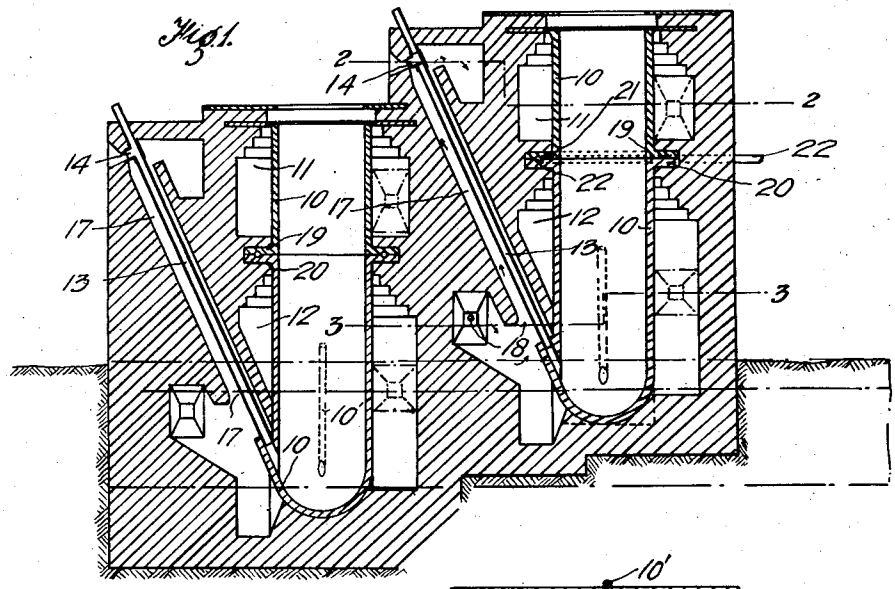
Oct. 9, 1928. 1,687,188

G. K. WILLIAMS

REFINING OF LEAD BULLION CONTAINING OTHER METALS

Filed Feb. 9, 1927

Fig. 1.



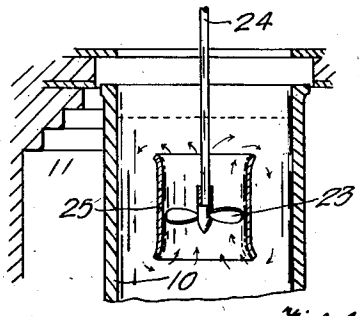


Fig. 4.

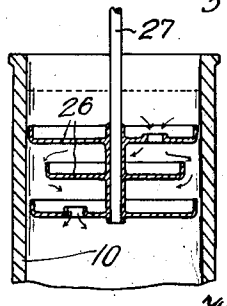


Fig. 5.

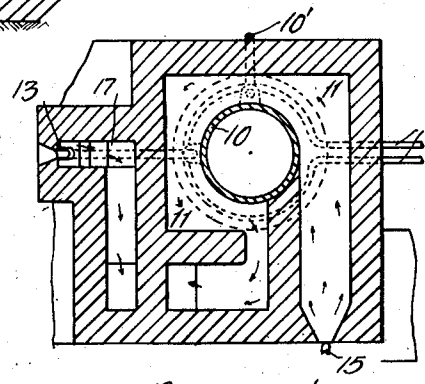


Fig. 2.

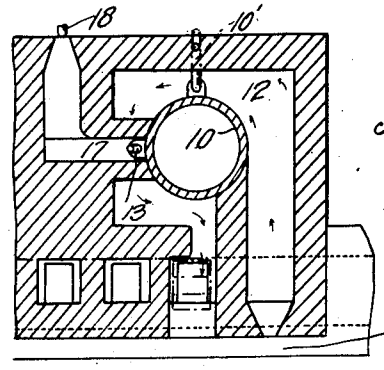


Fig. 3.

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UNITED STATES PATENT OFFICE.

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REFINING OF LEAD BULLION CONTAINING OTHER METALS.

Application filed February 9, 1927, Serial No. 166,988, and in Australia March 6, 1926.

This invention relates to the refining of lead bullion containing other metals, such as copper, gold and silver.

In this specification, the following terms will have the following meaning:

Alloying metals—copper or gold or silver and mixtures thereof, which form alloys with zinc (with or without lead) and which being present in the initial bullion, it is desired to remove, both for their own values and for the purpose of providing lead sufficiently free therefrom for commercial purposes.

Alloy—such alloys of zinc (with or without lead) and the said "alloying metals".

Residual bullion—the bullion remaining after treatment which is relatively low in one or more of the "alloying metals".

Crusts—such alloys of the alloying metals with zinc and lead (with or without lead) which are formed by the cooling of the bullion as distinct from the alloys which are formed as conjugate solutions.

In the refining of lead bullion by the well-known "Parkes" process, it is the practice to incorporate a certain amount of zinc with the molten bullion sufficient for the formation of certain alloys with zinc and the said metals desired to be removed. The bullion is then cooled, whereby the alloys separate from the bullion, and as the temperatures obtaining during such cooling are below the melting points of the above alloys so liberated such alloys separate in the form of crusts. Such crusts, owing to their specific gravity being lower than that of the liquid bullion, rise to the surface and are then removed, leaving residual bullion relatively low in such metals.

The crusts obtained by the aforesaid "Parkes" process usually contain a considerable amount of entangled lead, the removal of which has been effected, either by subjecting the said crusts to liquation, or to presses.

In the operation of the "Parkes" process, as universally practised, the amount of zinc added to the bullion and the temperatures employed are insufficient for the formation and maintenance of conjugate solutions in a liquid system enabling the separation of such solutions from each other.

Now, the object of this present invention is to provide means whereby lead bullion containing the said alloying metals may be refined for the removal therefrom of the said alloying metals, providing on the one hand alloys relatively rich in such alloying metals and low in lead, and on the other hand residual bullion sufficiently low in such alloying metals as required for commercial purposes, in a more economical and efficient manner than heretofore.

According to this invention the refining of lead bullion may be effected either as a continuous or as an intermittent process, and the different alloying metals may be preferentially removed from the bullion giving alloys rich in one or more of the said alloying metals in specific order.

Now, I have found that if an amount of zinc beyond a certain quantity greater than that which is used in the "Parkes" process is incorporated with bullion containing the said alloying metals, and a sufficiently high temperature is maintained to liquefy the system layers of conjugate solutions are formed, the top solution comprising the said alloy, and the bottom solution bullion, which, when cooled to about its eutectic temperature produces residual bullion.

This invention therefore comprises certain improvements in the refining of lead bullion containing alloying metals and consists of incorporating zinc with the said bullion in sufficient quantities and maintaining the required temperature, whereby distinct molten layers of conjugate solutions are formed, the upper of which consists of the said alloy which may be separated, and the lower of which consists of bullion which, if desired, can be cooled to about its eutectic temperature, producing on the one hand residual bullion, and on the other hand alloys in the form of crusts relatively rich in zinc.

This invention also comprises the preferential separation of the alloys of the alloying metals by the regulation of the amount of zinc incorporated with the bullion, and the temperature to which the mixture is submitted, whereby conjugate solutions are formed, the upper of which comprises an alloy rich in a certain alloying metal as distinct from the other alloying metals.

For example: Lead bullion containing copper, gold and silver may be treated in accordance with this invention by incorporating a certain quantity of zinc with the bullion and maintaining the same at such a

temperature that an alloy relatively rich in copper and gold and low in silver, and a residual bullion relatively low in copper and gold and high in silver can be obtained. Or alternatively by incorporating larger amounts of zinc with the lead bullion an alloy relatively rich in copper and gold and silver can be obtained and a residual bullion relatively low in copper and gold and silver.

Consequently by this method of treatment I am enabled to effect the removal from the bullion of the copper and gold and silver in one operation, or by successive operations in which the quantities of zinc present are controlled to preferentially remove the copper and the gold, and then the silver. This preferential treatment is capable of many modifications owing to the different affinities possessed by zinc for the different alloying metals. Zinc has a slightly greater affinity for copper than for gold so that by incorporating a relatively small amount of zinc with the bullion and heating the same to the required temperature alloys relatively higher in copper than in gold can be obtained, but for practical purposes owing to the fact that such differences in the affinities of zinc for copper and gold are slight I prefer to form alloys as relatively rich as possible in both gold and copper.

In the practical application of this invention regard should be had of the quantity of zinc present in the crusts formed during the cooling of the bottom solution to about its eutectic temperature, and the zinc contents of such crusts are availed of to supply a proportion of the zinc required to be present in the various treatments carried out during the refining operation, whereby economies are effected in the consumption of zinc necessary for the carrying out of the process.

Thus, in carrying the invention into practical effect, it is preferred that a suitable amount of zinc be incorporated with the lead bullion and the temperature of the same maintained at the required degree for the liquefaction of the alloy, whereby conjugate solutions are formed, the upper of which consists of the alloy which is separated, and the lower of which consists of bullion which when cooled to about its eutectic temperature gives residual bullion on the one hand and alloys in the form of crusts on the other hand which are availed of for forming a portion of the amount of zinc required for the purpose of forming the said conjugate solutions.

In preferential treatment it is not essential that the bottom solution produced in each treatment should be cooled to about its eutectic temperature in order to produce residual bullion relatively free from the alloying metal or metals. However, to obtain the highest efficiency with respect to the zinc consumption and quantity of crusts formed during the cooling of the bottom solution, it is advisable that such bottom solution be cooled to about its eutectic temperature.

This improved method of refining lead bullion may be carried out either as intermittent or as a continuous treatment and is applicable to the ordinary open kettles which are at present in use or to reverberatory furnaces or any other suitable containers, or to special kettles as hereinafter described or to a combination thereof, that is to say, one part of the treatment may be carried out in a reverberatory furnace or a suitable container, and the other part in a suitable kettle.

One method of applying the invention to refining in ordinary open kettles, the requisite quantity of zinc (in the form of spelter with or without crusts obtained from the cooling of the bottom solution of the corresponding treatment of the previous charge) is incorporated with the charge of bullion in the kettle (which may be either the lead bullion to be refined containing the said alloying metals, or residual bullion from a preceding preferential treatment) and the mixture is heated to the requisite temperature for the formation of conjugate solutions, the top solution of which comprises the desired alloy, which is separated, and the bottom solution is either cooled in the kettle or else transferred to some other vessel of suitable type and then cooled, preferably to about the eutectic temperature of the residual bullion

The crusts formed during the cooling of the bottom solution are separated from the bullion and added to the corresponding treatment of the next charge.

The above method of treatment may be carried out in a reverberatory furnace or any other suitable container wherein the desired temperatures may be maintained and molten layers of conjugate solutions formed. When operating in reverberatory furnaces precaution should be taken for avoiding oxidation of the bullion such as by a reducing atmosphere in the said furnace or by forming a surface liquid layer of a substance such as common salt. Or such a reverberatory furnace may be used for preheating the bullion to the required temperature before being fed into the separating kettle. Instead of effecting the incorporation of the zinc with the lead in the kettle itself, such incorporation may be effected in a separate vessel such as by causing the liquid bullion to pass through a bath or layer of molten zinc previous to being fed to the kettle. Or instead of both forming the conjugate solutions and separating the same in the one kettle or other suitable container the process may be applied by using one kettle or vessel for incorporation of the requisite quantity of zinc with the bullion and maintaining the required temperature for the formation of conjugate solutions and then discharging the same into

a separate kettle or suitable container when the bullion is cooled to the requisite temperature for the separation of the alloy comprising the conjugate solution and also, if required, the crusts formed.

When such treatment is carried out in the ordinary open kettles which are at present in use, the thickness of the surface layer of top conjugate solution comprising the alloy is relatively small, owing to the large surface area, so that considerable difficulty is experienced in effecting a separation of the same without undue contamination by, and entanglement of, the lower layer of solution. Moreover, such open kettles as at present in use are adapted only for intermittent treatment of bullion in accordance with this invention.

Consequently the treatment of the said bullion in accordance with this invention is preferably effected in such manner that the heated mixture is in the form of a relatively long narrow column, to which differential temperatures are applied, whereby one portion of the column, such as the upper portion, may be maintained at a higher temperature, and the lower portion at a lower temperature, with means for controlling the said temperature, and this invention comprises the treatment of the said lead bullion in a vessel or kettle wherein the abovementioned conditions are maintained. Kettles of this description are adapted for either intermittent or continuous treatment of bullion.

A kettle of this description is illustrated in the accompanying drawings wherein

Figure 1 is a view in sectional elevation;

Figure 2 is a view in sectional plan of part of Figure 1 taken on the line 2—2;

Figure 3 is a view in sectional plan of a part of Figure 1 taken on the line 3—3;

Figures 4 and 5 are vertical sections of portion of a kettle showing the accommodation of means for ensuring the admixture of the metal therein.

The kettle 10 consists of a deep narrow vessel having means such as an upper circular flue 11 and a lower circular flue 12 whereby the different portions thereof may be differentially heated and a higher temperature imparted to the upper portion than to the lower.

The kettle is provided with an upwardly projecting spout 13 from its lower portion, the discharge 14 of which is at a lower level than the top of the kettle, and means may be provided, such as by a surrounding flue 17 whereby the said spout may be also heated maintaining the same at the required temperature.

As the upper portion of the kettle 10 is subjected to considerably higher temperatures than the lower portion the same is more liable to deterioration and cracking, so that the kettle 10 is preferably formed in two parts having flanges 19 and 20 by which the said parts may be bolted or otherwise fastened together, whereby the upper part may be renewed without having to dismantle the lower part. The joint between the two flanges 19 and 20 is made tight by forming a concentric groove 21 of circular cross section therebetween, the same being adapted to accommodate a pipe 22 through which a cooling medium (such as water) is caused to circulate, thereby causing any metal entering the joint to freeze and leakage thereby avoided.

The upper flue 11 surrounding the upper portion of the kettle 10 is provided with a liquid fuel burner 15 or other source of heat whereby the same is maintained at the requisite temperature.

The lower flue 12 surrounding the lower portion of the kettle 10 is also provided with a liquid fuel burner 16 or other source of heat whereby the same is maintained at its requisite temperature.

In some cases it may be necessary to maintain the lower portion of the kettle 10 at a lower temperature than would ensue by the mere absence of heating means in the lower flue 12 and in such a case a cooling medium (such as cool air) may be passed through the said flue 12, the same being for the time being cut off from the main combustion flue, or if necessary water circulating pipes may be disposed within the said flue 12.

When adapting this invention for continuous treatment the bullion is continuously fed into the top of the kettle with the requisite amount of zinc and the residual bullion is likewise continuously discharged from the bottom of the kettle, the alloy comprising the upper layer of conjugate solution being continuously or intermittently withdrawn. In some cases it may be desirable to incorporate the necessary amount of zinc with the bullion before being fed to the top of the kettle and this may be effected in a separate container or furnace. When adapted for preferential removal of alloying metals the treatment is carried out in a series of kettles, the residual bullion discharged from each kettle (save the last) being fed into the next kettle in the series together with such amounts of zinc as may be necessary, the alloys comprising the upper layer of conjugate solutions formed in each kettle being separately withdrawn either continuously or intermittently.

The following two methods of operating such treatment are mentioned by way of example.

The bullion is continuously fed into the kettle 10 together with the desired quantity of zinc, the upper part of the kettle 10 being maintained above the point of liquefaction of the alloy comprising the upper layer of conjugate solution by means of the burner 15 in the flue 11, whilst the lower part of the kettle 10 is maintained at a gradually decreasing temperature towards the bottom by regulating the temperature in the flue 12, the tem-

perature at the entrance to the spout 13 being at approximately the eutectic temperature of the residual bullion.

The continuous feed of the lead bullion into the kettle 10 causes a continuous formation of an upper layer of conjugate solution comprising an alloy of one or more of the alloying metals and a continuous discharge of residual bullion from the spout 13. In the passage of the bullion through the kettle crusts are formed in the lower portions thereof due to cooling. These crusts rise into the upper portion of the kettle, where they augment the aforesaid layer of conjugate solution. If necessary, means may be provided for ensuring the more or less complete admixture and if desired the same may comprise a stirrer 23 fitted to a spindle 24 and disposed within a cylinder 25 located in the upper portion of the kettle (see Figure 4). Alternatively as illustrated in Figure 5 a centrally disposed spindle 27 may be fitted with plates or trays 26 having staggered openings therein to allow of the downward passage of the bullion in the kettle. The temperature of the upper portion of the kettle 10 is maintained above the liquefaction temperature of the alloy required, and thus the continuous feed of bullion containing alloying metals and zinc into the kettle 10 will cause the continuous formation of conjugate solutions, the upper layer of which comprises an alloy rich in one or more of the alloying metals.

Consequently the bullion is continuously subjected to treatment as it passes through the kettle 10 whereby the particular alloying metal or metals is or are separated therefrom so that when the said bullion reaches the lower portion of the kettle 10 which is maintained at about the eutectic temperature of the residual bullion, it is relatively free from the said alloying metal or metals.

By maintaining the upward projecting spout 13 at a temperature above the eutectic temperature of the residual bullion, this residual bullion is prevented from freezing as it flows upwardly through the said spout 13, whereby a continuous delivery may be effected, through the discharge 14, so that by continuously or periodically removing the upper layer of alloy by either tapping or bailing, and by maintaining the delivery of residual bullion through the spout 13, a continuous feed may be maintained into the kettle 10 of the bullion containing the alloying metal.

As an illustration of the above modification of this invention I give the following example of certain work performed by me at Port Pirie, South Australia:

Example I: A bullion assaying:

Silver	57.7 ozs. per ton
Gold	1 grain
Copper	0.004 per cent
Zinc	0.2 per cent

was continuously fed into the top of a kettle similar to that illustrated in the accompanying drawings together with periodic additions of zinc (spelter) equivalent to 18-lbs per ton of bullion treated, the upper portion of the kettle was maintained at a temperature of approximately 700° C. and the bottom part of the kettle was cooled to a temperature of approximately 335° C. and the spout at a temperature of approximately 400° C. A layer of conjugate solution was continuously formed in the upper part of the kettle and was periodically removed by bailing and was found to be 15.7-lbs. per ton of bullion treated and to assay:

Silver	8200 ozs. per ton (equivalent to 25.1%)
Gold	6-dwts. per ton
Copper	0.57 per cent
Zinc	63.3 per cent
Lead	10.5 per cent

whilst the residual bullion discharged from the spout of the kettle assayed:

Silver	0.2-ozs. per ton
Zinc	0.56 per cent
Gold	Trace
Copper	Trace

The kettle used in the above experiment was 2-feet in diameter and 9-feet deep and a rate of feed was maintained for a considerable period of over 100-tons per day, but it was found that a much greater rate of feed could be maintained, the operation being limited by the supplies of bullion available and the temporary nature of the plant.

The work done in the above mentioned experiment at Port Pirie was limited by the nature of the material of which the kettle used was composed, viz: cast iron, but indications have been obtained that if the upper part of the kettle were made of material which would withstand a temperature of from 800° C. to 850° C. so that alloys of a higher melting point could be formed as conjugate solutions a differential separation can be effected of the alloying metals copper and gold and silver and the following is an example of a method of treatment based upon the above mentioned indications:

Example II: A bullion assaying:

Silver	60 ozs. per ton
Gold	0.13-ozs. per ton
Copper	0.095 per cent
Zinc	Trace

being fed continuously into the first of a series of two kettles as shewn in Figure 1 together with periodic additions of zinc equivalent to 9-lbs. per ton, the top portion of the kettle being maintained at a temperature of about 850° C. and the lower portion of the kettle cooled to a temperature of approximately 330° C. and the spout maintained at a tem-

perature of about 400° C. conjugate solution formed at the top of the kettle equivalent to 7.7-lbs. per ton of bullion treated could be periodically removed assaying:

Silver	662-ozs. per ton
Gold	37.2 ozs. per ton
Copper	26.5 per cent
Zinc	53.5 per cent
Lead	12.0 per cent

whilst the residual bullion assayed:

Silver	57.7	ozs. per ton
Gold	1	grain
Copper	0.004	per cent
Zinc	0.2	per cent

could be continuously fed into the second kettle giving the same result as the above mentioned example.

According to another modification of this invention the zinc necessary for the formation of the conjugate solution may be fed into the kettle at the commencement of the operation so that a layer of zinc or conjugate solution high in zinc is disposed in the upper part of the kettle through which the bullion is caused to continuously pass until the layer of conjugate solution becomes enriched to a sufficient extent with the alloying metals desired to be removed. By this method of treatment the bullion is fed in continuously and the residual bullion removed continuously and the alloy removed periodically. If desired an amount of zinc as is required to make up for that withdrawn in the residual bullion may be added to the feed of bullion. This method of operation dispenses with careful calculation as to the amount of zinc fed with the bullion.

As an illustration of this modification of the invention the kettle 10 is first charged with bullion up to the level of the discharge 14 of the spout 13, and zinc, or alloy relatively high in zinc, is then added thereto to the upper level of the top of the kettle. Bullion (either the lead bullion to be refined containing the said alloying metals, or residual bullion from a preceding treatment) is then fed continuously into the said kettle 10, being caused to pass down through the surface layer of molten zinc or alloy, in such a way that it is brought into intimate contact with the same, and if necessary, for this purpose suitable trays or baffles or stirrers may be provided for ensuring the more or less complete contact.

The temperature around the upper part of the kettle 10 is maintained at the necessary degree for the liquefaction of the alloy by means of the burners 15 in the flue 11, whilst the lower part of the kettle is maintained at a decreasing temperature by means of the lower flue 12 until the bottom thereof is at about the eutectic temperature of the residual bullion. The spout 13 of the said kettle is also maintained at a temperature slightly above the said eutectic temperature by means of the flue 17, so that the said residual bullion is prevented from freezing, and is permitted of a continuous flow through the said spout 13.

The crusts which are formed by the cooling in the lower part of the kettle rise into the upper portion of the kettle, where they come in contact with the bullion feeding into the kettle and the conjugate solutions which exist in that portion of the kettle, the upper layer of which is relatively high in zinc. The continuous feed of bullion into the kettle causes the gradual enrichment of the upper layer of the conjugate solutions in alloying metals by incorporation of the same therein. At the same time intermittent additions of zinc (spelter) may be made in order to maintain the level of the solutions to compensate for the zinc withdrawn in the residual bullion. The flow of bullion into the kettle is maintained until the content of alloying metal or metals in the residual bullion rises beyond a certain determining limit. When this limit is reached the upper layer of conjugate solution comprising the alloy rich in the said alloying metal or metals is removed by tapping or bailing and a further requisite quantity of zinc (spelter) or alloy rich in zinc is added.

By operating in this way no accurate determination of the amount of zinc (spelter) to be added is necessary, the continuous flow of the bullion functioning to increasingly enrich the conjugate solutions formed until the desired degree of enrichment is attained. Whilst the layer of conjugate solution in the upper portion of the kettle is of high zinc content and low in alloying metals the residual bullion discharging from the lower portion of the kettle is correspondingly low in the said alloying metals and as the percentage of the said alloying metals in the said upper layer of conjugate solution increases there is a corresponding increase in the percentage of alloying metals in the residual bullion. Consequently the content of the alloying metals in the residual bullion discharged affords a relatively accurate determining point at which the alloy should be removed and a fresh charge of zinc fed into the kettle.

By way of an illustration of this modification of an application of this invention the following is given by way of example:

Example III: The bullion treated assayed as follows:

Silver	57.7	ozs. per ton
Gold	1	grain
Copper	0.004	per cent
Zinc	0.2	per cent

A kettle similar to that illustrated in the accompanying drawings 2-feet in diameter and 9-feet deep was charged with bullion up to the level of the discharge of the spout and 1600-lbs. of zinc (spelter) was fed on to the

top of the said bullion forming a layer of conjugate solution approximately 18-inches thick in the upper portion of the kettle. The bullion assaying as above indicated was then fed in continuously to the top of the kettle, the upper portion of which was maintained at a temperature of approximately 700° C., the lower portion of the said kettle being cooled to a temperature of approximately 335° C., and the spout at a temperature of approximately 400° C. At the commencement of the operation the residual bullion discharging from the spout of the kettle assayed as follows:

Silver	0.05 ozs. per ton
Zinc	0.6 per cent

The bullion was continuously fed in to the top of the kettle together with periodic additions of zinc equivalent to 8.5-lbs. per ton, and this feed was continuously maintained until the silver content of the residual bullion discharging from the spout had increased to 0.2-oz. per ton. The operation was stopped and it was found that approximately 200 tons of bullion had been passed through the kettle. The alloy comprising the conjugate solution in the upper portion of the kettle was bailed off and found to be 2680-lbs. equivalent to 13.4-lbs. per ton of bullion treated, assaying:

Gold	7-dwts. per ton
Silver	29.4 per cent=9604 ozs. per ton
Copper	0.67 per cent
Zinc	59.3 per cent
Lead	10.0 per cent

In the above description of this invention reference has only been made to the alloying metals present as governing the amount of zinc and the temperature required for the formation of conjugate solutions. It will, however, be understood that other factors will govern these conditions, such as for example the presence of other metals such as Antimony, Arsenic and Bismuth which are usually regarded and designated as "Impurities". Consequently in determining the amount of zinc added and the temperature required for the purposes of this invention regard will be had to the aforesaid "impurities" in the bullion.

The amount of zinc and the temperature required for the formation of conjugate solutions comprising the desired alloying metal or metals may be determined by a simple test on a laboratory scale. For this purpose a small miniature kettle may be used comprising a narrow deep kettle similar in shape to that illustrated in the accompanying drawings having also a similar spout and likewise means for differentially heating the body of the said kettle and the said spout. If such experimental work is required to be carried out at temperatures above that which cast iron will withstand such a kettle may be constructed of any suitable material such as refractory material. The bullion may be heated in a separate vessel and a certain definite quantity of zinc added, such as an amount equivalent to say 8-lbs. per ton. This mixture is then continuously fed into the kettle which is maintained at a temperature of approximately 335° C. at the bottom, and the spout at a temperature of about 400° C. and the upper portion of the kettle at such a temperature as is required to just maintain the conjugate solutions formed, that is to say, if there is any indication of crusts in the top of the kettle it may be assumed that the temperature is too low and should be increased. The feed is continued and the kettle maintained at these temperatures until equilibrium is established as indicated by periodic assays of the residual bullion discharged from the spout. In this way indications may be obtained as to whether or not greater or lesser quantities of zinc are required and the experiment is continued with varying amounts of zinc until the correct amount of zinc is determined as indicated by the condition of the residual bullion discharged from the spout after equilibrium of the system is established following each successive variation in the amount of zinc added.

I claim:

1. A process for the refining of lead bullion containing alloying metals consisting of incorporating zinc with the said bullion in such quantity and subjecting the same to such differential temperatures that molten layers of conjugate solutions are formed the upper layer comprising an alloy rich in a certain alloying metal or metals and separating such alloy in liquid system.

2. A process for the refining of lead bullion which consists of feeding the said bullion continuously through a suitable vessel together with the requisite quantity of zinc and subjecting the same to differential temperatures as it passes through the said vessel, the temperature at the top being such as to cause the formation of conjugate solutions comprising an alloy relatively rich in one or more of the alloying metals, the temperature at the bottom being at or about the eutectic temperature of the residual bullion separating the said alloy and continuously discharging the said residual bullion.

3. In the refining of lead bullion containing alloying metals incorporating zinc with the said bullion in such quantities and maintaining such a temperature that molten layers of conjugate solutions are formed comprising an upper layer of an alloy rich in a certain alloying metal or metals separating such alloy in liquid system, maintaining the remaining bullion at progressively decreasing temperatures to about the eutectic temperature

of the residual bullion and separating such residual bullion in liquid system.

4. In the refining of lead bullion containing alloying metals the preferential separation of such alloying metals by incorporating a sufficient amount of zinc in the said bullion and maintaining the same at such temperature that conjugate solutions are formed comprising an alloy rich in a certain alloying metal or metals separating such alloy, cooling the remaining bullion to a point above its eutectic temperature and reheating the same at such a temperature or temperatures that other conjugate solutions are formed comprising an alloy or alloys rich in the remaining alloying metal or metals, separating such alloy or alloys and removing the residual bullion.

5. In the refining of lead bullion containing alloying metals continuously feeding the said bullion in a molten condition through a number of kettles in series together with the requisite quantity of zinc and maintaining a higher temperature at the top portion of the said kettles in the said series than at the bottom portion thereof whereby conjugate solutions are formed in the upper portions of the kettles rich in certain alloying metals, removing the said alloys from the upper portions of the said kettles and maintaining the temperature of the lower portion of the last kettle at a point just above the eutectic temperature of the residual bullion in each kettle and removing the residual bullion from the last kettle in the series.

6. In the refining of lead bullion containing alloying metals continuously feeding the said bullion in molten condition through a series of kettles together with the requisite quantity of zinc and maintaining such a temperature at the upper portion of the first kettle that a molten layer of conjugate solution is formed comprising an alloy rich in certain alloying metal or metals, maintaining such a temperature at the lower portion of the first kettle that the bullion discharging therefrom is relatively low in the alloying metal or metals contained in the alloy comprising the conjugate solution in the upper portion of the said first kettle and continuously feeding the bullion discharged from the first kettle through a second kettle with or without further quantities of zinc and maintaining such temperature at the upper portion of the said second kettle that further conjugate solutions are formed comprising alloys relatively high in other alloying metal or metals, cooling the bullion in the lower portion of the second kettle to a temperature just above the eutectic temperature of the residual bullion periodically or continuously separating the alloy formed in the upper portion of the second kettle and continuously removing the residual bullion from the lower portion of the second kettle.

7. In the refining of lead bullion containing alloying metals continuously feeding the said bullion in molten condition through a layer of molten zinc in the upper portion of a suitable kettle, maintaining the said upper portion of the said kettle at such a temperature that molten layers of conjugate solutions are formed comprising an alloy of a certain alloying metal or metals maintaining the lower portion of the said kettle at a temperature just above the eutectic temperature of the residual bullion therein, continuously discharging the residual bullion from the bottom of the said kettle until its contents in the alloying metal which is associated with the alloy in the aforesaid conjugate solution reaches a predetermined limit, removing the said conjugate solution comprising the said alloy relatively rich in such alloying metal and adding a further quantity of zinc to form a further layer of molten zinc in the upper portion of the kettle and repeating the operation.

8. In the refining of lead bullion containing alloying metals incorporating such quantities of zinc with the said bullion and maintaining the same at such a temperature in the form of a narrow deep column of molten metal, the upper portion of such column being at such a relatively high temperature that molten layers of conjugate solutions are formed and maintaining the lower portion of the said column at a relatively low temperature just above the eutectic temperature of the residual bullion, continuously removing the said bullion and removing the alloy comprising the said conjugate solution.

9. In the refining of lead bullion containing gold, silver and copper, incorporating zinc with the said bullion in such quantities and maintaining the same at such a temperature that molten layers of conjugate solutions are formed, the upper of which comprises an alloy relatively rich in copper and gold and low in silver, separating the said alloy, maintaining the temperature of the remaining bullion just above the eutectic temperature of the residual bullion relatively low in copper and gold and high in silver, subsequently treating the said residual bullion with the requisite quantity of zinc and maintaining the same at such a temperature that conjugate solutions are formed comprising an alloy relatively rich in silver and low in copper and gold, separating such alloy and discharging the said residual bullion relatively low in copper, gold and silver.

In witness whereof I hereunto affix my signature.

GEORGE KENNETH WILLIAMS.