from the well. As a result the blockage material has only been temporarily moved upwards, after which it settled back into its original position.*

Notes [H]: These are obviously correct observations. The coiled tubing annular velocities could not have exceeded 0.13 m/s which would avoid lifting out particles of any significance. The suggestion to perform this type of clean-out should have been challenged.

Page 13 – Data analysis

Quotes: *A blockage in the well was encountered at 2422 m. The location of the blockage is marked below in the well schematic (Figure 11). 7 meters of the blockage were milled out by CT. The remaining thickness of the blockage is unknown, but is expected to extend to at least 3m. After the injection/pressure test to 30bar it was confirmed that a clay plug would need to be several meters, likely >10m in thickness to hold such pressure (Panterra Geoconsultants, verbal).*

Notes [I]: It is not clear what scientific ground there is for the > 10 m thickness of the plug. Potentially, this quantity (> 80 liters) support reasonable mobility of the clays and therefore effort should been taken to isolate the clay stone from access towards the lower end (screens) and upper end (liner hanger) of the base pipe. It has been reported that local (small) fractures may exist in the Rodenrijs clay stone, which previously resulted in losses during drilling operations. In return, the Rodenrijs clay stone should be able to flow fluids back into the wellbore during drawdown conditions.

Page 14 – Data analysis

Quotes: Figure 12.

Notes [J]: The top screen is stated to be placed at 2548 m, which is 12 m shallower than the top Delft sandstone. The clay fines should be able to flow through the mesh of the screens. As a minimum, the screens should be placed across the Delft sandstone only.

Page 14 – Data analysis

Quotes: *The clay retrieved by the wireline bailer operations was analysed by PanTerra Geoconsultants (5). The clay sample was found to originate from the Rodenrijs Claystone, which was found between 2463 and 2560 m (6). The microfossils found in the sample matched a sample as retrieved from well VDB-04. From this analogy the sample was allocated more precisely to the upper 30 m of the Rodenrijs Claystone. Therefore it would come from approximately between the 7" casing shoe (2470 m) and 2500 m MD.*

Notes [K]: A good indication of the origin of the clay particles.

Page 15 – Source of clay in blockage

Quotes: *The iron scraps found in the well could indicate steel damage to the liner or the screens. Damage to the screen section is highly unlikely as source of the blockage because of the following:*

- *Holes in pre-perforated pipe 12.5 mm*
- *Clay sample from above 2500m, which is 50m above the uppermost screen joint.*

Notes [L]: The shape and material specifications of the iron scraps could be of value. However, an investigation indicated that the iron scraps do not origin from the screens so further analysis is not considered critical.

Page 16 – Source of clay in blockage

Quotes: *In addition, in case of a failed packer, the annular area would be required to be plugged somehow at a later stage. Since this was also proven to be plugged to be plugged by the CT injection tests. The slickline operations were all performed inside the 4 ½" liner, which provides no explanation for an increase in plugging of the 4 ½" x 7" annulus after the 3rd injection test.*

Notes [M]: If the clays appear to be mobile enough to enter an eroded hole in the base pipe, certainly that clay should be able to provide a 'seal' in the 4-1/2" x 7" annular void as well after the squeeze as a result of the pressure test.

Page 19 – Review of data

Quotes: *The liner hanger has a reported internal diameter (ID) of 98.8 mm (3.89"). This is slightly less than the ID of the 11.6 ppf 4 ½" liner (4"). The length of this restriction is ca. 1 m in length. Above this section the liner hanger opens up in two ca. 1 m steps to 4.27" and 5.26". Total liner hanger length is 2.7 m. The TOL has an ID of 5.26" and OD of 5.77".*

Notes [N]: These differences in ID may also result in unfavourable flow behaviour. Consequent erosional effects may also be present, but potential extra wall thickness & different material specifications may have resulted in superior protection in comparison to the BTC void situation.

Page 21 – Review of data

Quotes: *The ESP production tubing was retrieved and visually inspected. No damage on the casing connections (as experienced in 2013) was found. In 2013 spot measurements on casing wall thickness were performed to investigate corrosion on the tubing joints. No wall thickness reduction in comparison to the installation was observed. (14). After retrieval of the ESP production tubing in 2014 the wall thickness of the tubing has been measured. The results of this measurement showed no notable decrease in wall thickness (15).*

Notes [O]: Reassuring & valuable information on both the ESP and tubular performance.

Page 22 – Conclusion

Quotes: *The environment and the presence of Cl- may lead to some corrosion on an unprotected steel surface. Due to the presence of hydrocarbons in the well a protective film would normally be found on the steel casing which protects it from corrosion. The fluid analysis showed however increased levels of Fe from 2012 to 2013. This may be indicative for corrosion in the well.*

Notes [P]: Depending on the expected design life of the well, it may be valuable to conduct a corrosion prediction study. The limited amounts of hydrocarbons may not be enough to provide the required amount of corrosion protection. All data (pressure, temperature, rates, hydrocarbon presence, chlorides, pH, etc) is available to conduct such a study. The study may result in a recommendation for an alternative material selection for the permanent (non-retrievable) parts of the well components. It may also provide assurance that the proposed material selection is acceptable. Smart Engineering in Schiedam could conduct such a study at reasonable costs.

4 Report Detailed design - HON-GT-01-S2 v1.2

In this section, report *Detailed design - HON-GT-01-S2 v1.2* is being reviewed. The 'page' numbers and paragraph names are referring to the sections in this report. The 'quotes' are copied out of the report for easy reference and the 'notes' address comments, suggestions and/or questions applicable to that text.

Page 4 – Current well status

Quotes: *7 meters of the blockage were milled out by CT.*

Notes [Q]: 60 liters of clay material, representing a 7 m capacity of the liner, were recovered at surface.

Page 8 – Production & commercial considerations

Quotes: *o >80% of current production contribution is from Delft Sandstone.*

Notes [R]: This measurement was conducted by a temperature log. The remaining 20% is contributed by the top of the Alblasserdam.

Page 8 – Production & commercial considerations

Quotes: *The production should be limited to 170 m3/hr to not exceed the API recommended fluid velocity in the injection well.*

Notes [S]: This would depend on the selected lower completion size.

Page 10 – Well design

Quotes*: With the above considerations (Chapter 4) the design has been set up for the sidetrack. Three variations are discussed per item based on the ability to retrieve the current lower completion:*

Notes [T]: Successful recovery of (part of) the lower completion may provide additional valuable information on the failure mechanism. Also if the clay plug is still present in the liner pipe at recovery at surface, an analysis on the actual content could provide more insight.

Page 10 – Trajectory

Quotes: *From the kick off angle is built for a short section to ensure the trajectory of S2 does not intersect the original well HON-GT-01.*

Notes [U]: It is advisable to drill as straight as possible with minimum doglegs to reduce risk of screen damage during installation.

Page 11 – Completion

Quotes: *Larger size base pipe (5 ½") with screens (6" OD) should not be used due to the limited ID (6.184) of the 29ppf 7" (special drift) casing installed in the well.*

Notes [V]: (…and the even smaller hole size). Agreed.

Page 11 – Completion

Quotes: Several.

Notes [W]: Screens (wire-wrapped/pre-packed/shrouded metal mesh/expandable/other) exist in numerous varieties in shapes, designs, strengths, sizes, material selections, etcetera.

Screens should be selected for maximum sand retention and minimum productivity impairment, which obviously may be potentially conflicting criteria. Formation Particle Size Distribution (PSD), correct slot or micron rating (empirical methods), sand software, sieve analysis techniques (such as dry sieving and laser light scattering) and sand retention tests may aid in obtaining an optimum design. There are several empirical and semi-empirical selection methods, but not all are providing reliable results.

The wire-wrap screens technology exists since the 1970s. They present advantages (Keystone slots/high manufacturing efficiency/profile materials can be stainless steel) but also show disadvantage (inaccurate wire spacing can allow production of formation sand or plugging can be damaged when installed through doglegs, high angle and horizontal sections because of vertical orientation between wrapped wires and support rods).

Screens have been subject to destruction testing by numerous oil & gas companies. Testing has shown that there is a lot of variety in screen performance/endurance between the product suppliers even if the design appears to be similar. Superior welding, material selection and tolerances may extend field life drastically.

Having selected the optimum screen will certainly contribute to field life extension, even more than the ESP and completion tubing, due to its permanent character.

5 Conclusions

A plug formed by clay from the Rodenrijs claystone is clearly identified as the cause of the blockage seen the presence of the clay layer, the results from the bailer runs, the most likely common source of the particular particles and the pressure containment as observed during the pressure test on the well.

Proper screen selection is essential in maintaining the longest possible continues production life of the well. There is a large variety of screens on the market. A successful recovery of the old screens could provide valuable information.

A recovery attempt of the lower completion could provide additional information on the failure mechanism of the liner pipe, clay plug information and information on other particles potentially present in the plug/pipe.

Increase the size of the lower completion and will lengthen the production life of the well. Increase the wall thickness is also believed to improve the production life. Premium internally flush connection is a must.

Setting up (or maintain if already in place) a complete monitoring system on ESP performance and the composition of well effluents will be a valuable tool in identifying changes in down hole conditions.

It is advisable to perform a corrosion analysis to ensure the material selection of the lower completion components satisfy the required production life of the well.

It is advisable to identify the mobility of clay particles from the Rodenrijs clay stone and to identify whether this would require additional measures of protection.

It is important to drill smooth as possible borehole.