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Renovation of large-bore PE 100 pipes in the open-cut mining area of Welzow-Süd

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Introduction

In 2002 Germany a country poor in raw materials had to import more than 70% of its sources of energy. Particularly in the new Federal countries of eastern Germany solely lignite secures some ten thousand jobs. The lignite companies and the power stations resident in that region are important industrial centres in these coal-mining districts of poor structure [1].

Unlike pit coal, lignite does not need to be subsidized. It is thus the only domestic source of energy which is competitive [1]. About 93 % of the total output of lignite in Germany is used for the generation of current. For the generation of competitive base-load current lignite is indispensable. Nearly 28 % of current consumption in Germany is based on lignite. In his annual review the Federal Lignite Union of Germany reports on increased sales of the German lignite industry.

The improved output of 181.8 million tons results from the higher availability of power stations and the putting into operation of the new power station of Niederaußem near Cologne. Output in the Lausitz increased by 3 % to 59.3 million tons [2].

Renovation of large-bore PE 100 pipes

Profile of Vattenfall Europe Mining AG

Since January 2003 the lignite mining company LAUBAG and current generating company VEAG joined to become Vattenfall Europe Mining AG (VE-M) [3].

Energy from Brandenburg and Saxony

Vattenfall is a mining company in the new Federal countries with operating facilities in the territory of Brandenburg and in the free state of Saxony. With about 5700 employees it is among the most important employers in the economic domain of this region and is training centre for about 400 young people. In addition, Vattenfall is bound to create 500 training posts in Eastern Germany companies in the years 2003 to 2005 [2,3].

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Open-cut mining of lignite in the mining areas of Cottbus, Welzow-Süd and Nochten come up to about 59 million tons per year. Lignite mining in these deposits is permitted for about 50 years.

Multibillion investment for the future

The most modern lignite power stations in the world, such as the power stations of "Schwarze Pumpe" (Fig. 2), Boxberg, Lippendorf and Jänschwalde [3] could be realized by Vattenfall multibillion investment in new power stations and environmental technology equipment for existing plants.

In a Vattenfall-owned briquette factory at the power station site of "Schwarze Pumpe" about 5% of the total crude lignite is refined to become high-quality fuel lignite briquette, powdered lignite and fluidized lignite which are used in households and municipal and industrial heat economy.

In parallel to crude coal mining surfaces that have been used for mining purposes are recultivated. The volume of Vattenfall performances exceeds, however, mining and refining of crude lignite. Its central railway department realizes transport duties in a railway network of about 360 km. In addition Vattenfall offers world-wide consulting services up to the development of new open-cut mining systems and their management.

Fig. 1: Open-cut lignite mining with mine bridge

Fig. 2: Lignite power station "Schwarze Pumpe"

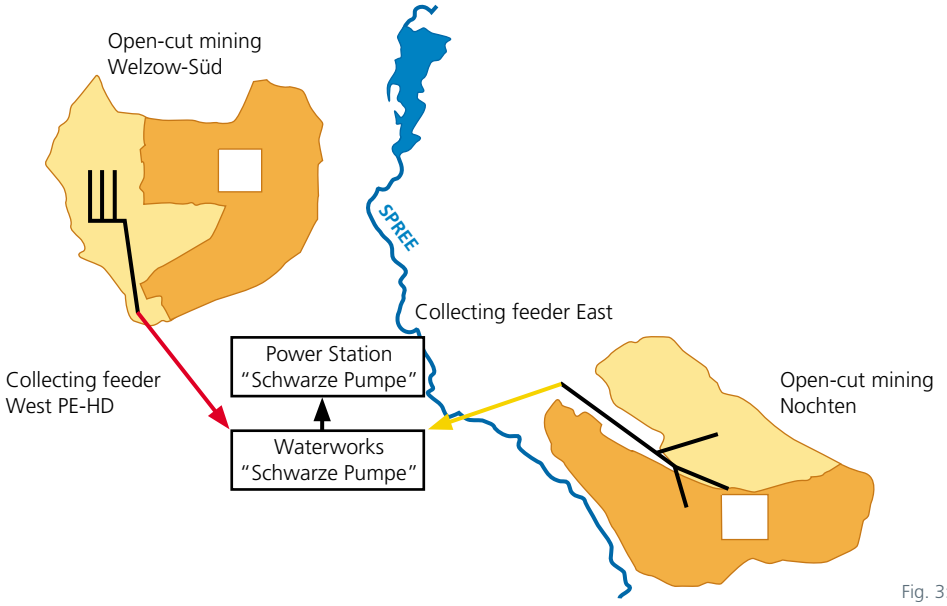

Fig. 3: Situation plan of the open-cut mining Welzow-Süd

Open-cut lignite mining

Lignite is recovered by open-cut mining and requires a temporary draining of groundwater-bearing strata on top of the lignite. The extraction of one ton of lignite requires an average quantity of ground water to be drained of 3 to 7 m^3. Ground waters drained via so-called spring wells are led to nearby rivers through pipelines or open gutters. In case that the water quality does not comply with the official stipulations, a water treatment in special cleaning plants is necessary [4].

Renovation of the collectingfeeder West

Vattenfall operates pipeline systems of nominal widths DN 100 to DN 1200 with a length of some kilometres. The following pipe materials of pressure rates up to PN 10, sometimes up to PN 16 are used:

- steel (DN 100 to 1000)
- PE (DN 100 to 900)
- GRP (DN 500 to 1200)
- concrete (no longer applicable and replaced)

What will be renovated?

In this case concrete pipelines for the drainage of mine water from the open-cut mining Welzow Süd (Fig. 3) laid in 1957/58 are renovated. The mine water is transported by three concrete pipelines DN 1000 with a length of about 5.5 km to the industrial site of "Schwarze Pumpe" where – depending on its quality – it is worked up either to drinking or to service water.

What is the reason for renovation?

The analysis of damages that the concrete pipelines suffer show typical ocherous traces, corrosion of steel installations and fittings and corrosion in the form of leakages. Scraping of pipelines using traditional hard-foam bodies did not give rise to any improvement.

In addition, Vattenfall is expecting increasing aggressiveness of ground water against concrete due to acid mine waters in the next years. Analyses revealed an elevated acidification of the drained ground waters showing a pH-value drop from 6.5 (neutral) to 3.5 (acid).

Those acid mine waters are produced when pyrite (iron disulfide minerals) is exposed to atmospheric oxygen during the mining process. Reaction products are free protons, iron and sulfate ion.

Experiences gained from the operation of the existing pipeline systems at the Vattenfall facilities have shown that in the course of operation these reaction products lead to a hydraulic loss of operating efficiency. Inspections of the pipes revealed a uniform very strong crusty deposit at the internal pipe surface with very high roughness.

The crusty material was identified to be ferrous oxidized hydroxo sulfate. The process is called "formation of Schwertmannit" and depends on very particular ambient conditions (e.g. temperature and concentration of the solution). At the time being regular scraping of the pipelines will counteract the hydraulic loss of operating efficiency.

Basic requirements

Guarantee of a trouble-free operation of the collecting feeder West

Only a trouble-free operation of the collecting feeder West will guarantee that the supply contract of Vattenfall and the power station of "Schwarze Pumpe" can be met for further 40 years.

Securing the supply of cooling water to the power station of "Schwarze Pumpe"

A part of the cooling water needs of the power station are covered by the concrete pipelines. Any failure of two or three concrete pipelines would, however, endanger the supply of cooling water to the power station of "Schwarze Pumpe" (2 x 800 MW).

Due to the damage pattern and the change of operating conditions renovation of the three concrete pipelines DN 1000 of 5.5 km length each and the technologically necessary junctions was indispensable.

Meeting the directives for the transport of drinking water

Depending on the quality of ground water it is treated to become either drinking water or service water via the mine water treatment plant. The therefore used pressure pipes and fittings are thus bound to meet the requirements of the guidelines of the DVGW work sheets W 320, W 322, W 323 and the standards DIN 19630, DIN 19533 and DIN 8074/75.

Renovation method

From a technical point of view the project engineers of Vattenfall assessed the stability of the existing concrete pipelines, renovation of which could thus be carried out using a relining method.

Outside pipe diameter

In addition and due to the conditions of the old pipe the outside diameter of the inline pipe should not exceed d = 950 mm.

Optimized investment and operating costs

Furthermore an optimization between capital expenditure (material and installation cost) and operating cost to be expected (energy and maintenance) was required.

On the basis of these general conditionsthe following demands on the pipeline system were made:

- Service life: 50 years
- Average flow: 3900 m^3/h
- Operating temperature: 4 – 25 °C
- Pressure rate: PN 4 (5)

Choice of pipe material

PE 100 - A superior material for this project

Since 1992 Vattenfall was familiar with the advantages of PE-HD pipes for the transport of sewage. The reason which was, however, instrumental in choosing PE 100 pipes and fittings for this project resulted from many technical advantages gained from this pipe material and its high economic efficiency.

Technical advantages of PE 100

It is in particular the good chemical resistance, the clearly more favorable behaviour to abrasion compared with traditional pipe materials (according to the Darmstadt process), scrapability and weldability which ensures the durable tightness of the system. Ecologically friendly reasons are the minimum required energy for the manufacture of PE 100 pipes and the possibility of recycling. Tailor-made PE 100 pipe dimensions are achieved by a flexible manufacturing process.

Economical efficiency of PE 100

Resulting from their relatively low specific weight of 0.959 g/cm^3 pipes and fittings made of PE 100 are clearly more favorable to handling and pipelaying which in many cases may have a positive effect on the arising installation cost [5]. Positive experiences were well known to the operator of the pipeline since several years.

Proof of long-term strength

ISO 9080 (formerly ISO/TR 9080) describes an extrapolation method with the aid of which scientifically sound assessments can be made as to the long-term strength of thermoplastic pipe materials. This method uses the Arrhenius law. Due to service life observations made on pipe samples under internal pressure at higher temperatures, expected service life at lower temperatures can be calculated. Extrapolation factors are given in ISO 9080. The minimum time to failure curve of DIN 8075 for PE 100 follows the same principle. Table 1 specifies the hydrostatic strength extrapolation limits and the adequate strengths for pipes made of the material *Hostalen CRP* 100 black. An evaluation of ISO 9080 shows that pipes made of *Hostalen CRP* 100 black even up to a temperature of 40 °C provide still a minimum strength which is required for pipes made of PE 80 at an applied temperature of 20 °C ($_{LPL}$ = 8.4). With reference to the requirements and provided that manufacture was properly made pipes made of *Hostalen CRP* 100 black are expected to achieve a mathematical service life according to ISO 9080 of more than 100 years.

One of the reasons for the use of PE 100 [6] for this project was this strength reserve compared with PE 80 pipe materials.

Pipe manufacture

Pipes and fittings were manufactured at SIMONA AG in Ringsheim/Germany. The head office of the company is situated in Kirn/Nahe with worldwide activities in all important markets due to nine subsidiaries.

The company's activities are focused on the European markets, where SIMONA AG is represented with its own subsidiaries in France, Spain, Italy, Great Britain, Switzerland, Poland and the Czech Republic.

Further more SIMONA operates subsidiaries in USA and Hong Kong as well as an office in Shanghai. In many other countries SIMONA is represented by local and international partners. Due to the flexible and most modern pipe manufacturing equipment tailormade pipe dimensions can be produced without any problem.

Table1: Hydrostatic strength extrapolation limits and the equivalent strengths for pipes made of the material *Hostalen* CRP 100 black

Applied Temperature (°C)	Extrapolation Limit (years)	Minimum Required Strength $_{LPL}$ (MPa)
20	109.7	10.9
25	109.7	10.2
30	109.7	9.6
35	109.7	9.0
40	109.7	8.4
45	61.4	7.99
50	35.1	7.5
60	10.9	6.7

Fig. 5: Pipe length made of Hostalen CRP 100 black, manufacturer SIMONA AG

Execution of the installation

Choice of pipe dimensions

On the basis of extensive calculations and in taking into consideration hydraulic calculations as well as general conditions stipulated by the old pipe the following inline pipe has been chosen: d = 950 mm and s = 28 mm.

On a total length of 535 m near the pulling-in pits and the shafts, the PE 100 pipe to be installed is not surrounded by the old pipe (Fig. 4).

To a great extent the pipeline route runs through wooden and agriculturally used sectors and sometimes through walled areas where buildings were erected on top of it in the past.

The currently existing fifteen pipeline junctions, each in a shaft, are no longer necessary. The technologically necessary low reference points at shaft 11 and 2 as well as the high reference point near shaft 9 resulting from the existing position of the pipe must be maintained.

Shafts that are no longer necessary for the operation of the collecting feeder are demolished until about 1 m below their top edge. After completion of the pulling-in process the shafts are backfilled and the upper surface is restored in conformity with the neighboring surfaces.

Pipe joining technology

The delivered pipes (length of each 24 m) were welded to pipe runs of several hundred meter lengths on site (Fig. 5) using the heating element butt welding method.

This is a process where the surfaces to be connected are heated to welding temperature by means of a heating element and after its removal are brought together under application of pressure which results in a homogeneous undetachable positive joint (Fig. 6).

All welding parameters, such as matching, heating-up, removal of heating element, pressure built-up and cooling under joining pressure are specified in the current edition of DVS 2207 for pipes and sheets made of PE-HD.

Pulling-in the pipes

During planning stage pulling forces, admissible pulling lengths, bending radii and the allowed total pulling and bending elongation have of course been calculated for the respective pipe dimensions.

Forces necessary to pull-in the pipe lengths with rise and inclination have been chosen in such a way as to avoid that the admissible tractive force applicable for the pipe material *Hostalen CRP* 100 black was exceeded.

Bending elongations which could occur during the pulling-in process had also been chosen as to avoid that the admissible total bending and pulling elongation for PE 100 was not exceeded.

Fig. 4: Pipe length with pulling-in pit

Fig. 6: Heating element butt welding machine with protective cover

Fig. 7: Pipe lengths in an inspection shaft

Filling the gap between the pipes

The gap between concrete and pulled-in PE 100 pipe was packed after pipelaying works using a hydraulic binder from natural raw material (Fig. 7). Rapid binding, outstanding flowability and high strength were requirements made on the binder [7].

Outlook

Since more than ten years pipes and fittings made of PE 80 and PE 100 have successfully been used at Vattenfall for the transport of iron and sulphate containing mine waters.

Developments in the future at Vattenfall in cooperation with pipe material producers and processing factories are aimed at minimizing the incrustation process.

Homopolar and electrically bonded internal pipe surfaces and particularly modified and doped pipes will be examined as well.

First pilot tests show that when using adequate materials a minimized incrustation process is possible [4].

Acknowledgement

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