



# A European endeavor for optimizing Zonal Isolation, Drilling and Exploitation of EGS projects

## INSTALLATION OF THE WELLTEC PACKERS IN THE BEDRETTO UNDERGROUND LAB FOR GEOSCIENCES AND GEOENERGIES (BULGG):

ACTIVITIES CARRIED OUT IN THE FRAMEWORK OF THE  
GEOthermica/ZoDrEx RESEARCH PROJECT

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## 1. Introduction

One of the objectives of the GEOTHERMICA/ZoDrEx research project is to test and demonstrate reliable zonal isolation techniques to improve the ability to create EGS through the accurate placement of the associated stimulation treatments. In this frame, Welltec designed and developed a new high expansion packer and flow valve to handle the typical downhole conditions in geothermal applications including e.g. borehole ovalization and breakouts.

Welltec and Geo-Energie Suisse installed and tested the packers for stimulation tests in the Bedretto Underground Laboratory for Geosciences and Geoenergies (BULGG). The work was divided in a packer installation phase from 16.08.2021 to 27.08.2021 and a stimulation phase from 18.10.2021 to 15.11.2021. For this purpose, Welltec organised the drilling of a borehole nearby to the already existing borehole ST2. This report aims to summarize the packer installation phase.

To facilitate the reading of the report, some of the figures were left out of the text and can be found in the Chapter 5. Figures.

## 2. Installation of the Welltec packers

The Welltec borehole was drilled between 12.04.2021 and 16.04.2021 into the maximum stress direction. It has a length of 120 m, an inclination of 5° and a diameter of 8.5'' (216 mm). Moreover, as the Welltec borehole is only inclined by 5°, the terms borehole length or borehole depth were used interchangeably.

The borehole is cut at 101 m by a fracture, which has a distinctive signature and which can be traced all the way through the other boreholes to the tunnel. Based on the ATV and OTV logs, two sections (Figure 1 and Figure 2) with little signs of pre-existing fractures were selected for the planned stimulation tests.

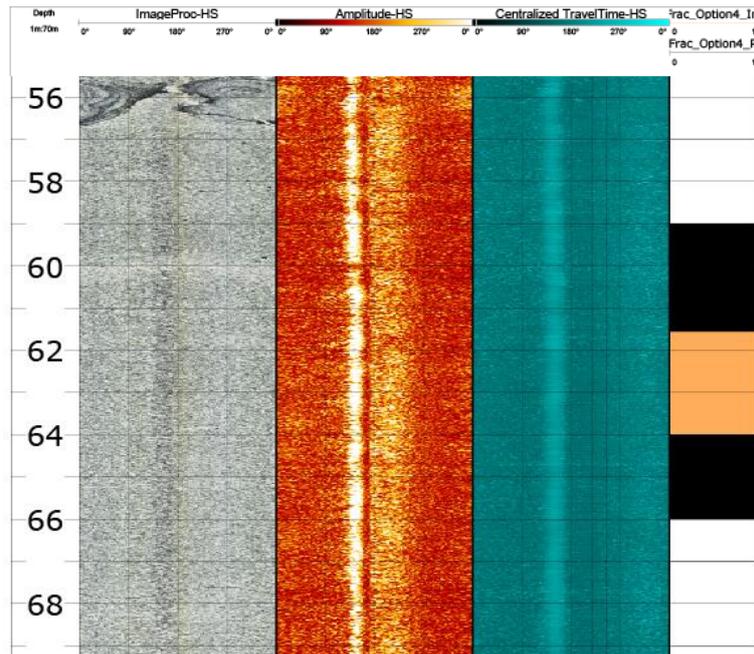


Figure 1. Interval 1: Detail of the packer placement with the Acoustic/Optical televiewer logs

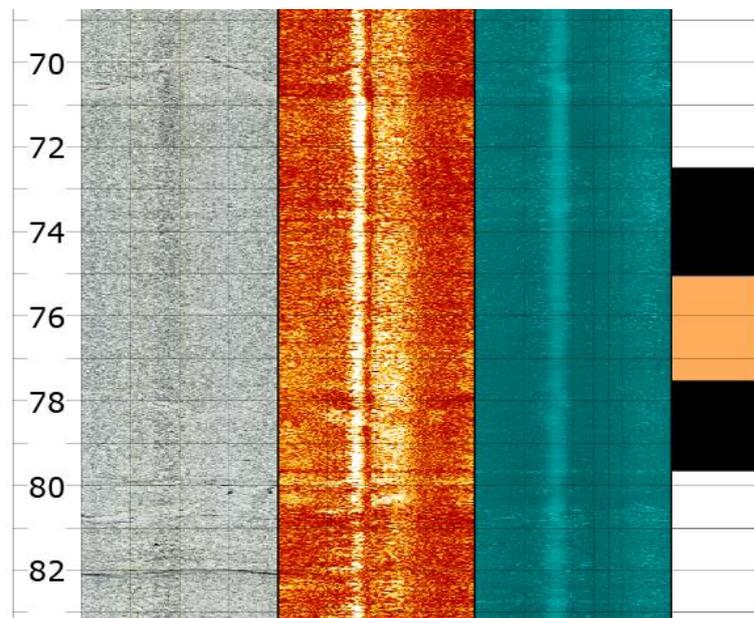


Figure 2. Interval 2: Detail of the packer placement with the Acoustic/Optical televiewer logs

The packer installation operation started with the installation of a pushing rig in front of the Welltec borehole. The pushing rig was necessary to overcome the friction force due to the 5° inclination of the borehole. The floating shoe, which closes the bottom of the 7" casing (Figure 7), was installed on the pushing rig and lowered into the borehole. Then, two packers, marketed under the WAB (Welltec Annular Barrier) trade name with a length of 3 m and an outer diameter of 7", were screwed onto the floating shoe (Figure 8, Figure 9 and Figure 10), followed by three joints of 2 m. Following this, came

the next two WAB, twenty joints of 3 m length and one last joint of 2 m length. In the final configuration, the stick-out of the last joint is 0.44 m from the flange. Therefore, the bottom of the casing is closed at a depth of 83.017m. The first interval is between 61.253 m and 63.985 m while the Welltec Flow Valve (WfV) is at 62.65 m. The second interval is between 75.027 m and 77.76 m while the WfV is at 76.43 m. Both intervals have a length of 2.733 m. The detailed Tally list of the final packer configuration can be found in Chapter 6 Annexes Welltec Tally list of the packer installation.

The tightness of the joint-joint, joint-packer and packer-packer connections was reached through the torquing of the connections with an AUTOTORQ hydraulic chain pipe wrench of model PW3 and a hydraulic aggregate of type HYFLOW 230V-2 (Figure 11). The necessary torque values were calculated by the Welltec engineers and the corresponding pressures to be reached with the hydraulic aggregate can be read on Figure 3. The pressures on the joint-joint (L80), joint-packer (Combined) and packer-packer (P110) connections were 2800 psi, 3000 psi and 3500 psi respectively.



Figure 3. Calculated torque vs pressure for different pipe outer diameters (OD) for an AUTOTORQ hydraulic chain pipe wrench of model PW3 as provided in its manual. A virtual line with an OD of 7" was drawn, indicating the torque needed for a joint-joint (L80), joint-packer (Combined) and packer-packer (P110) connection and the necessary pressure to be reached with the hydraulic aggregate.

For the packer expansion operation, a junction piece (Figure 12) was torqued onto the last casing joint and a wellhead piece (Figure 14) was screwed onto it. The tightness between the junction piece and the wellhead piece was insured by O-rings (Figure 13). Then, a pressure gauge, the necessary valves, a high-pressure hose and a pump were connected to the wellhead piece to fill the casing with water and to evacuate the air (Figure 15 and Figure 16). Following this, the packers were expanded by increasing the pressure inside of the casing and inside the packers with a pump of model P21/7-400 affording flowrates up to 6.8 l/min and pressures up to 40 MPa. As shown in Table 1, the expansion of the 4 packers was carried out in steps of 2 minutes, increasing at each step the pressure by 3.5 MPa (500 psi) up to a last step of 10 minutes at 34.8 MPa (5000 psi). The packer expansion operation started

on 27.08.2021 at 12:35 UTC and lasted until the opening of the valve at 13:32 after the 10 minutes step.

Step	Time interval [min]	uphole pressure [MPa]
1	2	10.0
2	2	13.7
3	2	17.0
4	7	20.5
5	6	24.0
6	2	27.5
7	3	31.0
8	23 *	32.5
9	15	34.8
<b>10 Open valve</b>		

Table 1. WAB expansion sequence

\*The security valve of the pump P21/7-400 opened at 32.5 MPa. Therefore, it had to be slightly turned to be able to go up to 35 MPa.

No open fractures could be recognized on the ATV/OTV logs. It is assumed that all the water flowing out of the borehole comes from the high inflow zone at 100 m depth. On 17.08.2021 at 14:00 UTC, before the packer installation, the outflow from the borehole was 3.37 l/min. Once the packers were installed and before the packer expansion, on 27.08.2021 at 11:00 UTC, the outflow from the annulus between the borehole and the casing was 4.2 l/min. During the packer expansion, the water flowing out of the borehole was not monitored and it was measured only on 14.09.2021. By then, the outflow from the annulus between the borehole and the casing was 2.63 l/min, indicating a bypass. On 22.10.2021, the outflow from the annulus was 2.5 l/min (Figure 4), before the hydraulic tests that are covered with more details in the next chapter. However, in the boreholes CB2 and ST1, the intervals CB2-7 (Figure 5) and ST1 int12 (Figure 6), which contain the high inflow fracture, show a clear increase of pressure, starting from the moment when the packers were fully expanded on 28.07.2021 at 13:30. This indicates that the packers provide a partial sealing.

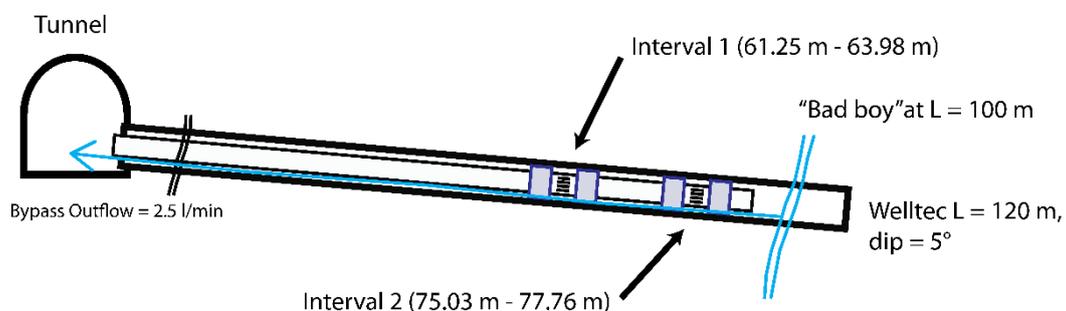


Figure 4. Schematic view of the final configuration of the packers and the intervals top and bottom depths before the hydraulic tests.

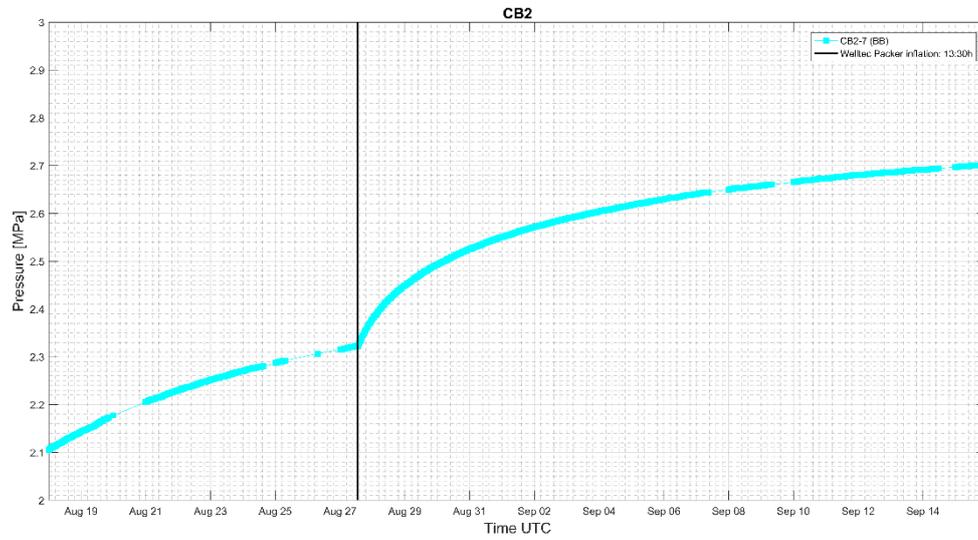


Figure 5. Pressure reaction at the interval CB2-7 during the Welltec packer expansion

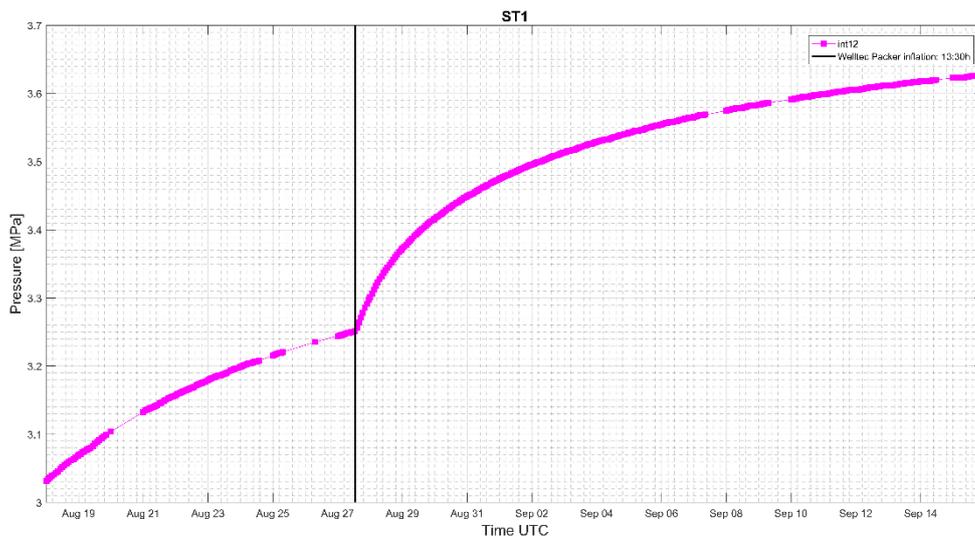


Figure 6. Pressure reaction in ST1 at the interval 12 during the Welltec packer expansion

### 3. Hydraulic tests

This chapter describes the second field campaign of the Welltec work, the stimulation phase from 18.10.2021 to 15.11.2021. Table 2 summarizes shortly the operations.

Date	Interval	Action
22/10/2021	1	Manoeuvre to open the Sliding Sleeve
22/10/2021	1	Hydraulic tests
28/10/2021	1	Manoeuvre to open the Sliding Sleeve
28-29/10/2021	1	Hydraulic tests
29/10/2021	1	Manoeuvre to close the Sliding Sleeve
29/10/2021	2	Manoeuvre to open the Sliding Sleeve
30/10/2021	2	Hydraulic tests
01/11/2021	2	Manoeuvre to close the Sliding Sleeve
01/11/2021	1	Manoeuvre to open the Sliding Sleeve
01-15/11/2021	1	Hydraulic tests

Table 2. Timeline of the hydraulic tests and the sliding sleeve manoeuvres performed in the Welltec borehole

The goal of the stimulation phase of the Welltec work consisted in the hydraulic stimulation of the interval 1 and in a second step of interval 2. To operate in inclined boreholes, Welltec has developed and uses a tractor tool that can overcome the friction forces by driving down the boreholes with wheels. To open the sliding sleeves, the tractor tool has keys to latch on the sliding sleeve, anchors to immobilize the tractor and a piston to move the keys and thereby operate the sliding sleeve (Figure 17, Figure 18).

On 22.10.2021, the first manoeuvre to open the sliding sleeve of the interval 1 was performed with the tractor tool. After the attempt, no change in the flow coming out from the annulus between the borehole and the casing was observed and no flow came out of the interval through the casing. A few days later, Welltec engineers confirmed that the manoeuvre had failed because it had been performed in the wrong direction. During the operation to retrieve the tractor, the cable head of the tractor tool snapped. Due to the failure of an equipment, the pulling pressure applied on the cable head could indeed not be measured. The snapping of the cable head downhole caused a delay in the hydraulic test campaign until the tool was fished out. However, not knowing at that moment that the opening manoeuvre hadn't succeeded, a hydraulic test was performed with the pump P21/7-400 with injection flowrates up to 6.5 l/m and interval uphole pressure of 34.8 MPa.

The shifting tool was successfully retrieved on 27.10.2021 with a new tractor tool that had to be delivered to the Bedretto site (Figure 19). The retrieved tool was tested in a spare sliding sleeve and in spare casing parts on the floor of the lab to control if there was some damage from the cable head snapping and its stay in the borehole (Figure 20, Figure 21, Figure 22 and Figure 23). A manoeuvre to open the sliding sleeve of interval 1 was performed on 28.10.2021, this time with a working equipment which could measure the pulling pressure on the cable head. No change in the flow coming out the

annulus was observed and no flow came out of the interval. Several hydraulic tests were carried out between the 28.10 and 29.10.2021 with injection flowrates up to 7 l/m and interval uphole pressure of 36.61 MPa. The manoeuvre to close the sliding sleeve of interval 1 was carried out on 29.10.2021.

The same day, the manoeuvre to open the sliding sleeve of interval 2 was carried out. This time, flow came out of the interval and no more water came out between the borehole and the casing. Water was injected into interval 2 by increasing the flowrates step-wise up to 7.5 l/m and the interval uphole pressure up to 3.61 MPa. The hydraulic tests showed that a 50% bypass occurs at this interval, i.e. 50% of the water injected into the interval came back out from the annulus.

These drastic changes in the outflow from the annulus between the borehole and the casing increased the suspicion that the packers don't deliver a proper sealing and that the manoeuvre to open the sliding sleeve of interval 1 might have failed. It was decided to investigate this matter by closing the sliding sleeve of interval 2 and to re-attempt to open the sliding sleeve of interval 1. After these manoeuvres, no change in the flow coming out the annulus could be observed and no flow came out of the interval. The hydraulic tests carried out on 01.11.2021 showed similar flow and pressure behavior as the previous tests at interval 1. Thus, on 02.11.2021 6 injection cycles were performed with flowrates up to 6 l/m and interval uphole pressure of 35.21 MPa. The last cycle consisted in a shut-in phase of 14 days. During this time, the pressure dropped only by 0.17 MPa, i.e. a final pressure of 35.04 MPa was recorded before opening the interval. The tightness of this system was a further hint that the interval 1 was not open.

A camera run performed inside the casing on 16.11.2021 showed a similar sliding sleeve position for both intervals, confirming that the last manoeuvre to open the interval 1 had failed. Therefore, the similarity of pressure reaction of all hydraulic tests performed at interval 1 lead to the conclusion that this interval was never opened.

During the injection phases into interval 1 (into the closed casing volume), a difference of +0.5 l/min with the base flow-rate out of the annulus (2.5 l/min) was observed. During the shut-in phases a difference of -0.4 l/min with the base flow-rate out of the annulus (2.5 l/min) was also observed. As this effect happens at all the injection phases, we suspect that it is caused by the pressure increase in the casing, pushing the packers harder against the borehole wall. However, the details of the causes for this effect are still under investigation.

By the time of writing this report, Welltec is still investigating the causes for the failed manoeuvres to open the sliding sleeve of interval 1. GES and Welltec are investigating if the pressure of the packers on the borehole wall could be sufficient to cause fracture initiation along the packers, which could explain the observed bypass in the annulus between the borehole and the casing.

ETH was running a seismic monitoring system at the moment of the hydraulic tests and seismic monitoring system might have detected seismic events during the injections tests. Discussions with ETH are under way.

## 4. Conclusion

In the frame of the GEOTHERMICA/ZoDrEx research project, Welltec designed and developed a new high expansion packer and flow valve to handle the typical downhole conditions in geothermal applications including e.g. borehole ovalization and breakouts. Welltec and Geo-Energie Suisse installed the packers in the Welltec borehole in the Bedretto Underground Laboratory for Geosciences and Geoenergies (BULGG) between 16.08.2021 and 27.08.2021. The packers were fully expanded on 28.07.2021 at 13:30. The outflow out of the borehole decreased but did not stop. However, the pressure increase in the intervals in the nearby boreholes CB2 and ST1, which are crossed by the same fracture as the one at the end of the Welltec borehole, indicate that the packers provide at least some sealing. The execution of the hydraulic tests at the two intervals is also a part of this report. However, the effect of the sealing on the stimulation tests is addressed in another report.

## 5. Figures



*Figure 7. the pushing rig and the floating shoe placed onto ready to be lowered into the borehole*



*Figure 8. the second WAB and the WFV being torqued onto the 1st packer*



*Figure 9. Closer view of the second WAB and the WFV being torqued onto the 1st WAB*



*Figure 10. The 2nd WAB being lowered into the borehole with the pushing rig*



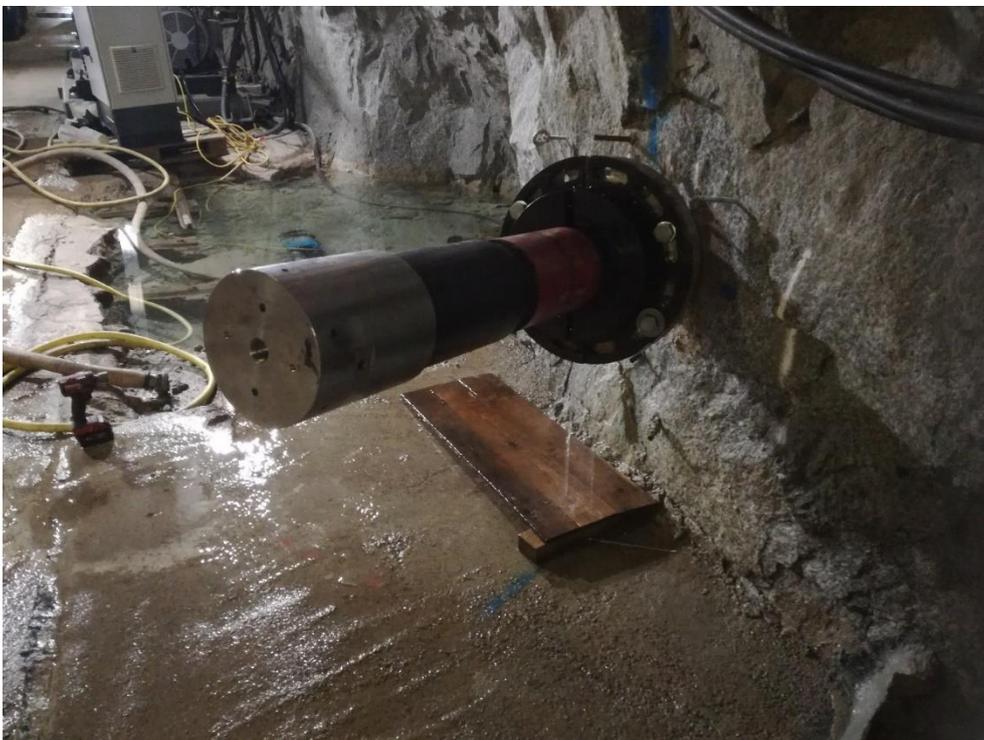
Figure 11. The hydraulic aggregate and the AUTOTORQ hydraulic chain pipe wrench



Figure 12. The junction piece before torquing it onto the last 2 m casing joint



*Figure 13. Detail of the O-rings ensuring the tightness between the junction piece and the metallic wellhead piece for the injection*



*Figure 14. The metallic wellhead piece screwed onto the junction piece shown in Figure 12*



Figure 15. Detail of the pressure gauge and valves on the metallic wellhead piece for the packer expansion



Figure 16. The pump used for the packer expansion



Figure 17. The Welltec tractor tool before assembly.



Figure 18. Parts of the tractor tool. On the first plane (on the right), the part with the keys that latch onto the sliding sleeve. On the second plane (on the left), the part with the piston and the ankers. The ankers are not visible on the picture. On the third plane (in the center), the part with the wheels.



*Figure 19. The tractor tool for fishing operation ready to be lowered into the borehole.*



*Figure 20. The fished tractor tool being tested at the surface in spare casing parts and a spare sliding sleeve*



*Figure 21. The fished tractor tool being tested at the surface. To open the sliding sleeve, the keys are below the sliding sleeve before setting them out, setting out the ankers and pulling the sliding sleeve by closing the piston.*



*Figure 22. The sliding sleeve is open after the testing of the fished tractor tool.*



*Figure 23. The sliding sleeve in the open position seen from inside with the head of the tractor tool visible on the last plane.*



3. Field logbook of the installation field campaign and the hydraulic tests campaign

Attached in document: ActivityReport\_LogBook\_06.10.2021\_Welltec.xlsx