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## Evidence relative to the effect of mechanical mixing of charges in the fire assay

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EVIDENCE RELATIVE TO THE EFFECT OF MECHANICAL MIXING OF  
CHARGES IN THE FIRE ASSAY.

T246

by  
James Keller Beach.

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A

T H E S I S

Submitted to the faculty of the  
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

D E G R E E O F

BACHELOR OF SCIENCE IN MINE ENGINEERING.

Rolla, Mo.

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Approved by

L. Copeland

Professor of Metallurgy.

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## STATEMENT OF THE PROBLEM.

While mixing has always been suggested in the text books, on assaying, yet it seems that experimental data as to the effect of lack of mixing, or insufficient mixing, is not available. This thesis was conducted in an effort to determine just what variation and irregularity in the fusion of gold and silver ore was caused by non-mixing; i. e., whether the fusion took place in the same length of time, whether the fusion was complete, whether the values were collected and, in general, just what irregularities were incurred.

STATEMENTS ON SUBJECT OF MIXING CHARGES,  
By Various Authors of Text Books.

Ricketts emphasises the fact that the fusion should be well mixed and in several places states that "Charge should be well mixed", but gives no reason for his statement. Chas. H. Fulton, Manual of Fire Assaying says, " In almost every instance when a crucible assay is to be made, the ore and flux added should be thoroughly incorporated by mixing, so that, theoretically, at least, every particle of the ore comes in contact with flux and reagent, which is the most favorable condition to produce a thorough reaction between them." R. W. Dodge, Notes on Assaying: " Ore should be well mixed." Ricketts and Miller, Notes on Assaying: " Ore and flux should be very thoroughly mixed." L. S. Austin, Fire Assay: "Always mix." "Where a reducing mixture is made, mixing should be so thorough as to make all parts appear quite uniform in color." Manuel of Assaying of Gold, Silver, Copper and Lead Ores, by Walter Lee Brown, Edition of 1905: " Ore, flux and lead should be mixed."

In several other text books on Assaying, nothing was mentioned relative to the mixing of charge.

## METHODS INVOLVED.

The experiment was first started with the idea of doing all mixing on a sampling cloth and noting the number of turns of the cloth, but this was soon found to be impracticable, due to the losses incurred from dusting and because the very fine particles of ore adhered to the cloth and made the results somewhat uncertain. Again by this scheme there was trouble in getting relative mixing. By using certain order in which the ore, flux and litharge were put into the crucible without any mixing, certain results and irregularities were noted. Then by using the same order of placing the components of the charge into the crucible and mixing, gradually increasing the number of turns of the spatula or the material in the crucible, other observations were made. Then a different order of placing the ingredients into the crucible was employed and here again the charges were given a relatively good or a relatively poor mix by varying the number of turns of the spatula. This method was employed first with an ordinary silicious ore, then with a copper matte, followed by a similar treatment on a galena (Pb. S.) ore.

SILICIOUS ORE.

The results of this series of experiments are shown in tables I, II, III, and IV.

TABLE NO. I.

Ounces of Silver per ton ore.

| With<br>ordinary:<br>mixing. | Assay after number of turns of spatula. |       |       |       |       |       |       |       |  |
|------------------------------|---|-------|-------|-------|-------|-------|-------|-------|--|
|                              | 0 turns                                 | 4     | 10    | 25    | 50    | 75    | 100   | 150   |  |
| 41.52                        | 38.70                                   | 39.80 | 40.24 | 41.20 | 41.28 | 41.40 | 41.52 | 41.40 |  |
| 41.56                        | 38.56                                   | 39.52 | 40.08 | 40.84 | 41.40 | 41.48 | 41.50 | 41.64 |  |
| 41.40                        |   |       |       |       |       |       |       |       |  |
| 41.48                        |   |       |       |       |       |       |       |       |  |
| 41.49                        | 38.63                                   | 39.66 | 40.26 | 41.02 | 41.34 | 41.44 | 41.51 | 41.52 |  |

The Following charge was used on the silicious ore. The following materials being named in the order in which they entered the crucibles.

C H A R G E .

Litharge = 25 gms.  
 Soda = 20 gms.  
 Argol = 4 gms.  
 Ore = 1-2 A. T.  
 Borax Flux = 5 gms.  
 Nails = 2

TABLE II.

Ounces of Silver Per Ton Ore.

| With      | Assay after number of turns of Spatula. |        |        |        |        |        |        |        |
|-----------|---|--------|--------|--------|--------|--------|--------|--------|
| Ordinary: | 0                                       | 4      | 10     | 25     | 50     | 75     | 100    | 150    |
| Mixing    | Turns                                   | Turns  | Turns  | Turns  | Turns  | Turns  | Turns  | Turns  |
| 41.52     | :36.80                                  | :38.32 | :40.92 | :40.64 | :41.36 | :41.40 | :41.52 | :41.41 |
| 41.56     | :36.88                                  | :38.20 | :40.16 | :40.92 | :41.28 | :41.48 | :41.50 | :41.64 |
| 41.40     | :                                       | :      | :      | :      | :      | :      | :      | :      |
| 41.48     | :                                       | :      | :      | :      | :      | :      | :      | :      |
| 41.49     | :36.84                                  | :38.26 | :40.59 | :40.78 | :41.32 | :41.44 | :41.51 | :41.52 |

The above results were obtained when the charge ingredients were placed in the crucible in the order named below.

C H A R G E .

Soda = 25 gms.  
 Litharge = 50 gms.  
 Argol = 4 gms.  
 Ore = 1-3 A. T.  
 Borax Glass = 5 gms.  
 Nails = 2



T A B L E    I I I .

Ounces of Silver per ton Ore.

| With      | Assay after number turns of Spatula. |        |        |        |        |        |        |        |
|-----------|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|
| ordinary: | 0                                    | 4      | 10     | 25     | 50     | 75     | 100    | 150    |
| mixing.   | Turns:                               | Turns: | Turns: | Turns: | Turns: | Turns: | Turns: | Turns: |
| 41.52     | :35.12                               | :36.40 | :36.80 | :38.52 | :40.80 | :41.40 | :41.42 | :41.40 |
| 41.56     | :35.04                               | :36.16 | :37.04 | :39.28 | :40.46 | :41.48 | :41.50 | :41.64 |
| 41.40     | :                                    | :      | :      | :      | :      | :      | :      | :      |
| 41.48     | :                                    | :      | :      | :      | :      | :      | :      | :      |
| 41.49     | :35.08                               | :36.28 | :36.92 | :38.90 | :40.72 | :41.44 | :41.51 | :41.52 |

The proceeding results were obtained when the charge entered the crucible in the following manner.

C H A R G E .

|          |   |     |       |
|----------|---|-----|-------|
| Ore      | = | 1-2 | A. T. |
| Soda     | = | 25  | gms.  |
| Argol    | = | 4   | gms.  |
| Litharge | = | 20  | gms.  |
| Borax    | = | 5   | gms.  |
| Nails    | = | 2.  |       |

T A B L E IV.

Ounces of Silver Per Ton Ore.

| With<br>ordinary:<br>mixing : | Assay after number of turns of Spatula. |        |        |        |        |        |        |        |
|-------------------------------|---|--------|--------|--------|--------|--------|--------|--------|
|                               | 0                                       | 4      | 10     | 25     | 50     | 75     | 100    | 150    |
|                               | Turns:                                  | Turns: | Turns: | Turns: | Turns: | Turns: | Turns: | Turns: |
| 41.52                         | :38.22:                                 | 39.20: | 40.88: | 41.68: | 42.48: | 41.40: | 41.52: | 41.40  |
|                               | :                                       | :      | :      | :      | :      | :      | :      | :      |
| 41.56                         | :38.54:                                 | 39.64: | 40.96: | 41.44: | 41.24: | 41.48: | 41.50: | 41.64  |
|                               | :                                       | :      | :      | :      | :      | :      | :      | :      |
| 41.40                         | :                                       | :      | :      | :      | :      | :      | :      | :      |
|                               | :                                       | :      | :      | :      | :      | :      | :      | :      |
| 41.48                         | :                                       | :      | :      | :      | :      | :      | :      | :      |
|                               | :                                       | :      | :      | :      | :      | :      | :      | :      |
| 41.49                         | :38.38:                                 | 39.42: | 40.92: | 41.56: | 41.36: | 41.44: | 41.51: | 41.52  |
|                               | :                                       | :      | :      | :      | :      | :      | :      | :      |

The results of Table IV when the charge was put into the crucible in the order given below.

C H A R G E .

Soda = 25 gms.

Litharge = 20 gms.

Borax Glass = 5 gms.

Argol = 4gms.

Ore = 1-~~8~~ A. T.

Nails = 2.

REMARKS ON TABLE NUMBER I, II, III, and IV.

The thoroughness with which the mixing of the charge is performed certainly has a great effect on the values received from the charge and also an effect on the length of time required to complete the fusion. Undoubtedly the great boiling and frothing of the crucible contents as the fusion proceeds gives a much more thorough mixing than any mechanical means could possibly perform, yet it is a fact that to have this frothing and boiling take place, considerable mechanical mixing must be given the charge ingredients.

It may be that in the case where the mixing be not thoroughly done mechanically, the lead is reduced and at the bottom of the crucible before the silver is freed or has been exposed totally to the lead. A number of experiments performed in the Laboratory of the Missouri School of Mines, proved that if a charge containing silver and gold be fused so as to be thoroughly liquid and then a mixture of litharge and reducing agent be thrown on the surface of the charge, the lead is reduced to the metallic state and rains through the charge but it does not collect the silver or gold. It seems that extreme care in obtaining a thorough mixture in the crucible is not necessary, where no higher results can be obtained by mere mixing beyond a certain point. No higher results were obtained by giving the charge 150 turns of the spatula than by giving the charge 50 turns.

It is obvious, as will be seen by these tables,

that with no mixing the value returned is much lower than the real silver content. Not a great deal of difference in this case is caused by the order in which the materials are put into the crucible but the result without mixing is useless in any case.

REMARKS ON TABLE I.

The fusion, in the case where no turns of the spatula were given, required two and a half hours but resulted then in a fairly liquid slag with a clean ~~batter~~. With 0 turns of the spatula the fusion was done and poured shortly before fusion (1) was done.

With 25 and 50 turns of the spatula, required only 45 minutes for the fusion and resulted in a liquid slag and clean ~~batter~~.

The last observations were made with 75, 100 and 150 turns of the spatula and showed the fusion to be entirely done 25 minutes after placing same in the muffle, the length of time being about the same in all cases. Mixing, therefore, certainly has a big effect on the length of time needed for the fusion.

Conditions in Tables II, III, and IV were the same as given in table one.

TABLE IV.

Copper Matter.

Ounces of Silver per Ton Ore.

| With<br>ordinary:<br>mixing | Assay after number turns of Spatula. |         |         |         |         |         |         |         |
|-----------------------------|--------------------------------------|---------|---------|---------|---------|---------|---------|---------|
|                             | 0                                    | 4       | 10      | 25      | 50      | 75      | 100     | 150     |
|                             | Turns                                | Turns   | Turns   | Turns   | Turns   | Turns   | Turns   | Turns   |
| 30.96                       | :29.20:                              | :29.30: | :29.88: | :30.42: | :30.88: | :30.90: | :30.92: | :30.88  |
| 30.82                       | :29.34:                              | :29.50: | :29.82: | :30.48: | :30.80: | :30.96: | :31.00: | :30.98  |
| 31.04                       | :29.04:                              | :29.42: | :30.00: | :30.62: | :30.82: | :       | :       | :       |
| 30.98                       | :29.16:                              | :29.46: | :30.02: | :30.58: | :30.90: | :       | :       | :       |
| 30.95                       | :29.19:                              | :29.42: | :29.92: | :30.52: | :30.85: | :30.93: | :30.96: | :30.93  |
| 100%                        | 94.31                                | 95.05   | 96.67   | 98.61   | 99.67   | 99.93   | 100.03  | 99.93   |
|                             |                                      |         |         |         |         |         |         | Average |
|                             |                                      |         |         |         |         |         |         | " %     |

The charge was of the following composition and entered the crucible in the order given.

C H A R G E .

- Soda = 20 gms.
- Ore = 1-2 A. T.
- Litharge = 150 gms.
- Nitre = 14 gms.
- Borax = 3 gms.

REMARKS ON TABLE V.

The results here are much more uniform than were the case with the silicious ore.

The fusions in table V. all resulted in a slag very liquid and which, when cool, broke from the button without the aid of a hammer leaving a bright, clean button which when cupelled showed very little trace of copper. This experiment also showed that some series of mixing is needed but that it is not necessary to attempt excessively complete mechanical mixing.

TABLE VI.

Galena Ore.

Ounces of Silver Per Ton Ore.

| With ordinary mixing | Assay after number turns of Spatula. |        |        |        |        |        |        |        |         |
|----------------------|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|---------|
|                      | 0                                    | 4      | 10     | 25     | 50     | 75     | 100    | 150    |         |
|                      | Turns                                | Turns  | Turns  | Turns  | Turns  | Turns  | Turns  | Turns  | Turns   |
| 37.64                | :36.02                               | :36.86 | :37.14 | :37.42 | :37.58 | :37.56 | :37.64 | :37.68 |         |
| 37.76                | :36.18                               | :36.90 | :37.18 | :37.30 | :37.54 | :37.60 | :37.60 | :37.64 |         |
| 37.58                | :36.08                               | :36.72 | :37.00 | :37.32 | :37.62 |        |        |        |         |
| 37.42                |                                      |        |        |        |        |        |        |        |         |
| 37.60                | :36.14                               | :37.78 | :37.14 | :37.34 | :37.56 | :37.58 | :37.62 | :37.66 | Average |

The charge was put into the crucible in the order given below.

C H A R G E.

- Soda = 25 gms.
- Litharge = 12 gms.
- Argol = 3 gms
- Ore = 1-2 A. T.
- Borax = 8 gms.
- Nails = 3.



REMARKS ON TABLE VI.

Here the values were much more uniform than with the silicious ore, there being only one ounce variation from the silver return with no mixing, to the return with 150 turns of mixing. It is believed that in this case the lead of the galena ore itself formed the principal carrier of the gold and silver contained in the ore. The fusion occupied 45 minutes, resulting in a clear button and liquid slag.

## CONCLUSIONS.

That in all cases mixing should be done and that the greater the amount of mixing, up to 75 turns of the spatula, the bigger will be the value returned by the assay.

That the more the mixing the greater will be the rapidity at which the mixture will fuse.

That the more the ore be mixed, the more fluid will the slag be.

It was observed that the slag made with more mixing was less mobile than was the slag with less mixing.

That the extra time consumed by doing more mixing would be compensated by a quicker fusion. It looks as though the loss was due to some of the silver ~~not~~ ~~not~~ coming into contact with lead. If silver be reduced in exceedingly fine condition, there is no reason to suppose it will all come in contact with the lead. The lead must be reduced in contact with each silver particle.

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