COLLECTION MONETA • 194

FROM UNDERGROUND TO END-USERS

Global Monetary History in Scientific Context

Meeting at the University of the Pacific, San Francisco, Stockton,
16-22 May 2016

Georges Depeyrot & Dennis O. Flynn, eds.

MONETA, WETTEREN 2016

COLLECTION MONETA • 194

FROM UNDERGROUND TO END-USERS

Global Monetary History in Scientific Context

Meeting at the University of the Pacific, San Francisco, Stockton, 16-22 May 2016

Georges Depeyrot & Dennis O. Flynn, eds.

MONETA, WETTEREN 2016

Cet ouvrage a été publié avec le soutien du laboratoire d'excellence TransferS (programme Investissements d'avenir ANR-10-IDEX-0001-02 PSL* et ANR-10-LABX-0099).

This book has received support of TransferS (laboratoire d'excellence, program "Investissements d'avenir" ANR-10-IDEX-0001-02 PSL* and ANR-10-LABX-0099).

ISBN 978-94-91384-62-2
Dépôt légal 2016/9381/03

MONETA, Hoenderstraat 22, 9230 Wetteren, Belgium, Fax (32) (0)9 369 59 25
www.moneta.be

A chemical revolution
The development in assaying at Danish mints c. 1830-50

Michael Märcher[1]

Introduction

This paper focuses on the important change in silver assaying techniques in the first half of the 19th century through a study of the development at the Danish mints.[2]

One of the two Danish mints of the 19th century was situated in the capital Copenhagen. The other mint that existed 1771-1863 was located in the then second largest city of the realm, Altona, now a suburb of the German city of Hamburg.

The change in assaying was part of the chemical revolution of the nineteenth century. It is one of several examples of how medieval minting techniques were relatively quickly replaced in the 19th century as coin production was mechanized and modernized. The massive increase in the coin production's quality and quantity during the 19th century led to new possibilities, and it was put to use everywhere in the monetary policy. The mints were preconditions for the creation of the new, stable, and modern monetary systems. As technical infra-structure installations the mints were part of the technology-based modernization and state-building directed to some degree by the new and often more centralized governments of the Nation-States of the 19th century. New, stable, common, and uniform monetary systems were of course vital to the development of banking, trade, and finance systems. But the importance was not limited to these economic sectors of society nor to the technological aspects. The stable and common monetary system with widespread use of coinage was – like a common language – a uniting factor; it brought different parts of society closer together both in the local, regional, and national level and between urban and rural areas.

Assaying

The assaying of metals involves taking a representative sample of a given quantity of metal to establish its components. At the two mints, assaying was undertaken to establish the fineness of a given quantity of gold or silver. Copper for copper coins was usually only thoroughly investigated if it was apparently abnormal, for instance, due to an unusually high lead content.

During the coin production process, assaying was undertaken several times. The precious metal was assayed before being melted down, for instance, after it was delivered. The first assay was necessary in order to be able to estimate the quantity that needed to be melted down to produce the correct alloy. Before the casting of the melted down substance, a control assay was undertaken, *the crucible test*, and the metal was tested twice, with *the scrap test* and *the piece test,* later on in the production process.[3]

---

[1] National Museum of Denmark.

[2] This paper is based on a chapter (p. 74-82) in a dissertation published 2012 (in Danish, here translated by Patrick Marsden) about the technology and production of the Danish mints: Michael Märcher: *De kongelige møntsteder i Altona og København 1813-1873. Teknik og production* [The royal mints in Altona and Copenhagen 1813-1873. Technology and production]. Odense 2012. References to archival records, books, articles etc. behind the relevant chapter in the book are not repeated in this article, but can be found in the book. The only exception is quotations that are given a reference.

[3] The samples that were taken, a proportion of which were kept for some time by the mint assayer as documentation, were, in the case of silver, most often c. 7.3 grams (=½ *lod*) (3.7 grams (=¼ *lod* in Copenhagen before 1832). Gold samples were much smaller.

In the 19th century, various methods of assaying were used.[4] The mints had to use the most precise method, if it was compatible with the time spent and the economic costs. Assaying was undertaken at the mints during this period in two different ways: *the dry way* (the cupellation test) and *the wet way* (the Gay-Lussac method).[5] The minting of silver, which finance was based upon, dominated the century and silver assaying, therefore, will be focused upon in this article. The two mints, like other European mints, switched from using the cupellation test, which had been used since the Middle Ages, to the method for assaying silver 'discovered' by Gay-Lussac in 1830. The assaying of gold, on the other hand, did not change significantly in the period and the cupellation test continued to be used.

The cupellation test

Both mints had several rooms where assaying was undertaken and assay furnaces (fig. 1) for both gold and silver. Assaying was a chemical investigation that involved specialised equipment, such as assay balances (fig. 2).

The cupellation test, which had been used since the late medieval period to assay silver, involved melting down the sample together with lead in a cupel (fig. 3), perhaps inside a muffle (fig. 4), in an assay furnace, so that copper and other impurities separated from the silver. The sample taken was then divided into two exactly equal parts, which were weighed as precisely as possible. The samples were then formed into thin sheets using small, hand-operated rollers, after which they were ready. The so-called assaying lead had to be as pure as possible and more lead had to be used if the silver was of low quality. The quantity of lead was determined by a preliminary test, for instance, c. 10-12 as much lead as the sample had to be used if the silver was presumed to be 750‰ silver. The empty cupels were placed in the muffle, which was then put into the assay furnace. The furnace was heated until the cupels were red hot and the lead was then placed in them. After the lead had melted, one of the silver sheets, as mentioned above, was placed in each cupel. Due to the temperature and the lead oxides formed, the base metals separated as slag from the silver. Most of the slag was absorbed by the cupel. After cooling down and cleaning, the two parts of the sample were weighed and compared. The two parts, after the period spent in the furnace, ought to have weighed exactly the same, as they had the same weight before the melting down and were assumed to be of the same fineness. It was thus a control test. If the two parts did not correspond, a new assay had to be undertaken. If they tallied, the cupellation had been successful. Weighing and comparison with the weight before the melting down enabled the fineness to be calculated.

At European mints, it had become clear since the second half of the 18th century that the method resulted in an unsatisfactory degree of fineness. This was an accepted aspect of coin production, since at the time there was no better method to replace it. The margin of error was c. 0.4-1.6 grams (=½-2 *gren*), the uncertainty was often 4-6 ‰, depending upon the fineness of the silver. This was estimated on the basis of a silver loss of circa. 1-7 ‰ in the cupel, depending upon the fineness of the silver. Metals like gold and platinum also might not be separated from the silver. In addition, the temperature differences in the furnace and between different furnaces were a source of error, and the depth of the cupels and the porosity of the tests also influenced the results. On the other hand, the method was very quick, with tests usually taking no more than 30 minutes. It was also a particularly well-known technique that had been used in mints

[4] See P.R. Hinnerup: *Haandbog for Juvelere, Guld- og Sølvarbeidere*, Copenhagen 1839; E. Schlösser: *Die Münztechnik*, Hannover 1884 and e.g. H.C. Ørsted 1828: Et Capitel af den elektromagnetiske Probeerkunst, *Magazin for Kunstnere og Haandværkere*, nos 82-83, pp. 441-49.

[5] *The touch test*, where the precious metal sample is used to make a line on a touchstone, which then is compared with touch needles of various known degrees of fineness, was probably sometimes used as *a preliminary test* before the more precise assaying of silver took place. This was aimed at quickly estimating the approximate fineness of the sample, which could then be used as the basis for subsequent more precise assaying.

for hundreds of years. Therefore, few doubts existed about the cupellation test until J.L. Gay-Lussac (1778-1850) presented a new method in 1830.

The assaying of gold was also undertaken using the cupellation test. However, higher temperatures were required and silver had to be added to the gold samples (2½-3 as much as the gold sample) before they were placed in the cupels with the melted down lead. It was necessary to be able to separate, amongst other metals, copper from the gold in the cupel. After the time spent in the furnace, the remaining sample, consisting of melted together gold and silver, was rolled, made glowing hot and formed into a thin spiral. It was then boiled in different solutions of nitric acid, so that the silver dissolved. The gold was left and the fineness of the sample could be determined on the basis of the weights before and after. In connection with the transition to the gold standard in the 1870s, the Copenhagen mint invested in new gold assaying equipment. In preparation for the large-scale gold assaying that was soon to be undertaken and in order to acquire platinum for tools, mint assayer Groth went on a study tour that included a visit to Berlin in 1873.[6] After this, the mint purchased a gas assay furnace in Berlin and platinum equipment from Johnson Matthey & Co. in London.[7]

The Gay-Lussac assaying method

The Gay-Lussac method "may be regarded as a dividing line between medieval technology and modern science."[8] The development in assaying was part of chemistry becoming generally more scientific, in other words the transition to modern chemistry. It was also an example of how new knowledge within chemistry could be of economic importance.

The new and more difficult method involved titration that is a chemical method to determine the quantity of a substance in a solution. The silver sample was dissolved in nitric acid. A standard salt solution was added to this, causing a precipitation reaction to occur: silver chloride was formed and precipitated. It was necessary to establish exactly how much salt solution needed to be added in order for all the silver to be precipitated. In other words, how much salt solution had to be added to reach the equivalent point? The reaction was visually observed. When the reaction was approaching, the strong standard solution was replaced with a weaker solution. These solutions were made up of refined salt and distilled water. The strong salt solution, *die Normalauflösung*, was used to estimate the fineness. At a temperature of 15 degrees Celcius, 100 cm^3 of the solution would make 1 gram of silver precipitate as silver chloride. The 10 times weaker solution, *die Zehntauflösung*, was subsequently used to precisely determine the fineness, as 1 cm^3 of this at the same temperature made 1 mg of pure silver precipitate. To establish exactly how much salt solution was needed to precisely satisfy the silver solution, it was sometimes necessary, near the end of the test, to add a small amount known silver solution followed by a small amount of salt solution, this being repeated until a result was obtained. By comparing the added quantity of salt solution, possibly minus what had been necessary to add to compensate for the extra added silver solution, with the original silver sample's weight, the fineness of the silver sample could be determined more precisely than in the cupellation test. The margin of error in the 1830s was only 1-1½ ‰. However, the method was more difficult than the cupellation test. The sources of error included the temperature in particular, but also the precision of the measurements, evaporation and silver samples contaminated with mercury or lead. The new method also took longer if undertaken by an inexperienced person. The time spent, however, very much depended upon whether the sample's approximate fineness was known in advance. This was almost always the case in the

[6] The plan involved visits by Groth to Berlin, Dresden, Hanover and possibly also Vienna.

[7] The gas assay furnace was bought from Th. Issem's *Fabrik für Gas Schmelz-, Emmaillir- und Probiroefen*. The firm of Johnson Matthey & Co., which still exists (www.matthey.com) and has undertaken chemical analyses since 1817, had in the 1860s developed platinum containers for assay samples, which could replace glass flasks, thus saving both acid and time spent, as well as minimising the risk of accidents during the assaying process.

[8] Maurice Crosland 1978: *Gay-Lussac*, Cambridge, p. 188.

assaying of coins, bars and meltings, but otherwise the touch test or the cupellation test could be utilised as a preliminary test.[9]

The new method and Denmark in the 1830s

The method's introduction in the Danish realm differed from the general European pattern. In France, a commission consisting of, amongst others, several renowned chemists, including Gay-Lussac, worked towards the development of a better assaying method in 1829-30. After numerous experiments undertaken by the most important assayers and mints in Europe, including H.F. Ausborn at the mint in Altona, it became clear that the cupellation test produced a fineness that was on average nearly ½ % too low.[10] On this basis, a new method was developed, where the new aspect was not the titration itself, but rather the equipment and procedure, which enabled sufficiently precise measuring to be undertaken. The new method was soon introduced in France, and during the 1830s large parts of Europe followed, including Belgium, England, the Netherlands, Sweden, Austria and large parts of Germany. In the Danish realm, it was partially introduced in 1841, but was not generally adopted until 1847.[11]

In 1830, the Danish Finance Deputation received a paper about the new assaying method, after which the newly-established College of Advanced Technology (Den Polytekniske Læreanstalt) was asked to produce a report on the method.[12] This was completed a year later. The report was based upon experiments conducted at the College of Advanced Technology itself, as well as a visit to Paris to learn the method in Gay-Lussac's minting laboratory by journeymen goldsmith, and later mint assayer and mint master, P.R. Hinnerup. The report highlighted the new method's inaccuracy of 1-1½ ‰ compared to the cupellation test's 4-5 ‰, which is why the new method was particularly effective as a control test. It also drew attention to the fact that the method was slower. The mints had previously been informed about this subject and both mints acquired equipment in Paris, which could be used to undertake the new method. The mint masters had to adopt a position regarding the College of Advanced Technology's report. Freund in Altona stated that the monetary system could easily switch to the new method, but it would result in a difference in fineness between the coins minted before and afterwards. In addition, it was hardly realistic to introduce the method as long as the Hamburger Bank (fig. 5) did not use or recognise it. It was, however, desirable to use the method for adjusting the cupellation test. Mint master Svendsen, after undertaking tests, was in agreement that the new method could replace the old one, but believed that at the time it was probably only appropriate to use it as a supplementary test. The mints could not introduce the new method because of the neighbouring countries, which in 1832 had not yet introduced it. The silver that the mints bought, sold or minted was valued using the old method, and thus lower, in the neighbouring countries, if only the realm adopted the new method. Similar contemporary concerns in Berlin over an increase in the price of purchased silver and a potential solitary approach, meant that the new method was not introduced in Prussia in the first half of the 1830s. The matter was laid to rest for the time being in Copenhagen in 1832, when the Finance Deputation, based upon the views of the College of Advanced Technology and the two

[9] For further details of the method and its associated difficulties, see J.L. Gay-Lussac 1833: *Vollständiger Unterricht über das Verfahren, Silber auf nassem Wege zu probiren*, Braunschweig; Hinnerup 1839; Schlösser 1884; Konrad Schneider: Untersuchungen zur Edelmetallverhüttung und Probierkunst in Hamburg, *Zeitschrift des Vereins für Hamburgische Geschichte*, vol. LXXI, 1985, pp. 1-44.

[10] Samples for assaying were sent by the commission to assayers at the mints in Vienna, Madrid, London, Utrecht, Naples, Hamburg, Altona and Paris, as well to various assayers in Madrid, Amsterdam, Naples and Paris. This shows how respected the mint in Altona was. Certain important mints were not involved in the investigation, possibly due to the political circumstances of the time.

[11] The new method was associated with *Dresdener Münzvertrag (the Dresden Coinage Convention),* which covered most of Southern Germany and was concluded in 1838. This arrangement also played a role in the introduction of the method in Prussia.

[12] Gay-Lussac's *Instruction* was published in 1830, but it was not until 1832 that the larger work on the method was published. Crosland 1978, p. 220.

mint masters, decided that the new method should not replace the old one, but that the new method should henceforth be used, as much as possible, as a guideline for the cupellation test.[13] It was thus the economic circumstances, rather than any practical problems associated with the method, that decided the matter. This also applied during the 1840s. Up until 1847, the matter demonstrates how the realm's economic dependency upon Hamburg in the first half of the 19th century affected the techniques used by its mints.

There does not seem to have been significant monetary consequences of refraining from adopting the method during the 1830s. It is likely to have been due to the situation in Hamburg, where the price of the realm's coins was fixed. The introduction of the new method in Hamburg was a very long and complicated process, which continued until the 1870s. However, after the middle of the century, attempts were made in Hamburg to correct the taken cupellation tests for the silver loss in the cupel, as well as drawing attention to and valuing coins and silver on the basis that their stated fineness was based upon the new method. The new method, on the other hand, was of economic significance. A coinage would produce around ½ % more coins, if the new method was used. This was a persuasive and important argument in any country. However, it is first thought to have been used in the Danish realm in the 1840s.[14]

The matter reared its head again in the realm in 1839, when Ehlers submitted a proposal for the introduction of the method. The reason for this was that Ehlers had learnt and practised both types of assaying in Paris, during a long study tour. His proposal did not include much that was new, apart from pointing out that many countries now used the method, in contrast to the situation in 1830-32. Mint assayer Hinnerup, who was undoubtedly the person in the kingdom with the most experience of using the method, supported this and pointed out that for an experienced person the new test took no longer than the cupellation test. In addition, there was no reason to fear confusion in finance, inflation, removal of earlier coins or problems in relation to other countries, if minting utilised the new method, as it would mean that the 875 ‰ standard coin would contain the 875 ‰ it should, rather than the circa 879 ‰ it now did due to the cupellation test's margin of error. At home, coins were accepted at face value, as long as the state also accepted them at face value and made sure that the prices did not rise. Abroad, coins would always be valued according to their weight and fineness, without paying great attention to their face value, so the connection between face value and the weight of bullion in the coin was not so important. Sending coins abroad and the removal of earlier coins could not produce revenue, when the earlier coin was as little as, for example, 4 ‰ better, as coins usually lost more than this during circulation.

Hinnerup, however, did not have a good grasp of the silver trading problems. Mint master Svendsen pointed out that when silver was bought for minting, then the fineness of the purchased silver, in order to avoid the expense of alloying the metal during the melting down, should match the fineness of the coins produced. Therefore, the mints ought to use the same assaying method as the silver market in Hamburg. Freund said something similar and emphasised the importance of Hamburg when it came to the international value of the country's large standard coins. After the new method had been introduced to the minting of both the Swedish specietalers and couranttalers from Saxony, these coins were now traded in Hamburg at a lower exchange rate. The 875 ‰ Swedish specietalers produced using the new method were traded as if their fineness was 2-2½ *gren* (1 *gren* = c. 0.3472%) lower (11 *lod* 15½-16 *gren*). Freund feared that the Danish 875 ‰ specietalers would be valued to only contain c. 869.8-870.7 ‰ (13 *lod* 16½-16¾ *gren*) to the detriment of the whole realm. Both mint masters, therefore, had reservations in relation to the new method and the large standard coins. Svendsen

[13] The new method's use at the two mints in the 1830s was limited to sometimes being used to correct the cupellation test. This occurred more frequently in Copenhagen than in Altona.

[14] The Hamburger Bank was especially aware of developments at the Bank of England. When this institution generally started to use the new method in 1853-54, the Hamburger Bank did the same. See more on this subject in Adolph Soetbeer 1855: *Beiträge und Materialien zur Beurteilung von Geld- und Bank-Fragen mit besonderer Rücksicht auf Hamburg*, Hamburg, 39ff.; Friedrich von Schrötter: *Das Preussische Münzwesen 1806-1873*, vol. 1, Berlin 1926, p. 325 and Schneider 1986, 37pp.

was probably also against it, as he was aware that the Swedish mint master N.V. Almroth (1797-1852), an acquaintance of his, had publically been called a fraudster who had depreciated the Swedish currency, after the exchange rates for Swedish currency had fallen in Hamburg following the introduction of the method in Sweden.[15]

The new method and the Danish mints in the 1840s

When Freund, like Svendsen, confirmed his opposition to the new method's introduction for the large standard coins in 1840, he drew attention to the fact that the 8, 16 and 32 skillings could probably tolerate the change in fineness that the new method would result in. Even though they were standard coins, they were not international coins. In order to avoid possible melting down, it would actually be good if they were slightly less fine. As usual the Finance Deputation listened to Freund's advice, and in September 1841 it was decided with a resolution that the 8, 16 and 32 skillings should be minted using the new method in the future. The resolution includes Ehler's brief reflections on the matter, as well as Freund's arguments and wordings. The decision apparently did not lead to any monetary or production problems, and in 1845 it was decided that the 10 and 20 skillings of the Danish West Indies should also be minted using the method.[16]

During the 1840s, large-scale melting down and mintings were undertaken at the mints in an attempt to order monetary matters, especially in the duchies Schleswig and Holstein. Coins were also melted down abroad, primarily in Hamburg. The Danish specietalers were amongst the coins being melted, which damaged the realm's monetary system. The combination of these factors encouraged Collin to again raise the matter of the new assaying method and the standard coins in 1844. He wanted Freund to reassess the issue and wrote that the new method "was a means to hold our specietalers so much further from the crucible."[17] This did not change Freund's opinion. He stuck to his view of 1840, and pointed out that the realm's location in relation to Hamburg and the expected lower exchange rate after the introduction of the new method would not protect the standard coin from melting down "but carry it much more to the crucible."[18] This is what had happened to the Swedish specietalers and Sweden was located further away from Hamburg. Freund's opposition was again decisive and the case was dropped once more.

In 1847, the matter reared its head again, probably because Ehlers drew attention to the fact that nearly all of Europe, even Greece and Sardinia, now used the new method. Collin in the Finance Deputation took the case up once again and this time Svendsen also argued in favour of the method. Apart from pointing out that it was now also used in Russia, Svendsen then estimated that the current large minting taking place in Copenhagen would yield 10,000 rigsbanktalers more if the new method was used. This was a significant amount. The immediate economic advantages had to be compared with the importance of the exchange rate in Hamburg. Freund argued against this, referring to the fact that Hamburg itself had not yet used or accepted the fixing of fineness based upon the new method. It was irrelevant what the rest of the world did, and most important to the realm was still the Hamburger Bank, "which is the great touchstone our coinage for [hundreds of years] has been assayed by and it is my firm conviction that it is not advisable to undertake any change in the test before the Hamburger Bank itself has

[15] The Swedish mint master and professor Almroth was well-informed about international matters and taught chemistry, which may have been of significance to the early introduction, from a Scandinavian perspective, of the new assaying method in Sweden.

[16] The fact that the matter was not resolved until 1841, even though the discussions mainly took place in 1840, was due to monetary developments and the changes that the coinage had to undergo following the king's death in 1839.

[17] "var vel et Middel til at holde vore Species saa meget længere fra Digelen." Danish National Archives, Mønten i Altona, Indkomne breve, 1844, 8.

[18] "men meget mere befordrer den til Diglen." Danish National Archives, Mønten i Altona, Kopibog, 1844, 30/1.

introduced the wet way to judge by."[19] Freund's advice was not followed. The potentially lower valuation in Hamburg could or should no longer stop the transition to the modern and more accurate method, which meant more coins per quantity of silver. The Finance Deputation announced that, in the light of international developments, they could not wait any longer to introduce the method. It must not, on the basis of the assaying method, be profitable to remint the kingdom's relatively finer coins. It was, however, profitable since so good smelting and refining facilities now existed, that the circa 4 ‰ which the Danish standard coins now were too fine, became interesting in relation to the melting down costs. In March 1847, came the resolution that all silver minting was to be undertaken using the new method.[20]

Just as the matter up until the decision in 1847 illustrates the dominant role of Hamburg, so the decision is an example of the change in the 'dependency' relationship between the realm and Hamburg, which started before the middle of the century, amongst other things, due to the Danish National Bank's less cautious credit policy from 1835 onwards. In 1847-48, considerable quantities of the large standard coins were minted, but the exchange rate in Hamburg is not thought to have been affected by the transition to the new method. The relatively late transition to the new method was thus probably a success, with mintings that produced more coins per quantity of silver and a probably reasonably unaffected exchange rate. The absence of reference to any negative monetary consequences of the introduction of the new method or significant melting down of Danish currency abroad must indicate that the new method did not have a negative impact upon the coinage. It must, on the contrary, have had a positive impact, as fewer of the realm's coins were apparently melted down in other countries. In terms of production, the new method was more precise, which meant products of better quality that now corresponded better with the Coinage Act's stipulation for a fineness of 875 ‰. In addition, as already mentioned, the method meant an immediate economic profit, as a quantity of silver now produced a relatively larger number of coins.

Summary

Silver assaying changed at European mints during the 19th century: in the second quarter of that century a better, modern scientific method quite quickly replaced the less precise method that had been used since the Middle Ages. The old cupellation test, in which impurities were separated from silver using lead oxides and heating, was replaced by a method that was developed around 1830 in Paris by a number of the leading chemists of the time. The new Gay-Lussac method involved titration, in which silver dissolved in nitric acid was precipitated using standard salt solutions. With this new method, the fineness of silver could be determined more accurately. The deviation was circa 1-1½ ‰, compared to the circa 5‰ that the cupellation test measured too low. The new method was thus economically beneficial, meant an improvement in the quality of coin production and was also of monetary significance.[21] After its discovery in

[19] "som er den store Probeersten vort Myntvæsen i … har været proberet paa og er det efter min faste Overbevisning ikke raadeligt at foretaget nogen Forandring med Pröven förend Banken i Hamborg selv har indfört den vaade Pröve at regne efter." Danish National Archives, Finansministeriet, Sager til Møntjournalen, A725.

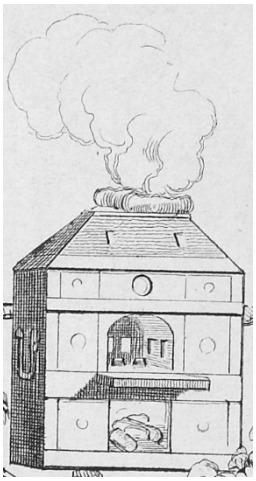
[20] In terms of production, the new method posed a problem, as the two mints had to have a piece of chemically pure silver of precisely the same fineness as a standard for there to be complete uniformity in the assaying. This was not a task that the mints or the College of Advanced Technology could undertake. However, the Copenhagen refiners Drewsen & Hansen produced a usable bar. It was tested at the College of Advanced Technology to 998.70 ‰, found to be uniform, divided in two and then sent to the two mints. In January 1847, the chemist H.C. Drewsen had gained permission to open a gold and silver refinery in Copenhagen. This was not a problem in relation to the mint's monopoly or its refinery, which was demolished in 1850. From 1848 onwards, silver medals were to be manufactured using the new method.

[21] For more information in English about the consequences of the improved coin quality etc. in a Danish perspective, see e.g. Michael Märcher: Coins, metals, and reforms: A survey of Danish monetary history 1813-1873, in Georges Depeyrot (ed.): *Moneys and Economies during 19th Century (from Europe to Asia). Collection Moneta 139*, Wetteren 2012b, 77-95; Michael Märcher: The 19th century development in minting technology in Denmark and Japan – and monetary transitions in Denmark, Japan, and

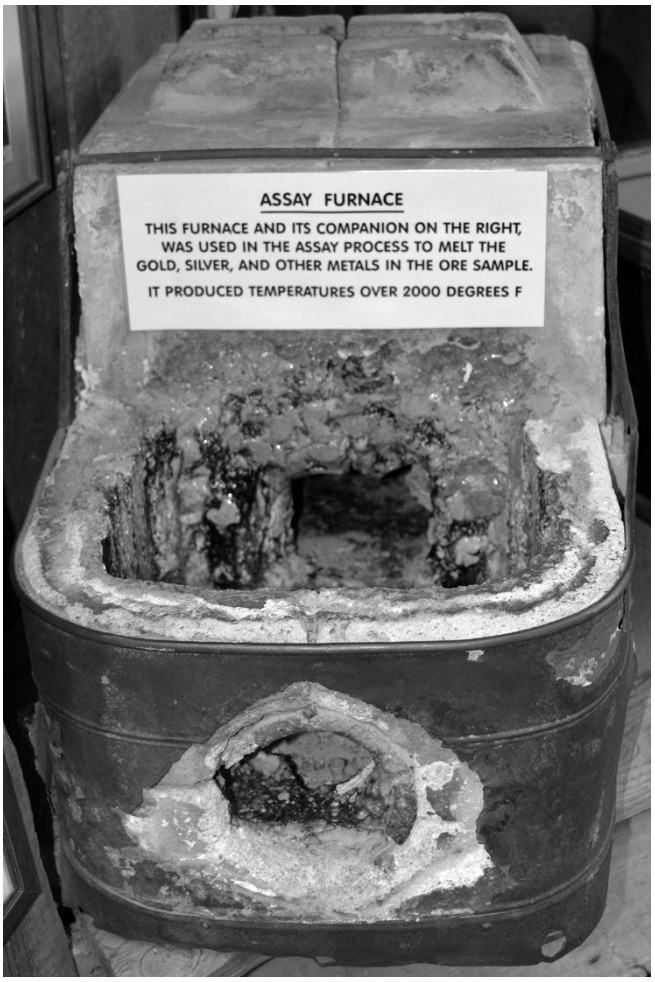
1830, the technique was soon widely adopted. Gold, however, continued to be assayed using the cupellation test during the period.

In the Danish realm, the new method was taken seriously. Testing was undertaken and a competent person was sent to Paris. Due to financial dependency upon the purchase of silver and the fixing of the exchange rates in Hamburg, the method was not introduced in the realm in the 1830s, as the Hamburger Bank did not recognise the new technique. The fineness of coins or bars was valued lower in Hamburg, if they were produced using the new method. This meant that the new technique was just used as a control in the realm during the 1830s and from 1841 onwards only in the minting of small coins. It was not until 1847, by which time nearly all of Europe was already using it, that the method was generally introduced into coin production. Despite possible disadvantages stemming from the method's lack of use in Hamburg, the financial administration could no longer risk the realm's relatively finer coins being extensively melted down in the numerous countries that gradually came to utilise the new method. In addition, the method resulted in immediate economic profit, as quite a few per thousands of extra coins could be minted from the same quantity. The introduction was apparently largely unproblematic. The monetary system reaped the qualitative advantages of the new technique, whilst the state and other customers reaped the financial benefits.

Bornholm, in Georges Depeyrot (ed.): *When Orient and Occident Meet. Collection Moneta 176*, Wettern 2014, 169-187.; Michael Märcher: Screw presses, Boulton presses, and Uhlhorn presses – The 19th century development in Danish coin striking machinery, in Georges Depeyrot & Michael Märcher: *Mints, Technology and Coin Production*, Wettern 2015 (Collection Moneta vol. 191), 221-257.

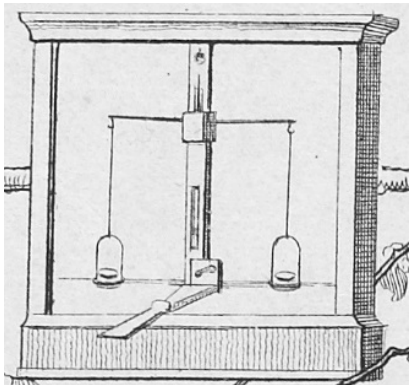


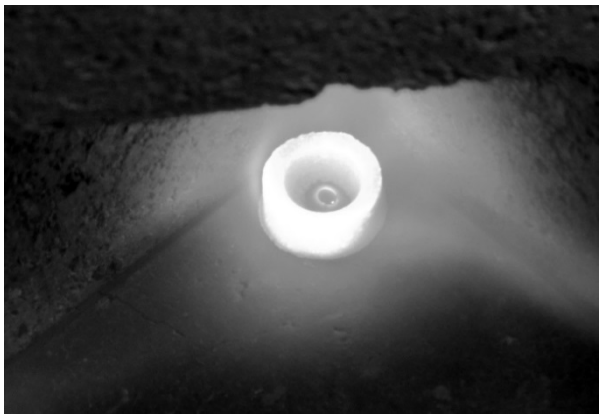
1a) Assay furnace with two cupels. An assay furnace was a small furnace in which it was possible to precisely control the air supply. Illustration from Schlösser 1884.

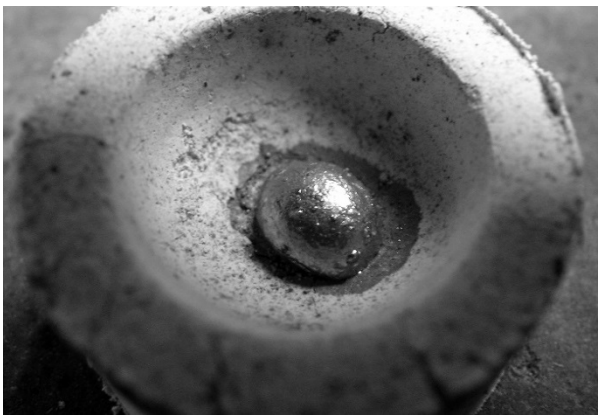


1b-c) Assay furnaces on display at The Way It Was Museum at Virginia City, Nevada.

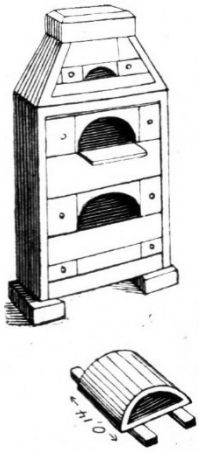
2) Assay balances were incredibly precise scales that were placed in glass cases, so that wind and other factors did not affect them. The scales had scale pans that were of precisely the same weight and completely smooth internally. The scale pans at the two mints were made of silver. During weighing, weights were placed in the scale pans or a sample in each scale pan. The weights were adjusted until an equal weight was achieved. Afterwards, the scale pans, including their contents, were swapped as a control, after which the weights should also have been equal. Very small weights were used with the precise assay balances. In 1858, the mint in Copenhagen owned a set of French assay weights of platinum, weighing between 0.0005 gram and 1.000 gram. Illustration from Schlösser 1884.







3) Cupels were small cup-shaped containers, in which the lead and the sample were placed and separation occurred. Their function was to absorb slag and they could not be made of a material that was affected by lead oxides. The cupels at the two mints were made of bone and/or wood ashes. The cupels shown are of a height, outer diameter and inner diameter of respectively 10, 22 and 14 mm. They have been used in modern assay 'testing' by German goldsmith and metal conservator Ulrich Sieblist. They consist of a) a newly-made, a roasted and a used cupel, b) a cupel in a heating furnace and c) a cupel with a silver sample after assaying. Note how the cupel has absorbed the slag. Photo: Ulrich Sieblist.



4) Muffle and muffle furnace. An assay furnace was a type of muffle furnace. A muffle was a fireproof iron container with a curved lid that was open at the ends. It ensured that the object to be heated did not come into direct contact with the flames. Illustration from Schlösser 1884.

5) The Hamburger Bank, obverse of silver medal from 1826 to celebrate the new bank building, 42 mm.

Contents

This volume contains proceedings of a 2016 California meeting, following the pattern established by the DAMIN program *La Dépréciation de l'Argent Monétaire et les relations Internationales – Silver Monetary Depreciation and International Relations* (www.anr-damin.net). This series of conferences encourages cross-disciplinary conceptualizations of monetary history in global context. Past meetings have encouraged fruitful interchanges among numismatists and monetary historians and the 2016 California conference was designed to encourage inclusion of mining historians – along with contributions from Geology – in coordination with contributions by numismatists, monetary historians, and business historians. Specialized expertise is essential for advance of scholarly research, of course, but insights from one specialty can (and do) trigger innovative ideas across traditional disciplinary boundaries. Contents of this volume attest to benefits from cross-disciplinary fertilization.

Given emphasis upon nineteenth-century topics at this 2016 California conference, organizers decided to meet initially for two days in San Francisco, a city founded in response to California's post-1848 Gold Rush, yet propulsion of metropolitan San Francisco to global status depended upon post-1859 Comstock Lode silver discoveries in Nevada (as emphasized in conference presentations). The conference venue shifted on Day 3 eighty miles eastward to the School of International Studies, University of the Pacific, in Stockton, a deep-water port founded at the time of the California Gold Rush. A lecture at Lake Tahoe on Day 4 focused on provision of water from the Nevada-side of the Sierra Nevada Mountains – gravity fed eastward down into the Carson Valley – then pushed up to the Comstock Lode farther eastward during the 19th century. The venue for Day 5 was historic Virginia City, Nevada, which is sinking due to its location directly atop a vast maze of mines shafts of the Comstock Lode, world dominant source of silver for decades. (There was also a side-visit to Sutro Tunnel, designed to drain wastewater from deep within Comstock Mines westward down into the Carson Valley.) An afternoon in Old Town Sacramento, historic port-city and railroad town through which Nevada silver was exported, highlighted the return trip to San Francisco on Day 6. It is hoped that in-person views of California/Nevada geological formations, challenging transportation routes, mines, coins, and environmental legacies have helped participants to visualize integrated systems that have historically linked – and continue to link – underground activities to diverse end-market destinations over thousands of years.

This volume is the proceedings of the San Francisco/Stockton/Lake Tahoe/Virginia City/Sacramento conference with the participation of Simon James BYTHEWAY (Nihon University, Tokyo), CAO Jin 曹晉 (Tübingen University), Julien CAVERO (Labex TransferS, ENS, Paris) Georges DEPEYROT (CNRS, Paris), Dennis O. FLYNN (University of the Pacific, Stockton), Saul GUERRERO (Independent scholar, London), Claudia de LOZANNE JEFFERIES (City University, London), Ursula KAMPMANN (Lörrach), Ivar LEIMUS (Estonian History Museum and Tallinn University), Michael MÄRCHER (National Museum, Copenhagen), David J. ST. CLAIR (California State University), Brigitte TOUITOU-MICHON (Paris) Agnès TRICOCHE (Labex TransferS, CNRS, Paris).

M

MONETA

Hoenderstraat 22, 9230 Wetteren, Belgique

FAX (32) (0)9 369 59 25

www.moneta.be

ISBN 978-94-91384-62-2