Corrosion inspection of a DN 1800 mm vertical main pipe

Adrian Rieder, dipl. Ing. NDS-U, Head of water distribution

Water Supply Zurich, 8023 Zürich, Switzerland
adrian.rieder@zuerich.ch

ABSTRACT:

Key words:
Work safety, corrosion inspection on vertical steel pipe DN 1800 mm

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An important large main pipe tunnel ring ensure the supply of drinking water in Zurich. As a part of the guarantee work in 2015, the 6.9 km long tunnel pipeline and also the 130 m long vertical main pipe, completed in 2000, was inspected. On the occasion of the inspection at that time, defective sections were identified in the shaft. Particular corrosion symptoms were observed especially in the welding seams of the steel pipes.
The vertical pipe had been emptied in November 2018 and a second inspection of the main pipe was done. The aims of the inspection were to determine and assess the condition of the vertical pipe and the internal corrosion protection after almost 20 years of operation. The Zurich Water Supply was also interested in a middle- and long-term condition prognosis of the pipe, the corrosion protection and the shaft. The inspections were carried out in consideration of the requirements for work safety. The corrosion protection cement layer was removed locally. The weld seams and the steel pipe were exposed and the degree of corrosion attack was determined by ultrasonic measurements and potential difference measurements. This report gives an overview about the work results.

Stichworte:
Arbeitssicherheit, Korrosionsuntersuchung in grosskalibrigen Steigschacht DN 1800 mm

Korrosionsuntersuchung Steigleitung DN 1800 mm Trinkwasserstollen Uetliberg

Ein grosskalibriger Ringstollen der Wasserversorgung Zürich stellt zu einem wichtigen Teil die Versorgung der Trinkwasserversorgung sicher. Im Rahmen einer Garantieabnahme im 2015 wurde, neben der Stollenleitung, auch der im Jahr 2000 erstellte Steigschacht visuell inspiziert. Die Sohle der senkrecht erstellten Leitung befindet sich in 130 m Tiefe. Anlässlich der damaligen Inspektion wurden im Schacht schadhafte Abschnitte identifiziert, insbesondere bei den Schweissnähten der Stahlrohre wurden Korrosionsmerkmale festgestellt. Der Grad und Fortschritt der Korrosion konnten jedoch aufgrund der unter engem Zeitdruck durchgeführten visuellen Inspektion nicht abschliessend beurteilt werden; eine fortschreitende Schädigung der Schweissnähte war zu befürchten.
Im November 2018 wurde der Steigschacht entleert und eine weitere Inspektion der Steigleitung erfolgte. Die Ziele der Untersuchung waren die Ermittlung und Beurteilung des Zustandes der Steigleitung und des Korrosionsschutzes nach annähernd 20 Jahren Betrieb und eine Prognose zur mittel- und langfristigen Zustandsentwicklung des Bauwerks. Die Untersuchungen erfolgten unter Einhaltung der Vorgaben zur Arbeitssicherheit. Örtlich wurde der Korrosionsschutz abgetragen, die Schweissnähte und das Stahlrohr freigelegt und mittels Ultraschallmessungen und Potential-Differenzmessungen der Grad der Korrosionsangriffe bestimmt.

Management Summary

The Zurich water supply supplies around 1 million people in the city and agglomeration of Zurich with drinking water. In three production plants, lake water, ground water and spring water is treated to high-quality drinking water. A large, deep tunnel and shaft system make sure the distribution between the waterworks and the most important reservoirs. The connection from the reservoir on top to the deeper main pipe system is ensured by four vertical shaft constructions.
As a part of the guarantee work in 2015, the 6.9 km long tunnel pipeline and also the 130 m long vertical main pipe, completed in 2000, was inspected. On the occasion of the inspection at that time, defective sections were identified in the shaft. Particular corrosion symptoms were observed especially in the welding seams of the steel pipes.
The vertical pipe had been emptied in November 2018 and a second inspection of the main pipe was done. The aims of the inspection were to determine and assess the condition of the vertical pipe and the internal corrosion protection after almost 20 years of operation. The Zurich Water Supply was also interested in a middle- and long-term condition prognosis of the pipe, the corrosion protection and the shaft. The inspections were carried out in consideration of the requirements for work safety. The corrosion protection cement layer was removed locally. The weld seams and the steel pipe were exposed and the degree of corrosion attack was determined by ultrasonic measurements and potential difference measurements. The main problem is the low mortar coating, often only 1 to 2 mm thick. If the alkalinity of the mortar is reduced, corrosion will occur on the steel surface. If the operating conditions do not change, it can be summarized that there is no immediate demand for rehabilitation during the next 5 to 10 years.

The Zurich Water Supply ring system

The Zurich Water Supply (WVZ) supplies around 1.0 million people in the city of Zurich and the agglomeration of Zurich with drinking water. Lake water, ground water and spring water is treated in three production plants to produce high-quality drinking water. A large-calibre, low-lying tunnel and shaft system ensures the distribution between the waterworks and the most important reservoirs. Each plant is connected to the drinking water tunnel. This reduced the hydraulic load (water hammer) on the main and distribution network and also improved the security of water supply. The drinking water tunnel between the production plants, the reservoirs with the associated pressure zones and the delivery points ensures that water can be supplied to the reservoirs from another plant in the event of a failure or planned shutdown of one plant.

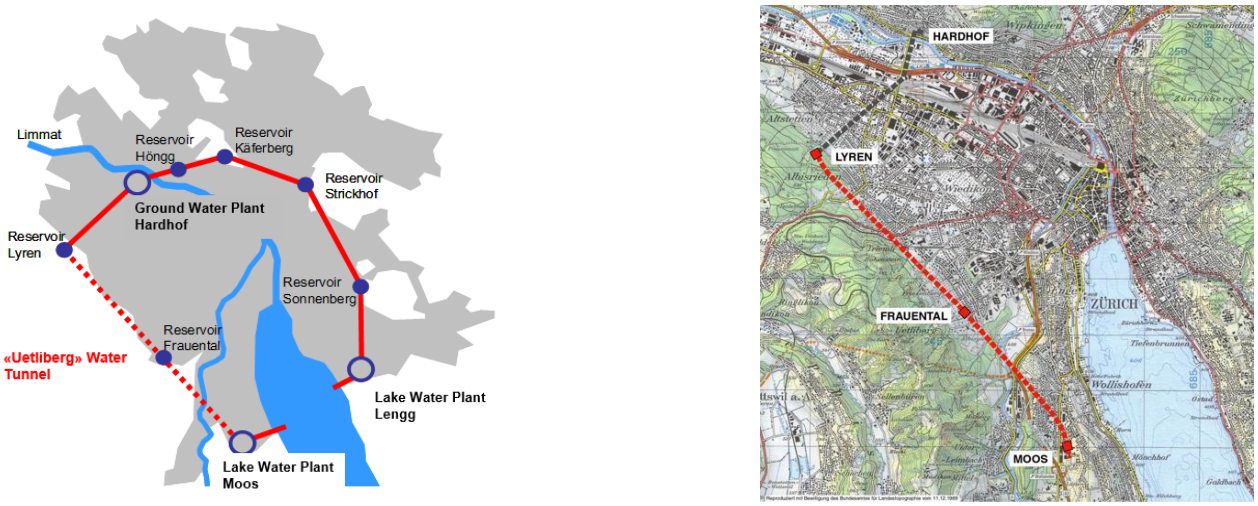


Figure 1: Water ring system, with the new 6.9 km long "Üetliberg"water tunnel as a part of the water network.

There is also more flexibility when pipeline working on the pipe network is ongoing. Since the pressure zones were redesigned (1975 – 1985), the entire urban area has been divided into a few pressure zones. The pressure is between 3 – 10 bar in each zone. With the implementation of the "drinking water tunnel", water hammer are now eliminated, so we have clearly less damages and bursts in the network. Finally, this operating regime leads to a more standardized flow direction, which helps to optimize the water exchange in the distribution network.

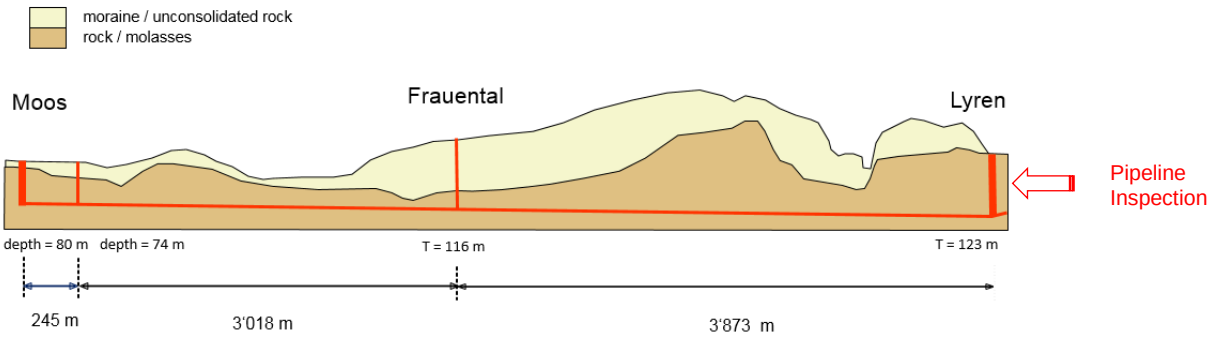


Figure 2: Length profile along the water tunnel

First inspection of the water tunnel and the vertical main pipe "Lyren" (October 2014)

September 2010, the drinking water tunnel "Üetliberg" was put in operation. After four years of operation, the tunnel was completely emptied and inspected. This inspection was made before the guarantee period expired. The Lyren vertical main pipe shaft was already constructed in 2010 and the pipeline has now been in operation for 15 years. In addition to the guarantee-inspection it was decided to carry out an initial inspection of the vertical main pipe.

Safety and emergency concept, hygiene regulations

The risks of the inspection were identified and recorded by a safety and emergency concept. Specialists developed a safety and emergency concept for the inspection of the vertical pipe. In order to guarantee the drinking water quality in the pipe network, the greatest possible hygiene had to be ensured. All equipment, work materials and clothing were disinfected. The number of persons participating in the inspection was kept to a minimum. For example, only new ropes were used to inspect the vertical shafts.

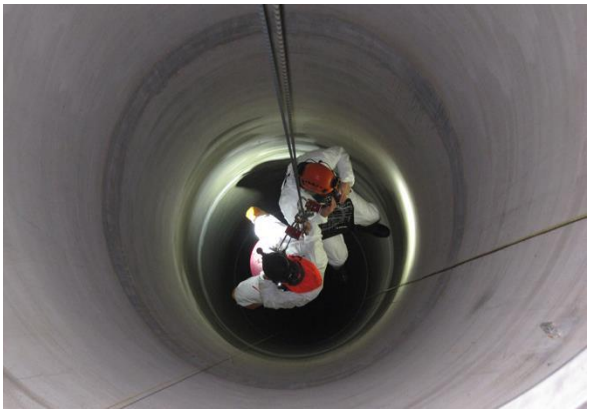


Figure 3: Vertical main pipe „Lyren“, start of the visual inspection (October 2014).

First findings in the vertical main pipe

In summary, pitting corrosion at the welding joints and local detachment of cement mortar and blister formation were found. Especially the weld seams were concerned, the internal corrosion was found all over the pipeline. The corrosion problem has already established itself under the mortar layer. However, the dynamics of the corrosion process could not be estimated at this time.

At present, corrosion does not yet present any danger to the operation or safety of the pipeline. The degree of corrosion was difficult to estimate by the visual inspection. It was difficult to estimate the degree of corrosion by visual inspection, but the corrosion protection was no longer fully guaranteed around the joints. This will continue to damage the weld seam. In order to verify this initial inspection of the pipeline shaft, an enhanced inspection of the overall condition must be carried out so that possible rehabilitation options can be prepared and planned.

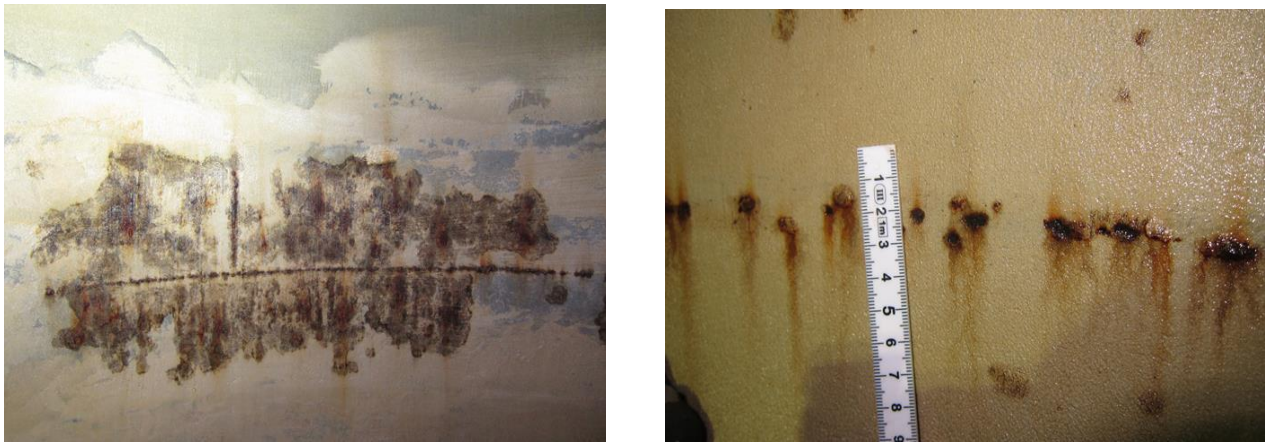


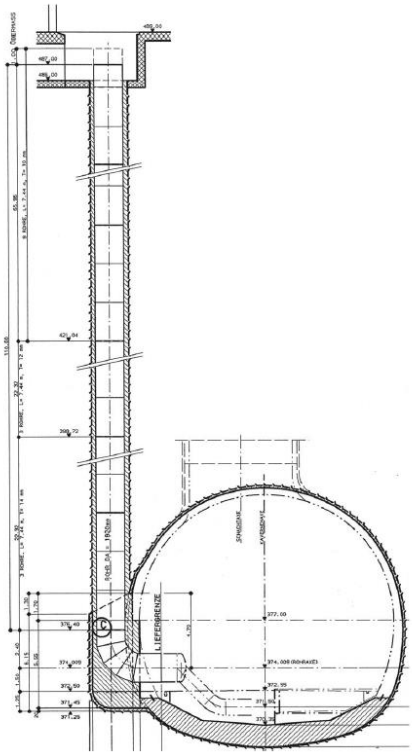
Figure 4: Pittings and corrosion attacks along the weld seam, local missing of the cement mortar layer (October 2014)

Main inspection in November 2018

Due to pipeline construction work in the Lyren cavern, the vertical pipe was emptied. Therefore a second inspection of the pipeline could be carried out. The goal of the inspection 2018 was to determine and assess the actual condition of the pipe and in particular the degree of corrosion. Zurich Water Supply was also expected to predict a prognosis of the condition development.
In addition to the visual inspection, zones were defined where the corrosion protection was removed locally. This made it possible to analyze the steel pipe and the degree of corrosion. In addition, ultrasonic measurements for wall thickness measurement and potential difference measurements were carried out in places.

Construction of the vertical pipe

The steel pipe is continuously welded. The wall thicknesses is between 10 to 14 mm, pipe length 7.44 mm and the pipe diameter is 1820 mm. The pipes were placed individually in the shaft from above and welded with a surrounding welding seam on-site. The gap between the rock reinforcement and the steel pipe was completely filled with concrete B35/25, PC 300 kg/m^3. No waterproofing was applied. Cement mortar was applied to the inside of the steel pipe. After the welding seams had been completed, the corrosion protection was supplemented with cement mortar applied manually over a length of around 40 cm each.



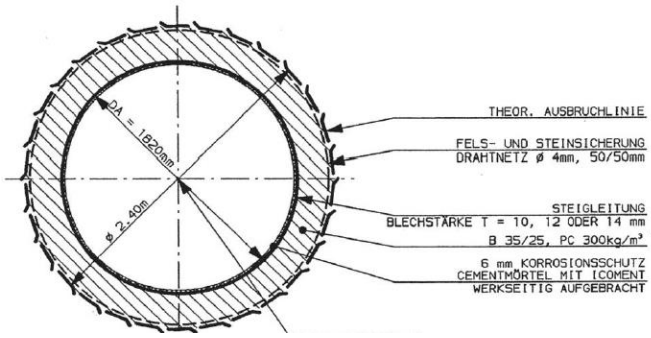


Figure 5: profile through the shaft "Lyren". *Figure 6: typical profile vertical pipe*

The security for the pipeline inspection was again guaranteed by specialists. All hygiene specifications were adopted and implemented in the same way as for the initial inspection.

Results

Most of the corrosion attacks are present in the circumferential welding seams. These welds were welded on site. Areas with brown rust spots are often visible over the entire circumference of the manually applied cement mortar coating, there the covering is very slight in places and less than 1 mm thick locally. Probes in these areas shows that below the dark and brown colored mortar areas, the steel surface shows black and brownish corrosion characteristics. These are surface corrosion attacks with very low material removal. The corrosion depth is only 0.1 mm to 0.3 mm. In a few places brown rust blisters were present, but the leaking water was pH neutral. There are areas with cracking, sometimes limestone and/or brown discolorations are visible and the mortar is hollow. At these places corrosion with small depth on the steel are present. Local softening of the mortar surface was found in a few places.
The layer thickness of the mortar and the wall thickness of the steel pipes were measured selectively. However, the measurement of the steel pipes does not allow any conclusions about corrosion on the outside of the pipe. The measured wall thicknesses correspond approximately to the nominal values for the original steel pipe. The layer thicknesses of the mortar coating is partially too thin, not enough mortar was applied here by hand.

Figure 7: Typical corrosion attacks along welding seam

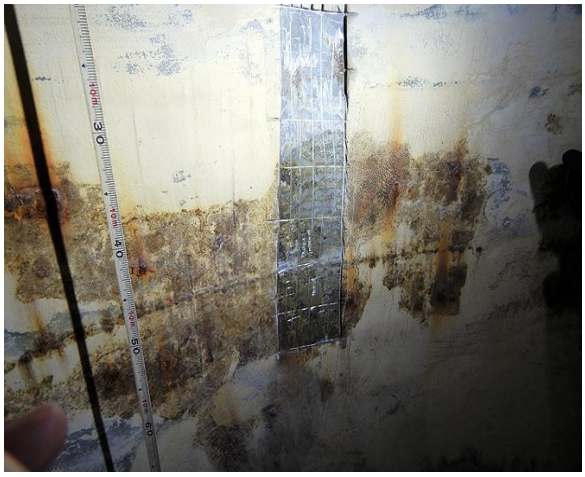


Figure 8: Only minor attacks are visible under the exposed mortar

Conclusion and outlook

The degree of corrosion was less significant than expected in the first inspection of 2014. We can estimate, that under constant operation conditions, low corrosion rates can be assumed in the future. In the next 10 years is expected to double the wall thickness loss. Corrosion depths of approx. 0.6 mm may be visible locally.

The situation may change if there is no cement mortar coating. Due to the local formation of macro elements a material removal of up to 0.5 mm per year is also possible.
In summary, it can be concluded that the condition of the vertical pipe is generally good after approx. 20 years of operation. There is no immediate need for action in the next 5 years. It is important, however, that during operational shutdowns, the pipeline should be checked for any flaked pieces of cement mortar.

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Adrian Rieder c/o Water Supply Zurich
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