

# Technology Transfer in the Salt Industry in Central Europe in the 16th Century

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## ABSTRACT

At the outset of modern times, the salt industry in Europe was at a stage of development that can be traced back in its essential structure to the 12th or 13th century. The characteristics of the technical process in the spring-fed salterns included simple winning methods at the spring and evaporation of the brine in lead or iron pans over a wood fire in the salt-boiling houses. In Alpine salterns, there was also the important stage of brine collection in dish-shaped cavities. The following technical innovations were thus developed and implemented at various production sites in the 16th century: (1) Improved winning techniques at brine springs, with not only fresh water winning systems (Süßwasserabschöpfanlagen, Reichenhall) but also rationalization of the winning process (Lüneburg) attaining a role of central importance. The production technique at Wieliczka (tread-wheels) also belongs to this category of innovation. (2) Optimization of the evaporation process by producing larger salt-boiling pans (Austria) or by using pre-warming pans (Sulz am Neckar or Schwäbisch Hall in Germany). (3) Construction of straw graduation works from 1562 onwards in salterns whose brine had a low salt content. (4) Introduction of coal firing in place of wood firing (England, Germany). (5) Construction of long brine canals to locations providing adequate woodland for wood firing (Ischl, Ebensee, Traunstein).

In the course of the 16th century, technology transfer in the salt industry implied on the one hand a transfer of technical know-how from other economic sectors (winning technique from mining) but on the other hand — and this applies to virtually all innovations connected with salt production — the development and implementation of new technical equipment (pans) and structures (graduation system, hearth constructions). Technical innovations and the transfer of these innovations thus played a major role in leading the salt industry in Europe to an upswing and to a time of prosperity which was then, however, followed by stagnation in extensive areas of the continent with the outbreak of the Thirty Years' War in Central Europe (1618–1648).

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## INTRODUCTION

The 16th century Europe, salt was won in different ways: sea salt in salterns, rock salt from salt mines (e.g. Wieliczka and Bochnia), pan-boiled salt from brine collected in dish-shaped cavities or artificially flooded chamber (= Sinkwerke, e.g. Hall in Tyrol), pan-boiled salt from brine springs (e.g. Lüneburg or Reichenhall in Germany) and pan-boiled salt from seawater (e.g. in England). Attention is focused in this paper on the production of rock salt and in particular of pan-boiled salt from brine springs (see generally Bridbury, 1955; Multhauf, 1978; Bergier, 1982; Palme, 1983; Hocquet, 1985; Piasecki, 1987; Hocquet, 1987; Emons and Walter, 1988; Lamschus 1989; CIHS-Bibliographie 1, 1990; Hocquet and Palme, 1991). To improve the production sequence and rationalize winning methods, an active search for new techniques began in the 16th century, follow-

ing a long stagnation period. For this reason there is ample evidence of inventions and technology transfer during the second half of the 16th century — or earlier in the case of handling techniques at brine springs — with the majority of inventions relating in particular to graduation techniques and to new pan and hearth constructions. The innovations were thus focused on the one hand on reducing wood-energy consumption, and on the other on increasing production whilst keeping energy consumption at the same level (Gleitsmann, 1980, p. 104ff.).

## INVENTIONS AND PATENTS

### *Inventors' privileges*

Technical development in the 16th century within the territory forming the Holy Roman Empire of the German Nation was encouraged by the granting of the first inventor's patents to individuals. Evidence

found to date shows 78 patents granted in the period up to 1600 A.D. In addition, there were national sovereign patents on a smaller scale, especially in the Duchy of Saxony; these are not dealt with in further detail at this juncture. Table 1 lists those inventions awarded an imperial inventor's privilege for an invention designed to improve salt production. Sixteen inventors can be identified here. If the number of saltern patents is related to the total number of all patents granted, it becomes apparent that the 16 recorded patents represent a proportion of almost 21%, a substantial quantitative value offering impressive evidence of the significance of salt-centred issues in the 16th century as compared with other branches of the economy (Pohlmann, 1960, p. 282; Gleitsmann, 1985, p. 73f).

The motivation for all efforts aimed at improving economic organization and implementing technical innovations in the 16th century is based primarily on the increasing demand for salt as a product. Various factors stimulating demand can therefore be verified. Among the most important are the marked increase in population (Kellenbenz, 1977, Vol. 1, p. 216) in the "long, peaceful 16th century" following the plague-ridden centuries, and the increased use of food-preservation methods — especially for fish (Fellmann, 1961, p. 58). Furthermore, salt production was becoming increasingly attractive to the owners of salt-boiling houses as an economic venture because it generally provided good earnings. To quote one example: of the 1.5 million gulden representing the revenue of the Duchy of Bavaria in 1600, an imposing 300,000 came from salt production at Reichenhall (Vogel, 1971, p. 61).

### Raising techniques

Various water-raising techniques were developed and used in a wide range of constructional elements in the Mediterranean region in pre-Christian times. These techniques include — with respect to the systems used in salt-winning facilities in the Middle Ages and at the outset of modern times — raising water with a scooping bucket, with a winch or hoist, with a chain bucket system and with a piston pump. These techniques were now reapplied, improved, further developed and supplemented with newly developed methods in Central Europe and in England in the Middle Ages and thereafter.

In 15th and 16th century saltern operation, various raising techniques are found side by side in the production facilities. Yet it is certain that brine-raising by scooping bucket and draw wells in particular was a widespread, simple method. We find this technique in the Lüneburg saltern until 1569 and in Schwäbisch Hall even as in the 18th century (Carlé,

TABLE 1

Imperial inventor's privilege relating to salt production in the territory of the Holy Roman Empire of the German Nation in the 16th century

Year of invention	Inventor
1558	Berthold Holzschuher
1559	Hans Rudolf Blumenkher
1560	Hans Conrad
1568	Wolf Rauchhaupt
1570	Markus Rohling
1571	Georg von Harstall
1572	Hieronimus Neuner u.a.
1575	Jeremias Neuner
1577	Dr. Georg Kandler
1579	Martin Zobel
1580	Johann Rudolf Weiss u.a.
1580	Stephan Hadoth
1580	Jobst Teichmann
1590	Andreas von Afflen d.Ä. und d.J.
1594	Balthasar Motzart
1598	Johann Marquart von Rheinsberg u.a.

Source: Müller 1941, p. 102ff; Pohlmann 1960, p. 282; Gleitsmann 1985 p. 70ff; Piasecki 1987, p. 301ff.

1965, p. 72). Alongside this method, however, the winching technique with buckets or scoops, as described by Schickhardt in 1593 with reference to the Saulnot saltern in France, remained in use especially in salt mining (Staatsarchiv Stuttgart, N 220 T 58).

These raising techniques soon proved inadequate in those salterns with a higher production capacity. An efficient system had to be found of raising the brine on the one hand and, in many cases even more important, of dealing at the same time with the frequently greater quantity of "fresh waters" ("Wildwasser" or "süßen Wasser") accruing. For this reason, a search for other possibilities was made in Reichenhall at an early stage. Artificial hydraulic power for raising spring water, generated by what was described as a "Kunstmaschine" — in fact a chain bucket system driven by a wooden wheel eight meters in diameter and fitted with 64 leather scooping buckets — was built according to plans by Erhard Hann of Zabern from 1437 onwards (Kurtz, 1978, p. 29). This technique, however, was ousted as early as 1507 (Kurtz, 1978, p. 31) by the construction of a Paternoster pumping system (Heinzenkunst), as had been used back in the 1450s for mining at the Rammelsberg in Goslar (Troitzsch, 1982, p. 170). For this purpose, Grasser constructed a triple chain system running in pipes, with leather pouches attached to the chain (Stadtarchiv München, P 1361/VI/28).

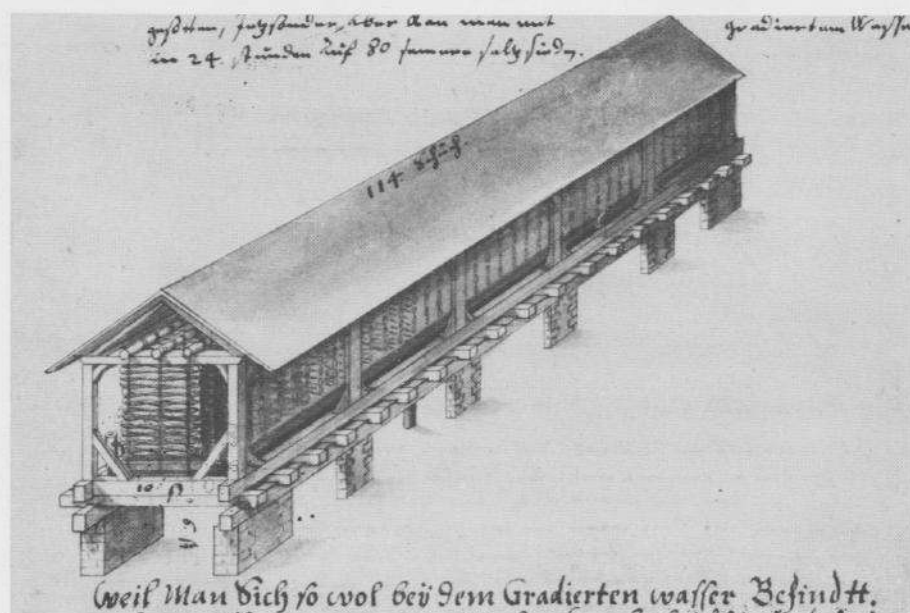


Fig. 1. Trickling works (straw graduation house) at the Sulz saltern in south-western Germany, dating from 1595. (Hauptstaatsarchiv Stuttgart, N 220 T 60. Alle Rechte vorbehalten.)

Various forms of mechanical brine and fresh-water scooping systems are found to have been implemented in European salterns in the early 16th century, for instance in Salins, Rosières and Dieuze (Hägermann and Ludwig, 1984, p. 162f) or in 1543 in Allendorf (Multhauf, 1978, p. 68). The mid-16th century, however, saw the dawning of the suction and pressure pump era. This technique, designed before 1450 by the Siennese engineer Taccola (Troitzsch and Weber, 1982, p. 170) and known in mining since the 1530s, if not earlier, was in use in Reichenhall in 1555 (Kurtz, 1978, p. 34f.), in Lüneburg (Reinhardt, 1981, p. 52, Fig. 2) in 1569, and in Salins (Hägermann and Ludwig, 1984, p. 162) in France in 1592.

#### Graduation houses

The first important 16th century invention developed specifically for salt production was a straw graduation house or Leckwerk, a precursor of the thorn graduation works known since the 18th century. The invention is to be attributed (Piasecki, 1987, p. 102ff.) to Caspar Seeler and Berthold Holzschuher — the latter had been awarded an imperial inventor's privilege for his invention in 1558 — who had developed the process in the 1550s and offered it to Duke Albrecht Vth of Bavaria for his Reichenhall saltern in 1559 (Flurl, 1809, p. 32). In this case, however, negotiations on the project, described only indirectly by Seeler in the talks, never made headway, although the planned system was not viewed in a negative light according to reports from Reichenhall.

In the same year in which Seeler began his negotiations with the Bavarian sovereign, he also started negotiating with the Prince-Bishop of Würzburg on re-establishing the saltern in Kissingen. The negotiations ran more smoothly than in Reichenhall, and the outcome was a contract concluded in 1562 between the bishop on the one hand and Seeler and Holzschuher on the other on the lease of the saltern (Piasecki, 1987, p. 119, Fig. 9). In the following years the leaseholders built in Kissingen the first "Leckwerk" or trickling works for brine graduation in Germany, most likely the first in Europe (Multhauf, 1978, p. 54).

The structure illustrated in Fig. 1 showing the straw graduation house at the Sulz saltern erected in Wurtemberg in southern Germany in 1595, has all the structural elements of the invention making a good visual impression. The elongated, roofed structure was placed on a stone base and had in its lower part open wooden crates sealed against brine leakage, with plaited straw mats suspended on a wooden frame above them. The lads employed at the works threw the brine against the straw mats with large scoops. As the brine trickled off, its salt concentration increased because some of the water evaporated.

#### Pans

Another aspect of salt-works to which saltern operators turned their attention increasingly in the 16th century was the design and construction of the salt-boiling pan. Georg von Harstall first offered his invention to the Landgrave of Hesse who, however,

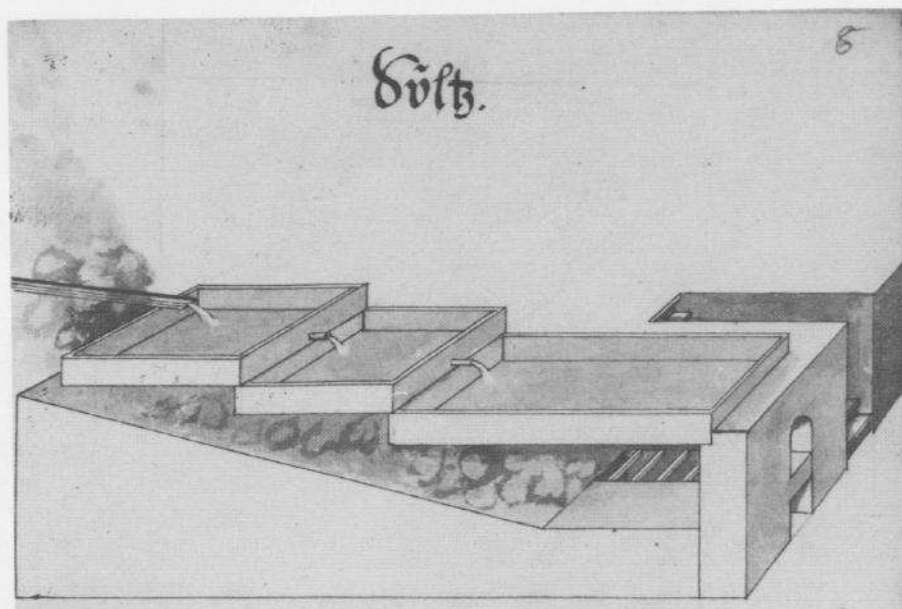


Fig. 2. Pan system with two pre-heating pans, dating from 1595, at the Sulz saltern. (Hauptstaatsarchiv Stuttgart, N 220 T 60. Alle Rechte vorbehalten.)

showed no interest in the invention after consulting his own salters (Rach, 1935, p. 27). Harstall then had better luck with the Duke of Saxony, who offered the inventor the opportunity of demonstrating his new technique in Salzungen in 1571 (Rach, 1935, p. 25 and Piasecki, 1987, p. 181). Harstall's invention, which was used with various modifications in a large number of salterns in subsequent years, provided (Fig. 2) for a second, generally smaller pan to be placed beside the actual salt-boiling pan in which the salt-winning process took place, and below which an appropriate fire was kept going, in such a way that the hot fumes escaping from the fire heating the salt-boiling pan would flow past below the prewarming pan to preheat the brine in that pan. The preheated brine was then to be used to top up the salt-boiling pan for the evaporation process. The inventions in both Salzungen and Sulz show that the prewarming pan was placed at a higher level than the salt-boiling pan and that the two pans were connected by a defined brine outlet. The workers at the salt-boiling houses only needed to open a tap or draw a plug to make the brine flow from the prewarming pan into the salt-boiling pan, with any increase in brine temperature in the prewarming pan implying a saving in energy (wood).

#### Coal firing

The introduction of coal as a substitute for wood in the salt-boiling industry in continental Europe dates back to the late 1550s. At the Allendorf saltern, the knowledgeable salter Johannes Rhenanus, who

published a two-volume handwritten work on salt-erns and the salt industry with special reference to Germany (Cramer, 1879; Walter, 1989), set up experiments with coal which he obtained as homeward freight from Liège (Koch-Sternfeld, 1836, p. 77; Multhauf, 1978, p. 69). In the time following, in which teething troubles gave way increasingly to success, he exploited the coal deposits at the Meissner, not far from Allendorf, permitting more and more pans to be converted from wood to coal firing in the salterns in his charge (Piasecki, 1987, p. 206ff; Emons and Walter, 1988, p. 165).

Technology transfer for the use of coal in the salt-boiling process apparently ran from England to Germany, though the names of those involved in the transfer and the exact route remain unknown. In England, which was still importing some 24,000 tons of salt in the early 16th century, the Tudors sponsored the development and re-opening of the domestic salt-boiling facilities, so that the innovative use of coal is recorded there from 1546 onwards. By the end of the 16th century, this technique had asserted itself throughout England—in contrast to continental Europe (Bergier, 1982, p. 89f and Multhauf, 1978, p. 56f.).

One fundamental problem in the use of coal was the hearth construction. A special iron grid, as drafted and described by Schickhardt in 1593 for a hearth at the Saulnot saltern (Fig. 3), had to be developed for this purpose. The bars of this grid were placed very close together to prevent coal from dropping through. Schickhardt noted in the margin of his clear, techni-

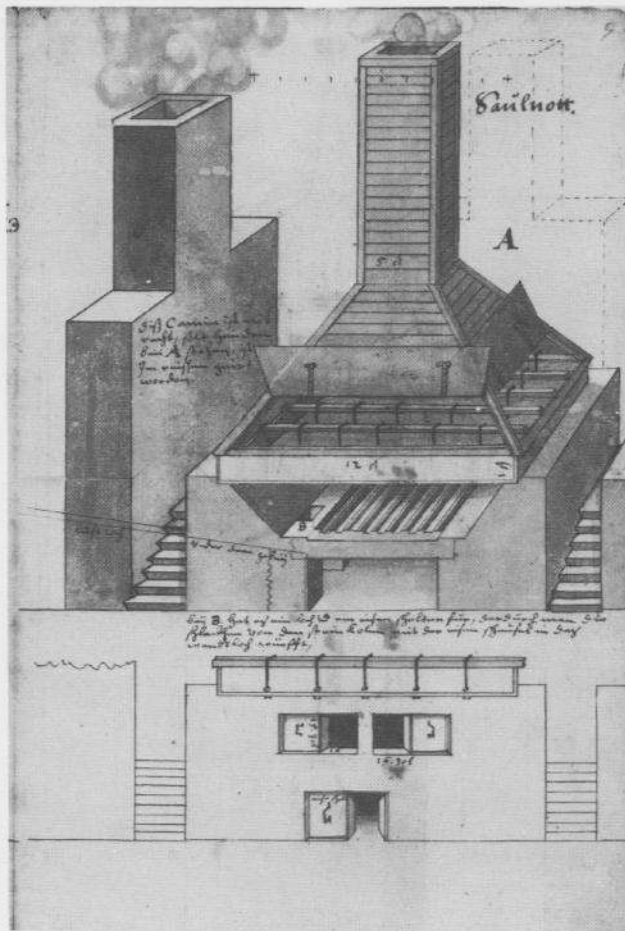


Fig. 3. Pan system with pan-cover and iron grid for coal firing dating from 1593, at the Saulnot saltern in France. (Hauptstaatsarchiv Stuttgart, N 220 T 58. Alle Rechte vorbehalten.)

cally advanced drawing, which shows the hearth in horizontal projection and in cross-section: "der Rost hat 22 eisern stangen, die ligen wegen der stein kolen nur ein Zol von einand" (The grid has 32 iron bars which are only one inch apart because of the coal; Hauptstaatsarchiv Stuttgart, N 220 T 58).

### Brine canals

Although it was indicated earlier in this paper that the demand for salt underwent a steady rise in the further course of the 16th century, it is emphasized once again that the problem of obtaining sufficient wood at reasonable prices was becoming increasingly virulent. It is hardly surprising, then, that the idea of transporting the brine to a location still offering enough woodland for economically efficient salt-boiling was taken up in the innovative period of the salt industry, especially in the second half of the 16th century. Initial concrete plans for implementing projects of this complexity were developed in southern Germany, where proposals

were put forward in 1559 to channel brine from Berchtesgaden to Reichenhall (Klaiber, 1940, p. 42), and in 1577 to run excess brine from Frankenhausen to Poserna in Saxony (Fürsen, 1897, p. 51ff. and Piasecki, 1987, p. 231f.). Both ventures — although planned partially in very great technical detail — failed, however, so that the first major brine conduit, taking brine from Hallstatt to Ischl, was not built until 1595 (Schraml, 1932, p. 197).

### Rock-salt mining

Whilst many of the smaller Central European boiling salterns whose brine had a low salt content were seeking to expand their production through the implementation and transfer of new techniques, the owners of rock-salt mines or of salterns whose brine had a high concentration of salt showed a stronger tendency to increase their output by restructuring their organization and production.

We now turn our attention to the mines at Wieliczka (Piotrowicz, 1984, p. 177ff.), whose workforce in the early 16th century numbered about 500. To increase production, horizontal mining to exploit previously untouched deposits was now given priority. However, vertical development had provided a third working level at a depth of 120 meters by the end of the 16th century. At the same time, the workforce strength was doubled by 1570 to about 1000, a three-shift system was expanded to cover the entire day, and the annual working hours of all workers underwent a substantial increase. The 16th century also saw the introduction of pit ponies for underground haulage as well as continuous further development of the whim method of raising salt. Evidence of the high level of organization and technology is found in the fact that underground surveying and plotting work was under way as early as the second half of the 16th century, to enable deposits to be managed according to plan and to provide maps of all galleries. These combined measures brought about a substantial increase in production at Wieliczka in the 16th century, so that the annual production figure there had reached a scale of 25,000 tons of rock salt by 1600. In comparison: under the rule of Kazimierz the Great (1333–1370), the combined output of the mines at Wieliczka and Bochnia was no more than 10,000 tons.

### TECHNOLOGY TRANSFER AT THE SALT-BOILING CENTRES

Trickling works technology was transferred almost exclusively by salters, many of whom held an imperial or national sovereign patent and who offered their know-how and their knowledge of

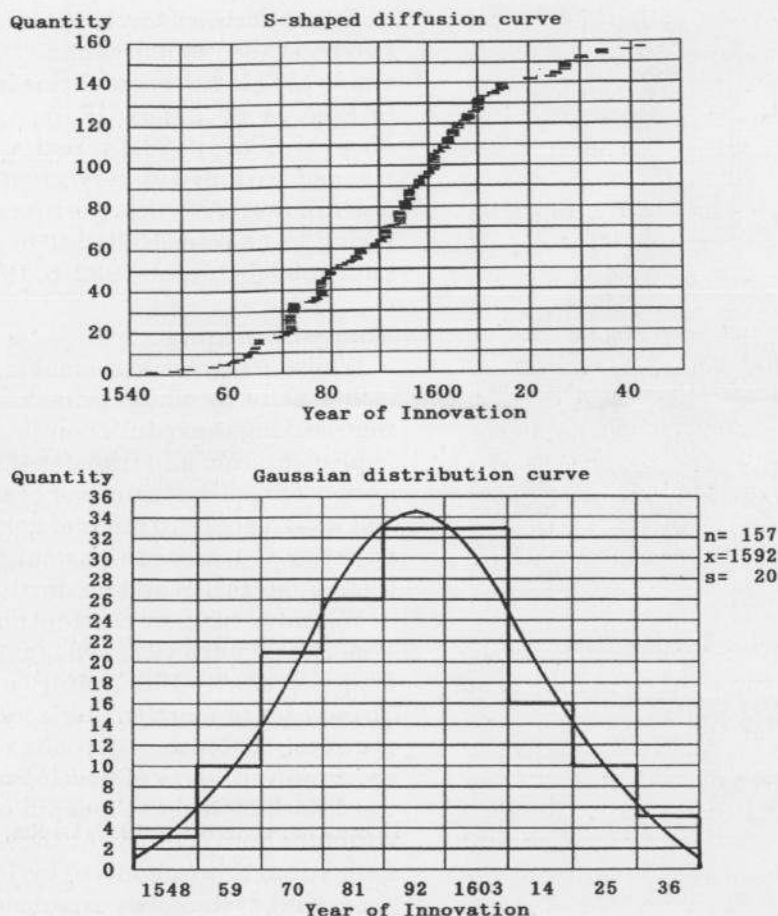


Fig. 4. Illustration of the technology transfer of 157 individual innovations at Central European salterns by means of an S-shaped diffusion curve and a Gaussian distribution curve derived from it (by Peter Piasecki).

various salterns. There is, for instance, evidence that persons working on behalf of Caspar Seeler and Berthold Holzschuher established contacts — beyond those already mentioned with the Reichenhall and Kissingen salterns — with the salterns at Sooden (Blöcher, 1931, p. 70) in the Taunus region in 1566, with Niedernhall and Sulz (Krünitz, 1823, vol. 133, p. 699) in south-western Germany in 1567, and with Sulza (Wirth, 1991, p. 356) in Thuringia in 1568. There is also evidence of contacts with the Aigle (Silberstein, 1961, p. 71) saltern in Switzerland and with Lüder (Piasecki, 1987, p. 323ff.) in Germany. Although their plans could not be implemented immediately at all these locations, this personal style of technology transfer illustrates the dynamics with which the technical innovations were diffused. The process of innovation was curbed above all at those salterns where an ownership structure handed down from the Middle Ages in the form of salterns' guilds (Sälzergilde) impeded the technical modernization process. Yet there is evidence of 37 implemented graduation works innovations at 37

different saltern locations on German territory in the period between 1563 and the mid-17th century (Piasecki, 1987, p. 120ff. and 1990, p. 170ff.).

Whilst the relevant technology for the trickling works technique was transferred through the above-mentioned salterns until about 1600, there was then a change in the situation. Thölde's book "Haliographia" (Thölde, 1603, p. 58ff.), published in 1603, provided the first generally accessible information on and description of straw graduation houses. It can thus be established that know-how relating to the functioning, structure and mode of operation of this technique was available to be copied by all salterns some 30 years after the invention was patented.

The diffusion of other new techniques in the salt industry was just as dynamic as the spread of the trickling works technique. New pans with prewarming pans were set up at 15 salterns between 1571 and 1614, 13 salterns were converted from wood firing to coal firing between 1560 and 1626, and long brine conduits were planned in detail or implemented at 12 salterns. The innovative dynamics of the period

from about 1560 to 1610 are also illustrated by the establishment, reestablishment or attempted establishment of many new salterns, 73 of them documented in the years between 1543 and 1615 (Piassecki, 1987, p. 203, 227, 249, 283f.; 1989, p. 170ff; 1990, pp. 173–176).

In conclusion, let us take a look at the intensive technology transfer of all new techniques in Fig. 4, where the S-shaped diffusion curve is shown in the upper part and the Gaussian distribution curve derived from it for the period from about 1550 to 1650 in the lower part. The temporal structure of this innovative epoch in the Central European salt industry is evident too, as the graph also shows the respective upswings and declines. The development in rock-salt mining with its wide range of activities fits well into this context.

## CONCLUSIONS

In the course of the 16th century, technology transfer in the salt industry implied on the one hand a transfer of technical know-how from other economic sectors (winning technique from mining) but on the other hand — and this applies to virtually all innovations connected with salt production — the development and implementation of new technical equipment (pans) and structures (Graduation system, hearth constructions). Technical innovations and the transfer of these innovations thus played a major role in leading the salt industry in Europe to an upswing and to a time of prosperity which was, however, followed by stagnation in extensive areas of the continent with the outbreak of the Thirty Years' War in Central Europe (1618–1648).

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