# Development and installation of an underground measurement technique at the pilot mine "Auguste Victoria" for a mid- to long-term monitoring of the mine water level rise

Steffen Kruse[1], Michael Bendrat[1], Christian Melchers[1], Bernd vom Berg[1], Holger Witthaus[2]

*[1]Technische Hochschule Georg Agricola, Research Institute of Post-Mining, Herner Strasse 45, 44787 Bochum, Germany*
*[2]RAG Aktiengesellschaft, Servicebereich Technik- und Logistikdienste BT GPK Grubenwasserkonzept, Shamrockring 1, 44623 Herne, Germany*

**Abstract** Monitoring mine water level rise in a coal mine after its closing is an important issue. Therefore, a measurement technique will be established in the mine to provide direct and continuous recordings of different measured parameters. The development and installation of such an underground measurement data logging system for short- and long-term observation of the mine water level rise at the mine "Auguste Victoria" (Germany, Marl) allows to gain in situ measurement data. This information leads to a better understanding of the mine water level rising process.

**Key words** IMWA 2017, underground measurement, data logging system, mine water level rise

## Introduction

After the activity of German hard coal mining, the mine water level will rise. For a better understanding of the rising process, the concept must include the determination of suitable locations for the installation of the measurement system and the specification of suitable water and air parameters. Therefore, a sturdy and failsafe system must be adjusted to the underground conditions and has to pass a testing period in a laboratory and at surface conditions before it is installed in the underground mine "Auguste Victoria". With the help of this measurement logging system, data of the mine water level rise can be attained in its spatial and temporal progression. By doing so, the target state can be permanently compared to the actual one. The evaluation of the obtained data has to give evidence of the successive rebound of mine water in existing mine facilities after mine closure and supplemented existing monitoring systems(RAG 2014).

## Best practice

### System requirements

The monitoring parameters were selected regarding both the recording of the mine water level and the chemical analysis of the mine water. Likewise, there was the plan to measure the methane concentration and the air pressure response in the underground workings during the mine water rise. Where the recording of the mine water level in abandoned mine workings is concerned, measuring the water pressure plays a crucial part. The pressure of the in-situ water column corresponds with the mine water level. Therefore, the exact mounting heights of the pressure transducers have to be documented. Furthermore, the individual pressure transducers ensure that the hydraulic potential of the mine working is recorded directly, something which allows to determine the flow direction of the mine water. Moreover, the flow speed of the mine water was to be measured. Regarding the recording of the chemical composition, it was required to record the mine water temperature as well as the specific electrical conductivity (Melchers & Dogan 2016).

To develop a suitable monitoring system, product information was evaluated and possible solutions were discussed with renowned mining companies and companies of the chemical and deep sea business. Specific technical concepts had to be developed in order to measure the parameters mentioned above. One key requirement on the monitoring system to be developed was its longevity – the system had to last as long as possible. This requirement was fulfilled by constructing an electrical component design of a most simple structure using as few components as possible. In addition, direct connections were chosen where possible between the actual probe and the evaluation system. This resulted in the parallel connection concept selected, i.e., every single probe is connected by a separate conductor. If one probe fails or the pertinent transmission cable to the surface is damaged, then only one measuring probe stops working. Power to all underground system components is supplied from the surface. These reflections resulted in the system diagram shown in figure (1):

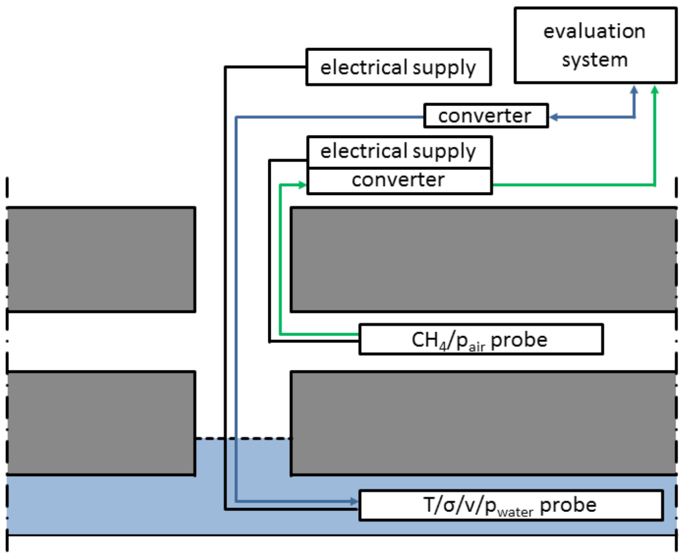


***Figure 1*** *system overview of the entire concept*

Other requirements on the system components were due to the extreme environmental conditions underground. Only such components were chosen for installation at the colliery "Auguste Victoria" which – as they would be located under water later – withstand a water pressure of 100bar. Those components include the water sensors, the enclosure of the water probe including its gaskets and the connecting cables and their bushings. They were selected because they are robust and resistant to mine water and mechanical strain. The power supply and the communication have to overcome a distance of several kilometres. To ensure that the sensors intended for air pressure and methane concentration would be of a long life, they were chosen for use in an environment of high humidity. Moreover, all sensors have to work maintenance-free and all components that are either installed underground or have an interface to underground installations must be of intrinsically safe design and explosion prevented typification checked in an individual detailed expertise by a third party. The following tables (1 and 2) summarise the measuring parameters.

***Table 1*** *Water measuring parameters*

| Parameters | Range | Resolution | Accuracy |
|---|---|---|---|
| temperature [°C] | 10–60 | 0.01 | +/- 0.05 |
| water pressure [bar] | 0–100 | 0.003 | +/- 0.15 |
| specific electrical conductivity [mS/cm] | 0–200 | 0.004 | +/- 0.1 |
| flow rate and direction [m/s] | +/- 3 | 0.002 | +/- 0.03 |

***Table 2*** *Air measuring parameters*

| Parameters | Range | Resolution | Accuracy |
|---|---|---|---|
| atmospheric pressure [hPa] | 0–2000 | 1 | +/- 2 |
| methane concentration [vol.%] | 0–100 | 0.01 to 0.1 | +/- 5 |

## Selection and test of system components

The market research undertaken showed that the system components available on the market did not fully meet those requirements. As this system has to be installed at short notice as part of this project, components had to be selected and modified that were principally suitable. Here, the particular challenge was that the measuring components had to be supplied with low electrical power over a very long cable distance. This low electrical energy is one of the requirements of the explosion protection standard. For the air sensors, components were found which met nearly all requirements, so only slight modifications were necessary. The data transmission components, however, were completely newly developed for this system. The electrical power supply could also be established using components which only needed minor modifications. For monitoring the water measuring values a deep-sea probe was modified. As only few experiential tests were available for the mine water use of this probe, and there is no opportunity of a fault analysis with subsequent improvements in case the probe fails later, several test were conducted; these tests tested the probe approximating real conditions in mine water at the surface and underground.

For the first test runs of the system, a not modified probe was used which was equipped with the sensors required, including an inductive conductivity sensor, a temperature sensor, a pressure sensor and an X-Y flowmeter. The first test environment was located at the surface mine water channel at the water treatment plant “Gravenhorst” of the colliery “Ibbenbüren”. This mine water has a high iron content, and the probe remained in the water for c. two weeks. The next test run was done at another surface mine water channel at the colliery "Ibbenbüren", i.e. a mine water channel of the water treatment plant "Püsselbüren". This mine water had a high salt content and again the probe remained in the water for c. two weeks. After the test runs had been completed, the probe was returned to the manufacturer who performed a functionality test on the probe. After it had successfully passed this functionality test, the probe was tested further in underground conditions. The test environment chosen was that of a suitable location at the colliery "Auguste Victoria". In this case, the probe remained for about six months in the mine water. After this test, the probe was again submitted to a functionality test by the manufacturer and no malfunctions of the sensors or the probe were identified. The middle electrode of the flow sensor was strongly affected by corrosion, but, according to the sensor manufacturer, this would not impair the functionality of the flow sensor. The probe suspension, made of V4A, disintegrated due to corrosion; thus, it became clear that the suspension had to be modified as well for the probe to be developed. Moreover, the examinations showed the response of the entire probe and its sensors and connecting plugs in mine waters. Even the thickness and impact of settlements as well as the impact of corrosion on the probe enclosure, the sensors and the connecting plugs and gaskets could be examined. In addition, where possible, the values measured in the tests were compared with those measured in the laboratory for the pit and thus checked for plausibility. Furthermore, the automatic data recording and processing were examined and optimised for permanent operation. The experience gathered here was utilised in the concept that was implemented later and contributed to an overall improvement of the system.

The system that was finally implemented benefited from the experience and reflections made here. Now, the probe is suspended on a rack that will protect it against broken stone and parts floating in the water. Here, the probe is suspended to move freely within the rack so that any inclination caused by any level convergences can be offset by realigning the probe. The installation and fastening of the cables is largely done at the ceiling of the gallery to avoid possible damage caused by rock fall. For each individual measuring location, the cable path was chosen with due diligence and accuracy by carrying out a number of mine visits.

The rough selection of the locations for recording the mine water level and its rise were done based on the rise concept devised by RAG for the colliery "Auguste Victoria". Mutual mine visits of all measuring locations helped to determine the exact measuring points. Such measuring points were intended for all main waterways as well as the influent and effluent points in the pit. These points include in particular the overflow from the coal field "Haltern" [1W], the influx from the colliery "Brassert" [2W], the influent and effluent points of the colliery "Lippe" [3W], and the main waterway [4W]. The selected locations allow a direct recording of the most important mine waterways and thus essentially of the major waterway. On the other hand, the locations selected also ensure an area measurement of the worked field at the colliery "Auguste Victoria".

The location of the measuring components for recording the air pressure and the methane content is intended at below sea level in the shaft 3/7 [13L] at the "Auguste Victoria" location at a depth of 841.6m. By doing so it can be ensured that this measuring point will be flooded at a very late point in time and that the measurement can be carried out for a very long period. The following tables (3 and 4) and plans of the mine workings (2 and 3) provide an overview of the measuring points. All details were determined in close collaboration with RAG.

***Table 3*** *Location of measuring points for the water parameter*

| No | Operating point | Name | Pressure sensor below sea level [m] | Direction from | to |
|---|---|---|---|---|---|
| 1W | 0205/0205 | C 301 / RS6 SO 30 | 1106.1 | AV3 | Haltern |
| 2W | 0215 | C 215 / Q 5 SW 38 | 991.4 | AV1/2 | Wulfen |
| 3W | 0513/0505 | D 440 / DB NW 60 | 1111.6 | AV8 | Wulfen |
| 4W | 0513 | C 513 / Q6 NO 60 | 1113.1 | AV8 | Wulfen |

***Table 4*** *Location of measuring point for the air parameters*

| No | Operating point | Name | Below sea level [m] |
|---|---|---|---|
| 13L | 0131 | Tipper loading side, 4th level, AV3 north | 841.6 |

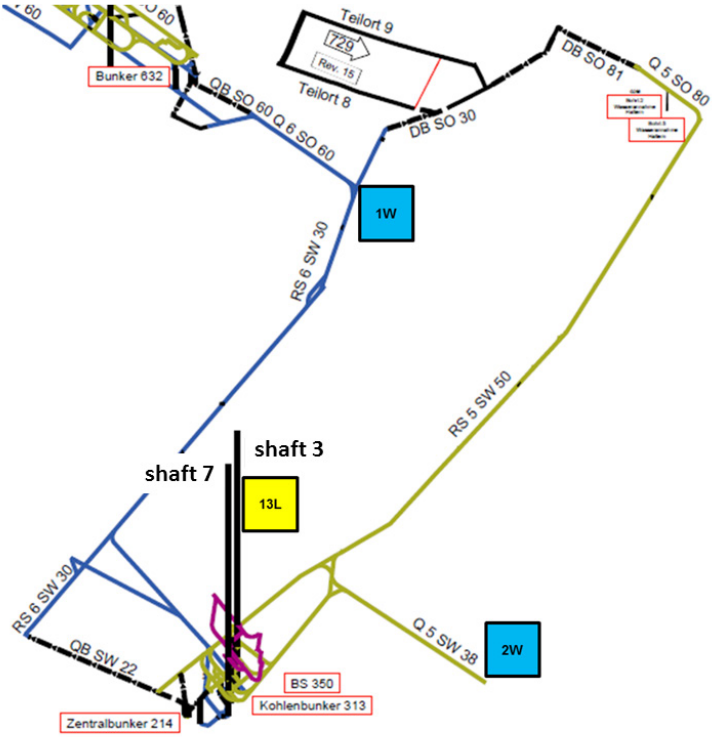


***Figure 2*** *Measuring points in the worked field 20/30*

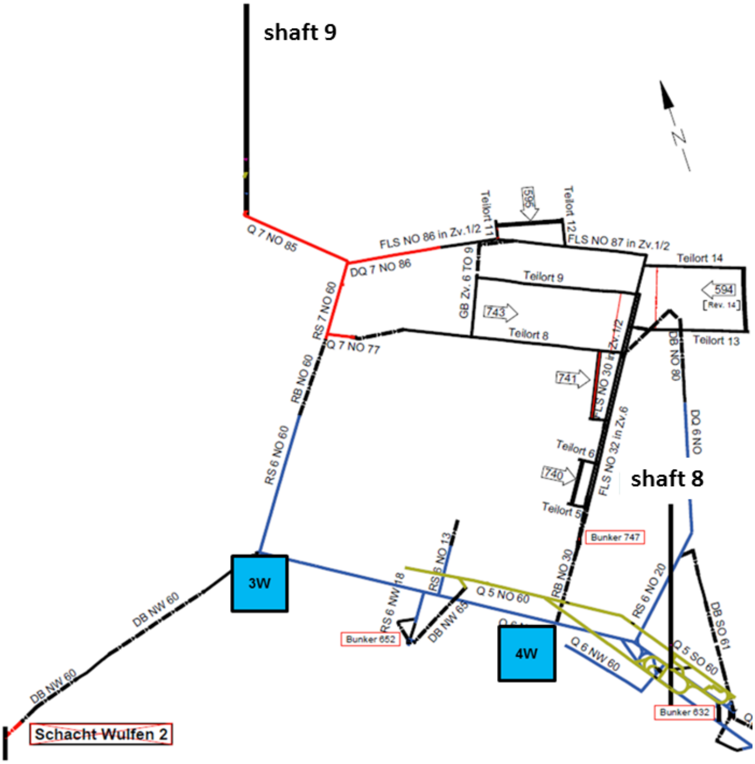


*Figure 3* *Measuring points in the worked field 50*

## Conclusions

The monitoring system was successfully installed at the colliery “Auguste Victoria” in spring 2017. It is expected that its commissioning will be completed by summer 2017 and first measuring values will be available. After this, the in-situ measurement technique will provide direct and continuous recordings of the parameters. And with its help the obtained data will give evidence of the successive rebound of mine water in existing mine facilities after mine closure. The rise of the mine water at the mine “Auguste Victoria” will take several years. According to statutory approval the rise has to be realised stepwise. In the following figure (4) you see one of the water measuring probes inside the frame.

The measurement data logging system will be installed in further mines once the pilot installation has been successfully tested in field. By applying the monitoring system in different mines, it is possible to build up a comprehensive database. The data complements conventional mine water level rise monitoring at drill holes and shafts in order to optimise current planning processes.

***Figure 4*** *water measuring probe with frame*

**References**

Melchers C, Dogan T (2016) Study on Mine Water flooding that occurred in Hard-Coal Mining Areas in Germany and Europe. In Kretschmann J, Melchers C (Eds) Done for good. Challenges of Post-Mining. Anthology by the Research Institute of Post-Mining, Bochum: 147—152

RAG (2014) Konzept zur langfristigen Optimierung der Grubenwasserhaltung der RAG Aktiengesellschaft für Nordrhein-Westfalen. 29 pp