Chemical Analysis of 1794 & 1795 U. S. Silver Coins – Part 4 (Revised)

David Finkelstein & Christopher Pilliod – November 4, 2018

1. Introduction

This is the fourth article of a multi-part series. Part 1 was published in the September 23, 2018 *John Reich Newsletter (JRN)* and provided the historical overview of events that laid the foundation for this project. Part 2 was published in the October 7, 2018 *JRN* and reviewed the technologies available today to perform chemical analysis, the issues analyzing a silver-copper alloyed coin, and the goals of this project. Part 3 was published in the October 21, 2018 *JRN* and provided the X-ray Fluorescence (XRF) and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) analysis data for 1794 and 1795 copper and silver coins. Part 3 also provided the statistical analyses performed on the ICP-AES data, and preliminary conclusions based on the statistical analyses. The articles can also be downloaded from the *Newman Numismatic Portal* (https://nnp.wustl.edu/).

The Mint and Coinage Act of April 2, 1792 specified that silver coins were to contain 1485 parts of *pure* silver and 179 parts copper alloy. This equated to a standard of 1485 / 1664 or 89.24278% or 89.24+% pure silver, and 10.75722% or 10.76-% copper.

Documents written by Mint Directors Henry William de Saussure and Elias Boudinot specify that the Mint attempted to produce some, most, or all of the 1794 and 1795 dated silver coins to a standard of 90% silver and 10% copper.[1] Statistical analysis results based on the ICP-AES data presented in Part 3 support de Saussure's and Boudinot's statements. It was concluded that the Mint initially targeted 1794 silver coin production to a standard of 89.24+% silver and 10.76-% copper, and by early 1795, the Mint was targeting silver coin production to a standard of 90% silver and 10% copper. This was a violation of the Mint and Coinage Act.

Also per Part 3, residual levels of lead observed in the 1794 and 1795 Half Dollars support the theory that the Mint used the *Lead Refining Process* during 1794 and 1795 to refine silver bullion deposits. In order to corroborate this hypothesis, an analysis of the silver bullion deposits made with the Mint during 1794 and 1795, and an analysis of the warrants issued by the Mint to purchase lead is required. This article provides these analyses.

2. Gross Weight .vs. Standard Weight

Silver bullion deposits were made with the Treasurer of the Mint. The actual weight of each deposit was referred to as the *Gross Weight* (see Figure 1). Gross weights were logged in Mint ledgers in Troy ounces and pennyweights.

Each bullion deposit was sorted into piles of similar items. Each pile was weighed, and a small sample of each pile was assayed. The Assayer then calculated the future weight of the bullion deposit after the bullion was refined and the appropriate amount of copper alloy was melted with the silver. This future weight was referred to as the *Standard Weight*. Based on the standard weight, the value of the bullion deposit was calculated in United States money (see Figure 1). Standard weights were logged in Mint ledgers in Troy ounces and pennyweights.

Note that a distinction has to be made between *refining* and *melting*. Silver bullion deposits were refined by the Mint in multiple manageable batches or heats. Each refined heat was weighed, and using pencil and paper, the math was performed to calculate the appropriate amount of copper to add to the silver. The silver and copper was then melted, and poured into one or more ingots. Whereas the refining target was 100% pure silver, the melting target was either 89.24+% silver and 10.76-% copper, or 90% silver and 10% copper. Although this step in the Mint's workflow is referred to as Melting & Refining, it is actually Refining & Melting.

3. Analysis Of Silver Bullion Deposits Made In 1794 And 1795

Refer to Table 1 for the list of the 29 silver bullion deposits that were made with the Mint during calendar years 1794 and 1795. Note that the gross and standard weights of silver bullion deposits 1 and 6 in Table 1 do not match their corresponding gross and standard weights in Figure 1. Figure 1 is an image from the *Register of Silver Deposits*.[2] The gross and standard weights for silver bullion deposits 1 and 6 in the Register of Silver Deposits are incorrect. Per an entry in the *Waste Book* dated August 24, 1794, the weights were incorrect due to "*the inaccuracy of the Avoirdupois weights by which it was first weighed*" (see Figure 2).[3]

Note that the rows for 9 silver bullion deposits in Table 1 are shaded. The shading indicates that these deposits were not refined during 1794 or 1795.

- Silver deposit 8 was made by John Vaughan on July 9, 1795. Mint ledgers indicate that this bullion deposit was not processes during 1795..

- Silver deposits 19 through 22 were made by James Swan on July 14, 1795. When the deposits were assayed, higher than normal levels of gold were detected in the bullion. The deposits were then withdrawn from the Mint. Refer to Part 3 of this article series.

- Although silver deposits 26 through 29 were made during calendar year 1795, they were not transferred to the Chief Coiner for refining until January 15, 1796.

If an entry in Table 1 has "-I" after the deposit number, the bullion deposit consisted entirely of ingots. 22 of the first 25 silver bullion deposits were in ingot form.[4] Regardless as to the original form of the silver bullion in these deposits (e.g., foreign coins or jewelry), the bullion was melted, poured into ingots, then deposited with the Treasurer of the Mint.

Some may assume that every silver bullion deposit was refined by the Mint. This is an incorrect assumption. Based on the assay results, the silver percentage of a bullion deposit was at standard, above standard, or below standard. Only those bullion deposits that were below standard had to be refined.

3.1 At Standard: The "Already Refined & Melted" Column

Silver deposits 2 through 6 consisted of ingots that were deposited by Mint Director David Rittenhouse, Philadelphia merchant Charles Gilchrist, and the Bank of North America on August 22 and 23, 1794. Note that the gross weight of each deposit was also the standard weight of each deposit. This indicates that the ingots were already melted to the appropriate silver and copper alloy standard for silver coins. Although it may never be proven, these ingots were most likely melted by Assayer Albion Cox before they were deposited with the Mint.

Since these deposits were at standard, they did not have to be refined and melted again. The gross weights of these deposits are therefore included in the *Already Refined & Melted* column of Table 1.

3.2 Above Standard: The "To Be Melted" Column

Twelve of the 29 silver bullion deposits in Table 1 have standard weight values that are larger than their corresponding gross weight values. This is because the silver percentage in these deposits were greater than the standard (or above standard) for silver coins. Likewise, the copper alloy percentages in these deposits were less than the standard for silver coins.

Since the copper alloy percentages in these 12 deposits were too low, these 12 deposits did not have to be refined. All that was required was to first weigh manageable batches of each deposit, melt each batch, and add in the appropriate amount of copper alloy to raise the copper alloy percentage. This reduced the silver percentage to the appropriate standard for silver coins. The gross weights of these deposits are therefore included in the *To Be Melted* column of Table 1.

3.3 Below Standard: The "Had To Be Refined" Column

Three of the first 25 silver bullion deposits in Table 1 have standard weight values that are lower than their corresponding gross weight values. This is because the silver percentages in these deposits were less than the standard (or below standard) for silver coins. Likewise, the copper alloy percentages in these deposits were greater than the standard for silver coins.

Per Table 1, the gross weights of silver bullion deposits 1, 12 and 14 were greater than their corresponding standard weights. These deposits contained too much alloy, therefore they had to be refined to their precious metal content to remove all of the alloy, then melted with the appropriate amount of copper alloy to achieve the standard for silver coins. The gross weights of these deposits are therefore included in the *To Be Refined & Melted* column of Table 1.

3.4 The Amount of Silver Bullion Refined During 1794 And 1795

Based on the analysis in Sections 3.1 through 3.3, it is hypothesized that only silver bullion deposits 1, 12 and 14 were refined during calendar years 1794 and 1795. The gross weights of these three deposits totaled 96,687 Troy ounces or 3.01 metric tons (see Table 1).

4. Warrants To Purchase Lead From 1792 Through 1795

[Note: The authors thank R. W. Julian for identifying a few inaccuracies in this section after Part 4 was released on November 4, 2018. This section has been revised.]

Analysis of Mint warrant ledgers stored at the National Archives and Records Administration (NARA) indicate that the Mint purchased "lead pots and muffles", "bar lead", "sheet lead", "pig lead" and "lead".[5] Whereas "lead pots and muffles" were equipment used by furnace workers, it is assumed that "bar lead", "sheet lead", "pig lead" and "lead" was used to refine bullion deposits via the Lead Refining Process. Between October 16, 1792 and December 19, 1795, the Mint purchased approximately 5.98 metric tons of bar lead, sheet lead, pig lead and lead (see Table 2).[5]

Note that Mint purchase warrants for lead specify "lbs." or "tons" without the system of measurement. These weights are avoirdupois. During the 18th century, an avoirdupois ton was equivalent to 2,240 avoirdupois pounds.

Although some payment warrants specify the amount of lead purchased, most warrants do not. For those warrants that do not specify the amount of lead, extrapolations were made based on what the Mint paid for known quantities of lead around the same time of these purchases, or the selling prices of lead published in Philadelphia newspapers.

The prices for lead in Philadelphia remained constant from 1792 through 1795. Bar lead was selling at $7.00 *"per cwt"* or per hundredweight, and pig lead was selling at $5.33 to $5.67 per hundredweight (see Figure 3). Note that in the 18th century, the hundredweight was equivalent to 112 avoirdupois pounds.

5. The Lead Needed For Silver Refining During 1794 & 1795

Paul-Jacques Malouin (1701-1778) was a French physician and chemist. He was the leading contributor on chemistry in multiple publications and encyclopedias published during his time. In 1751 he authored *Affinage des métaux* (The Refinement of Metals). Page 160 of that publication provides an overview of how to refine silver via the "*lead method*". The following is a translated section from Malouin's publication:

> *"Refinement of metals is practiced differently in different countries and according to the different views of those who do the refining. For refining silver, there is a lead method, which is done with a well-dried, red-hot cupel heated in a reverberating furnace. Then, lead is added. The quantity of lead used is not always the same. You use more or less lead depending on whether the silver that you want to refine is suspected of having many or few alloys. To know how much lead is needed, put one part silver with two parts lead in the cupel. And if you see that the button of silver is not very clean, add more lead, little by little, until you have put in enough. Then calculate the amount of lead that you used, so you will know how much is necessary to refine the silver. Let the lead melt before adding the silver, and also the litharge that forms on the molten lead must melt. This is what is called in artistic terms bare lead or lead sheet . If you were to put the silver in too soon, you would risk the material jumping out. If, on the contrary, you delayed longer than it takes for the lead to become bare, you would ruin the procedure because the lead would be overly weakened by calcination".*

Per Table 1, silver bullion deposits 1, 12 and 14 had to be refined, then melted with copper to the appropriate standard for silver coins. Based on their standard weights, and depending on whether the Mint melted to a standard of 89.24+% silver and 10.76-% copper, or 90% silver and 10% copper, the amount of pure silver in the three silver bullion deposits can be calculated (see Table 3).

For example: John Vaughan made silver bullion deposit #14 on July 9, 1795.

1. After the deposit was sorted and assayed, the standard weight was calculated to be 1,966 ounces 14 pennyweights (or 1,967 Troy ounces rounded).

2. At a standard of 89.24+% silver and 10.76-% copper, 1,967 Troy ounces has 1,967 * 0.8924 or 1,755.3508 or 1,755 Troy ounces of silver.

3. At a standard of 90% silver and 10% copper, 1,967 Troy ounces has 1,967 * 0.90 or 1,770.3 or 1,770 Troy ounces of silver.

4. Depending on whether silver bullion deposit #14 was melted to a standard of 89.24+% or 90% silver, there were 1,755 to 1,770 Troy ounces of silver in the silver bullion deposit.

At an 89.24+% silver standard, there were 64,303 Troy ounces or 2.00 metric tons of silver in the three silver bullion deposits that were refined during 1794 and 1795. At a 90% silver standard, there were 64,849 Troy ounces or 2.02 metric tons of silver in the three silver bullion deposits. Per *Affinage des métaux*, at least two parts lead to one part silver was required. Based on the silver totals in Table 3, a minimum of 4.00 to 4.04 metric tons of lead was required to refine silver bullion deposits 1, 12 and 14.

6. Conclusion

It is postulated that the Mint refined 3.01 metric tons of silver bullion deposits during calendar years 1794 and 1795. These deposits contained 2.00 to 2.02 metric tons of pure silver. Per the "*lead method*", as documented by Paul-Jacques Malouin, a minimum of 4.00 to 4.04 metric tons of lead was required to refine these silver bullion deposits. Based on the lead purchases identified in Table 2, it is estimated that the Mint acquired approximately 5.98 metric tons of lead prior to December 20, 1795.

Although it is unclear if the process documented by Paul-Jacques Malouin is the exact process that the Mint used during 1794 and 1795 to refine silver bullion deposits, it provides a good estimate for the amount of lead required. It is therefore highly probable that the Mint purchased enough lead to support the refining of the silver bullion deposits via the Lead Refining Process during calendar years 1794 and 1795.

To be continued…

References

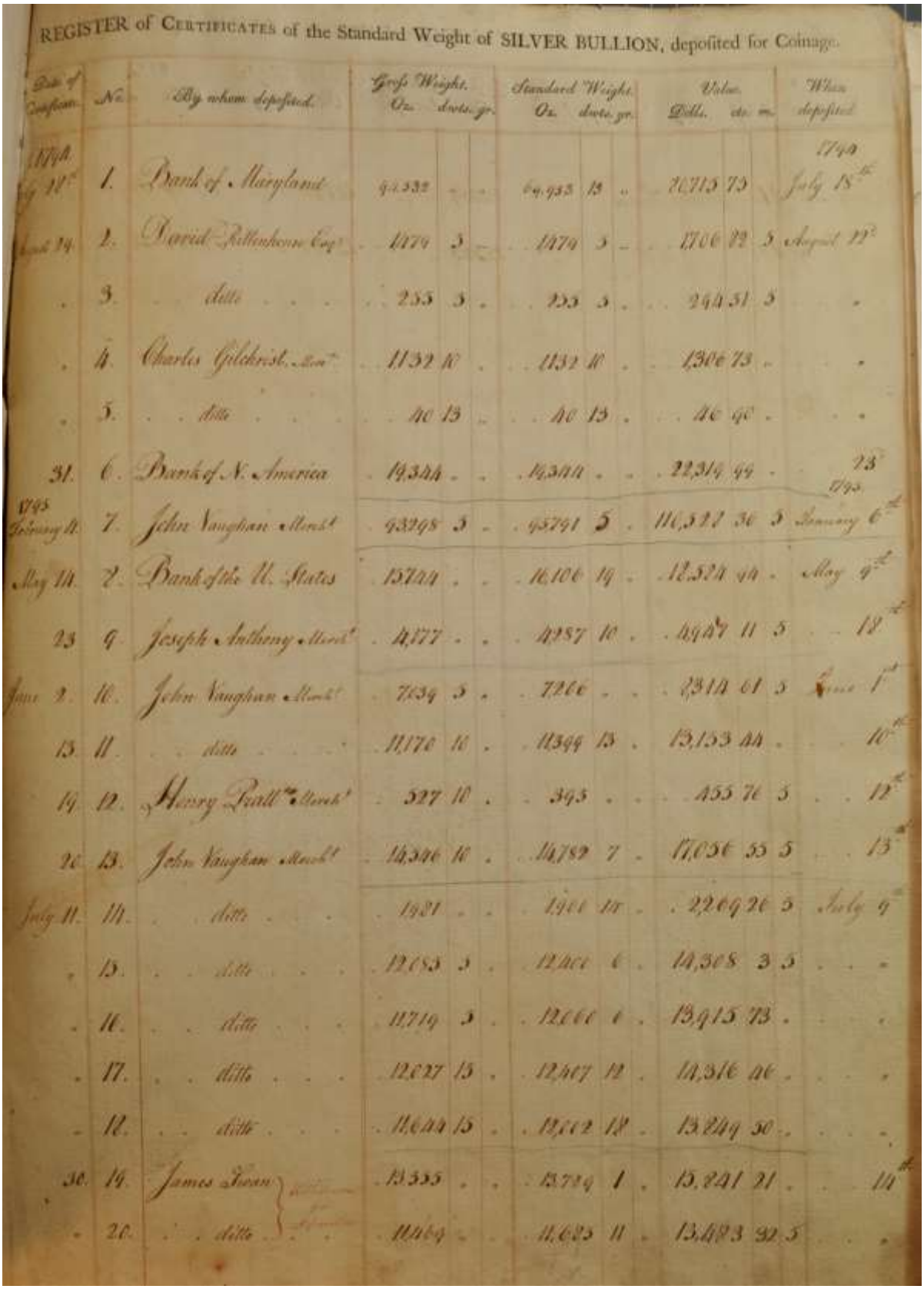
1. American State Papers. Documents, Legislative and Executive, of the Congress of the United States, Gales and Seaton, 1832, Finance, pages 356-358.

2. National Archives and Records Administration, Records of the U. S. Mint, Record Group 104, Register of Silver Deposits.

3. Ibid, Waste Books.

4. Ibid, Register of Silver Bullion.

5. Ibid, List Of Warrants For Expenses Paid, July 1792 To Dec. 1817.



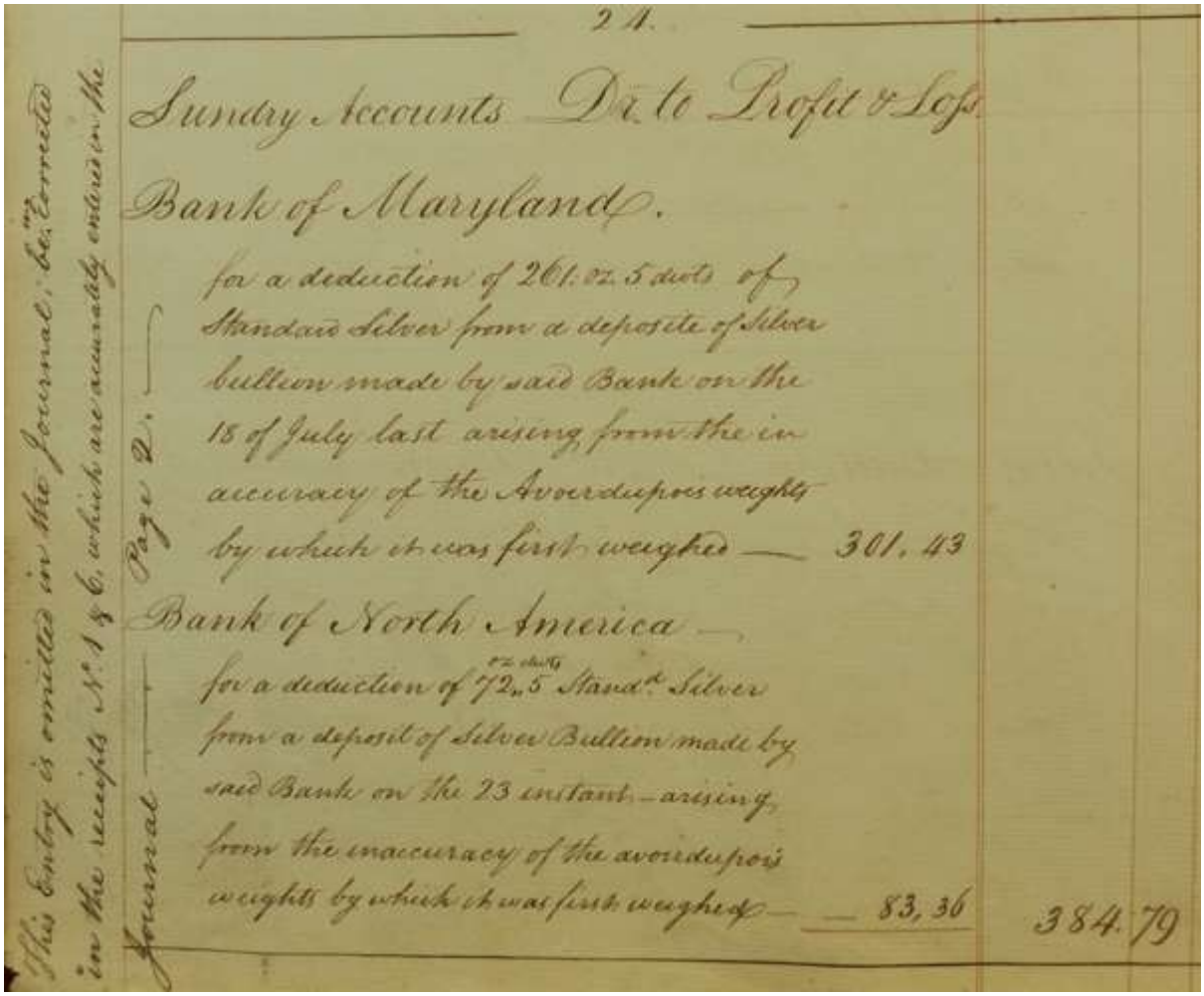
REGISTER of CERTIFICATES of the Standard Weight of SILVER BULLION, deposited for Coinage.

Date of Certificate	No.	By whom deposited	Gross Weight. Oz. dwts. gr.	Standard Weight. Oz. dwts. gr.	Value. Dolls. dc. m.	When deposited
1794 July 10	1.	Bank of Maryland	64332	64933 13	70715 73	1794 July 18
August 14	2.	David Rittenhouse Esq	1179 3	1179 3	1706 82 5	August 19
	3.	ditto	255 3	255 3	294 31 5	
	4.	Charles Gilchrist Assr	1132 10	1132 10	1306 73	
	5.	ditto	40 13	40 13	46 90	
31.	6.	Bank of N. America	19344	19344	22314 99	23 1795
1795 February 11.	7.	John Vaughan Assist	93398 3	95791 5	110,522 36 5	January 6
May 11.	8.	Bank of the U. States	15722	16106 19	18524 98	May 9
23	9.	Joseph Anthony Assist	4177	4287 10	4947 11 5	18
June 2.	10.	John Vaughan Assist	7634 5	7826	9018 61 5	June 1
13	11.	ditto	11176 10	11399 13	13,153 44	10
19	12.	Henry Pratt Assist	327 10	393	455 76 5	12
20	13.	John Vaughan Assist	14346 10	14782 7	17,056 55 5	13
July 11.	14.	ditto	1931	1911 18	2209 26 5	July 9
	15.	ditto	12683 3	12866 6	14,308 3 5	
	16.	ditto	11719 5	12066 6	13,915 73	
	17.	ditto	12027 15	12407 12	14,316 06	
	18.	ditto	11644 15	12002 18	13849 30	
30.	19.	James Swan	13355	13734 1	15,841 21	11
	20.	ditto	11269	11625 11	13,483 92 5	

Figure 1 - Register of Silver Deposits: Deposits 1 – 20

Silver Dep #	Depositor	Date of Deposit	Gross Wt Tr oz . dwt	Std Wt Tr oz . dwt	Already Refined & Melted	To Be Melted	To Be Refined & Melted
1	Bank of Maryland	07/18/94	94,179.00	69,692.08			94,179.00
2-I	David Rittenhouse	08/22/94	1,479.05	1,479.05	1,479.05		
3-I	David Rittenhouse	08/22/94	255.05	255.05	255.05		
4-I	Charles Gilchrist	08/22/94	1,132.10	1,132.10	1,132.10		
5-I	Charles Gilchrist	08/22/94	40.13	40.13	40.13		
6	Bank of N. A.	08/23/94	19,271.15	19,271.15	19,271.15		
7-I	John Vaughan	01/06/95	93,298.05	95,791.05		93,298.05	
8-I	Bank of the U. S.	05/09/95	15,744.00	16,106.19		15,744.00	
9-I	Joseph Anthony	05/18/95	4,177.00	4,287.10		4,177.00	
10-I	John Vaughan	06/01/95	7,039.05	7,206.00		7,039.05	
11-I	John Vaughan	06/10/95	11,170.10	11,399.13		11,170.10	
12	Henry Pratt	06/12/95	527.10	395.00			527.10
13-I	John Vaughan	06/13/95	14,546.10	14,782.07		14,546.10	
14-I	John Vaughan	07/09/95	1,981.00	1,966.14			1,981.00
15-I	John Vaughan	07/09/95	12,085.05	12,400.06		12,085.05	
16-I	John Vaughan	07/09/95	11,719.05	12,060.06		11,719.05	
17-I	John Vaughan	07/09/95	12,027.15	12,407.12		12,027.15	
18-I	John Vaughan	07/09/95	11,644.15	12,002.18			
19-I	James Swan	07/14/95	13,355.00	13,729.01			
20-I	James Swan	07/14/95	11,469.00	11,685.11			
21-I	James Swan	07/14/95	14,459.00	14,798.10			
22-I	James Swan	07/14/95	13,523.00	13,802.07			
23-I	Bank of the U. S.	09/21/95	16,961.05	17,360.17		16,961.05	
24-I	Bank of the U. S.	09/21/95	16,795.00	17,114.12		16,795.00	
25-I	Bank of the U. S.	09/21/95	16,999.10	17,426.18		16,999.10	
26	Henry Pratt & Co	10/10/95	299.05	217.18			
27	James Olden	10/24/95	1,029.00	748.08			
28	John Vaughan	11/21/95	710.03	719.00			
29	Edward Stow Jr.	12/21/95	1,016.05	1,037.04			
	Total Troy oz.		418,931		22,179	232,563	96,687
	Total Troy lbs.		34,911		1,848	19,380	8,057
	Total Metric tons		13.03		0.69	7.23	3.01

Table 1 – Silver Bullion Deposits: 1794 & 1795


21.

Sundry Accounts Dr. to Profit & Loss

Bank of Maryland.

for a deduction of 261. oz. 5 dwts of Standard Silver from a deposite of Silver Bullion made by said Bank on the 18 of July last arising from the inaccuracy of the Avoirdupois weights by which it was first weighed — 301. 43

Bank of North America —

for a deduction of 72 oz 5 dwts Standd Silver from a deposit of Silver Bullion made by said Bank on the 23 instant — arising from the inaccuracy of the avoirdupois weights by which it was first weighed — 83, 36 384. 79

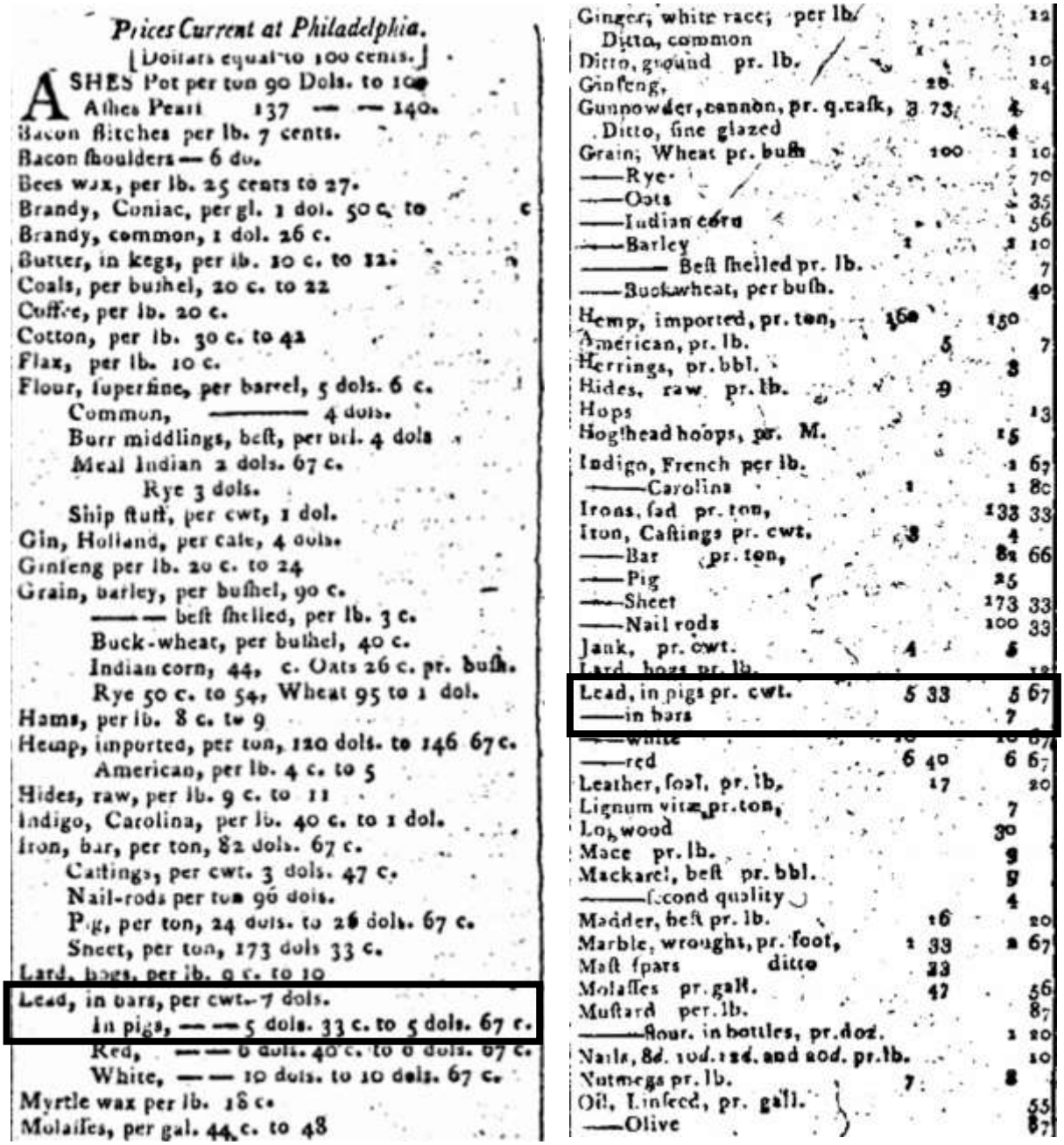
Journal — Page 2.

This entry is omitted in the Journal, &c. &c. Corrected in the weights N.o 1 & 6. which are accurately entered in the

Figure 2 – Waste Book: August 24, 1794

Warrant	Purchased From	Warrant Date	Warrant Amount	Lead (Troy lbs.)	Actual / Estimated	Text From The Warrant
17	James & Shoemaker	10/16/92	368.97	140	Actual	1451 lbs. of copper and 140 lbs. of lead
37	George Ludlam	12/12/92	33.33	500	Actual	500 lbs. bar lead
1	Mary Jones	04/01/93	9.03	?	Estimated	copper, cock metal and lead
79	Robert Haydock	11/13/93	18.13	204	Actual	204 lbs. of sheet lead
17	George Wescot	07/31/94	153.33	2,240	Actual	ton of pig lead for refining
38	Richard Bache	11/11/94	30.50	?	Estimated	copper, brass and lead
15	Tench Francis	01/19/95	430.25	6,300	Estimated	his bill for lead dated Dec. 22nd 1794
69	George Ludlam	09/26/95	101.30	?	Estimated	for lead & making a pump
37	George Ludlam	11/06/95	28.53	448	Estimated	for bar and sheet lead
59	George Ludlam	12/12/95	78.60	1,232	Estimated	for lead to the 28th Nov. last
61	George Ludlam	12/19/95	145.37	2,125	Estimated	for fourteen pigs of lead and portage.
		Estimated Avoirdupois lbs.		13,189		
		Troy lbs. equivalent		16,028		
		Metric tons equivalent		5.98		

Table 2 – Lead Purchases: October, 16, 1792 – December 19, 1795



Prices Current at Philadelphia.

[Dollars equal to 100 cents.]

ASHES Pot per ton 90 Dols. to 100
Afhes Pearl 137 — — 140.
Bacon flitches per lb. 7 cents.
Bacon fhoulders — 6 do.
Bees wax, per lb. 25 cents to 27.
Brandy, Coniac, per gl. 1 dol. 50 c. to c
Brandy, common, 1 dol. 26 c.
Butter, in kegs, per lb. 10 c. to 12.
Coals, per bufhel, 20 c. to 22
Coffee, per lb. 20 c.
Cotton, per lb. 30 c. to 42
Flax, per lb. 10 c.
Flour, fuperfine, per barrel, 5 dols. 6 c.
Common, ——— 4 dols.
Burr middlings, beft, per bbl. 4 dols
Meal Indian 2 dols. 67 c.
Rye 3 dols.
Ship ftuff, per cwt, 1 dol.
Gin, Holland, per cafe, 4 dols.
Ginfeng per lb. 20 c. to 24
Grain, barley, per bufhel, 90 c.
——— beft fhelled, per lb. 3 c.
Buck-wheat, per bufhel, 40 c.
Indian corn, 44, c. Oats 26 c. pr. bufh.
Rye 50 c. to 54, Wheat 95 to 1 dol.
Hams, per lb. 8 c. to 9
Hemp, imported, per ton, 120 dols. to 146 67 c.
American, per lb. 4 c. to 5
Hides, raw, per lb. 9 c. to 11
Indigo, Carolina, per lb. 40 c. to 1 dol.
Iron, bar, per ton, 82 dols. 67 c.
Caftings, per cwt. 3 dols. 47 c.
Nail-rods per ton 96 dols.
Pig, per ton, 24 dols. to 28 dols. 67 c.
Sheet, per ton, 173 dols 33 c.
Lard, hogs, per lb. 9 c. to 10
Lead, in bars, per cwt. 7 dols.
In pigs, — — 5 dols. 33 c. to 5 dols. 67 c.
Red, — — 6 dols. 40 c. to 6 dols. 67 c.
White, — — 10 dols. to 10 dols. 67 c.
Myrtle wax per lb. 18 c.
Molaffes, per gal. 44 c. to 48

Ginger, white race, per lb. 22
Ditto, common
Ditto, ground pr. lb. 10
Ginfeng, 28 24
Gunpowder, cannon, pr. q. cafk, 3 73 4
Ditto, fine glazed 6
Grain, Wheat pr. bufh. 100 1 10
——Rye 70
——Oats 35
——Indian corn 56
——Barley 1 10
——— Beft fhelled pr. lb. 7
——Buckwheat, per bufh. 40
Hemp, imported, pr. ton, 160 150
American, pr. lb. 6 7
Herrings, pr. bbl. 3
Hides, raw pr. lb. 9
Hops 13
Hogfhead hoops, pr. M. 15
Indigo, French per lb. 1 67
——Carolina 1 1 80
Irons, faid pr. ton, 133 33
Iron, Caftings pr. cwt. 3 4
——Bar pr. ton, 82 66
——Pig 25
——Sheet 173 33
——Nail rods 100 33
Junk, pr. cwt. 4 6
Lard, hogs pr. lb. 12
Lead, in pigs pr. cwt. 5 33 5 67
——in bars 7
——White 10 10 67
——red 6 40 6 67
Leather, foal, pr. lb. 17 20
Lignum vitæ, pr. ton, 7
Log wood 30
Mace pr. lb. 9
Mackarel, beft pr. bbl. 9
——fecond quality 4
Madder, beft pr. lb. 16 20
Marble, wrought, pr. foot, 1 33 2 67
Maft fpars ditto 33
Molaffes pr. gall. 47 56
Muftard per lb. 87
——flour, in bottles, pr. doz. 1 20
Nails, 8d. 10d. 12d. and 20d. pr. lb. 10
Nutmegs pr. lb. 7 8
Oil, Linfeed, pr. gall. 55
——Olive 87

May 16, 1792 **March 8, 1794**

Figure 3 – Lead Prices: Gazette of the United States, Philadelphia, PA

Dep #	Depositor	Date of Deposit	Gross Wt Tr oz . dwt	Std Wt Tr oz . dwt	Troy oz. Silver @ 89.24+% Standard	Troy oz. Silver @ 90% Standard
1	Bank of Maryland	07/18/94	94,179.00	69,692.08	62,195	62,723
12	Henry Pratt	06/12/95	527.10	395.00	353	356
14	John Vaughan	07/09/95	1,981.00	1,966.14	1,755	1,770
	Total Troy oz.		96,687		64,303	64,849
	Total Troy lbs.		8,057		5,359	5,404
	Total Metric tons		3.01		2.00	2.02

Table 3 – Silver Bullion Refined During 1794 & 1795