PROCESS CONTROLLING, UNDERSTANDING, AND OPTIMIZATION IN A SOLUTION SALT MINE THROUGH THE DATA ACQUISITION SYSTEM.

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Abstract

In the northwestern part of the Netherlands lies the deepest solution salt mine in the world. The company operating the mine is Frisia Zout bv (part of the K+S group).

Extracting the NaCl from caverns at a depth of nearly 3000 m has a lot of challenges. Continuously monitoring, among others, the flows, pressures and salt concentrations is necessary to safely and economically mine the salt. A system has been set up at Frisia to be able to monitor the data from a distance. Data has been put in graphs to monitor the trends daily. All gauges are also continuously monitored to maintain accuracy. With this system a better understanding of the mining process has been made and has led to many optimizations.

Mining locations

Frisia Zout (former Frima) started in 1995 with building the Barradeel location near Pietersbierum, which is located 6 km from the factory in Harlingen. The wells BAS-1, BAS-2 and BAS-3 (2003) were drilled from here and the wellheads are at this location. BAS-1 is shut and on stand-by basis for production. BAS-2 is shut and kept under high pressure for long-term testing. BAS-3 is currently in production.

The second location, the Bethanië location, near Tzummarum, was built in 2004 and lies 14 km from the factory. Here the newest cavern BAS-4 is situated. Both locations are normally unmanned and controlled from the control room at the plant in Harlingen.

All information of the producing wells at both locations is real time transmitted to the operators at the plant in Harlingen. Together with the check once a day by the operators, the control relies on the information gathered by the transmitters. This ensures that the process is continuously monitored and stays within an optimal and safe situation.

More information can be found under the heading “background information” and “solution mining principal”.

Automatic data acquisition and processing

The follow up of the leaching process is realized mainly by indirect analysis methods like production data, saturation development, leaching simulation and wireline measurements (blanket level, temperature, gamma, and neutron). If possible a direct measurement of the volume development with sonar can be made. Sonar measurements are costly and can only be made if the leaching strings are in perfect condition.

Until 2006 the data was just read and stored individually, but no daily processing and summarizing took place. This resulted in a large amount of data, from which no summaries on a daily or weekly basis were made. Incidental manual summaries were composed if needed.

In the first quarter of 2006 it was decided to automate the data acquisition of all the caverns in order to get a better understanding of the process, to keep the data in an orderly way and to be able to get a better grip to foresee and/or correct upcoming problems. The main objective was to become more efficient and to reduce time spent in gathering data in order to make periodical reports, etc. This would allow more time to make analyses from the gathered data and to be able to use daily trends to take preventive measures. Also data from all locations can be sent real time to experts for further analyses.

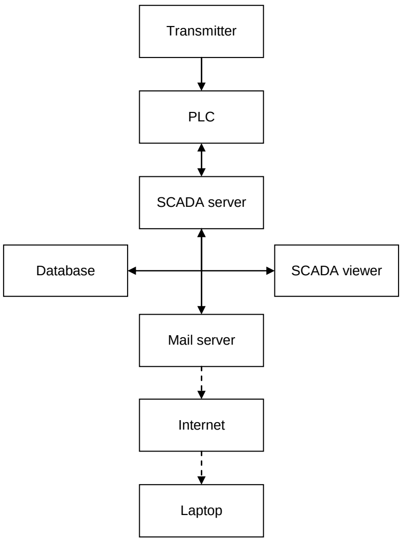
A further benefit is to incorporate laboratory data into the system. For example: the combination of the brine concentration with the measurements of flows and pressures, a better understanding can be made of the processes inside each individual cavern. First all trends had to be standardized in order to avoid misunderstandings by the operators.

Finally the automated system would make it possible to detect if the instruments (pressure gauges, etc) are operating correctly.

Framework current IT setup

The system at Frisia is set up to transmit the data in two ways. Under normal circumstances data is sent hourly, but if needed the frequency can be increased. Each morning the mining department at Frisia receives automatically an e-mail with attached an Excel sheet containing the different production information of all the caverns. A PDF file with the summary of the most important trends is also included.

If something drastically and/or unexplainable happens the control room operator can switch from the hourly routine status to minute/second data transmission. Data can then also be sent to different experts for a quick analysis.



Components	Location	Extra information
Transmitter	Mining location	e.g. level, pressure, flow and temperature
PLC	Pump building at location	
SCADA server	Control room at plant	Actual information
SCADA viewer	Control room at plant	Computer screen for operators
Database	Control room at plant	SQL logging (hour/minute/second)
Mail server	Control room at plant	
Internet		
Laptop	Anywhere in the world	

Figure 1. Framework current IT setup

See figure 1 for the framework of the setup. The different components are described below:

Transmitters

The most important parameters for the process are pressure and flow. The accompanying gauges are situated on the Xmas tree. They are doubled up to ensure continuous readings. The flow transmitters are situated before and after the main injection pump. These transmitters send a signal to the PLC that is situated at the location inside the pump building. The NaCl concentration information is simultaneously received from the laboratory.

PLC (Programmable Logic Controller)

The PLC situated in the pump building collects and sends the information via a network UTP cable to the SCADA server at the factory.

SCADA server (Supervisory Control and Data Acquisition)

The information received from the PLC’s is sent directly to the SCADA viewers. These operator’s interfaces are the computer screens in the control room located at the factory. Here all the trends can be displayed. Alarms are initiated in case of unusual events.

Besides the SCADA server a database server and a mail server are also present. The trend data in hours, minutes and seconds of all the transmitters at the two locations are saved in the database (SQL logging).

The SCADA server contains macro’s which are automatically executed at a defined time to generate Excel and PDF sheets with information of all caverns. These are immediately sent, via the mail server, through the internet to pre-programmed e-mail addresses.

Field examples

Pressure gauges quality control

To prevent misinterpretation of the data and due to the fact the locations are unmanned it is very important to know if the pressure gauges are working within the given accuracy. Each pressure gauge, on the active wells, has a fully functional back up. Within the sent e-mail to the mining department a graph shows when a pressure gauge is broken. In a normal situation the bar graph indicates a 0 yet if a pressure difference between two gauges is higher then 2 bars the graph indicates a 1. Figure 2 shows that two of the pressure gauges of WELL-B are malfunctioning.

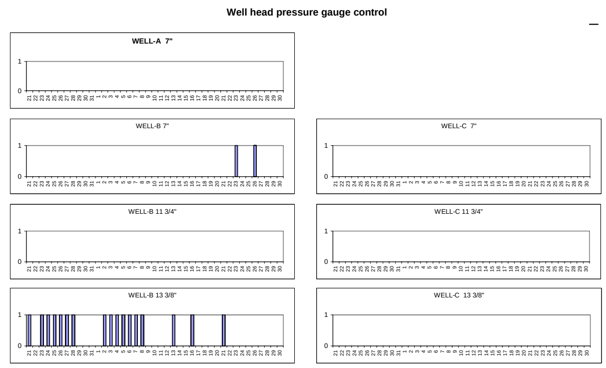


Figure 2. Example well head pressure gauge control sheet.

Leaking valve

After a regular bleed off of pressure of one of the caverns the 7" valve was not fully closed. This was a very small leak and could only be seen by the daily trending. In figure 3 the dip of 7" pressure on the 16th can be seen.

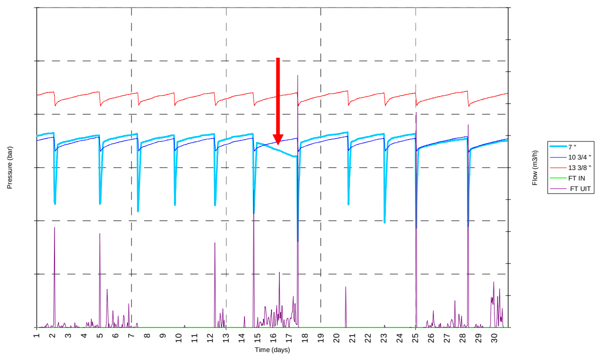


Figure 3. Example graph generated and present in PDF.

Sump detection

Beginning of May 2007 the outflow and pressures fluctuated in one of the wells. This was detected in the daily trends that were received by e-mail. This indicated that the situation was changing. The cavern was producing indirectly (injection via the 11 ¾" - 7" annulus and production via the 7" leaching string).

During the production of the brine, the bottom of the cavern can rise. The roof rises due to two processes. One, the cavern floor is pushed up due to convergence of the salt. At a depth of 3000 m the salt reacts plastically, this is because of the high temperatures and pressures. The second process that causes the bottom to rise is that during the brine production the insoluble impurities build up at the cavern bottom.

At the end of June the solids were detected in the samples taken by the lab. It was decided to shorten the 7" leaching string. Due to the early-warning, preparations could be made well in advance for the cutting operation. Also, till the operation was planned the well could closely be monitored.

Future developments

Future developments are foreseen in the following areas:

- Optimization of the demand requirements of the factory, regarding flow and concentration of the brine.
- Optimization of the mining process in case in the future multiple caverns are in operation.
- Incorporation of economical parameters in order to enhance the profitability of the operation. Examples are energy consumption, utilization of steam, etc.
- Monitoring the accuracy of other gauges (e.g. flow gauges, temp gauges).

Background information

The Netherlands, as part of the North West European lowlands, has not been blessed with metallic deposits in volcanogenic rocks. Resources are mostly limited to coal, oil, gas, soft limestone, salt, sand and gravel. These deposits are from the Carbon geological era, or younger. Mining in the Netherlands traces back to the winning of flint stone from marl some 2000 years BC. During the Roman times marl was exploited for building materials. Next came mining on small scale of near-surface coal by monks in the Middle Ages. The large scale economical developments of resources dates back only some 150 years ago, when King William II gave the first concession to a German consortium to start the first coal mine. Finally in the 20th century the exploitation of oil, gas and salt really got started.

Salt in the Netherlands was formed during the geological Zechstein period when North Western Europe was covered by an inland sea and hot and dry climatic conditions were present. The sea water evaporated and the salt precipitated at the sea bottom. Later clay and sand deposits were formed on top of the salt layers. These were underlain by sandstone deposits in which the oil and gas, from deeper carboniferous deposits, accumulated in many places against the salt.

The salt layers to the East of the Netherlands (Germany, Austria, etc.) are generally easier accessible, due to undeeper deposits, and have been exploited by underground mining since the middle ages. By that time salt was a very valuable mineral and was also used as payment to the army (the word salary origins from "sel" or salt). High prices of the imported salt from Germany started the exploration and exploitation of salt in the Netherlands near Boekelo and Delfzijl through solution mining by the "Royal Salt" company, one of the predecessors of Akzo Nobel. These 40 meter thick salt deposits, at 300-400 meter depths, were accidentally discovered during the last decennium of the 19th century, when searching for potable water supplies. Commercial winning started in 1919.

The Zechstein salt formation is found again at a depth of over 2000 meter near Harlingen in the western part of Friesland. The Zechstein Formation itself also has little tectonic deformation and consists of near horizontally bedded layers as well in several evaporitic cycles. The overburden of the Zechstein Formation in the Barradeel concession consists mainly of near horizontal layers of siliclastic rocks and chalk.

In 1996 a Dutch entrepreneur opened a solution mine there. The company was called Frima. In 2000 the German salt mining company Kali und Salz (K+S) took over the operation and renamed the company from Frima to Frisia Zout.

Solution mining principal

Salt saturated brine is produced at Frisia by solution mining of the rock. A large diameter borehole is drilled using standard oil industry drilling methods. First a series of pipes or "casings" are cemented into the borehole to provide environmental protection to the surrounding sediments. Next an injection pipe and a production pipe are lowered to the bottom of the borehole. Fresh water is pumped through the injection pipe. The resulting brine is lifted to the surface to feed the processing plant in Harlingen where, after purification, vacuum evaporation separates water and salt. The condensed fresh water is supplemented with water from a local canal and recycled for the leaching process.

Diesel is pumped into the roof of the salt cavern that is formed during the mining process. This oil floats on top of the fresh water and brine and acts to control the mining and protect the cavern roof from mining upwards instead of outwards. Significant geomechanical design work is engineered into these caverns to ensure long term safety and stability.

The caverns are in a 500 meter thick salt layer, which tops at around 2500 meters. The caverns have a diameter of up to 75 meters and are up to 400 meters long. These caverns are the deepest in the world. At these depths the salt has extremely high convergence ratio's (up to 100%). The high temperatures and pressures make the operation more complex and asks for a continuous monitoring system.

Acknowledgements

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References

1. Fokker, Peter, T. Bakker, F.H. Wilke and H.J. Barge (2002) Aspects of Deep Salt Mining –Salt Mining by Frisia Zout-, SMRI