Innovations in Salt Mining Technology in Austria from the 13th to the 18th century

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In the following pages an attempt will be made to show that the various innovations taken up and utilized by the Austrian salt mines stemmed from the respective sovereign, who had the necessary capital and was interested in improvements.

1. Innovations in the salt mine

The first innovations in Austrian salt production came from the salt mine itself. Here it was mainly the use of an efficient leaching process and then mainly the utilisation of exact mine surveying methods, which allowed a number of tunnels which did not run into one another. The development and the use of the compass meant an enormous advancement in technology for the salt mines.

1.1 Innovations in the leaching chamber

We can rightfully assume that alpine salt mining availed itself of the leaching process right from the start. Through this process the salt brine is extracted by subterranean leaching of the *Haselgebirge* - a mixture of salt, gypsum, clay and marl. From a tunnel (*Schaftricht*) one sunk a 20 - 30 m shaft, at the base of which one hewed out a leaching chamber. Fresh water was fed into this chamber via an inclined shaft. Once the fresh water had become concentrated enough for salt production (26 - 27% salt), it was bailed out through the shaft by means of a system similar to a draw-well[1]. The more recent innovative form consisted in constructing the leaching chamber to allow the brine to run off by itself. This was accomplished by closing off the leaching chamber located in the operating horizon towards the shaft side with a dam constructed of clay and gypsum sediment from the chamber. The brine was drawn out of a strainer box in the leaching chamber - the box was extended in height as the level of the brine in the chamber rose - and piped out through the dam wall. In contrast to a classic leeching chamber (without a dam), this type of chamber was designated as a *Wöhrwerk*. Among other things - for example primarily not having to complicatedly bail out the brine - the *Wöhrwerk* had the advantage that it could theoretically be continued at any desired height throughout the entire salt mine[2].

This innovative system was developed in Hallein, where it was already in use in the year 1271[3]. In the Salzkammergut region and in Tirol, however, it would not be until the 16th century that this extremely advantageous system would be used.

1.2 Exact surveying technique

As salt mining became more and more intensive, it became crucially necessary to utilise a precise surveying technique. For this reason, as early as the 13th century in the Hallein-Dürrnberg workings the course of the tunnels attained through the survey of the mine under ground was marked out on the surface to clarify the positions of the tunnels to one another and their location with regard to the borders of the mine marked off on the surface[4]. The oldest instruments for length measurement were cords, poles and staffs[5]. Later, these were augmented by special instruments such as the "*Bergstabel*" or "*Bergklafter*" (the latter: mining fathom); these were measuring rods that gave the length of the fathom valid in the various mining districts and that had, on average, a length of two metres[6].

The compass, which was necessary under ground to exactly maintain the required direction, was used in the 13th century by Arabs and Vikings for navigation. It appears questionable, however, whether the compass was already employed at this time for mining. We encounter the term only in the year 1474 in the hand of a surveyor from Schwaz[7].

Besides the magnetic determination of angles and directions, in alpine mining there was a form of analogous angular surveying through the scribing of angles in wax discs[8]. The turn of the Middle Ages to Early Modern Times saw the advent of the so-called "*Schinzeug*" (mine survey instrument) in the alpine mines as well. This device united angular and longitudinal measurement. It consisted of both a primary and secondary device. Both devices had contrivances attached for reading horizontal angles and plumb bobs for levelling. Both devices were newly positioned alternately. Between the primary and secondary device was a measuring cord that served for distance measurement. From this cord hung, in general, a bubble level for measurement of the angle of inclination. All three settable variables - i.e. length, horizontal and vertical angle - were noted down in so-called surveyors' books.[9]

Besides length measurement, one of the principal tasks in mine surveying was the pre-determination of distances when sinking shafts or driving tunnels. Here one used indirect methods with the help of cord triangles on the basis of intercept theorems und similar triangles. Using this method, one set suitable distances in relation to one another[10].

Mine surveying made decisive advances at the beginning of the 16th century once descriptive geometry became an integral part of the art of surveying to describe underground workings in the form of a plot.

Decisive impulses for the further development of mine surveying came from the salt mines themselves, since their numerous subterranean leaching chambers required a great deal more space than a tunnel customary in ore mining.

Under such circumstances it was necessary to employ trained surveyors so that mine catastrophes, e.g. due to intersections, could be avoided. Added to this was the fact that the Austrian saltworks were in the possession of the sovereigns, who generally invested very generously in technical concerns. Numerous new initiatives regarding mining and then technologies as well stemmed specifically from the Austrian salt mines - and as a result many impulses furthering mine surveying knowledge came likewise from the alpine salt mines[11].

In actual fact, the oldest mine plot in central Europe, on which the measurements made with compass and other surveying instruments were plotted for the first time true to scale and the respective lengths exactly noted, stemmed from the salt mine in Hall in Tirol from the year 1531[12].

2. Innovations in the saltworks

The sovereigns allowed a great deal of experimentation regarding rationalisation of the saltworks. The procurement of fuel became more and more questionable as wood became scarce. This became the greatest problem in the Hallstatt saltworks. Here, at the end of the 16th century, one built a pipeline for transport of the brine from the mine to Ebensee, some 65 km away. Much experimentation also went into the form of the salt pans to equip them to function more efficiently with less heat. In this regard, a sensational success was achieved by Johann Josef Menz, a physician in Bolzano, who set up the first coal-heated pan and who basically revolutionised primarily the salt-boiling pans.

2.1 Brine transport pipelines

The measures undertaken by the sovereigns to offset the scarcity of wood were initially only patchy. When in Hallstatt the salt requirements could no longer be met as a result of the increased demand for salt because of the procurement of Bohemia and Moravia by the Habsburgs, in 1595 Emperor Rudolf II ordered the construction of a brine transport pipeline from Hallstatt to Laufen and then to Bad Ischl. In 1596 the pipeline was extended to Ebensee, where it was then possible to build a considerably larger salt-making facility than in Hallstatt[13]. As well, in Ebensee the wood needed for boiling was available in considerable amounts[14]. The approximately 65 km long pipeline was naturally a pioneer project that was based on plans worked out by the mining expert Hanns Steinberger together with mine inspector Kalß from 1593[15]. The project was carried out by Kalß and completed with the construction of the Ebensee saltworks, which lasted until 1607[16]. This was already 20 years before the famous construction of the brine pipeline from Reichenhall to Traunstein, which also had to overcome a very considerable altitude and consequently required a more complicated technology[17], as compared with the pipeline from Hallstatt to Ebensee, which was able to follow a natural gradient.

2.2 Salt pan experiments

For the saltworks in Hall in Tirol the entire upper Inn valley and part of the Engadin region had been cleared of timber up to the start of the 16th century[18]. Using less wood for the pans became an absolute necessity. Interestingly enough, it was not saltworks experts who took up the problem, but itinerant alchemists, inventors, physicists, adventurers, and even local merchants and clergymen[19]. Some of these *Feuerkünstler* (lit: masters of fire) designed fantastic, fully unrealistic plans; others made well thought out suggestions. In the saltworks itself one always viewed these *Feuerkünstler* as foreign interlopers[20].

Experiments could be carried out only when the *Feuerkünstler* were expressly supported by the sovereign, and even then the pan house workers in Hall sometimes found ways to evade them[21]. The sovereigns, however, whose goal was to implement effective measures of rationalisation, were very interested in the *Feuerkünstler* and were also prepared to support them financially. Conversely, the pan houses were sceptical of all innovations.

One of the first, really significant *Feuerkünstler* was Martin Fencius from Bolzano[22]. His first project, which he started in the Hall saltworks in the year 1594, consisted in installing a vault and a air furnace underneath the stoking furnace. He believed that this would improve the aeration of the hearth and thus lead to better combustion, which of course would also save a lot of wood[23]. The idea as such was not so bad, but what was lacking in Fencius' later projects - Fencius was able to gain entrance to the saltworks frequently in the following years - was a solid scientific and technical foundation[24].

In 1607 Archduke Maximilian dispatched the Innsbruck bell founder, Heinrich Reinhard, who also produced salt pans, and the Hall scribe, Michael Pardeller, to Parma, whose saltworks were evidently making gigantic profits, where the two were to devote particular attention to the famous metal pans used there. Their report, however, closes with the observation that the large profits of the Parma saltworks were not attributable to more skilful manipulations or even a lower consumption of wood, but from the extraordinarily high salt prices, which were seven times higher than those in Tirol. For all that, Pardeller pressed for the ordering of a new pan[25]. Probably prestige reasons and interest in the foreign wonderwork played a role here[26]. What came of this, however, was that in the same year, 1607, bell founder Reinhard received the commission to cast a pan like the one he saw in Parma. Three years later, namely on 11 April 1611, Reinhard delivered the ordered pan to the saltworks[27]. The success of the new pan, however, was not very great.

In the year 1614 Martin Fencius reappeared with a project that was actually very reasonable. It involved using the steam originating from the boiling process to pre-heat the brine. However, this plan was rejected with reference to the fact that due to his previous experiments Fencius had already cost the saltworks 1651 Mark, 7 Kreuzer and 4 Pfennige[28].

When Archduke Leopold was appointed governor in Tirol in 1619, he no longer wanted to have anything to do with Fencius, who died on 13 March 1623[29].

Of all the *Feuerkünstler* of the 17th century, Hans Braun stood out due to his exceptional skills[30]. His innovative suggestions can be summarised as follows:

1. A brine pan should have a bottom with an area of 80 m^2, closed on all sides and have inclined openings only on the side towards the stoking furnace. The heat flowing through these openings should be utilised to dry the salt.
2. The pan should be set up on two thin, 24-ft-long iron bars and furnished with a grate.
3. To prevent heat losses, the dehydration compartments had to be tightly sealed.
4. The brine should be pre-heated in three stages in exactly described apparatus by utilising the surplus heat from the boiling process.
5. Instead of wood, stone coal should be used in future to heat the brine pans[31].

His really well thought out projects, however, were flatly rejected - much to the disadvantage of Tyrolean saltmining. His ideas were taken up, however, again and again and to some extent also realised[32].

For the sake of completeness, two further *Feuerkünstler* of a very special type should still be mentioned: the two adventurers Raphael Allemani[33] and Francesco de Giusti[34]. They still belonged to the circle of those medieval researchers who sought the philosopher's stone or the elixir of life[35]. The *Salzmair* (saltworks director) - the highest official in the saltworks - Anton von Tschiderer, undertook a journey in 1710 to the various saltworks in the Salzkammergut region to be able to bring back new ideas. Both the saltworks here as well as that in Hall in Tirol had been under the control of the Viennese Court Chamber since the 16th century. In 1712 the pan house office was instructed to erect a new pan facility based on the suggestions made by Tschiderer. The new Tschiderer pans were horseshoe-shaped with a larger pan area (about 100 m^2). The concentrated brine was pumped out of the central storage chamber by means of a water wheel[36].

2.3 The Tyrolean pan

The so-called *Tyrolean pan* had indeed the most sweeping success in rationalising the operation of the pan house.

In 1757, at the suggestion of Dr. Nikolaus Sterzinger, Professor of Medicine at the University of Innsbruck, a smaller coal-heated test pan was set up[37]. The improvement of the pan had to be evaluated while still in the planning stage and then somewhat later the Inspector of Mines, Anton von Lemberger, requested a small test pan[38]. The actual production of this salt pan, however, was carried out by the Bolzano physician Dr. Johann Josef Menz von Schönfeld[39]. Menz improved the test pan significantly and was appointed Saltworks and Mint Director by the Viennese Court Chamber[40]. A further Menz pan was constructed in 1765 and five new pans were set up ready for operation by 1775[41].

In actual fact, this so-called *Tyrolean pan* was very energy conserving. It was based by and large on the following system: 1. a rectangular instead of the previous round form; 2. a central and mobile furnace; 3. dehydration of the wet salt blocks directly next to the pan for better utilisation of the heating gases; 4. the use of copper pipes to pre-heat the brine; 5. the narrowing of the furnace grate as well as the shortening of the fire arcs; 6. the covering of the pan and the construction of vapour flues; 7. the increased saturation of the brine[42]. Dr. Menz had to fight a 30-year nerve-wracking battle for his ideas, which completely threw all previous views overboard - he was even suspended from duty - until a man in the Salt Mining Inspectorate in Aussee and later an official in the higher inspectorate in Gmund, Josef Freiherr von Lenoble, sided with him as a strong supporter and helped him to achieve success by speaking personally with the Emperor[43]. The newly introduced production methods, however, caused the cancellation of numerous working places, the consequence being resistance against Dr. Menz primarily from the workers in the saltworks[44].

The installation of the new pans also necessitated the building of new salt-boiling houses[45]. But only when Lenoble had achieved a significant success by building the Menz-type pan in Aussee in the year 1795 was the ban breached for the new pan and the new salt-boiling house[46]. Already in 1796 a *Tyrolean pan* was set up in Ebensee as well[47].

This new *Tyrolean pan* brought extremely positive results: in the Upper Austrian salt-boiling houses, for example, salt production was increased from 1776 to 1802 from 437,000 Viennese metric hundredweight - approximately 56 kg[48] - to 716,000 hundredweight, which is almost equivalent to a doubling of salt production[49].

Finally in the year 1821 the decision was made in the Upper Austrian Salzkammergut region to modify all pans to conform with the Tyrolean type. Accordingly, in the years 1822/26 in Ebensee a double-pan was constructed and in the years 1823/32 in Ischl a *Tyrolean pan*[50].

3. Concluding remarks and results

The sovereign or his governmental authorities were always the driving force behind innovations. They also saw to it that saltworks personnel were constantly rotated among the various saltworks. They also had the necessary capital to have innovations tried out. As the operators of the salt mines they were interested in ensuring that the saltworks and mines were at the latest state of technology. They were open-minded towards the *Feuerkünstler* as well. The elements slowing down such progressive developments were the pan houses and miners, whose primary concern was the conservative maintenance of operations as they had been before. They were often employed for decades in the saltworks or mines and therefore wanted only to preserve old practices. In point of fact, they rejected almost every innovation. For this reason there were often confrontations between the authorities and the pan house or mine workers.

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