1885

Smelting processes for silver extraction

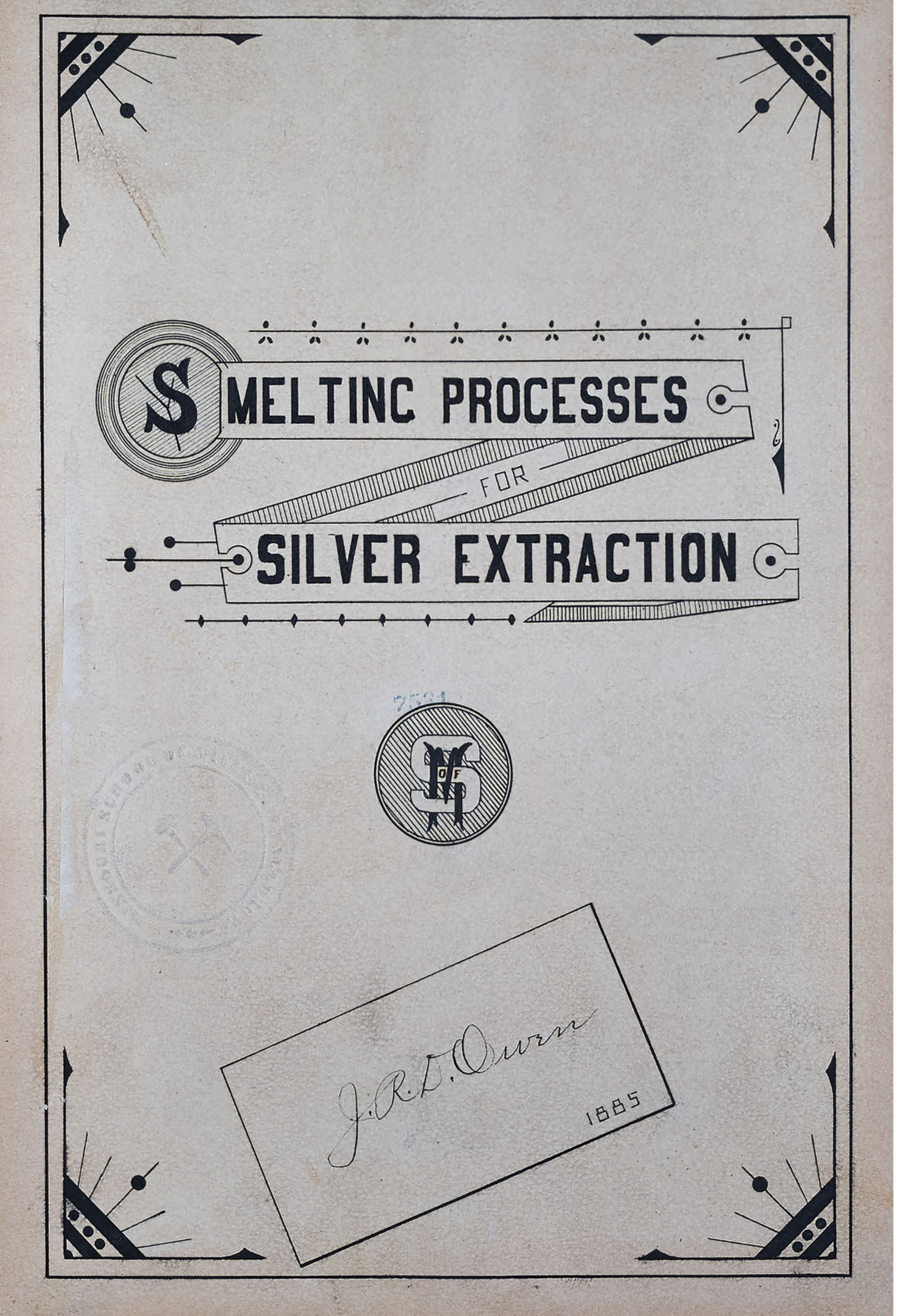
John R. D. Owen

THESIS

Silver Extraction

OWEN

1885



SMELTING PROCESS FOR SILVER EXTRACTION

J. R. D. Owen

1885

A Thesis for the degree
of Mining Engineer
by
J. R. D. Owen.

A Thesis for the degree
of Mining Engineer
by
J. R. D. Owen.

The base metals used for the extraction of silver from its ores by smelting are lead and Copper, and the different methods employed may be accordingly classified under the general headings of "extraction by means of lead" and "extraction by means of Copper.

A large portion of the mines now being developed in the new mineral districts of our great mineral belt are carrying a class of Carbonate and oxidized ores that require to be treated by the smelting process. This interest including both gelena, Silver and Copper, has already become one of such magnitude, that the question of the most thorough and economical treatment of these

The base metals used for
the extraction of silver from
its ores by smelting are lead
and copper, and the different
methods employed may be
accordingly classified under
the general headings of “extraction
by means of lead” and “extraction
by means of copper.
A large portion of the mines
now being developed in the
new mineral districts of our
great mineral belt are carrying
a class of carbonate
and oxidized ores that require
to be treated by the smelting
process. This interest including
both gelena, silver and copper,
has already become one of such
magnitude, that the question
of the most thorough and
economical treatment of these

ors is one of the highest importance.

Silver extraction by means of lead

Silver extraction by means of lead is classified according to the shape of the furnace used for the purpose. Thus we have:

I. Smelting in the open hearth.
II. Smelting in reverberatory furnaces
III. Smelting in shaft furnaces.

All these processes have one common purpose, the reduction of the lead to the metallic state and the concentration of the metallic silver in it; but the chemical reactions by which this is accomplished often differ greatly, and the efficiency of each method varies with local circumstances. To know therefore the reactions, and to weigh the circumstances in their economical bearings is the first duty of those

ors is one of the highest importance.

Silver extraction by means of lead.

Silver extraction by means of lead is classified according to the shape of the furnace used for the purpose.

Thus we have:

I. Smelting in the open hearth.
II. Smelting in reverberatory furnaces.
III. Smelting in shaft furnaces.

All these processes have one common purpose, the reduction of the lead to the metallic state and the concentration of the metallic silver in it; but the chemical reactions by which this is accomplished often differ greatly, and the efficiency of each method varies with local circumstances. To know therefore the reactions, and to weigh the circumstances in their economical bearings is the first duty of those

who wish to select a process
for a particular locality.

I. Smelting in the open hearth.

This method is the oldest and simplest, and up to the present time very few improvement have been made in its original features. This process as practiced in the American-hearth is distinguish-ed from the method followed in England and Scotland, chief-ly by the employment of hot blast in smelting very pure raw ores. The ores smelted in the Scotch-hearth must like wise be free from silica, not necessarily from other gangue. They are prepared for smelting by roasting in reverberatories, and the blast employed is cold. In both processes, infe-rior kinds of fuel, such as wood, peat, etc., can be used. The first condition of the econ-omical use of the hearth

who wish to select a process
for a particular locality.

I. Smelting in the open hearth.
This method is the
oldest and simplest, and up
to the present time very few
improvement have been made
in its original features.
This process as practiced in
the American-hearth is distinguished
from the method followed
in England and Scotland, chiefly
by the employment of hot
blast in smelting very pure
raw ores. The ores smelted
in the Scotch-hearth must like
wise be free from silica,
not necessarily from other gangue.
They are prepared for smelting
by roasting in reverberatories,
and the blast employed is
cold. In both processes, inferior
kinds of fuel, such as
wood, peat, etc., can be used.
The first condition of the economical
use of the hearth

in smelting lead ores or a mixture of these with silver ores is therefore purity of ore, especially absence of silica and foreign sulphuretted metals. The ore ought to be in the form of pieces not crushed.
If brought to the works in the latter form, it ought to be agglomerated in a reverberatory before it is smelted in the hearth, but if this has to be done it would be more economical to finish the smelting process in the reverberatory.
The above conditions being primarily requisite for the successful smelting in the hearth, and a large loss of both lead and silver by volatilization being certain unless a very extensive and costly system of condensing chambers or carnals is connected with the work, it is evident that for these reasons alone this method cannot come into use economically.

in smelting lead ores or a
mixture of these with silver
ores is therefore purity of ore,
especially absence of silica
and foreign sulphuretted metals.
The ore ought to be in the form
of pieces not crushed.
If brought to the works in the
latter form, it ought to be
agglomerated in a reverberatory
before it is smelted in the
hearth, but if this has to be
done it would be more economical
to finish the smelting
process in the reverberatory.
The above conditions being primarily
requisite for the successful
smelting in the hearth,
and a large loss of both
lead and silver by volatilization
being certain unless
a very extensive and costly
system of condensing chambers
or carnals is connected with
the work, it is evident that
for these reasons alone this
method cannot come into use
economically.

The ores though often rich in silver, are rarely free from siliceous gangue, foreign sulphurets, antimonurets; and dressing is prevented in some localities by the scarcity of water and high price of labor in mining districts. Besides it is extremely difficult to dress rich silver ores without incurring a serious loss of precious metal.

It is therefore useless at the present time to dwell upon the process of smelting argentiferous lead ores in the open hearth. But for the sake of comparison I will give an illustration of this process as carried on at Vallecillo, Mexico. The ore treated ~~are~~ is nearly pure galena. The special reasons for adopting this process at Vallecillo is that it requires but little fuel.

The hearths are like a box about 24 inches square, without a top and with one side taken away. The walls of the box

The ores though often rich in
silver, are rarely free from
siliceous gangue, foreign sulphurets,
antimonurets; and dressing
is prevented in some localities
by the scarcity of water and
high price of labor in mining
districts. Besides it is extremely
difficult to dress rich silver ores
without incurring a serious loss
of precious metal.
It is therefore useless at the
present time to dwell upon
the process of smelting argentiferous
lead ores in the open
hearth. But for the sake of
comparison I will give an
illustration of this process
as carried on at Vallecillo, Mexico.
The ore treated ~~are~~ is nearly
pure galena. The special
reasons for adopting this process
at Vallecillo is that it requires
but little fuel.
The hearths are like a box
about 24 inches square, without
a top and with one side taken
away. The walls of the box

are of half inch iron, inclos- a hollow space, in which cir- culates air or water.
The bottom of each box is a lead-bosh holding 900 to 1,000 lbs. of melted lead, and over the top of each is a can- opy leading to the stack.
Each hearth has three tuyeres, 2 inches in diameter, placed 6 inches above the lead bosh.
Hot blast is employed at a pressure of about ¾ of a lb.
In working this process it is easy to distinguish three pe- riods at which the charge un- dergoes notable changes.
1st. The preliminary or heating up stage, in which the water goes off, the whole mass becomes red-hot, and the sulphur commences to burn.
2. The burning sulphur raises the heat to the melting point of lead; the greater part of the lead finds itself in a re- ducing atmosphere, and runs out in metallic form, while

are of half inch iron, inclosing
a hollow space, in which
circulates air or water.
The bottom of each box is
a lead-bosh holding 900 to
1000 lbs. of melted lead, and
over the top of each is a
canopy leading to the stack.
Each hearth has three tuyeres,
2 inches in diameter, placed
6 inches above the lead bosh.
Hot blast is employed at
a pressure of about ¾ of a lb.
In working this process it is
easy to distinguish three periods
at which the charge undergoes
notable changes.
1st. The preliminary or heating
up stage, in which the
water goes off, the whole mass
becomes red-hot, and the sulphur
commences to burn.
2. The burning sulphur raises
the heat to the melting point
of lead; the greater part of the
lead finds itself in a reducing
atmosphere, and runs
out in metallic form, while

the rest is oxidized, carbonated or volatilized with the remaining metals of that kind, that are by this time passing off.

3rd After the second stage has lasted some time, the heat of the mass has so increased that the ferruginous and earthy impurities of the ore, combining with the litharge formed commence to sinter and agglomerate to a slag, inclosing the particles of lead as they run out, and finally cementing the whole charge to a mass which sticks to the walls of the hearth.

Before this period fairly sets in, the charge should be considerably reduced in bulk by the burning of the sulphur, melting of the lead, etc., and its further progress must be prevented by proper manipulations and by adding a new charge.

The ore treated contains about 72 % of lead. Each hearth produces about 2187 pounds of each, from 3500 pound of ore

the rest is oxidized, carbonated or
volatilized with the remaining
metals of that kind, that are
by this time passing off.
3rd. After the second stage has
lasted some time, the heat
of the mass has so increased
that the ferruginous and earthy
impurities of the ore, combining
with the litharge formed commence
to sinter and agglomerate
to a slag, inclosing the particles
of lead as they run out,
and finally cementing the whole
charge to a mass which sticks
to the walls of the hearth.
Before this period fairly sets in,
the charge should be considerably
reduced in bulk by the burning
of the sulphur, melting
of the lead, etc., and its further
progress must be prevented
by proper manipulations and by
adding a new charge.
The ore treated contains about
72% of lead. Each hearth
produces about 2187 pounds
of each, from 3500 pounds of ore

in 24 hours.
The cost of smelting 2187 lbs.
in the hearth is estimated at
$6. The lead made by this
process is of great purity
and very soft.
The slags contain a notable
amount of iron, and are rich
in lead in silver.

in 24 hours.
The cost of smelting 2187 lbs.
in the hearth is estimated at
$6. The lead made by this
process is of great purity
and very soft.
The slags contain a notable
amount of iron, and are rich
in lead in silver.

II. Smelting in Reverberatory Furnaces.

The application of the reverberatory furnace to lead smelting is limited by many conditions similar to those enumerated in the use of the open hearth. There were two processes in use some ten years ago, which were executed in the reverberatory; the roasting and reducing; and the roasting and precipitating process.

Foremost a condition for the economical employment of the roasting and reducing process is the absence, to a certain extent, of siliceous or argillaceous gangue. Whenever the ore contains more than 4% of these substances, or less than 58% of lead this process cannot be executed satisfactorily any longer because silicate of lead is formed, which is hard to reduce.

Moreover the process permits the presence of lime, heavy

II. Smelting in Reverberatory
Furnaces.
The application of the reverberatory
furnace to lead smelting
is limited by many conditions
similar to those enumerated
in the use of the open hearth.
There were two processes in use
some ten years ago, which were
executed in the reverberatory;
the roasting and reducing;
and the roasting and precipitating
process.
Foremost a condition for the
economical employment of the
roasting and reducing process
is the absence, to a certain
extent, of siliceous or argillaceous
gangue. Whenever the ore
contains more than 4% of these
substances, or less than 58% of
lead this process cannot be
executed satisfactorily any
longer because silicate of
lead is formed, which is
hard to reduce.
Moreover the process permits
the presence of lime, heavy

spar, zincblend, and other foreign sulphurets in small quantaties only. An important drawback in the employment of the reverberatory process is also the proportionately large quantaties of fuel required, and in this country the item of labor, which is larger in proportion to the production than in shaft furnace smelting.
The loss of Copper and the deterioration of the lead by the same metal is another objection
As mentioned above, there were two reverberatory processes in use some ten years ago, the roasting and reducing, and the roasting and precipitating process. These were again carried out in various localities in a somewhat different manner, the deviations consisting principally in a slower or quicker roasting and reducing, or the employment of a lower or higher temperature.

spur. zinc blend, and other foreign
sulphurets in small quantaties
only. An important drawback
in the employment of the reverberatory
process is also the
proportionately large quantaties
of fuel required, and in
this country the item of labor,
which is larger in proportion
to the production than in
shaft furnace smelting.
The loss of copper and the
deterioration of the lead by the
same metal is another objection
As mentioned above, there were
two reverberatory processes in
use some ten years ago, the
roasting and reducing, and
the roasting and precipitating
process. These were again
carried out in various localities
in a somewhat different
manner, the deviations consisting
principally in a slower
or quicker roasting and reducing,
or the employment
of a lower or higher
temperature.

Roasting and reducing process.
As an example of this process, the English process will be given.

The English Process.

The principal object of the English modification of the reverberatory process is to reach the greatest possible production; therefore larger furnaces with three working doors on each side, stone coal as fuel, and higher temperature is employed.
The furnace employed for this process varies somewhat in its construction and dimensions; the length of the hearth is usually about 11 feet, and its width 9 feet, it is supported on iron bars, on which is laid a course of flat tiles. On these is placed a course of fire-bricks on edge, in which is arranged the usual slag bottom.
The furnace has 6 working doors and a fire door and has the tapping-port placed near the flue end. In general the ores

Roasting and reducing process.
As an example of this process, the English process will be given.

The English Process.

The principal object of the English modification of the reverberatory process is to reach the greatest possible production; therefore larger furnaces with three working doors on each side, stone coal as fuel, and higher temperature is employed.
The furnace employed for this process varies somewhat in its construction and dimensions; the length of the hearth is usually about 11 feet, and its width 9 feet, it is supported on iron bars, on which is laid a course of flat tiles. On these is placed a course of fire-bricks on edge, in which is arranged the usual slag bottom.
The furnace has 6 working doors and a fire door and has the tapping-port placed near the flue end. In general the ores

treated are tolerably free from impurities, being composed of galena associated with carbonate and sulphate of lead and calcareous gangue.
The cobbed ores before delivery to the furnace, are ground between rollers and passed through sieves of 8 holes to the linear inch, a charge of ore weighs 2970 lbs.
Two men are employed at each furnace. In the treatment of rich ores, the ordinary methods of working consist in roasting them in such a manner that upwards of one-half of the sulphides of lead present in the ore is converted into a mixture of oxide and sulphate.
On raising the heat in the furnace to bright redness, the oxide and sulphate, formed in roasting, react on the undecomposed sulphide of lead present in the charge, and produce metallic lead, sulphurous anhydride, and a residue of slag.

treated are tolerably free from
impurities, being composed of
galena associated with carbonate
and sulphate of lead and calcareous
gangue.
The cobbed ores before delivery
to the furnace, are ground
between rollers and passed
through sieves of 8 holes to the
linear inch, a charge of ore
weighs 2970 lbs.
Two men are employed at
each furnace. In the treatment
of rich ores, the ordinary methods
of working consist in roasting
them in such a manner that
upwards of one-half of the sulphides
of lead present in the
ore is converted into a mixture
of oxide and sulphate.
On raising the heat in the furnace
to bright redness, the oxide and
sulphate, formed in roasting, react
on the undecomposed sulphide
of lead present in the charge,
and produce metallic lead,
sulphurous anhydride, and
a residue of slag.

Alternate raking and paddling of the charge is continued at regular intervals, until it is thought to be desulphurized which is generally the case at the end of four hours.
In smelting the ore it must on no account be allowed to liquefy, and as often as it shows a tendency to fuse, some slaked lime in powder is thrown on the charge and well worked into it with a rake. The consumption of lime amounts, allogether, to about 2% of ore treated.
The period of smelting occupies about 5 hours.
The weight of coal consumed is equal to 40% of the ore smelted. In treating 2970 lbs of ore there is produced 1980 lbs of lead + 640 lbs. of slag containing 50% of lead. Hence the loss by volitilization is about $3\frac{1}{2}$%.
About 8000 lbs. of ore are smelted in 24 hours with a consumption of 3200 lbs. of coal and with a

Alternate raking and paddling
of the charge is continued
at regular intervals, until it
is thought to be desulphurized,
which is generally the case at
the end of four hours.
In smelting the ore it must
on no account be allowed
to liquify, and as often as
it shows a tendency to fuse,
some slaked lime in powder
is thrown on the charge and
well worked into it with
a rake. The consumption of
lime amounts, altogether, to
about 2% of ore treated.
The period of smelting occupies
about 5 hours.
The weight of coal consumed
is equal to 40% of the ore smelted.
In treating 2970 lbs of
ore there is produced 1980 lbs
of lead & 640 lbs. of slag containing
50% of lead. Hence the loss
by volatilization is about 3 ½ %.
About 8000 lbs of ore are smelted
in 24 hours with a consumption
of 3200 lbs. of coal and with a

production of crude bullion of 4800 lbs.
analysis of gray lead slag.

PbO.	47.87%
ZnO	7.52
CaO	12.68
Al_2O_3	3.01
Fe_2O_3	2.86
SiO_2	12.52
$PbSO_4$	9.85

Roasting and precipitating process.
The treatment of somewhat siliceous ores by fusion in the reverberatory furnace with either scrap iron or cast-iron, was formerly carried on to a limited extent in France, but was ultimately discontinued, on account of the great cost added to the unsatisfactory nature of the results obtained. The furnace employed sloped from the fireplace to the chimney, placed at the opposite extremity of the hearth, where there was a working door with a tapping-hole beneath it,

production of crude bullion
of 4800 lbs.
Analysis of gray lead slag.

PbO.	47.87%
ZnO	7.52
CuO	12.68
Al_2O_3	3.01
Fe_2O_3	2.86
SiO_2	12.52
$PbSO_4$	9.85

Roasting and precipitating process.
The treatment of somewhat siliceous
ores by fusion in the reverberatory
furnace with either scrap
iron or cast iron, was formerly
carried on to a limited extent
in France, but was ultimately
discontinued, on account of the
great cost added to the unsatisfactory
nature of the results obtained.
The furnace employed
sloped from the fireplace to
the chimney, placed at the opposite
extremity of the hearth,
where there was a working door
with a tapping-hole beneath it,

in front of which was situated the usual reservoir for the reception of the reduced metal. The charge consisted of about 880 lbs. of galena, containing nearly 80% of lead, mixed with from 220 to 260 lbs. of scrap or cast iron.

When the temperature had become sufficiently elevated the charge was stirred at frequent intervals, and lead became reduced at the expense of the iron, which was converted into sulphide.

From galena containing 80% of lead from 67 to 70% of metal was extracted, the matt containing from 5 to 12 % of lead; 4% passed off by volatilization, and the slags retained from 4 to 5%. The process of smelting raw ores with iron in reverberatory furnaces is both wasteful and expensive, and therefore, practically, unsatisfactory.

in front of which was situated
the usual reservoir
for the reception of the reduced
metal. The charge consisted
of about 880 lbs. of galena,
containing nearly 80% of lead,
mixed with from 220 to 260
lbs. of scrap or cast iron.
When the temperature had become
sufficiently elevated the charge
was stirred at frequent intervals,
and lead became
reduced at the expense of the
iron, which was converted
into sulphide.
From galena containing 80% of
lead from 67 to 70% of metal
was extracted, the matt containing
from 5 to 12 % of lead;
4% passed off by volatilization,
and the slags retained from
4 to 5%. The process of smelting
raw ores with iron in
reverberatory furnaces is both
wasteful and expensive, and
therefore, practically,
unsatisfactory.

III. Smelting in shaft furnaces.
The blast furnace is almost universally adopted in all parts of the world for the smelting of argentiferous lead ores, or a mixture of lead ores with silver ores.
These carry usually considerable quantities of earthy matter and silica, besides the various combinations of metals other than lead and silver.
For this reason alone they are not suited for any of the reverberatory processes.
But in addition the blast furnace requires less fuel and labor in proportion to the yield. It is true the volatilization of the lead is somewhat greater in the blast furnace than in the reverberatory, but this may be partly avoided by a proper shape and height of the furnace, and by far the largest percentage of lead volatilized and also silver can be caught in properly

III. Smelting in shaft furnaces.
The blast furnace is almost
universally adopted in all
parts of the world for the
smelting of argentiferous lead ores,
or a mixture of lead ores
with silver ores.
These carry usually considerable
quantities of earthy matter and
silica, besides the various combinations
of metals other than lead and silver.
For this reason alone they are
not suited for any of the
reverberatory processes.
But in addition the blast
furnace requires less fuel
and labor in proportion to
the yield. It is true the volatilization
of the lead is somewhat greater in the blast
furnace than in the reverberatory,
but this may be partly avoided
by a proper shape and height
of the furnace, and by far
the largest percentage of lead
volatilized and also silver
can be caught in properly

constructed system of condensing chambers, especially when showers of water are used to cool the fumes.
There are two processes in use, which are executed in the blast furnace; the precipitating, and the roasting and reducing process.
Galena ores containing little silver, and no other gangue are usually subjected to the precipitating process, those containing much silver, and besides the above substances a large percentage of foreign sulphurets, arseniurets, etc., to the roasting and reducing process. In the latter, a precipitating action is also often introduced by the oxides of iron already in the charge, or by a small addition of materials containing them

The Precipitating process.
This process is the simplest lead-smelting process in use It is based on the greater

constructed system of condensing chambers, especially
when showers of water are
used to cool the fumes.
There are two processes in
use, which are executed in
the blast furnace; the precipitating,
and the roasting and reducing
process.
Galena ores containing little silver,
and no other gangue are usually
subjected to the precipitating
process, those containing much
silver, and besides the above
substances a large percentage
of foreign sulphurets, arseniurets,
etc., to the roasting and
reducing process. In the latter,
a precipitating action is also
often introduced by the oxides
of iron already in the charge,
or by a small addition of
materials containing them

The precipitating process.
This process is the simplest
lead-smelting process in use
It is based on the greater

affinity of the sulphur for the iron than for the lead, and with ores containing only galena and quartzose or argillaceous gangue it can be carried out according to strictly stoichiometrical principles. But when foreign sulphurets are present it becomes less advantageous. The presence of those of copper, antimony, arsenic, etc., is especially undesirable, because these are also acted upon by the iron and the portions reduced to metal deteriorate the lead, while the sulphurets go into the matte, which besides much lead carries the greater part of the silver, if silver be present with it, thus necessitating further processes for its extraction.

The Roasting and reducing process. This method is eminently adopted to the treatment of ores rich in silver, comparative

affinity of the sulphur for
the iron than for the lead;
and with ores containing
only galena and quartzose or
argillaceous gangue it can be
carried out accordingly to strictly
stoichiometrical principles.
But when foreign sulphurets
are present it becomes less
advantageous. The presence
of those of copper, antimony,
arsenic, etc., is especially
undesirable, because these are also
acted upon by the iron and
the portions reduced to metal
deteriorate the lead, while the
sulphurets go into the matte,
which besides much lead
carries the greater part of the
silver, if silver be present
with it, thus necessitating
further processes for its extraction.

The Roasting and reducing process.
This method is eminently adopted
to the treatment of ores
rich in silver, comparative

poor in lead, and containing various foreign sulphurets, combinations of arsenic and antimony, and earthy and quartzose gangue. Its main advantage consist in a nearly perfect extraction of silver in the first smelting, because inconsiderable quantaties only of matte are formed; but considerable more fuel is needed than in the forgoing process, on account of the roasting; the contents of silica cause often a loss of lead in the slag; and when copper is present in the ore it is lost if the roasting has been carried out sufficiently to guard against a loss of silver by the formation of matte. The process consists in a roasting, (the purpose of which is to change the sulphides as much as possible into oxides and to volatilize a part of such deterious substances as antimony, arsenic,

poor in lead, and containing
various foreign sulphurets,
combinations of arsenic and
antimony, and earthy and
quartzose gangue. Its main
advantage consist in a nearly
perfect extraction of silver
in the first smelting,
because inconsiderable quantaties
only of matte are formed;
but considerable more
fuel is needed than in the
foregoing process, on account
of the roasting; the contents
of silica cause often a loss
of lead in the slag; and
when copper is present in
the ore it is lost if the roasting
has been carried out sufficiently
to guard against a
loss of silver by the formation
of matte. The process consists
in a roasting, (the purpose
of which is to change the sulphides
as much as possible
into oxides and to volatilize
a part of such deterious substances
as antimony, arsenic,

and zinc,) and a subsequent reducing smelting. In the latter it is intended to reduce the oxides of lead and silver; to decompose, by means of iron, either added or reduced from the oxide in the charge, the sulphides of lead and silver, which may not have been oxidized during the roasting, and to carry the earthy quartzose into the slag.

and zinc,) and a subsequent
reducing smelting. In the latter
it is intended to reduce the
oxides of lead and silver;
to decompose, by means of iron,
either added or reduced from
the oxide in the charge, the
sulphides of lead and silver,
which may not have been
oxidized during the roasting,
and to carry the earthy quartzose
into the slag.

Roasting and reducing process.

This process is divided into the following steps.

1. Preparation of the ore for roasting.
2. Roasting the ore in reverberatory furnaces.
3. Smelting the roasted ore in shaft furnaces for the production of argentiferous lead.

1. Preparation of the ore for roasting. This consist simply in crushing the ore so that is will pass through a sieve of .06 inch mesh.
The crushing is usually done by the Blake Crusher and Cornish rolls, or by machines similar in construction.

2. Roasting the ore in reverberatory furnaces.
These furnaces are 60 feet long and 12 feet wide, and are provided with eight doors on each side, seven of which

Roasting and reducing process.

This process is divided into
the following steps:

1. Preparation of the ore for roasting.
2. Roasting the ore in reverberatory furnaces.
3. Smelting the roasted ore in shaft furnaces for the production of argentiferous lead.

1. Preparation of the ore for roasting.
This consists simply in
crushing the ore so that it
will pass through a sieve of
.06 inch mesh.
The crushing is usually done
by the Blake Crusher and
Cornish rolls, or by machines
similar in construction.

2. Roasting the ore in reverberatory
furnaces.
These furnaces are 60 feet long
and 12 feet wide, and are
provided with eight doors on
each side, seven of which

are working doors, through which the ore is moved forward toward the fire by means of long shovels, and the eighth is used for firing.
These doors are equidistant on each side, but are not opposite to each other.
The fire bridge is kept cool by a stream of water passing through it. The charge for roasting consist of 2000 lbs. of ore, and is introduced into the furnace by means of a hopper.
The charge is allowed to remain in front of each working door 6 hours, it is then pased along to the next working door in the direction of the fireplace, where it remains another 6 hours.
This operation is continued every six hours until the charge reaches the last working door, thus requiring 42 hours for the roasting of a charge. The roasted charge is drawn as a pasty mass

are working doors, through
which the ore is moved forward
toward the fire by means of
long shovels, and the eighth
is used for firing.
These doors are equidistant on
each side, but are not opposite
to each other.
The fire bridge is kept cool by a
stream of water passing through
it. The charge for roasting
consists of 2000 lbs. of ore, and
is introduced into the furnace
by means of a hopper.
The charge is allowed to remain
in front of each working
door 6 hours, it is then
pased along to the next working
door in the direction of the
fireplace, where it remains
another 6 hours.
This operation is continued
every six hours until the
charge reaches the last working
door, thus requiring 42
hours for the roasting of
a charge. The roasted charge
is drawn as a pasty mass

from the furnace, through a slide-door situated in the hearth in front of the last working door, into a cart made of boiler-plate.

By this method of roasting a charge of 2000 lbs. is with-drawn every 6 hours, making the total amount roasted in 24 hours 8000 lbs.

One of these furnaces requires the attendance of four men, who work in shifts of 12 hours each. When the amount of sulphur in the roasted ore exceeds 2% it is reroasted.

3. Smelting the roasted ore in shaft furnaces for the production of argentiferous lead.

This operation is carried on in the water jacket blast-furnace, with siphon tap.

The furnace being of the rectangular pattern, the ground plan of the base is that of a rectangle 9 by 7½ feet,

from the furnace, through
a slide-door situated in the
hearth in front of the last
working door, into a cart made
of boiler-plate.
By this method of roasting
a charge of 2000 lbs. is withdrawn
every 6 hours, making
the total amount roasted in
24 hours 8000 lbs.
One of these furnaces requires
the attendance of four men,
who work in shifts of 12
hours each. When the amount
of sulphur in the roasted
ore exceeds 2% it is reroasted.

3.Smelting the roasted ore in
shaft furnaces for the
production of argentiferous
lead.
This operation is carried on
in the water jacket blast
furnace, with siphon tap.
The furnace being of the
rectangular pattern, the ground
plan of the base is that of
a rectangle 9 by 7 ½ feet,

with the corners cut off, thus allowing the uprights which support the deck plate to have foundation outside of the crucible binders. These uprights are rolled beams. The deck plate is also made of rolled beams placed some distance apart, the space between them being utilized as a condit for any vapors escaping from the furnace. The crucible binders are made of ribbed wrought iron. This substitution of wrought-iron for cast-iron ex- throughout the whole structure. The water jacket, which is in sections, is made of steel in the following manner. The sheet forming the fire side of the jacket is shaped into a box over 6 inches deep without cutting the corners, so as not to have any rivited or welded joints exposed to the fire. The back plate is formed into a shallow box fitting

with the corner cut off, thus
allowing the uprights which
support the deck plate to have
foundation outside of the
crucible binders. These uprights
are rolled beams. The deck plate
is also made of rolled beams
placed some distance apart,
the space between them being
utilized as a condit for any
vapors escaping from the furnace.
The crucible binders
are made of rubbed wrought
iron. This substitution of
wrought-iron for cast iron ex
throughout the whole structure.
The water jacket, which
is in sections, is made of
steel in the following manner.
The sheet forming the fire
side of the jacket is shaped
into a box oven 6 inches
deep without cutting the corners,
so as not to have any
riveted or welded joints
exposed to the fire.
The back plate is formed
into a shallow box fitting

into the other, the concave side of both boxes facing outward, the outer edges of the two parts being flush and in which position they are riveted and calked, thus leaving the joint entirely on the outside. Attached to the outside of the jacket are hoppers open at the top and through which the cold water is supplied to keep the jackets cool, and from which there is an overflow for the hot water. This form is known as the open topped jacket.
The end jackets do not come down to the crucibles by about 7 inches. The space so left is filled up with a small closed top jacket, which can be readily removed.
This construction does away with the old-fashioned brick breast, and in case of necessity enables the furnace man to rapidly open and close up the furnace at any

into the other, the concave
side of both boxes facing
outward, the outer edges of
the two parts being flush and
in which position they are
riveted and calked, thus leaving
the joint entirely on the
outside. Attached to the
outside of the jacket are hoppers
open at the top and through
which the cold water is supplied
to keep the jackets cool,
and from which there is
an overflow for the hot water.
This form is known as the
open topped jacket.
The end jackets do not come
down to the crucibles by about
7 inches. The space so left
is filled up with a small
closed top jacket, which can
be readily removed.
This construction does away
with the old-fashioned brick
breast, and in case of
necessity enables the furnace man
to rapidly open and close
up the furnace at any

time it becomes desirable so to do.

The shape of the furnace internally is as follows: From the tuyeres upwards the water jacket has a bosh on the sides, thus increasing the width to 5½ feet; the ends are perpendicular from the top of the jacket; the sides are perpendicular to the feed door, making the shaft 5 by 5½ feet. The height should be adapted to the character of the ore to be worked.

Knowing the composition of the roasted ore, a charge is calculated, the slag desirable being between a sub and singulo silicate.

On the kind of ore depends the relation of the bases in the slag; ferruginous ores allowing of a slag containing much iron. With non-ferruginous ores a slag with a large percentage of lime is more economical, as limestone

time it becomes desirable
so to do.
The shape of the furnace
internally is as follows:
From the tuyeres upwards
the water jacket has a bosh
on the sides, thus increasing
the width to 5 ½ feet; the ends
are perpendicular from the
top of the jacket; the sides
are perpendicular to the feed
door, making the shaft 5 by
5 ½ feet. The height should be
adapted to the character of
the ore to be worked.
Knowing the composition of
the roasted ore, a charge
is calculated, the slag desirable
being between a sub and
singulo silicate.
On the kind of ore depends
the relation of the bases in
the slag; ferruginous ores allowing
of a slag containing
much iron. With non-ferruginous
ores a slag with a large
percentage of lime is more
economical, as limestone

only costs ¼ what iron ore does. Magnesia, manganese, alumina, and zinc, as well as the impurities, must be taken into consideration.
The charge is given to the weigher, and the ores and fluxes are weighed accurately in a wheelbarrow, as a few pounds in a 500-pound charge make quite a difference in the slag. The charge is then dumped at the furnace door. Fuel is charged at the feed door in alternate layers with the charges. Both coke and charcoal are used in varying proportions.
The amount of fuel used varies from 12 to 14%.
Ores containing only 6½% of lead has been successfully smelted. The resulting products of smelting are lead, containing silver and more or less impurities; matte, a sulphide of iron, and slag. The bullion is tapped out by the siphon tap and

only costs ¼ what iron ore does.
Magnesia, manganese, alumina,
and zinc, as well as the
impurities, must be taken into
consideration.
The charge is given to the
weigher, and the ores and
fluxes are weighed accurately
in a wheelbarrow, as a
few pounds in a 500-pound charge
make quite a difference in
the slag. The charge is then
dumped at the furnace door.
Fuel is charged at the feed
door in alternate layers with
the charges. Both coke and
charcoal are used in varying
proportions.
The amount of fuel used varies
from 12 to 14%.
Ores containing only 6 ½ % of lead
has been successfully smelted.
The resulting products of smelting
are lead, containing silver
and more or less impurities;
matte, a sulphide of iron, and
slag. The bullion is tapped
out by the siphon tap and

Cast into bars; matte coming
coming out with the slag at
the breast, flows into an iron
pot.
30 to 40 tons of ore are
smelted in 24 hours.
At Pribram, Bohemia 40 to
45 tons of ore and fluxes are
smelted in 24 hours.
The slags contain only .0023 %
of silver and 1.5% of lead.
The campaign last 3 months
the longest having been 158 days.
At Railroad District, Nevada,
41 Tons of ore and fluxes ~~are~~ smel-
ted in 24 hours. (28 tons of ore
and 13 tons of flux).
The cost of smelting 1 Ton of
ore is estimated at $14.50.

cast into bars; matte coming
coming out with the slag at
the breast, flows into an iron
pot.
30 to 40 tons of ore are
smelted in 24 hours.
At Pribram, Bohemia 40 to
45 tons of ore and fluxes are
smelted in 24 hours.
The slags contain only .0023%
of silver and 1.5% of lead.
The campaign last 3 months
the longest having been 158 days.
At Railroad District, Nevada,
41 Tons of ore and fluxes are
smelted in 24 hours. (28 tons of ore
and 13 tons of flux).
The cost of smelting 1 Ton of
ore is estimated at $14.50.

Desilverization of the argentiferous lead.

Before the discovery by the late Hugh Lee Pattison, of the process by which the silver in argentiferous lead may be concentrated in a comparative small amount of that metal, the whole of the lead obtained by smelting was, when sufficiently rich, subjected to cupellation. This process is founded on the circumstance, first noticed by Mr. Pattison, in the year 1829, that when lead containing silver is melted in a suitable vessel, and afterwards suffered slowly to cool, with constant stirring at a temperature near the melting point of lead, small metallic crystals begin to form within the liquid alloy, which as rapidly as they are produced sink to the bottom, and on being removed are found to contain less silver than the lead originally operated on, the still fluid alloy from which the crystals have been separated is at the same time rendered proportionately richer in silver.

Desilverization of the argentiferous
Lead.

Before the discovery by the late Hugh Lee Pattison, of the process by which the silver in argentiferous lead may be concentrated in a comparative small amount of that metal, the whole of the lead obtained by smelting was, when sufficiently rich, subjected to cupellation. This process is founded on the circumstance, first noticed by Mr. Pattison, in the year 1829, that when lead containing silver is melted in a suitable vessel, and afterwards suffered slowly to cool, with constant stirring at a temperature near the melting point of lead, small metallic crystals begin to form within the liquid alloy, which as rapidly as they are produced sink to the bottom, and on being removed are found to contain less silver than the lead originally operated on, the still fluid alloy from which the crystals have been separated is at the same time rendered proportionately richer in Silver.

Modification of Pattison's Process.

The arrangement employed for this process essentially consist of two cast iron vessels, the first which is called the melting pot, and the other the crystalizing-pot, which must be placed at such a level that the metal from the melting-pot may be run directly into it.
Below the level of the crystalising pots must be one or more receivers for the reception of the enriched lead. Instead of using machinery for stirring the lead, the same object is more simply and effectually accomplished by introducing a jet of high pressure steam into the molten metal. This method is about 30% cheaper than the Old Pattison method.
The Old Pattison method is almost entirely out of use.
Marselle's Modification of the Pattison process is in use at Pribram Bohemia.

Modification of Pattison's Process.

The arrangement employed for
this process essentially consist
of two cast iron vessels, the first
which is called the melting
pot, and the other the crystalizing
pot, which must be placed
at such a level that the metal
from the melting pot may be
run directly into it.
Below the level of the crystalising
pots must be one or more receivers
for the reception of the enriched
lead. Instead of using
machinery for stirring the lead,
the same object is more simply
and effectively accomplished
by introducing a jet of high
pressure steam into the molten
metal. This method is about
30% cheaper than the Old Pattison
method.
The Old Pattison method is almost
entirely out of use.
Marselle's Modification of the Pattison
process is in use at Pribram Bohemia.

Desilversation by zinc.

Parke's Process:

When lead and zinc are melted together and the fused mixture allowed to cool slowly, the zinc solidifies first, forming a layer on the surface of the metallic bath which may be readily removed in the form of a crust containing nearly the whole of the silver present in the original lead. This process is operated as follows. A charge of 7 tons of lead to be desilverized is fused in a large cast-iron pot, close to which is placed a smaller one for the fusion of the necessary zinc.
As soon as the whole of the lead has become melted it is made to boil, by the insertion of a green pole, and the oxides which rise to the surface are removed by a perforated skimmer. The temperature of the metal is now raised to the melting point of zinc, and zinc is added

Desilversation by zinc.

Parke's Process:
When lead and
zinc are melted together and
the fused mixture allowed
to cool slowly, the zinc solidifies
first, forming a layer on
the surface of the metallic bosh
which may be readily removed
in the form of a crust containing
nearly the whole of the
silver present in the original
lead. This process is operated
as follows. A charge of 7 tons
of lead to be desilverized is
fused in a large cast iron pot,
close to which is placed a smaller
one for the fusion of the necessary
zinc.
As soon as the whole of the lead
has become melted it is made
to boil, by the insertion of a
green pole, and the oxides which
rise to the surface are removed
by a perforated skimmer.
The temperature of the metal is
now raised to the melting point
of zinc, and zinc is added

in the fused state in the proportion of about 1½ lbs. for each ounce of ~~zinc~~ silver contained in the lead operated on. The mixture is now well stirred during about 2 hours, the fire subsequently withdrawn and the metal allowed gradually to cool; during the process of cooling, any of the zinc alloy which may adhere, in the form of solid rings, to the sides of the pot must be removed by means of a piece of wood, and as soon as the surface has sufficiently hardened it is collected by skimming with a perforated ladle.
The alloy thus obtained is a mixture of lead and zinc containing silver, and is subjected to a process of liquation in an inclined retort, where it is heated somewhat above the melting point of lead.
The zinc, after being as far as possible freed from lead by liquation, is distilled in a Belgian furnace in

in the fused state in the proportion of about 1 ½ lbs. for each ounce of ~~zinc~~ silver contained in the lead operated on. The mixture is now well stirred during about 2 hours, the fire subsequently withdrawn and the metal allowed gradually to cool; during the process of cooling, any of the zinc alloy which may adhere, in the form of solid rings, to the sides of the pot must be removed by means of a piece of wood, and as soon as the surface has sufficiently hardened it is collected by skimming with a perforated ladle.
The alloy thus obtained is a mixture of lead and zinc containing silver, and is subjected to a process of liquation in an inclined retort, where it is heated somewhat above the melting point of lead.
The zinc, after being as far as possible freed from lead by liquation, is distilled in a Belgian furnace in

admixture of lime and coal-
dust; the residue in the retorts
consist of lead and pulverulent
matter. The former is remelted
skimmed and cupelled, and
the latter added to the charges
of the ordinary lead furnace.

Modification of Parks Process.

American Method:
Twenty tons
of bars are melted down slow-
ly in a large reverberatory fur-
nace. According to the amount
of impurities in the lead the
molten metal remains here
exposed to a low heat and
plenty of air, for a shorter
or longer time, the average be-
ing about 18 hours. After the
first 6 or 7 hours the covering of
oxides, containing most of the
copper and antimony and much
lead is taken off.
It amounts to from 1.5 to 2%
of the weight originally put
into the furnace.

admixture of lime and coal-
dust; the residue in the retorts
consist of lead and pulverulent
matter. The former is remelted
skimmed and cupelled, and
the latter added to the charges
of the ordinary lead furnace.

Modification of Park's Process.

American Method:
Twenty tons
of bars are melted down slowly
in a large reverberatory furnace.
According to the amount
of impurities in the lead the
molten metal remains here
exposed to a low heat and
plenty of air, for a shorter
or longer time, the average
being about 18 hours. After the
first 6 or 7 hours the covering of
oxides, containing most of the
copper and antimony and much
lead is taken off.
It amounts to from 1.5 to 2%
of the weight originally put
into the furnace.

The oxides forming after this are
not taken off, but left in
the furnace after tapping the
lead into the desilverisation kettles.
The drawing off from the fur-
nace into the desilverisation kettles
is effected by means of a
partly covered spout.
There are five desilverisation kettles
The two large ones, the so called
zinc pots, hold 42000 lbs. of metal
each. They are walled in side
by side, and immediately in
front of them are the smaller
liquation kettles nos. 3 and 4, which
hold 14000 lbs each. In front of
these is the smallest kettle,
holding 8000 lbs. which is used
for liquation to dryness.
The whole arrangement is in the
shape of a triangle, nos. 1 and
2 forming the base and no. 5
the apex. According to the rich-
ness of the material to be treated,
there is added from 1.8 to 2.6%
of zinc, either in no. 1 or no 2. kettle.
The zinc is added in three, and
sometimes four portions.

The oxides forming after this are
not taken off, but left in
the furnace after tapping the
lead into the desilverisation kettles.
The drawing off from the furnace
into the desilverisation kettles
is effected by means of a
partly covered spout.
There are five desilverisation kettles.
The two large ones, the so called
zinc pots, hold 42000 lbs. of metal
each. They are walled in side
by side, and immediately in
front of them are the smaller
liquation kettles nos. 3 and 4, which
hold 14000 lbs each. In front of
these is the smallest kettle,
holding 8000 lbs. which is used
for liquation to dryness.
The whole arrangement is in the
shape of a triangle, nos. 1 and
2 forming the base and no. 5
the apex. According to the richness
of the material to be treated,
there is added from 1.8 to 2.6%
of zinc, either in no. 1 or no. 2 kettle.
The zinc is added in three,
and sometimes four portions.

Each addition is with the lead for ½ to ¾ of an hour, the temperature being maintained above the melting point of zinc.
Then the fire is drawn and the Kettles are allowed to stand long enough to permit the Charge to cool, and the zinc-Silver alloy to rise to the surface, the lead below remaining liquid.
The scum is now taken off with perforated ladles and transfered to pot 3 or 4.
If it is the scum resulting from the first zinc addition, it is after a partial liquation, immediately transfered to pot no. 5 where the liquation is finished. The lead resulting from liquation is transfered from no. 3 or 4 back into no. 1 or 2 before the second addition of zinc is introduced
The scum resulting from the second, third or fourth addition is not liquated, but used again in a subsequent operation, in place of a first zinc

Each addition is with the lead
for ½ to ¾ of an hour, the temperature
being maintained above
the melting point of zinc.
Then the fire is drawn and the
kettles are allowed to stand long
enough to permit the charge to
cool, and the zinc-Silver alloy
to rise to the surface, the lead
below remaining liquid.
The scum is now taken off
with perforated ladles and
transferred to pot 3 or 4.
If it is the scum resulting
from the first zinc addition
it is after a partial liquation,
immediately transfered
to pot no. 5 where the liquation
is finished. The lead resulting
from liquation is transfered
from no. 3 or 4 back
into no. 1 or 2 before the second
addition of zinc is introduced
The scum resulting from the
second, third or fourth addition
is not liquated, but used
again in a subsequent operation,
in place of a first zinc

addition.
In a lot of 40120 lbs of work-
lead containing 0.198% of silver
the desilversation took place
as follows:
1. Added: zinc scum from pre-
vious operation 3000 lbs,
Left in lead after skimming
silver 0.116%.
2. zinc 600 lbs.
Left in lead after skimming:
silver 0.003%.
3. zinc 125 lbs.
Left in lead after skimming
silver 0.0006%
In desilverising 287383 lbs. 1.8%
zinc was used.

addition.
In a lot of 40120 lbs of work-
lead containing 0.198% of silver,
the desilverisation took place
as follows:

1. Added: zinc scum from previous operation: 3000 lbs.
   Left in lead after skimming:
   silver 0.116%.
2. Zinc 600 lbs.
   Left in lead after skimming:
   silver 0.003%.
3. Zinc 125 lbs.
   Left in lead after skimming,
   silver 0.0006%

In desilverising 287383 lbs. 1.8%
of zinc was used.

Distillation of the zinc silver alloy.

The rich zinc crust is liquated at some works in reverberatories, at others in kettles standing for that purpose near the large desilverisation kettles. It is, however, always the aim not to produce any oxides, and for that reason the temperature is kept exceedingly low, excess of air is limited as much a possible.
In this fact lies the fundamental difference between our American distillation and that at Tarnowitz.
The process of distillation is as follows:
Mr. A. Faber du Faur's tilting retort furnace is used.
The retort furnace is heated gradually by means of coke until the retort has become dark red. Then it is charged by means of a small copper shovel with liquated zinc crust, which has previously

Distillation of the zinc silver
alloy.
The rich zinc crust is
liquated at some works in
reverberatories, at others in
kettles standing for that purpose
near the large desilverisation
kettles. It is, however, always
the aim not to produce any
oxides, and for that reason the
temperature is kept exceedingly
low, excess of air is limited
as much as possible.
In this fact lies the fundamental
difference between our American
distillation and that at
Tarnowitz.
The process of distillation is
as follows:
Mr. A. Faber du Faur’s tilting retort
furnace is used.
The retort furnace is heated
gradually by means of coke
until the retort has become
dark red. Then it is charged
by means of a small copper
shovel with liquated zinc-
crust, which has previously

been cut into pieces about 1
to 1½ cubic inches.
A charge filling the retort
to the neck consist of from
250 to 400 lbs. of alloy with
which from 3 to 5 lbs. of small
charcoal, of bean size has
been mixed, next the condens-
er is put on. The temperature
is at once raised to a white
heat, and kept so until the
distillation is complete.
The operation last from 8 to 10
hours according to the percentage
of zinc in the alloy.
When sufficient metallic zinc
has been collected, it is remel-
ted in a kettle under a coal
covering, the oxide and impu-
rities are taken off, and the
metal cast into plates, which are
again used for desilverisation.
From 40 to 50% of the zinc orig-
inally added to the work lead
is regained in the form of
plates which contain only a
trace of silver.
The blue powder and oxide

been cut into pieces about 1
to 1 ½ cubic inches.
A charge filling the retort
to the neck consist of from
250 to 400 lbs. of alloy with
which from 3 to 5 lbs. of small
charcoal, of bean size has
been mixed, next the condenser
is put on. The temperature
is at once raised to a white
heat, and kept so until the
distillation is complete.
The operation lasts from 8 to 10
hours according to the percentage
of zinc in the alloy.
When sufficient metallic zinc
has been collected, it is remelted
in a kettle under a coal
covering, the oxide and impurities
are taken off, and the
metal cast into plates, which are
again used for desilverisation.
From 40 to 50% of the zinc originally
added to the work lead
is regained in the form of
plates which contain only a
trace of silver.
The blue powder and oxide

containing no more silver than
the metal, and comprising 10
to 20% of the original zinc, are
sold to zinc works.
When the distillation has been
carried on until there is only
a trace of zinc in the rich
lead, the condenser is taken
off, and the furnace is left
to itself for a few minutes.
Meanwhile a small wagon, carrying
a cast iron pot, is brought in
front of the retort, and by tilt-
ing the whole furnace the
rich lead is transferred in
a stream to the
After having cooled for awhile
the metal is poured into lead
moulds.

containing no more silver than
the metal, and comprising 10
to 20% of the original zinc, are
sold to zinc works.
When the distillation has been
carried on until there is only
a trace of zinc in the rich
lead, the condenser is taken
off, and the furnace is left
to itself for a few minutes.
Meanwhile a small wagon, carrying
a cast iron pot, is brought in
front of the retort, and by tilting
the whole furnace the
rich lead is transferred in
a stream to the
After having cooled for awhile
the metal is poured into lead
moulds.

German Cupellation process.

The Old German cupelling furnace, which is still in use in many Continental establishments, consists of a kind of reverberatory oven, having a circular hearth, and a lateral fireplace. The bottom which is regularly hollowed from the sides toward the middle, is composed of fire-brick set on edge upon a stratum of firmly-compressed slag, and is again covered with a coating of marl. This layer of marl corresponds to the test employed by English refiners, and is covered by a dome of iron plastered over with marl. About 5 tons of ordinary lead are usually cupelled at one operation, and of this a little less than three-fourths is introduced into the furnace before lighting up; the remainder is added at successive intervals during the progress of cupellation. The operation is continued until the greater portion of the lead has been removed in the

German Cupellation process.

The Old German cupelling furnace, which is still in use in many Continental establishments, consists of a kind of reverberatory oven, having a circular hearth, and a lateral fireplace. The bottom which is regularly hollowed from the sides towards the middle, is composed of fire brick set on edge upon a stratum of firmly compressed slag, and is again covered with a coating of marl. This layer of marl corresponds to the test employed by English refiners, and is covered by a dome of iron plastered over with marl. About 5 tons of ordinary lead are usually cupelled at one operation, and of this a little less than three-fourths is introduced into the furnace before lighting up; the remainder is added at successive intervals during the progress of cupellation. The operation is continued until the greater portion of the lead has been removed in the

form of litharge, and a plate of nearly pure silver remains.
The average loss of lead during cupellation by the German process is about 8%.
About 5 tons are cupelled in 80 hours with a consumption of 1½ cord of wood.
The Blicksilber obtained from this operation is refined either in a movable test, like that employed in the English process, or in a fixed cupel forming the bottom of a reverberatory furnace.

form of litharge, and a plate
of nearly pure silver remains.
The average loss of lead during
cupellation by the German process
is about 8%.
About 5 tons are cupelled in
80 hours with a consumption
of 1 ½ cord of wood.
The Blecksilver obtained from
this operation is refined either
in a movable test, like that
employed in the English process, or
in a fixed cupel forming the
bottom of a reverberatory furnace.

Refining.

English Method.

The cupellation of argentiferous lead is conducted on a hearth composed of bone-ash, which forms the movable bottom of a reverberatory furnace. The cupel, or test, is contained in an elliptical iron ring, seldom less than 5½ or 6 inches in depth, usually about 4 feet in its greater and 3 feet in its lesser diameter. To support and strengthen the bottom of the test, this frame is provided with four parallel cross-bars, 4½ inches wide, and, like the ring itself, half an inch in thickness. To prepare a test the frame is filled with bone-ash well beaten in layers, after having been previous moistened with water. After the framing has been filled with bone-ash, solidly beaten down, a cavity is scooped in its upper surface. The test is heated to redness, and a charge

Refining.
English Method.
The cupellation
of argentiferous lead is conducted
on a hearth composed of
bone-ash, which forms the
movable bottom of a reverberatory
furnace. The cupel, or test, is
contained in an elliptical iron ring,
seldom less than 5 ½ or 6 inches
in depth, usually about 4 feet
in its greater and 3 feet in its
lesser diameter. To support and
strengthen the bottom of the test,
this frame is provided with
four parallel cross-bars, 4 ½
inches wide, and, like the ring
itself, half an inch in thickness.
To prepare a test the frame
is filled with bone-ash well
beaten in layers, after having
been previous moistened with
water. After the framing has
been filled with bone-ash,
solidly beaten down, a cavity
is scooped in its upper surface.
The test is heated
to redness, and a charge

of the rich lead to be operated
on is introduced.
When first introduced into
the furnace, the liquid metal
becomes covered by a grayish
dross; but as soon as it has
acquired the full temperature
of the test, the surface of the
bath uncovers, and fused
litharge begins to make its
appearance. The blast is now
turned on through the nozzle
and the melted litharge is
thus driven from the back
of the test up toward the
breast where it flows out.
The appearance of the surface
indicates the precise period
at which the operation is
terminated; the blast is turned
off, and the fire removed
from the grate.
The plate of silver is thus
allowed to set, and as soon
as it has done so the test frame
together with the silver is
taken out and allowed to
cool. The silver is detached

of the rich lead to be operated
on is introduced.
When first introduced into
the furnace, the liquid metal
becomes covered by a grayish
dross; but as soon as it has
acquired the full temperature
of the test, the surface of the
bosh uncovers, and fused
litharge begins to make its
appearance. The blast is now
turned on through the nozzle
and the melted litharge is
thus driven from the back
of the test up toward the
breast where it flows out.
The appearance of the surface
indicates the precise period
at which the operation is
terminated; the blast is turned
off, and the fire removed
from the grate.
The plate of silver is thus
allowed to set, and as soon
as it has done so the test frame
together with the silver is
taken out and allowed to
cool. The silver is detached

from the cupel, and any
partickles of litharge, slag, or
bone-ash are removed by scraping
with a wire brush.
The plates atained vary in weight
from 5000 to 10000 ozs. and usually
Contains from 997 to 998 parts
of silver in a thousand.

from the cupel, and any
partickles of litharge, slag, or
bone-ash are removed by scraping
with a wire brush.
The plates atained vary in weight
from 5000 to 10000 ozs. and usually
contains from 997 to 998 parts
of silver in a thousand.

Extraction of Silver by means of Copper.

Silver extraction by means of copper is divided into the following steps:

1. Production of Copper matte containing the silver.
2. Extraction of the silver from the copper matte.
3. Production of copper from the copper residues, after the silver has been extracted.

1. Production of Copper matte containing the Silver.

This is accomplished by the reverberatory or blast furnace.

Production of matte by the reverberatory process.
The production of matte as carried on at the Boston and Colorado Works will be given as an illustration of the reverberatory process.
The production of matte is as follows;

Extraction of Silver by means
of Copper.
Silver extraction
by means of copper is divided
into the following steps:

1. Production of copper matte
containing the silver.
2. Extraction of the silver
from the copper matte.

3. Production of copper from
the copper residues, after
the silver has been extracted.

1. Production of copper matte
containing the Silver.

This is accomplished by the
reverberatory or blast furnace.

Production of matte by the
reverberatory process
The production of matte as
carried on at the Boston
and Colorado Works will
be given as an illustration
of the reverberatory process.
The production of matte is as follows:

1. Sampling the ore.

All the ores received are pilled separately on the sampling grounds. All the large pieces of gold ore are roasted in heaps, and are then passed through a crusher and rolls, and afterwards through a screen with four to the inch mesh. The tellurium ores are only crushed and passed through a ten to the inch mesh screen, and are ready for smelting. The surface silver ores are crushed and passed through a four to the inch mesh screen, and then go to the furnace. The ores rich in Sulphur are called heavy ores, and are crushed and roasted in large reverberatory furnaces.

2. Roasting the ores.

a. Roasting the ores in heaps.

The auriferous pyrites is broken to 2 inches square in a crusher and roasted in heaps of about 50 tons each.

1. Sampling the ore.
All the ores received are pilled separately on the sampling ground. All the large pieces of gold ore are roasted in heaps, and are then passed through a crusher and rolls, and afterwards through a screen with four to the inch mesh. The tellurium ores are only crushed and passed through a ten to the inch mesh screen, and are ready for smelting. The surface silver ores are crushed and passed through a four to the inch mesh screen, and then go to the furnace. The ores rich in Sulphur are called heavy ores, and are crushed and roasted in large reverberatory furnaces.
2. Roasting the ores.
a. Roasting the ores in heaps.
The auriferous pyrites is broken to 2 inches square in a crusher and roasted in heaps of about 50 tons each.

Two cord of wood is consumed
for roasting 50 tons.
Three men does all the sampling
and weighing, and takes care
of the piles. The roasted ore
is crushed and goes through
a sieve with a four to the
inch mesh, and is then ready
for the smelter. The roasting
occupies about 6 weeks.
The amount of sulphur remain-
ing in the ore is about 4%.
b. Roasting the ore in a rever-
beratory furnace.
The ore submitted to this process
is said to be calcined.
The tailings and finely divid-
ed copper ores are roasted
in a reverberatory furnace,
called a calciner, till they
contain not more than ½ to 4%
of sulphur. The total length
of the furnace is 40 feet
on the outside, including
the fireplace. Each furnace
has three step-hearths 10 feet
long. They are 11 feet wide,
and have six working doors,

Two cord of wood is consumed
for roasting 50 tons.
Three men does all the sampling
and weighing, and take care
of the piles. The roasted ore
is crushed and goes through
a sieve with a four to the
inch mesh, and is then ready
for the smelter. The roasting
occupies about 6 weeks.
The amount of sulphur remaining
in the ore is about 4%.

b. Roasting the ore in a reverberatory
furnace.
The ore submitted to this process
is said to be calcined.
The tailings and finely divided
copper ores are roasted
in a reverberatory furnace,
called a calciner, till they
contain not more than ½ to 4%
of sulphur. The total length
of the furnace is 40 feet
on the outside, including
the fireplace. Each furnace
has three step-hearths 10 feet
long. They are 11 feet wide,
and have six working doors,

two door to each hearth.
The hearths are 4½ inches, one
above the other, and are equally
divided in the length of the
furnace. The fire place is
arranged for wood, and has
a door at the side, It is 5
feet long and 2 feet 8 inches
wide. The width of the bridge
is 28 inches, the height of the
roof above the hearth is 28 inches
and at the flue-end it is 18
inches. The furnace is built
of red brick, firebrick being
used only in the fireplace
and on the first hearth.
A charge of one ton is intro-
duced on the hearth nearest
the flue, so that there are
3 tons in the furnace at a
time. As the charge is drawn
drawn once in 8 hours, it takes
24 hours to complete the roasting
of one ton of the ore.
Two men work 3 tons in 24 hours
1½ Cords of wood are consumed
every 24 hours. The Cost of roas-
ting is $4.45.

two doors to each hearth.
The hearths are 4 ½ inches, one
above the other, and are equally
divided in the length of the
furnace. The fire place is
arranged for wood, and has
a door at the side. It is 5
feet long and 2 feet 8 inches
wide. The width of the bridge
is 28 inches, the height of the
roof above the hearth is 28 inches,
and at the flue-end it is 18
inches. The furnace is built
of red brick, firebrick being
used only in the fireplace
and on the first hearth.
A charge of one ton is introduced
on the hearth nearest
the flue, so that there are
3 tons in the furnace at a
time. As the charge is drawn
drawn once in 8 hours, it takes
24 hours to complete the roasting
of one ton of the ore.
Two men work 3 tons in 24 hours.
1 ½ cords of wood are consumed
every 24 hours. The cost of roasting
is $4.45.

3. Fusion for matte.
The roasted ore is fused in a reverberatory furnace for matte. These furnaces are constructed to use wood, so that the fireplace, which is 5 feet at the top of the bridge, is only 2 feet 6 inches at the grate; it is 5 feet long and 4½ feet deep from the grate to the roof.
The opening in the fireplace for charging fuel is at the end of the furnace, and not at the side as is usual.
The bridge is 2½ feet wide, the fireplace side 2¼ feet and the laboratory side 1⅝ feet from the roof. The laboratory is 15 feet 7½ inches long, by 9 feet 9 inches wide. The working door is at the end.
The hearth of the furnace is slightly inclined toward the working door, and also to one side. It is made of two layers of bricks, upon which fine quartz-sand is placed, which is mixed

3. Fusion for matte.
The roasted ore is fused in a reverberatory furnace for matte. These furnaces are constructed to use wood, so that the fireplace, which is 5 feet at the top of the bridge, is only 2 feet 6 inches at the grate; it is 5 feet long and 4 ½ feet deep from the grate to the roof.
The opening in the fireplace for charging fuel is at the end of the furnace, and not at the side as is usual.
The bridge is 2 ½ feet wide, the fireplace side 2 ¼ feet and the laboratory side 1 ⅝ feet from the roof. The laboratory is 15 feet 7 ½ inches long, by 9 feet 9 inches wide. The working door is at the end.
The hearth of the furnace is slightly inclined toward the working door, and also to one side. It is made of two layers of bricks, upon which fine quartz-sand is placed, which is mixed

with a small quantity of wood ashes, and then agglomerated. When the hearth is made the temperature is lowered and the charge is introduced.
The charge is made of

Heap-roasted gold ores,	2000 lbs.
Roasted tailings,	2000 "
Oxidized silver ores,	1500 "
Roasted silver ores,	1500 "
Raw Pyrites,	800 "
Flourspar,	250 "
Rich Scorias,	500 "

The charge is introduced with a shovel by a side door. The ore is introduced first and then the rich slags. The charge is so arranged that ten tons of mixed ores will produce 1 ton of matte.
The slag is carefully calculated, so that it shall not be too basic, or otherwise it would cut the firebrick to get silica. The charge is evenly distributed over the surface of the hearth which is almost at a cherry

with a small quantity of
wood ashes, and then agglomerated.
When the hearth is
made the temperature is
lowered and the charge is
introduced.
The charge is made of

Heap-roasted gold ores,	2000 lbs.
Roasted tailings,	2000 “
Oxidized silver ores,	1500 “
Roasted silver ores,	1500 “
Raw Pyrites,	800 “
Flourspar,	250 “
Rich Scorias,	500 “

The charge is introduced
with a shovel by a side door.
The ore is introduced first
and then the rich slags.
The charge is so arranged
that ten tons of mixed ores will
produce 1 ton of matte.
The slag is carefully calculated,
so that it shall not be too
basic, or otherwise it would
cut the firebrick to get silica.
The charge is evenly distributed
over the surface of the hearth
which is almost at a cherry

red heat. As soon as the charge is made, the charging door is built up and luted with sand. The fireplace is thus charged and the furnace is left the full power of draft for 5 or 6 hours. At the end of this time they stir the furnace carefully 5 or 6 minutes to bring up every thing from the bottom. The furnace is left for 20 minutes to effect the separation of the scoria and matte.

The slag is now drawn with a rabble into moulds prepared for it. When all the slag is drawn off, a new charge of ore is introduced.

Four charges are made in 24 hours. While the slag is tapped the matte is left to accumulate, and is tapped only once in 24 hours. The matte is tapped and made into plates 3 feet long, 14 inches wide, and 4 inches thick in the middle the bottom being rounded. 3 men per shift of 12 hours are

red heat. As soon as the
charge is made, the charging
door is built up and luted
with sand. The fireplace is
thus charged and the furnace
is left the full power of draft
for 5 or 6 hours. At the end of
this time they stir the furnace
carefully 5 or 6 minutes to bring
up everything from the bottom.
The furnace is left for 20
minutes to effect the separation
of the scoria and matte.
The slag is now drawn with a
rabble into moulds prepared for
it. When all the slag is
drawn off, a new charge of
ore is introduced.
Four charges are made in 24
hours. While the slag is tapped
the matte is left to accumulate,
and is tapped only once
in 24 hours. The matte is
tapped and made into plates
3 feet long, 14 inches wide, and
4 inches thick in the middle,
the bottom being rounded.
3 men per shift of 12 hours are

required to work two furnaces.
8 cord of wood are consumed in
24 hours. The plate slag contains
on an average 5% of copper,
but is often poor enough to
be thrown away with the other
slags. It is generally a sili-
cate of protoxide of iron, but
is sometimes mere basic.
The poor slag contains 7 ounces
of silver and a trace of gold.
It is too poor to be treated and
is thrown away. All the slags
richer than this are put back
into the furnace.
The matte contains from 25 to
30% of copper, 20 to 30 ounces
of gold, 600 to 1000 ounces of
silver, and some iron, lead,
zinc, and antimony.
There are produced from this
operation the copper matte,
which passes to the next oper-
ation, the plate slag, which is
immediately put back into the
furnace, and the poor slag
which is thrown away.

required to work two furnaces.
8 cord of wood are consumed in
24 hours. The plate slag contains
on an average 5% of copper,
but is often poor enough to
be thrown away with the other
slags. It is generally a silicate
of protoxide of iron, but
is sometimes mere basic.
The poor slag contains 7 ounces
of silver and a trace of gold.
It is too poor to be treated and
is thrown away. All the slags
richer than this are put back
into the furnace.
The matte contains from 25 to
30% of copper, 20 to 30 ounces
of gold, 600 to 1000 ounces of
silver, and some iron, lead,
zinc, and antimony.
There are produced from this
operation the copper matte,
which passes to the next operation,
the plate slag, which is
immediately put back into the
furnace, and the poor slag
which is thrown away.

Production of matte by the blast furnace process.

As an illustration of this process the production of matte as carried on at Mansfield, Prussia, will be given.

The Production of matte at Mansfield is divided into the following steps:

I. Burning the Schist.
II. Smelting burnt ore with Slag for the production of Coarse-metal.
III. Roasting the Coarse-metal.
IV. Melting for fine-metal.

I. Burning the Schist.

This has for its object the Combustion or volatilization of a large portion of the bitumen, as well as the expulsion of water, arsenic, etc.; a portion of the sulphur is also eliminated at the same time, but care must be taken to retain a sufficient quantity to form a good coarse-metal

Production of matte by the blast furnace process.

As an illustration of this process, the production of matte as carried on at Mansfield, Prussia, will be given.

The production of matte at Mansfield is divided into the following steps:

I. Burning the Schist.
II. Smelting burnt ore with slag for the production of coarse metal.
III. Roasting the coarse metal.
IV. Melting for fine metal.

I. Burning the Schist.

This has for its object the combustion or volatilization of a large portion of the bitumen, as well as the expulsion of water, arsenic, etc.; a portion of the sulphur is also eliminated at the same time, but care must be taken to retain a sufficient quantity to form a good coarse-metal

with the Copper and a portion
of the iron.
The Schist is burnt in heaps
200 to 300 feet long, 30 to 40 in
width, 10 feet in height, and
containing 400 to 900 tons.
Ten pound of wood are con-
sumed for each ton of Schist
burnt; and the reduction in
bulk which takes place during
the operation is about 10%, and
the loss of weight is 16%.

II. Smelting burnt ore with slag
for the production of coarse
metal.

The roasted ore is taken from
the pile in which it is burnt
directly to the smelting furnace,
where it is fused with a mixt-
ure of slags and flour-spar, the
products obtained being coarse-
metal and poor slags.
This fusion takes place in a
blast furnace of which the total
height is about 30 feet.
These furnaces are circular
in form and are blown by

with the copper and a portion
of the iron.
The Schist is burnt in heaps
200 to 300 feet long, 30 to 40 in
width, 10 feet in height, and
containing 400 to 900 tons.
Ten pound of wood are consumed
for each ton of Schist
burnt; and the reduction in
bulk which takes place during
the operation is about 10%, and
the loss of weight is 16%.

II. Smelting burnt ore with slag
for the production of coarse
metal.

The roasted ore is taken from
the pile in which it is burnt
directly to the smelting furnace,
where it is fused with a mixture
of slags and flour-spar, the
products obtained being coarse
metal and poor slags.
This fusion takes place in a
Blast furnace of which the total
height is about 30 feet.
These furnaces are circular
in form and are blown by

six tuyers. The furnace is supported on eight short cast-iron pillars, carrying an iron ring, and is lined with fire-brick. The blast, which is heated to a temperature of 280°C., enters the furnace by six water tuyers, under a pressure of 2 lbs. per square inch, while the throat, which is closed by the cup-and-cone arrangement, admits of the waste gasses being collected by means of openings.
The materials to be charged on placed on a platform near the top, and usually consist of about 86.5% of roasted schist from operation I., 6.5% of flour-spar and 7% of slag from operation IV.
The fuel is introduced in alternate layers with the ore and flux, and a fresh charge is added as soon as flame makes its appearance at the top.
The slags flow off constantly and the coarse metal is from time to time tapped off on the opposite side of the furnace; this

six tuyeres. The furnace is
supported on eight short cast-
iron pillars, carrying an iron
ring, and is lined with firebrick.
The blast, which is heated
to a temperature of 280°C.,
enters the furnace by six water
tuyeres, under a pressure of
2 lbs. per square inch, while
the throat, which is closed by
the cup-and-cone arrangement,
admits of the waste gasses being
collected by means of openings.
The materials to be charged are
placed on a platform near the
top, and usually consist of about
86.5% of roasted Schist from
operation I., 6.5% of flour-spar
and 7% of slag from operation IV.
The fuel is introduced in alternate
layers with the ore and
flux, and a fresh charge is
added as soon as flame makes
its appearance at the top.
The slags flow off constantly and
the coarse metal is from time
to time tapped off on the opposite
side of the furnace; this

flows through an iron gutter, from which it falls into a cistern of water, where it is granulated.
120 to 135 tons of ore are smelted in 24 hours, with a consumption of 500 lbs of Coke per Ton.

III. Roasting the Course-metal.
This is accomplished in rectangular stalls inclosed on three sides by permanent stone walls, while the front is closed by a loose one of uncemented stones, which is taken down whenever the roasted regulus is required to be removed. Each stall is capable of containing from 200 to 300 cubic feet of coarse-metal and fuel. The bottom of the ores is first covered with a layer of wood, and upon this are piled from 20 to 25 tons of Course-metal. This operation requires from 10 to 12 days. The loss in weight is from 12 to 15%.

flows through an iron gutter,
from which it falls into a
cistern of water, where it is
granulated.
120 to 135 tons of ore are smelted
in 24 hours, with a consumption
of 500 lbs of coke per Ton.

III. Roasting the coarse metal.
This is accomplished in
rectangular stalls inclosed
on three sides by permanent
stone walls, while the front is
closed by a loose one of
uncemented stones, which is taken
down whenever the roasted
regulus is required to be removed.
Each stall is capable
of containing from 200 to 300
cubic feet of coarse metal and
fuel. The bottom of the ores is
first covered with a layer of
wood, and upon this are piled
from 20 to 25 tons of course metal.
This operation requires from 10
to 12 days. The loss in weight
is from 12 to 15%.

IV, Melting for fine-metal.

The furnace employed for this operation very closely resembles that used in the re-verberatory process for smelting for course-metal.

The charge consist of 1300 lbs. of a mixture of once roasted and twice roasted coarse-metal, 200 lbs. of slag from Operation II, and 250 lbs. of Siliceous sand. This mixture is charged into the furnace through a hopper in the usual way, and at the expiration of 8 hours, will have been reduced to a perfectly liquid condition; the regulus will have fallen to the bottom, and will be covered by a stratum of Siliceous slag. The slag is raked off and withdrawn through the door, and a new charge let down into the hearth and smel-ted as before. Once in 24 hours, or oftener if required, the tapping-hole is opened and the fine-metal which has accumulated in the bottom of

IV. Melting for fine metal.

The furnace employed for this operation very closely resembles that used in the reverberatory process for smelting for course metal.

The charge consists of 1300 lbs. of a mixture of once roasted and twice roasted coarse metal, 200 lbs. of slag from operation II., and 250 lbs. of Siliceous sand. This mixture is charged into the furnace through a hopper in the usual way, and at the expiration of 8 hours, will have been reduced to a perfectly liquid condition; the regulus will have fallen to the bottom, and will be covered by a stratum of Siliceous slag. The slag is raked off and withdrawn through the door, and a new charge let down into the hearth and smelted as before. Once in 24 hours, or oftener if required, the tapping-hole is opened and the fine metal which has accumulated in the bottom of the furnace is granulated by being run into a tank of water; this granulated regulus is subsequently dried, and is sent to the mill, in which it is reduced to a fine powder previously to being treated for the extraction of silver.

the furnace is granulated
by being run into a tank of
water; this granulated regulus
is subsequently dried, and is
sent to the mill, in which it
is reduced to a fine powder
previously to being treated for
the extraction of silver.

Separation of silver from copper.

By taking advantage of the peculiarly strong affinity of copper for sulphur; the slight disposition it possesses when compared with other metals, to combine with oxygen, and its high specific gravity, that most of the existing metallurgical processes for obtaining the pure metal have been arrived at. There are a number of plans for extracting silver from it or its compounds, which rest on these and other important physical and chemical peculiarities.

The extraction of silver by liquation.

This is one of the most ancient methods of extracting silver from copper. It is founded on the fact that when copper containing silver is alloyed with lead, and heated to a certain degree above the

Separation of silver from
copper.
By taking advantage
of the peculiarly strong affinity
of copper for sulphur; the
slight disposition it possesses
when compared with other metals,
to combine with oxygen, and
its high specific gravity, that
most of the existing metallurgical
processes for obtaining the
pure metal have been arrived
at. There are a number of
plans for extracting silver
from it or its compounds,
which rest on these and other
important physical and chemical
peculiarities.

The extraction of silver by
liquation.
This is one of the most ancient
methods of extracting silver
from copper. It is founded
on the fact that when copper
containing silver is alloyed
with lead, and heated to
a certain degree above the

melting point of lead, but below that of copper, the lead will become fluid and drain or sweat out of the alloy, carrying off most of the silver and leaving an impure copper. This method is out of use.

Extraction of silver by the amalgamation of coarse copper.

This process is based upon the circumstance that the silver which exists in coarse copper in a metallic state, when raised to a red heat, in connection with comon salt, is changed to a chloride; and when quicksilver is brought into intimate contact with this roasted mass, this chloride is decomposed, and an amalgam with silver and a small quantity of copper and iron is produced.

The amalgam thus formed, when removed to cast iron retorts and heated, is decomposed, the quicksilver distills off, and the silver is refined.

melting point of lead, but
below that of copper, the lead
will become fluid and drain
or sweat out of the alloy,
carrying off most of the silver
and leaving an impure copper.
This method is out of use.

Extraction of silver by the amalgamation
of coarse copper.
This process is based upon
the circumstances that the silver
which exists in coarse copper
in a metallic state, when
raised to a red heat, in
connection with comon salt, is
changed to a chloride; and when
quicksilver is brought into intimate
contact with this roasted
mass, this chloride is decomposed,
and an amalgam with silver
and a small quantity of copper
and iron is produced.
The amalgam thus formed, when
removed to cast iron retorts and
heated, is decomposed, the
quicksilver distills off, and the
silver is refined.

Extraction of silver by the amalgamation of copper matte.

This process which is very similar to that adopted in the usual amalgamation of silver ores, consist in roasting the mixture of sulphides of copper, silver, iron, etc., that form the matte, as it falls from the furnace, with a proper quantity of common salt and lime. The first furnish-es chlorine, by means of which the varous metals are turned into chlorides, while the lime decomposes the chlorides of iron and copper, but leaves the silver to be collected by the quicksilver in the subsequent treatment.
This system was once in use at Mansfield, Prussia, but was replaced by Ziervogel's method.

Extraction of silver by the
amalgamation of copper matte.

This process which is very
similar to that adopted in
the usual amalgamation of
silver ores, consist in roasting
the mixture of sulphides of
copper, silver, iron, etc., that
form the matte, as it falls
from the furnace, with a
proper quantity of common salt
and lime. The first furnishes
chlorine, by means of which
the varous metals are turned
into chlorides, while the lime
decomposes the chlorides of iron
and copper, but leaves the
silver to be collected by
the quicksilver in the
subsequent treatment.
This system was once in use
at Mansfield, Prussia, but
was replaced by Ziervogel's
method.

Augustins method of extracting silver from copper by means of a solution of salt.

The circumstance long known to chemists, that the chloride of silver is somewhat soluble in a concentrated solution of comon salt, was taken advantage of by Augustin, in an ingenious plan for the separation of copper and silver.

Copper mattes, yielding from 50 to 70 of copper, but free from metallic granules, and containing no lead, zinc, antimony, or arsenic, afford the best results when treated by Augustin's process.

The matte is powdered very finely, and roasted in a double-hearth reverberatory furnace. The roasted powder is ground and subjected to a second roasting, and near the end of the process, about 5% of salt is added, which changes the silver into a chloride. This powder is now brought into lixiviating

Augustin's method of extracting
silver from copper by
means of a solution of salt.
The circumstance long known
to chemists, that the chloride
of silver is somewhat soluble
in a concentrated solution of
common salt, was taken advantage
of by Augustin, in an
ingenious plan for the separation
of copper and silver.
Copper mattes, yielding from 50
to 70 of copper, but free from
metallic granules, and containing
no lead, zinc, antimony, or
arsenic, afford the best results
when treated by Augustin's process.
The matte is powdered very
finely, and roasted in a
double-hearth reverberatory
furnace. The roasted powder is
ground and subjected to a
second roasting, and near the
end of the process, about
5% of salt is added, which
changes the silver into a
chloride. This powder is
now brought into lixiviating

tubs and treated with hot brine, which filtering through, carries with it the chloride of silver. Passing into precipitation tubs, it is brought in contact with copper, which throws down the silver in the form of cement silver.
This is collected, dried, and refined. The copper dissolved in the precipitation of the silver is carried forward to other vessels and thrown down as cement copper with metallic iron. The lixiviated powder is smelted in a reverberatory furnace for coarse copper, which is refined in the German hearth

tubs and treated with hot brine, which filtering through, carries with it the chloride of silver. Passing into precipitation tubs, it is brought in contact with copper, which throws down the silver in the form of cement silver.
This is collected, dried, and refined. The copper dissolved in the precipitation of the silver is carried forward to other vessels and thrown down as cement copper with metallic iron. The lixiviated powder is smelted in a reverberatory furnace for coarse copper, which is refined in the German hearth.

Ziervogel's method of extracting silver from copper by means of warm water.

This method is founded on the circumstance, that when a mixture of copper and iron sulphides, containing silver is roasted in a state of fine division, in a reverberatory furnace with certain percautions, ferrous sulphate is first formed, this by further roasting, becomes ferric sulphate, which is finally decomposed into ferric oxide. At this period sulphide of copper is transformed into cupric sulphate, and on the temperature being further increased, cupric oxide is produced and sulphuric acid expelled. Finally, silver sulphide is converted into sulphate of silver; a salt readily dissolved in water, while nearly all the other ingredients of the roasted matte are insoluble in that menstrum. If the roasted material be now lixiviated with hot water, the silver will be

Ziervogel's method of extracting
silver from copper by means
of warm water.
This method is founded on
the circumstance, that when
a mixture of copper and iron
sulphides, containing silver is
roasted in a state of fine
division, in a reverberatory
furnace with certain percautions,
ferrous sulphate is first formed,
this by further roasting, becomes
ferric sulphate, which is finally
decomposed into ferric oxide.
At this period sulphide of copper
is transformed into cupric sulphate,
and on the temperature being
further increased, cupric oxide
is produced and sulphuric acid
expelled. Finally, silver sulphide
is converted into sulphate of
silver; a salt readily dissolved
in water, while nearly all
the other ingredients of the
roasted matte are insoluble in that
menstrum. If the roasted
material be now lixiviated with
hot water, the silver will be

obtained in a solution, from which it may be readily precipitated as cement silver by metallic copper.

obtained in a solution, from
which it may be readily
precipitated as cement silver by
metallic copper.

Production of Copper from the Copper residues after the silver has been extracted.

As the Ziervogel process is the one generally in use for the extraction of silver from Copper matte; the treatment of the Ziervogel tub residues will be the only method considered under this head.

The residues retained in the tubs in which the lixiviation for sulphate of silver has been conducted contain from 70 to 75 % of Copper, chiefly as oxide. This is now converted into black copper, by fusing in a blast furnace.
At Mansfield the Copper oxide is mixed with 8 % of Clay, worked into balls and dried; these balls have an addition made to them of about 10 % of siliceous sand, 5 % of pyrites, and from 10 to 15 % of slag from the same operation, or from the

Production of copper from
the copper residues after
the silver has been extracted.

As the Ziervogel process is
the one generally in use
for the extraction of silver
from copper matte; the
treatment of the Ziervogel tub
residues will be the only
method considered under this head.

The residues retained in the
tubs in which the lixiviation
for sulphate of silver has been
conducted contain from 70 to
75% of copper, chiefly as oxide.
This is now converted into
black copper by fusing in
a blast furnace.
At Mansfield the copper oxide
is mixed with 8% of clay,
worked into balls and dried;
these balls have an addition
made to them of about 10% of
siliceous sand, 5% of pyrites,
and from 10 to 15% of slag from
the same operation, or from the

process of refining.
The mixture is charged into the furnace alternately with layers of coke. The reducing action of the furnace thus converts the principal portion of the oxide into metallic copper while the Sulphur in the pyrites serves the purpose of cleansing the slag.
The black copper, which amounts to 66% of the fall from the furnace, contains 98.5% of copper, and is refined in the reverberatory furnace by polling.

Respectfully Submitted,
J. R. D. Owen

Rolla, Mo.
June 8th 1885.

process of refining.
The mixture is charged into the furnace alternately with layers of coke. The reducing action of the furnace thus converts the principal portion of the oxide into metallic copper while the Sulphur in the pyrites serves the purpose of cleansing the slag.
The black copper, which amounts to 66% of the fold from the furnace, contains 98.5% of copper, and is refined in the reverberatory furnace by polling.

Respectfully Submitted,
J. R. D. Owen

Rolla, Mo.
June 8th 1885.