

HISTORY OF UTILIZATION OF WATER POWER IN THE MINES OF FREIBERG, SAXONY

Peter L. Siems

Abstract: The date of earliest use of water power in the 800-year history of the Freiberg silver mines is unknown. Increasing difficulties of water seepage and water lifting in the northern Freiberg mines led to the construction of drainage adits (Hauptstollens). Water experts from Florence, Prague, Freiburg, and Nuremberg were employed in 1365 and 1379, to install state-of-the-art water knowledge in the mines. The first adit (Alte Fürstenstollen) was driven 1.5 km from the nearby deeply incised Freiberg Stream up an incline to the 60 m deep Alte Reiche Zeche. A system of drainage adits connected to many mines existed in the northern area by 1402. Many water wheels were situated underground as the mines became deeper than the adits. About 1540 the adits were extended to drain the southern mines at Brand-Erbisdorf and Zug. In 1558 building commenced of a network of reservoirs, canals and tunnels in order to bring water 20 km from the southern hills. The network was extended to a length of 40 km in the 18th and 19th centuries. J. F. Mende designed the first working 'water-column' engine for water lifting and installed it in the "Siegfried" mine in 1767-8. F.W. Schwamkrug designed a novel water-driven turbine in place of a piston and placed examples in three Freiberg mines in 1843 where they were used for water lifting or, in one mine, for man and ore hoisting. During this period, the increasing age of the mines, the advent of lower grade silver ore, greater depths, lower prices of silver due to New World imports, substitution of base metals for coinage, and declining profits caused a gradual withdrawal of capital for innovation and modernization.

Introduction

The earliest use of water to power water wheels in the 850-year history of the Freiberg silver mines is unknown but it was before the start of the 14th century. At that time, the numerous mines in the Freiberg district covered an area that stretched from Freiberg six kilometres north to Halsbrücke (the northern mines) and from Freiberg seven kilometres south to beyond Brand-Erbisdorf (the southern mines).

Most of the Freiberg mines in the eleventh and twelfth centuries were shallow open cuts and pits but by the beginning of the 13th century some mine shafts had reached depths of fifty metres to 100 metres. In the 13th century there were approximately fifty silver mines and a work force of approximately 1000 miners in the southern area and a possible smaller number but more productive, deeper and larger mines in the northern area (Baumann 1997a, 87). Many shafts and drifts had entered the water table and were meeting with increasing large amounts of water seepage. Hand whims and horse whims then in use at many shafts for lifting the underground water were slow, expensive and inadequate. Small and shallow collecting ponds on high ground adjacent to the mines were used to store a limited supply of water for providing water power to water wheels for hoisting ore and water at some underground mines before the middle of the 14th century. These ponds were liable to become dry in summer and freeze in winter and their water supply was often insufficient to power the water wheels during these seasons (Baumann 1997b, 114). The water shortages became worse over time as the mine workings became deeper and wider in area. The problems had caused a long decline in district-wide silver production, profits and closure of some mines by the middle of the 13th century.¹

To solve the problems of water seepage and water lifting in the northern mines, a drainage adit (named the Alte Fürstenstollen) with a length of 1.5 kilometres was driven before 1365 from the deeply incised Freiberg Mulde valley, southwards to the Reiche vein, which was the principal vein of the Reiche mine (now the Alte Reiche Zeche and a part of the Himmelfahrt mine in the nineteenth century) (Baumann 1997b, 114). This Alte Fürstenstollen adit was an incline that intersected the area of

the Reiche mine shaft at a depth of sixty metres (Fig. 1). The adit was paid for by the local ruler, a Margrave, who claimed Bergregal rights to a one-tenth tax on mined silver and was anxious to increase his income. Five more drainage adits from the deep valley of the Mulde followed in the late fourteenth century and two more in 1402.

The Margrave abstained from collecting his tenths whilst these adits were driven and he paid some subsidy (but not all that he had promised) towards the costs of the later adits. The adits were driven slowly in resistant rock by fire setting and hammer-and-wedge methods. The advance on mining crosscuts in the resistant Freiberg gneiss with a tunnel profile of 1.50 m by 0.50 m was, at most, fifteen metres per year, although in mining the softer veins it was sometimes considerably more (Weber 1997, 14). In addition to mining the drainage adits, ventilation shafts from the surface had to be provided at intervals of several hundred metres in order to exhaust the fumes from the fire setting method then in use for rock breakage. A network of drainage adits connected to many mines in the area north of Freiberg by 1402.

In about 1540, a second drainage adit, the Tiefer Fürstenstollen, was driven from the Freiberg Mulde valley to the Reiche mine, then southwards under the Rote Grube mine at Werner Square in the city of Freiberg to mines near Brand-Erbisdorf. Some additional adit branches from the Tiefer Fürstenstollen had to be mined in order to drain some of the southern mines (Strohbach and Heinrich, 5). Much later, in the nineteenth century, a deeper drainage adit was driven to the Reiche vein and intersected the area of the Reiche Zeche shaft at an approximate depth of 230 metres (Fig. 1).

The problem of water disposal by hoisting during the slow advance of the adits was acute. Foreign water experts from Florence, Prague, Nuremberg, and Freiburg on the River Rhine, were summoned to Freiberg in 1365 and 1379 to design and install improved water wheels for lifting ore and water (Weber 1997, 14). It is possible that water wheels were used for some ore crushing at this early time because Agricola in 1556 describes and depicts a wheel driving a bank of four iron

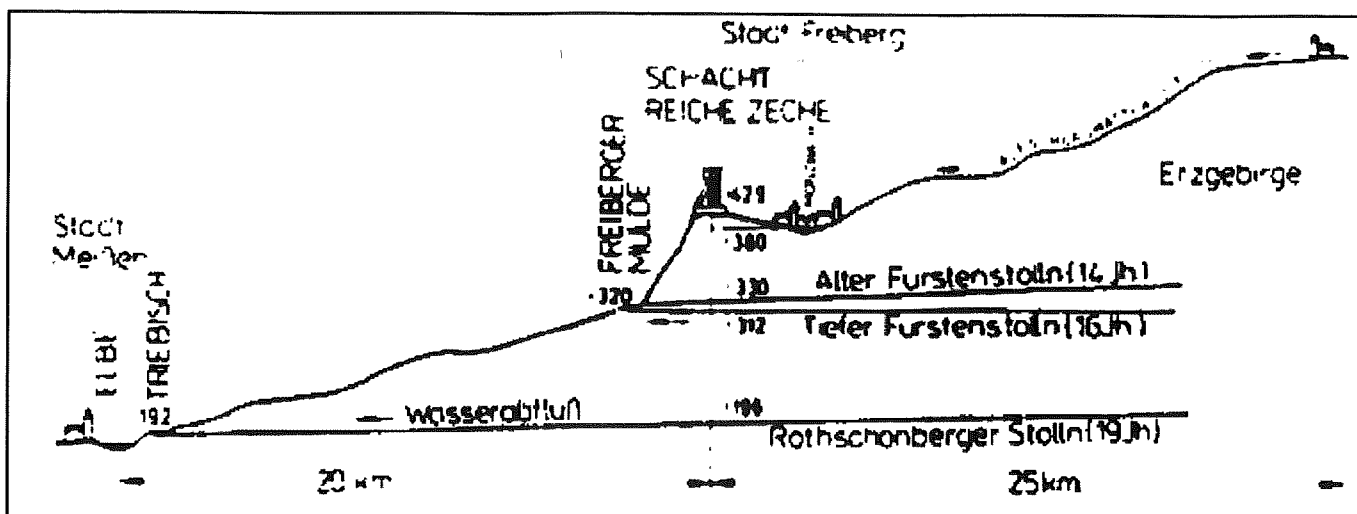


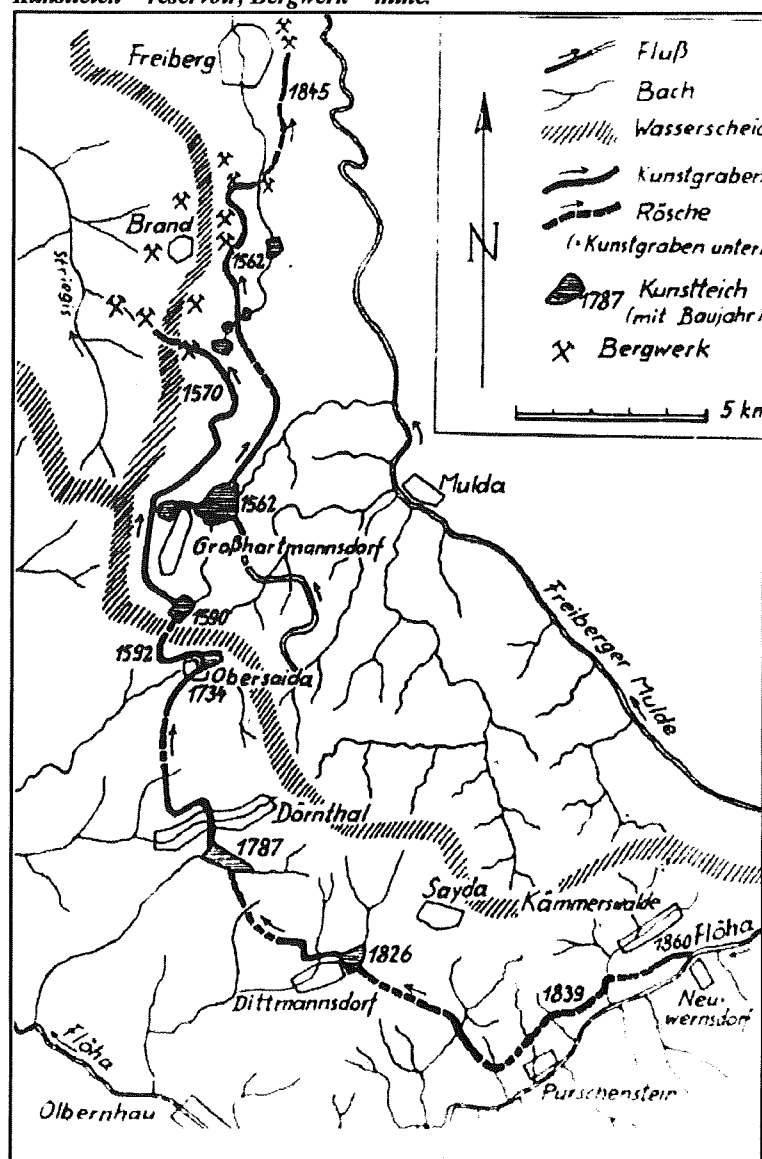
Fig. 1. A north-south vertical section of the water drainage adits driven from the Freiberg Mulde and the River Elbe to the Reich Zeche mine and Freiberg District. (From Beyer, No Date).

stamps; although boys from ten to sixteen years of age were generally used to crush and sort the ore.

between the Freiberg Mulde and the Flöha River. This drained a reservoir near Obersaida, and supplied an increased

In the following centuries, most new water wheels were placed underground as the mine workings became deeper than the drainage adit levels. Water supplies for the water wheels in the fourteenth and fifteenth centuries were continuing to be a problem particularly in summer as the small reservoirs adjacent to some mines still had inadequate capacities although some had been enlarged or were new. Simon Bogner (1500-1568), Senior Mine Manager at Freiberg, planned and supervised the installation from 1545 to 1555 of an extensive system of reservoirs, ditches and underground water tunnels which were required to power 38 new water wheels for hoisting water at the Freiberg and Brande mines. He introduced a number of walking beams on the surface to transmit the energy of water wheels. These improvements replaced the more expensive horse whims and hoist labourers (Weber 1997, 14).

Fig. 2. Plan of the network of reservoirs, ditches and tunnels, which delivered water from the foothills of the Erzgebirge to the Freiberg mines in 1850 (From Wagenbreth, 1978). Fluss = flow, Bach = stream, Wasserscheide = watershed, Kunstgraben = ditch, Rösche = tunnel, Kunstteich = reservoir, Bergwerk = mine.



Martin Planer (1510-1582) succeeded Bogner as Senior Mine Manager and in 1558 he started extending the network of reservoirs, ditches, and tunnels to bring water twenty kilometres from the high ground in the foothills of the Ore Mountains to the south of Freiberg. The stream water of the Münzbach was drawn and the Müdisdorfer water ditch and tunnel were constructed. From the latter the water reached first of all into the Lothar reservoir and from there by a small aqueduct over the Münzbach into the Berthelsdorfer smelter reservoir, from where the Thurmhofer water ditch discharged. By these means the energy requirements of the Thurmhof mine shafts (presently part of the Himmelfahrt mine in the northern area) were met. In 1562, the Lower Grosshartmannsdorf reservoir and water ditch (Fig. 2) were completed and provided water to the southern mines near Brand. The Upper Grosshartmannsdorf reservoir was constructed in 1590 to supply the mines south of Brand. Water from the Grosshartmannsdorf reservoirs was brought by tunnel under the watershed between the Freiberg Mulde and Münzbach into the Berthelsdorfer smelter reservoir (Baumann 1997, 114). Two years later, a line of water ditches and a tunnel, which was based on an original plan of Martin Planer, was cut below the watershed

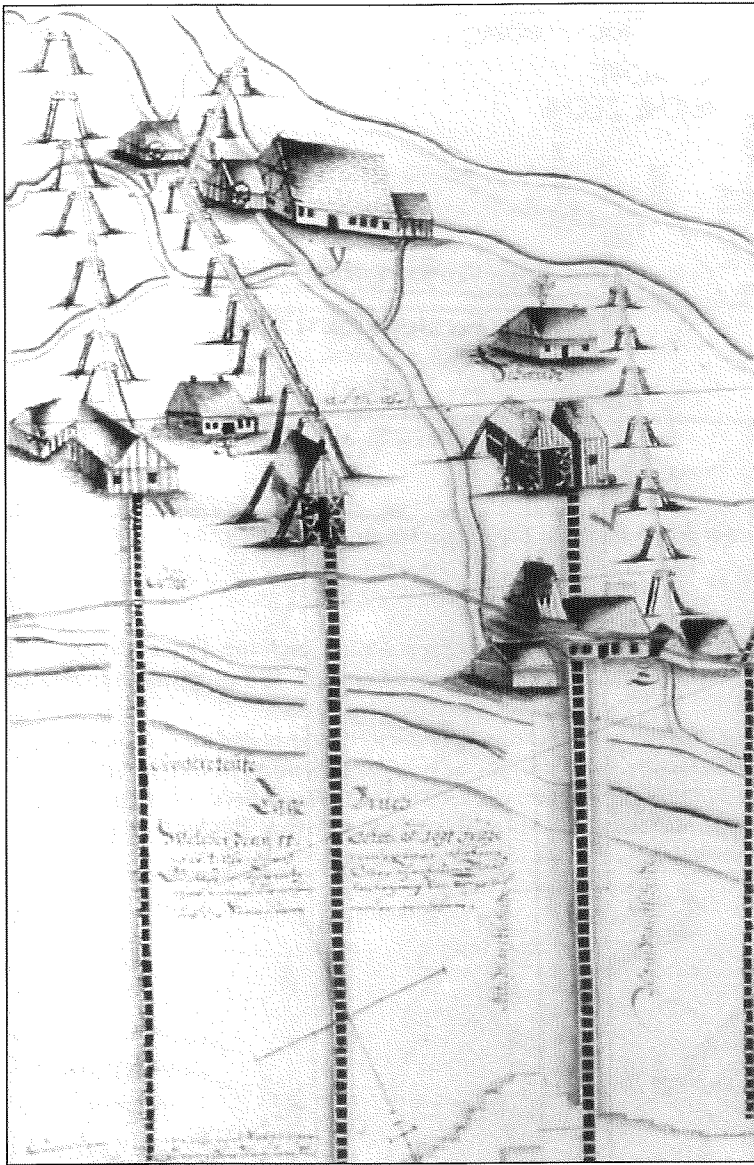


Fig. 3. "Freiberga subterranea." A watercolour plan by Mine Surveyor Andreas Berger, 1695-6, with mine shafts, leats, shaft houses, water wheels and a mine smithy. (State Archives, Freiberg).

Plate 1. A modern view of the covered ditch that supplies water from the Grosshartmannsdorf reservoirs to the Freiberg district.



water supply for mines south of Freiberg (Baumann 1997b, 115).

The Himmelfürst mine, south of Brand-Erbisdorf, by 1590, had reached a depth of 600 m and required from eight to nine water wheels on surface and underground to lift the underground water and ore. Later, in the seventeenth century, an increase in the amounts of water flowing into the Himmelfürst mine caused a fall in production. Regardless of the problems in the southern mines, in the last half of the seventeenth century approximately 716 mine shafts were working in the Freiberg district, with the most important mines: Thurmhof, Abraham, and Elisabeth, being all northern mines within the later consolidated Himmelfahrt mine area (Beyer 1998, 8-9; Weber 1997, 16). A mine surveyor, Andreas Berger, painted in 1693-96 a plan that shows the water ditches, leats, water-wheel houses, a mine smithy, shaft houses, and shafts of these northern mines (Fig. 3.) (Wilsdorf 1987, 253).

The importance of water supplies for hoisting water and crushing ore in the Freiberg mines was demonstrated in 1684 when the Prince of Saxony commanded the appointment of a Water Ditch and Tunnel Administration. All the rights to the water standing on high ground to the south of Freiberg became controlled by this administration, who then arranged for and oversaw the distribution of the water to the mines. The daily consumption of the water by the individual mines was strictly regulated by permanent weirs and by watchmen who controlled lock gates on the ditches (Baumann 1997b, 116; Weber 1997, 16).

In later years, additional collection reservoirs on streams were constructed: the Middle Grosshartmannsdorfer reservoir, the Obersaidaer reservoir, and the Dörntaler reservoir in 1787; the Benno tunnel and the Dittmannsdorfer reservoir in 1826. The latter was then and is now the highest situated water reservoir of the Freiberg mine district. The water supply in 1845 was sufficient to allow a tunnel and ditch to be mined so that water could be supplied to the Himmelfahrt mine. The Himmelfahrt was a consolidation in 1767 of mines to the east and north of Freiberg and became the most productive mine in the district in the 19th century² (Weber 1997, 8-9). The Martelbacher and Cämmerswalder adits were driven from 1827 to 1859 and connected to the Hemmberg and Flöha adits, which were driven from 1858 to 1863 with a connection to the Flöha River. The network then extended to a length of forty kilometres from Freiberg. The eleven reservoirs in the network had a water capacity of over five million cubic metres. At present, the Hemmberg and Flöha adits are closed and the Thurmhof and Einhorn water ditches that used to supply the southern Freiberg mining area are no longer used (Bauman 1997, 116). Water ditches (now covered by wood) and tunnels at lower elevations are still in use to supply water for urban use and the Reiche

Zeche mine shaft, part of the Himmelfahrt mine since 1767 (Plate 1).

To the north, near Halsbrucke, the local Anna and Altväter mines were supplied water energy by the construction of reservoirs, ditches and the Altväterbrücke, a long aqueduct built in 1680-85 under the supervision of Abraham von Schönberg, Principal Mine Manager of Freiberg district (Plate 2) (Weber 1997, 24). The aqueduct fell into disuse and was destroyed in 1890 (Wilsdorf 1987, 275).

Relatively few improvements to the use of water energy were made at Freiberg in the eighteenth century until 1770 when J. F. Mende was appointed to be the first district mechanical engineer. Mende improved the construction of the older horse and water driven winding engines and installed additional underground water wheels. He was probably responsible for the design of the stamp mill driven by the water wheel illustrated by Monnet (Fig. 4) (Monnet 1773, plate 22). The most ambitious and largest work that Mende designed and supervised was the construction of locks and a novel wide boat-lifting transporter on the Freiburger Mulde canal in 1788-89. The canal was used for transporting ore to smelters in the coal mining district at Zwickau for many decades (Beyer 1998, 18).

Christopher Polheim, a German engineer working in Sweden, developed in the early eighteenth century, a primitive siphon machine to remove underground water in a Swedish mine. The principle of a siphon had already been known since the seventeenth century. A German artillery major Georg Winterschmidt travelled with a delegation from the Harz mining district, to Sweden in 1747 to examine mining techniques. Winterschmidt studied the Polheim machine and, within a year, he had plans for similar water column engines to be constructed in the Harz mines. However, it was not until 1760 that the first water column engine was installed in a mine of the Bockwieser district in the Harz (Liessmann 1997, 86).

In the Freiberg district, Engineer Mende designed a working water column engine for water lifting and installed it in the Siegfried mine in 1768. This was the first in the Freiberg district (Weber 1997, 28). This and other early water column engines were piston machines, whose two pistons were moved by water power created by the pressure of a high column of water in an iron pipe, which could be placed in either a vertical or an inclined mine shaft. The engines required complex valve controls, which could withstand high water pressures. On opening the valves the water in the discharge pipe pushed back the piston and was expelled by the pressure of the cylinder and the cycle began again. Two driving cylinder-pump combinations could be connected together by means of a swing wheel. Such an engine working at twelve revolutions per minute with

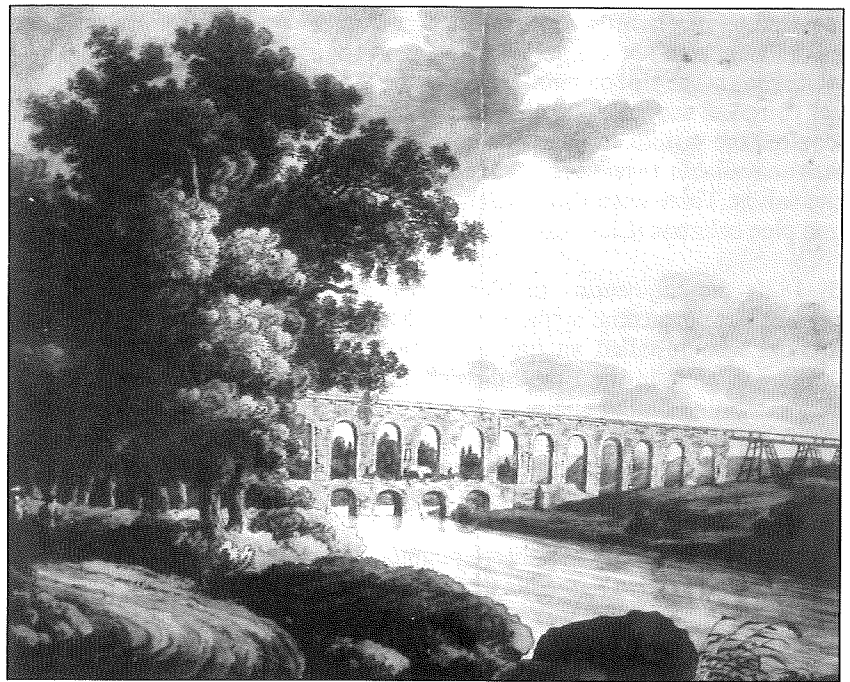
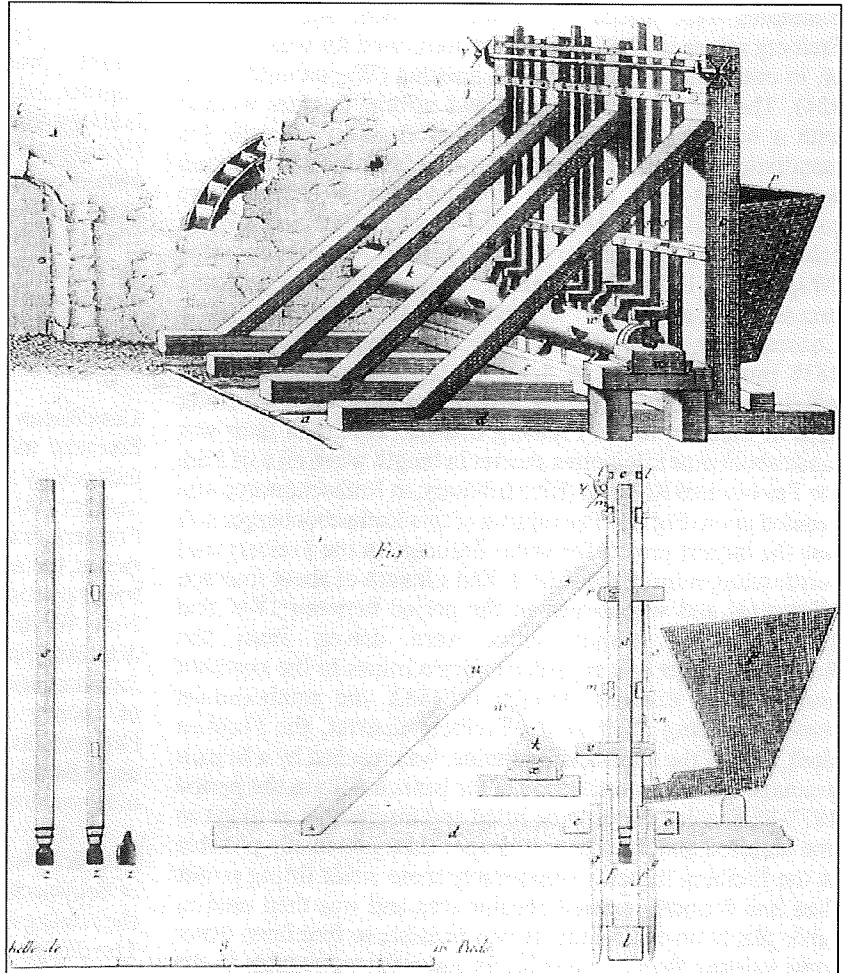


Plate 2. "The Altväter aqueduct near Freiberg." A watercolour by Adrian Zingg, 1780. (Town and Mine Museum, Freiberg).

a consumption of 1.6 cubic metres of drive water could lift 1.9 cubic metres of mine water. A water drainage adit at depth underground was a prerequisite for the installation of the engines. Compared to a water wheel, the water column engines

Fig. 4. A stamp mill driven by a water wheel at a Freiberg mine. (From Monnet 1773).



required relatively little water for their performance and that requirement could be controlled with a corresponding steeper inclination of the pipe column. However, the early engines were not complete successes because of the high water pressures required the pistons to have precise engineering machining, then unavailable, to prevent leakage of water from the cylinders and valves. There were also problems because of erosion of the iron pipe columns (Liessman 1997, 88).

By 1820, the engineering problems with the water column engines were overcome by the Freiberg Mechanical Engineer Brendel who installed an improved model in the Reicher Bergsegen mine in the Brand district. Later, other Freiberg mines installed similar engines; the last was placed in 1847 at the Vergnügte Anweisung mine (united in 1850 with neighbouring mines to form the Einigkeit mine) near Brand (Weber 1997, 28; Wagenbreth 1978, 524 and 529).

Two additional water-wheels were planned originally for the Reiche Zeche in 1846 but before these were constructed the use of a water column engine was considered and a comparison led to Brandel's proposal for a model with two cylinders, single acting engine with 56 cm working piston diameter, a 2.83 m piston lift and 4 strokes per minute. The energy performance was thirty five horsepower. The weight balance exceeded the hydraulic balance below No. 1 level at 147 m depth (Beyer 1997, 124). The required water supply of 6.3 cubic metres per minute was available from the Himmelfahrt water ditch. A similar water column engine is still in operation in an old stope of the Reiche Zeche mine. It discharges the mine water by means of a cast-iron pipeline in the level of the Fürstenstollen drainage adit at a depth of 101 metres.

A Freiberg engineer, F. W. Schwamkrug, designed an innovative water column driven turbine in place of a piston. Examples were placed in the Reiche Zeche and two other Freiberg mines in 1843 where they were used for water lifting or, in one mine, for men and ore hoisting (Wagenbreth 1978, 524). The water column piston and turbine engines worked with a high degree of energy and profitability. Despite the installation of the new turbine engines, additional underground water wheels and a water column piston engine were commissioned in the 1840s for the Reiche Zeche and a water column piston engine for the Vergnügte Anweisung mine (Wagenbreth 1978, 529). Their installation in the Reiche Zeche necessitated a greater capacity of the drainage adits. Consequently, General Mine Superintendent von Herder in 1838 proposed a plan to drive an expensive drainage adit, which would be twenty-three kilometres long, from the River Elbe at Meissen to the Freiberg district. This plan later was made about nine kilometres shorter in length when an adit from the Triebischtal River, an Elbe tributary, at Rothschoenberg was decided upon (Fig. 1). The mining of this Rothschoenberger adit was the largest project for water drainage in the Freiberg and surrounding mining districts. It had a length of about fourteen kilometres and was driven in the period between 1844 and 1877. Several branch adits were driven from the Rothschoenberger adit in order to drain mines in the northern and southern districts. Finally in 1882, the southernmost working mining shaft in the Freiberg district, the Franken shaft, part of the Himmelsfürst mine, was reached by a branch drainage tunnel. Construction of the branch adits in the period 1877-82 enabled water to be lifted and discharged as much as one hundred and forty metres deeper than previously possible in the Freiberg mines. Considerably more water lifting power than had formerly existed became free and was then used in other places on the mines. It was possible to free from water some existing flooded mine levels under the water table in the

Halsbrücker Spat of the northern district and mining of the Beihilfe mine in Halsbrucke could recommence (Baumann 1997b, 114).

Table 1. Non-steam winding engines built in the nineteenth century in Freiberg mines (modified from Wagenbreth, 1978).

Year	Mine	Shaft Depth	Horse Power	Remarks
Water Wheels				
1821	Churprinz	300 m	20 hp	-
1823	Beschert Glück	350 m	20 hp	-
1831	Junge Hohe Birke	450 m	20 hp	-
Water Wheels with a Reciprocal Wheel				
1823	Herzog August	370 m	10 hp	-
1824	Alte Mordgrube 3	50 m	10 hp	-
1843-44	Reiche Zeche	450 m	10 hp	-
Horse Whims				
1820-21	Herzog August	370 m	2 hp	-
1833-34	Vergnügte Anweisung	250 m	2 hp	-
Water Column Piston Engines				
1819-20	Reicher Bergsegen	250 m	8 hp	Water-lifting
1821-24	Alte Mordgrube	350 m	65 hp	Water-lifting
1826-33	Segen Gottes	250 m	57 hp	Water-lifting
1845-47	Vergnügte Anweisung	250 m	22 hp	?
1846	Reiche Zeche	450 m	35 hp	Water-lifting
Water Column Turbine Engines				
1843-44	Alte Hoffnung	?	40 hp	Water-lifting
1843-44	Gesegnete Bergmanns-Hoffnung	450 m	20 hp	Men & ore
1845-46	Segen Gottes	250 m	40 hp	Water-lifting

The first steam driven winding engine in a Freiberg mine, the Reicher Bergsegen, was installed in the comparatively late date of 1844. By 1850, water-wheels with or without reciprocal wheels, horse whims, water column piston and turbine engines, and steam engines were all used in the district for hoisting men, water, ore and for crushing ore (Table 1) (Wagenbreth 1978, 525 and 529). Steam engines were employed increasingly for hoisting and water disposal in the early 1860s. Their use coincided with construction of the last water driven winding engine in 1863 at the Ludwig shaft in the Himmelfahrt mine. An improved performance steam engine was installed in 1898 on the Reiche Zeche (Wagenbreth 1978, 529). The use of steam lasted only a few decades before the end of district-wide production in 1913.

Conclusion

Freiberg mines were in the forefront of improved mining technology from medieval time to the middle of the nineteenth century. Although innovations were developed and used in Freiberg during this period, the increasing age of the Freiberg mines, the advent of lower grade silver ore with greater depths, lower prices of silver and base metals due to imports from the New World, substitution of base metals for coinage, and declining profits all resulted in a gradual withdrawal of capital for innovation and modernization of the Freiberg mines. Lack of money resulted in the use of water wheels in the Himmelsfürst mine (a consolidation of southern district mines) until the end of its life in 1896 and in the Himmelfahrt mine until its closure in 1913.

Brendel's water column piston engine and the turbine engine of Schwamkrug represent peaks of mechanical engineering for the mining industry in the eighteenth and nineteenth centuries. The design of the Schwamkrug turbine was an important step

between the water wheels and the modern turbines and represented a form of turbine specific to mining and provided a transition to modern water-power utilization and for the general introduction of turbines in machinery.

Notes

1. A graph of metal production in the Freiberg district over the centuries is in Beyer 1998, 10.
2. The Himmelfürst mine unified mines in the southern district in a similar manner to the Himmelfahrt Fundgrube.

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Peter L Siems, Professor emeritus, College of Mines, University of Idaho
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