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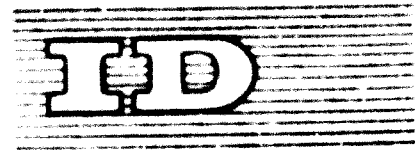
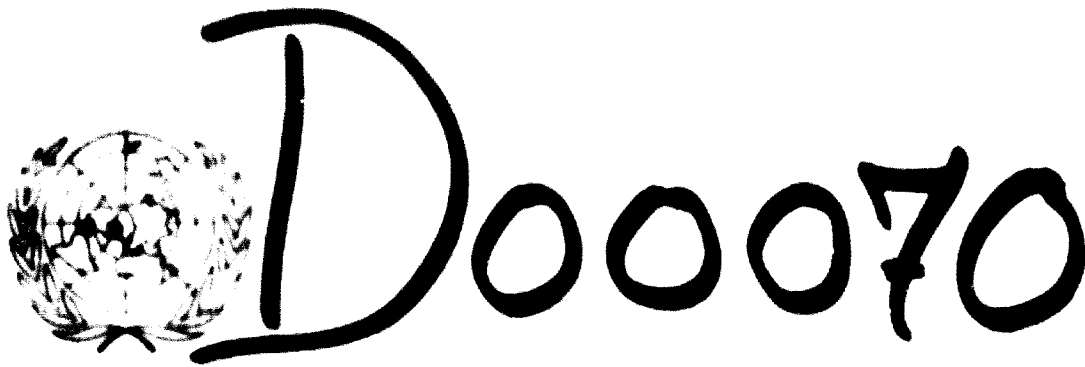
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**METALLURGY OF THE ZINC/LEAD BLAST FURNACE <sup>1/</sup>**

by

R. Healey  
Imperial Smelting Processes Limited  
Avonmouth  
England

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## METALLURGY OF THE ZINC/LEAD BLAST FURNACE

### Summary

The operation of the Imperial Smelting process and its ancillary equipment is described. Sinter and preheated coke are charged to the shaft of the furnace, while preheated air is blown in through tuyeres at the bottom. Lead is reduced near the top of the charge and runs down to be tapped off with the slag from the furnace hearth. Zinc is reduced to vapour in the hottest part of the furnace, just above the tuyeres, and passes via an offtake near the top of the shaft to a condenser.

The zinc vapour is absorbed in a spray of molten lead. The residual gas passes on and is used to preheat the blast air, while the condenser lead is circulated by a pump through a cooling system. As the lead cools the zinc separates and rises to the surface, where it is retained by an underflow baffle and diverted to a holding bath, while the lead returns to the condenser.

The zinc is tapped from the holding bath and can then be sold as Grade 4 metal (98.5% Zn). If desired it may be refined to reduce its lead content, by means of de-zincing to give Grade 2 (99.9 +  $\frac{1}{2}$  Zn), or by refluxing to produce Grade 1 (99.99 +  $\frac{1}{2}$  Zn).

## Introduction

1. Thermodynamically the reduction of zinc oxide carbon cannot be brought about under atmospheric pressure at temperatures below the boiling point of the zinc metal, and it is thus impracticable to attempt to produce liquid zinc directly from a blast furnace. The metal must therefore be produced initially as a vapour, and in consequence the reaction requires not only a high temperature to favour reduction, but also a large supply of heat per unit of zinc reduced in order to provide the necessary latent heat. As a result zinc reduction can take place only near the bottom of the charge where the heat supply is greatest, and further up the shaft the temperature is too low although chemically the furnace gases are still highly reducing.

The chemical potential of the gases can be utilised by including lead and zinc materials in the charge, since lead reduction is exothermic once the furnace has reached furnace temperature. Lead is thus reduced to liquid metal at the top of the charge and runs down, collecting copper, silver and gold on the way, to be tapped off with the slag from the furnace hearth, while zinc is reduced to vapour near the bottom of the charge and passes upwards with the gases to the furnace offtake.

The recovery of zinc vapour from the furnace gases is difficult because of their high oxygen potential and the low concentration (about 7% by volume) of the zinc, which result in heavy reoxidation as soon as the gases are cooled. The solution adopted in the Imperial Smelting process is to pass the gases to a separate chamber (the condenser) where they are scrubbed with a shower of molten droplets of lead by paddles rotating in a pool of liquid lead. Reoxidation is checked by the sudden drop in temperature, while the lead droplets simultaneously dissolve the zinc vapour from the furnace gases. The lead is pumped continuously from the condenser and circulated through a water cooled launder which removes the heat derived from the gases. It should be noted that this splash condenser is a device for recovering zinc vapour, and has no connection with the production of lead bullion from the furnace shaft.

As the lead flows along the water cooled launder its temperature falls and zinc is thrown out of solution, forming a second liquid layer floating on the lead surface. When the temperature has been sufficiently reduced the lead stream

reaches a separator containing an underflow weir which diverts the zinc to a holding bath from which it can be tapped. The cooled lead re-enters the condenser pool where it flows in countercurrent to the furnace gases, and is thrown up into a spray by the rotors as before. The cooled furnace gases are finally scrubbed with water to remove lead and zinc oxides carried over from the condenser, and their calorific value is recovered by burning them to preheat coke for the furnace charge and air for the hot blast.

5. Because the zinc is recovered from solution in lead, lead constitutes the major impurity. Simple liquation before casting is sufficient to produce Grade 4 zinc (98.5% Zn) but further refining is required to attain higher purity. There is then a choice of vacuum de-zincing (VDZ) the circulating condenser lead, giving Grade 2 zinc (99.9+% Zn) by distillation under reduced pressure, or full refluxing to produce Grade 1 (99.99+% Zn).

6. The operation of the zinc/lead blast furnace can thus be divided into a number of sections as listed below:

- Charge preparation
- Furnace shaft
- Slag and bullion handling
- Condensation system
- Separation system
- Zinc refining - liquation
  - vacuum de-zincing
  - refluxing

The remainder of the paper describes in more detail the processes occurring in each section taken in turn.

#### I. Charge preparation

7. The charge preparation system must supply the furnace with sufficient feed having the correct chemical composition and physical condition. An account of the weights of materials charged must also be kept. The materials to be handled are sinter, coke, lime flux and a small amount of recycled dross. The factors which must be controlled are sizing, temperature and weighing and proportioning.

(a) Sizing

8. Sinter is delivered from the Roasting Plant to the furnace feed bins after passing over a one inch screen which effectively removes all material finer than half inch. Large lumps (greater than four inches) are also removed by screening or by passing through spiked rolls. Further removal of fines occurs as the sinter is drawn from the feed bins by a vibrating conveyor fitted with a short one inch screen.

9. Attention to sinter sizing is justified by furnace performance. Ideally the whole charge, coke and sinter, should have uniform size to reduce segregation of the charge constituents in the shaft, and to induce even gas flow so as to favour maximum gas-solid contact. This results in more efficient usage of the fuel, that is more zinc can be smelted per unit of coke charged. Uniform charge sizing cannot be fully attained while using sinter (though much progress has been made in the iron blast furnace by the use of pellets) but it is well known that the fine fraction is the most harmful. Very large lumps are likely to be difficult to reduce and so are also undesirable.

10. Coke as received lies mainly in the size range  $2\frac{1}{2}$  to  $3\frac{1}{2}$  inches. Some breakdown occurs during preheating but it is not usual to screen the hot coke before charging to the furnace because of the difficulty of excluding air and the problem of making use of the coke fines. Hot coke screening is practised however, at Cockle Creek and Kabwe (Zambia).

11. A proportion of the total lime content of the charge is added at the furnace instead of being incorporated in the sinter in order to give better control of the slag composition. This furnace addition must be made in the form of hard burnt lime in order to avoid charging fine material: limestone would be objectionable because of its effect on the carbon dioxide content of the furnace gases.

(b) Temperature

12. The coke charge is preheated to a temperature of 700 to 800°C. Preheating serves two purposes: it is a useful method of supplying additional heat to the furnace, so economising on fuel usage, and it ensures that the coke is thoroughly dry before being charged.

13. Water in the furnace charge is partially reduced to hydrogen, but under the



conditions in the offtake about half of the water remains undissociated. The reaction of zinc with water is much more rapid than with carbon dioxide, so quenching the gas with the lead spray is much less effective in preventing re-oxidation. It is thus necessary to dry the coke before use, and a temperature of  $300^{\circ}\text{C}$  or more is required to ensure complete removal of water. Once this has been accepted it becomes logical to undertake full coke preheating.

14. The coke is actually heated in a vertical shaft fired by Imperial Smelting furnace gas which has passed through the condenser and the wet scrubbing system. This L.C.V. (low calorific value) gas is burnt in a separate combustion chamber and the hot gases then pass up through the shaft in contact with the coke.

15. The sinter charge is not preheated, but with suitable lagging of the storage bunkers the heat generated during sintering can be conserved to the extent that the sinter enters the furnace between  $200$  and  $300^{\circ}\text{C}$ . Actual preheating is not undertaken for two reasons: first, that the sinter is already dry and there is therefore no necessity to heat it, as in the case of the coke, and secondly, that a simple direct fired preheater, such as is used for the coke, would expose the sinter to hot gases which would bring about partial reduction and choking up of the bed. In view of these considerations the additional cost of providing sinter preheaters is not thought to be justified.

(c) Weighing and proportioning

16. Each feed bin is provided with a vibrating conveyor and weigh hopper. The conveyor is operated until the desired weight is registered, and the hopper is then emptied into the charge bucket of the automatic hoist. Two buckets are filled and hoisted together since the furnace has two double-bell charging points. In this way a record of the total weights of the various materials fed to the furnace is kept and the proportions of the various constituents are controlled.

17. Close control of the proportion of coke to sinter in the charge must be maintained in order to keep the carbon/zinc ratio in charge constant. Not all the input zinc is reduced in the furnace, some of it being lost to the slag as oxide, and the proportion which is lost is controlled by the carbon/zinc ratio, for a given sinter composition. Increasing the carbon/zinc reduces the zinc loss to slag, but since the rate of burning carbon is proportional to the air blast

rate to the furnace, which is normally constant, the amount of zinc charged, and hence the zinc output, is also reduced. The rate of zinc production must therefore be balanced against the proportion lost in slag. It is generally found to be most profitable to run with a zinc loss in slag of about 5% of the input.

## II. Furnace shaft

### (a) Shape and size

The standard Imperial Smelting furnace shaft has a rectangular cross section with semicircular ends. The shaft height is about thirty feet, of which the upper nineteen feet is brick lined, while the lower part is formed of two water jackets (the jackets have a thin lining of brick to reduce heat loss). The internal length is approximately twenty feet and the width is ten feet, giving an open sectional area of 185 square feet, but the lower row of water jackets slopes inwards reducing the width between the jacket faces to about six feet at the bottom. Feed materials are introduced through two sets of charging bells, to prevent gas leakage, while the preheated air blast enters through sixteen water cooled tuyeres near the bottom of the lower jackets. The normal height of the charge column is about twenty feet above the charging noses.

The elongated shape of the Imperial Smelting furnace contrasts with the circular section of the iron blast furnace. The rectangular shape was originally chosen to conform with the design of the lead blast furnace in which the comparatively low intensity of the air blast demands that the noses of the tuyeres should not be widely separated. Since that time the blowing rate to the Imperial Smelting furnace has been greatly increased, allowing the shaft to be widened and the tuyeres drawn back, but the basic shape has been retained because of the large quantity of heat and the high temperature necessary for zinc reduction. These factors, as explained earlier, result in a shallow reduction zone just above the tuyere level, without the extensive pre-reduction occurring in the upper shaft of the iron furnace. Under these conditions smooth working of the furnace can only be obtained if the whole of the cross section at the tuyere level is active, without the formation of a "dead-man" at the centre.

There is therefore a limit to the possible width of the furnace at the tuyeres.

(b) Charge and blast distribution

20. Although a rectangular furnace is necessary for the reaction zone at the bottom of the shaft, a circular section would be best for charge distribution since one double bell system could then be used with all the advantages of radial symmetry. Unfortunately, a satisfactory combination of circular top and rectangular bottom has not yet been devised.

21. The charge bells of the standard furnace are placed on the long axis of the shaft at a separation chosen to make the charge surface as level as possible, but a fairly deep depression under the centre of each bell cannot be avoided with this arrangement. Alternate charges of coke and sinter have been found to give less segregation than charging the materials in the same bucket.

22. Better control of charge distribution is very desirable to reduce segregation still further and to give better control of the pattern of gas flow. Development work on improved bell operation is proceeding with these objectives in view.

23. The air supply to the furnace is preheated by Cowper Stoves, as for the iron blast furnace, to a temperature of up to  $850^{\circ}\text{C}$  (Metal tubular heaters, limited to about  $750^{\circ}\text{C}$ , are still in use at some furnaces). Two stoves are used to supply the blast alternately, and are fired with L.C.V. gas from the wet scrubbing system following the lead splash condenser. The preheated air passes to the bustle mains surrounding the lower part of the furnace, and from here to the sixteen water cooled tuyeres.

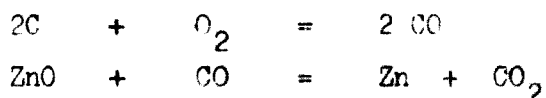
24. At present there is no standard system for control of the blast distribution among the tuyeres. Measurement has shown that the distribution can be very uneven, being only partially stabilised by the resistance of the charge in the furnace. If a blow hole or pipe begins to form stability is lost and the pipe is strengthened by extra air following the path of lower resistance. This has led to the development of control schemes based on differential pressure measurements with manual adjustment of the air flows, and automatic control of the air distribution is being established on the large (292 sq. ft.) furnace at Avonmouth. There is already evidence to show that stabilisation of the blast

distribution leads to more even working of the charge.

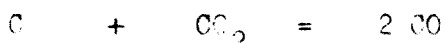
(c) Zones in the furnace - the tuyere zone

25. The column of charge in the furnace can be divided into a number of zones according to the predominant reactions occurring in them. There are basically three: the tuyere zone, the equilibrium zone and the charge preheating zone.

26. The main processes taking place in the tuyere zone are combustion of carbon, reduction of zinc and melting of the slag. The carbon is burnt principally to carbon monoxide which reacts with zinc oxide, producing zinc vapour and carbon dioxide.



Because of the high temperature in this zone some of the carbon dioxide then reacts with more carbon giving carbon monoxide.



The latter reaction is undesirable since it absorbs heat and consumes carbon without reducing zinc.

27. The most suitable coke for the Imperial Smelting furnace should therefore be strong, to resist mechanical breakdown (as for the iron blast furnace), and be non-reactive to resist chemical attack by carbon dioxide. Because of the high heat demand of the zinc reduction reaction, the use of very reactive coke would cause chilling of the tuyere zone to the point where there is a danger of combustion ceasing; in the iron furnace, by contrast, carbon monoxide can be utilized for reduction throughout most of the shaft height, and coke reactivity is less important.

28. Slag melting is the other important function of the tuyere zone. It is found that slag composition has a considerable effect on zinc reducibility. A high lime/silica ratio increases the melting temperature of the slag and reduces its zinc content (per cent of zinc oxide) though this effect is complicated by changes in the other slag constituents (mainly FeO and Al<sub>2</sub>O<sub>3</sub>). Addition of lime flux to the charge can only be beneficial if the consequent reduction in zinc assay of the slag more than compensates for its increased quantity.

(d) The equilibrium zone

29. A short distance above the tuyere zone heat transfer from the rising gases to the descending charge is virtually complete, gas and charge having both reached a temperature of about  $1000^{\circ}\text{C}$ . This state of physical and chemical equilibrium persists until the charge preheating zone (the upper two to three feet of the charge column) is reached. Chemical reaction is not possible since the reduction of lead oxide, and ferric to ferrous oxide, is completed in the preheating zone, and the temperature is not high enough for zinc reduction to begin.

(e) The charge preheating zone

30. As described earlier the sinter is charged "cold" at up to  $300^{\circ}\text{C}$ , while the coke is preheated to  $700^{\circ}\text{C}$  to  $800^{\circ}\text{C}$ . The new charge must then be heated to the temperature of the equilibrium zone by the upward flow of gas, which is correspondingly cooled in the process. Heat is supplied mainly from the sensible heat of the gases but also partly by the re-oxidation of some of the zinc vapour by carbon dioxide as the gas cools below the former equilibrium temperature.

(f) Top air addition

31. The gases leaving the charge will precipitate zinc oxide on any cold surface with which they come in contact, and some oxide is already deposited on the dust particles carried in the gas stream. To prevent massive build up in the upper shaft and offtake air is injected into the open space below the shaft roof, and also around the bell openings. This so called top air burns part of the carbon monoxide content of the shaft gas and raises the gas temperature above the re-oxidation point for zinc. It is probable that most of the oxide deposited on the gas borne dust is also re-reduced.

32. The gas finally passes via the furnace offtake to the inlet of the lead splash condenser.

(g) Shaft accretion

33. An important process which has not yet been described is the build up of accretion on the walls of the shaft below charge level. This is composed of various deposits of charge constituents cemented by zinc sulphide in the lower

hot zone of the shaft, and of zinc oxide bonded deposits in the upper zone nearer to the charge surface.

34. In the early period of Imperial Smelting furnace operation accretion growth in the shaft could not be controlled, and it was necessary to stop production three or four times a year to clean out the shaft. More recently methods of control have been evolved so that regular shaft clean-outs are no longer necessary, and campaigns of up to two years in duration have been attained. Premature termination of the campaign may still, of course, be brought about by other causes.

35. There are two ways of dealing with furnace accretion: to prevent its formation, or to develop quick methods for its removal. The second approach has been the most successful so far, and there is now a well developed technique of blasting down the accretion with explosives during a short stop at which condenser cleaning is also carried out. Shots can be inserted either from the top of the shaft after removing the bells, or through holes in the side walls.

36. The first approach, of complete prevention, was not possible in the past, but is now beginning to appear more practicable. Accretion in the lower (sulphide) zone tends to form at the water jackets above the dead spaces between the tuyeres where there is an inadequate supply of hot gases. A better understanding of the shape of the raceways in front of the tuyeres is now leading to the situation where it will be possible to specify their number and location so that there will be no dead spaces, and only a minimum of accretion build up in the lower shaft.

37. In the upper (oxide) zone accretion is again formed in regions at the walls where gas flow and charge movement are inadequate. In this case cooling of the gases causes re-oxidation of zinc, with the zinc oxide binding together particles of stationary charge. Gas flow in the upper shaft is controlled by charge voidage (segregation of coke and sinter) and, near the surface, by the shape of the stockline profile. It is hoped that improved control of charge and blast distribution will eventually eliminate upper shaft accretion.

### III. Slag and bullion handling

38. Slag and lead bullion are tapped from the furnace hearth at approximately

hourly intervals into a forehearth where settling takes place. The lead accumulates in the forehearth and is removed either by a lead well at one side, permitting continuous flow during the slag run, or from a taphole when the run is finished. The slag overflows from the top of the forehearth at a temperature of about 1250°C and is granulated by a jet of water. The granulated slag is later removed to the dump. A certain amount of speiss (iron arsenide of variable composition) also appears, and is disposed of with the slag.

39. Silver and gold present in the charge are collected by the lead, as is most of the copper. Copper is miscible with lead at the tapping temperature, so there is no difficulty in removing it from the furnace, but as soon as the lead cools copper is thrown out of solution. With low copper charges (up to, say, 3% copper in bullion) this causes no trouble, but at higher levels (5% and upwards) it is necessary to keep the lead as hot as possible during handling by tapping it from the forehearth at the end of the slag run. The present limit of normal operation is about 12% copper in bullion, though 20% has been reached during trial runs.

40. Copper recovery from slag varies from 70% to 80%, rising as the copper and lead contents of the sinter are increased. Some of the bullion is partially refined by sulphur addition to remove the bulk of the copper as matte and produce a grade of lead suitable for use in the lead splash condenser. The remaining lead may be refined by conventional methods or the bullion and copper matte may be sold according to which is most profitable at the particular site under consideration.

#### IV. Condensation and separation

41. The condenser is really the heart of the Imperial Smelting process since it was the answer to the problem of recovering zinc from the furnace gases that made production of zinc from a blast furnace possible.

##### (a) The condenser

42. The standard condenser is divided into three stages. Eight rotors work in the lead pool arranged in pairs across the direction of gas flow, two pairs in the first stage and one in each of the others. The rotors are designed to throw up a spray of lead droplets which effectively fills the gas space between the lead pool and the roof.

43. Cooled lead at about  $450^{\circ}\text{C}$  enters the back end of the condenser at a rate of up to 3000 tons per hour and flows forward against the direction of the gas flow, reaching a temperature of about  $550^{\circ}\text{C}$  in the first stage. The lead then passes through a submerged slot to a sump at the side of the condenser, from which it is pumped continuously to the cooling system. The pumping rate of the lead is regulated to match the heat to be removed from the gases by keeping the inlet and outlet temperatures at their target values. These targets are largely fixed by operating limitations: lead pumps do not run happily far above  $500^{\circ}\text{C}$ , while lower temperatures can only be achieved by very high pumping rates, but it is also possible that too rapid cooling of the furnace gas may cause formation of zinc "fog" (see below) with reduced condensation efficiency. The lead inlet temperature on the other hand, should be as low as possible in order to minimise the zinc content of the lead, but below  $440^{\circ}\text{C}$  there is trouble with local freezing of zinc (M.P.  $419^{\circ}\text{C}$ ).

44. The furnace gas enters the condenser at about  $1050^{\circ}\text{C}$  and is quickly cooled in the first stage to about  $650^{\circ}\text{C}$ . Cooling continues more slowly in the other stages and the gas leaves at about  $500^{\circ}\text{C}$ . Zinc is absorbed by the lead droplets directly from the vapour phase (properly speaking the "condenser" should be called the "absorber"), but it is believed that a small proportion of the zinc actually condense on nuclei present in the gas stream as particles of dust which are carried over from the furnace. The zinc "fog" so formed is too fine to be caught by the condenser and is carried on up the offtake.

45. Leaving the condenser the residual gas passes up a tower designed to settle mechanically entrained lead droplets and return them to the condenser. The gas is finally scrubbed with water to recover the zinc and lead which it carries, leaving an oxidised slurry known as blue powder, which must be returned to the furnace plant and subsequently resmelted. About 5% of the zinc volatilised in the furnace is recirculated in this way.

#### The separation system

46. The standard separation system consists basically of two cooling launders arranged in parallel through which the lead is made to flow, followed by a bath containing an underflow baffle to hold back the zinc thrown out of solution as the lead cools. Additional baths are required for gross removal and for



collection of the separated zinc, and finally the lead must re-enter the condenser through a weir system providing a gas seal.

47. The cold lead is saturated with zinc (about 2%) when it enters the condenser. The rate of lead flow is determined by the quantity of heat to be removed from the gases, once the target temperatures at the hot and cold ends of the condenser have been fixed, and it is found that much more lead must be circulated to cool the gases than would be required to dissolve the zinc. The zinc content of the lead increases by only about 0.25% during its passage through the condenser, and the hot lead therefore contains about 2.25% zinc (compared with a solubility of 4.3% at 550°C) when it enters the cooling launders.

48. The cooling launders are tall narrow channels each about 50 feet long. The upper part of the sides is water jacketed and the lower part refractory lined. This is the standard equipment but an alternative system with immersion coolers (movable water cooled tubes or plates) which dip into the lead as it flows through a wide refractory lined trough may be used instead.

49. Following the launders the lead reaches the so called "flux bath", where ammonium chloride is added to facilitate dross removal. The flux dross, containing lead and zinc oxides formed in the launder, is held back by an underflow weir and periodically removed. Next comes the separator bath, where the zinc rises to the surface and overflows into a holding bath, from which it can be tapped at intervals. The lead continues beneath a deep underflow weir to an enclosed channel (the "return launder") and so re-enters the condenser.

(c) Temperature control

50. The heat balance of the condenser is maintained by keeping the temperatures of the lead at the pump sump (where it leaves the condenser) and at the return launder (where it re-enters it) at their target values. Two controls are available to adjust these two temperatures: the speed of pumping of the lead and the area of the water jackets to which it is exposed.

51. The height of the lead stream in the launder is regulated by a steel overflow weir at the end, the height of which can be adjusted by movable steel plates. In this way the height of the water jackets in contact with the lead can be controlled; raising the height increases the cooling and reduces the return launder temperature. In the case of immersion coolers, the number of coolers in use can be altered easily to give control.

52. With the temperature at the return launder kept to target the pump sump temperature depends on the pumping speed. By working these controls together steady conditions can be sustained.

(d) Arsenic removal

53. There is always a certain amount of arsenic present in the raw materials, though the actual quantity varies greatly. About 60% of the arsenic charged to the furnace is disposed of in the slag, speiss and bullion, while the remainder is volatilised from the furnace shaft and passes into the condenser. Of this arsenic about 45% appears in the blue powder and is consequently recirculated to the Sinter Plant, while the rest is absorbed in the lead where it reacts with zinc to give zinc arsenide.

54. Zinc arsenide is solid at the temperature of the condenser lead (M.P. 1015°C) and would be expected to separate with the drosses which are collected in the flux bath. The density of the arsenide is not very different from that of liquid zinc however, and the separation is incomplete. Because of its arsenic and chloride contents the flux dross evolves arsine gas in contact with moisture, and for this reason it is returned directly to the furnace shaft.

55. The arsenic remaining in the zinc must be removed in order to meet the purity limits, and this is done by adding metallic sodium to form sodium arsenide which floats to the surface and can be skimmed off. This sodium treatment can be carried out immediately after tapping the zinc from the holding bath, or may be deferred until after refluxing.

(e) Cadmium

56. Cadmium present in the raw materials is partially volatilised during sintering, passing on with the gases to the Acid Plant. This cadmium is removed by the gas scrubbers and appears either as soluble cadmium in the liquors or as insoluble cadmium in the lead sludge. The liquors are treated by Ion Exchange for cadmium recovery but the sludge is recycled to the sinter returns circuit.

57. Because elimination during sintering is not complete, some of the input cadmium finds its way with the sinter to the Imperial Smelting furnace, where it is volatilised in the shaft and carried over with the zinc to the condenser. About half of this volatilised cadmium reports in the dross and blue powder and

is returned to the sinter mix, but the remainder appears in the zinc at the holding bath. This cadmium can be recovered only by refluxing, partial or total.

#### V. Zinc purification

58. Some purification of the zinc tapped from the holding bath may be necessary, depending on the grade which it is desired to produce. Three methods of purification are in use, liquation, vacuum dezincing and refluxing.

##### (a) Liquation

59. Simple liquation, after sodium treatment, is all that is necessary for the production of Grade 4 zinc. The zinc is tapped from the holding bath and sodium treated in the ladle, and is then poured into one end of a large bath through which it moves slowly, overflowing through a narrow notch at the far end into a holding bath.

60. Gentle top heating by gas burners is used to keep the temperature as low as possible without causing trouble with freezing of the zinc. Lead (and iron compounds) settle to the bottom of the liquation bath, from which they are removed at fairly long intervals (10 to 15 weeks).

61. After passing through the liquation bath the zinc collects in a holding bath where its temperature is raised by electric induction heaters, after which it is tapped off and cast into plates or blocks.

##### (b) Vacuum dezincing

62. Vacuum dezincing is a method of zinc purification which makes use of the heat content of the condenser lead as the source of energy. Originally developed for purifying lead at Port Pirie, Australia, it was first applied to zinc purification at Avonmouth.

63. The hot lead containing the zinc is pumped from the sump at the first stage of the condenser to the input syphon of a vacuum vessel in the form of an inverted truncated cone. The lead flows down a removable spiral launder close to the walls of the vessel, leaving through a barometric leg near the bottom which maintains the vacuum seal. On discharge from this the lead passes through an immersion cooled launder, to remove its residual heat, and so reaches the flux bath and returns to the condenser.

6d. The vacuum vessel contains in its centre a water cooled condenser, in the shape of a vertical tube, to the top of which is attached the line leading to the vacuum pump. Under moderately high vacuum zinc vapour is evolved from the metal flowing in the spiral launder, crosses the vapour space and is deposited on the central condenser, as a solid layer at first. As the thickness of the deposit increases its surface temperature rises until it reaches the melting point of zinc, after which the condensed metal runs off and is collected by a tundish immediately beneath the bottom of the condenser. The zinc then leaves by another electric leg leading to a holding bath from which it is tapped off.

7. Vacuum dezincking is capable of producing zinc of Grade 2 quality, containing less than 0.1% lead, but cannot by itself recover cadmium, which, being more volatile than the zinc, distills over with it. The cadmium content of the zinc may however be recovered by use of the cadmium column only of a conventional refluxer plant, which, since it does not require total boiling of the zinc, is less expensive to run than the lead column.

8. The vacuum dezincking process has the attraction of producing an improved grade of zinc without incurring the full cost of refluxing, though the economic advantages of either process must depend on the circumstances of each particular case. Another advantage of vacuum dezincking is that by its action it strips the metal of its lead instead of returning it saturated to the separation bath as does the conventional cooling launder - separation bath system. It is probable that this will result in increased condensation efficiency, though this point has not yet been proved in practice.

### Refluxing

9. Zinc purification by refluxing is a two stage process, in which the zinc is first boiled off from lead and other non-volatile impurities (in the lead column), after which cadmium is boiled off from the zinc (in the cadmium column). Because of the heavier load on the first stage it is normal to feed the cadmium column from two lead columns.

10. The lead column consists of a stack of carborundum trays, luted together at the edges and forming a fractionating column. The lower half of the column is surrounded by heating chambers fired with oil or gas, while the upper half is enclosed in a brick tower and forms a reflux column, the gases from the top

of which pass to a condenser. The cadmium column is generally similar in construction.

69. Operation is continuous. Zinc is fed from a melting bath into the top of the heated section of the lead column, from which purified zinc and cadmium vapours pass upwards while liquid zinc enriched with lead flows down. There are alternative ways of operating the lead columns in accordance with the products which it is desired to make.

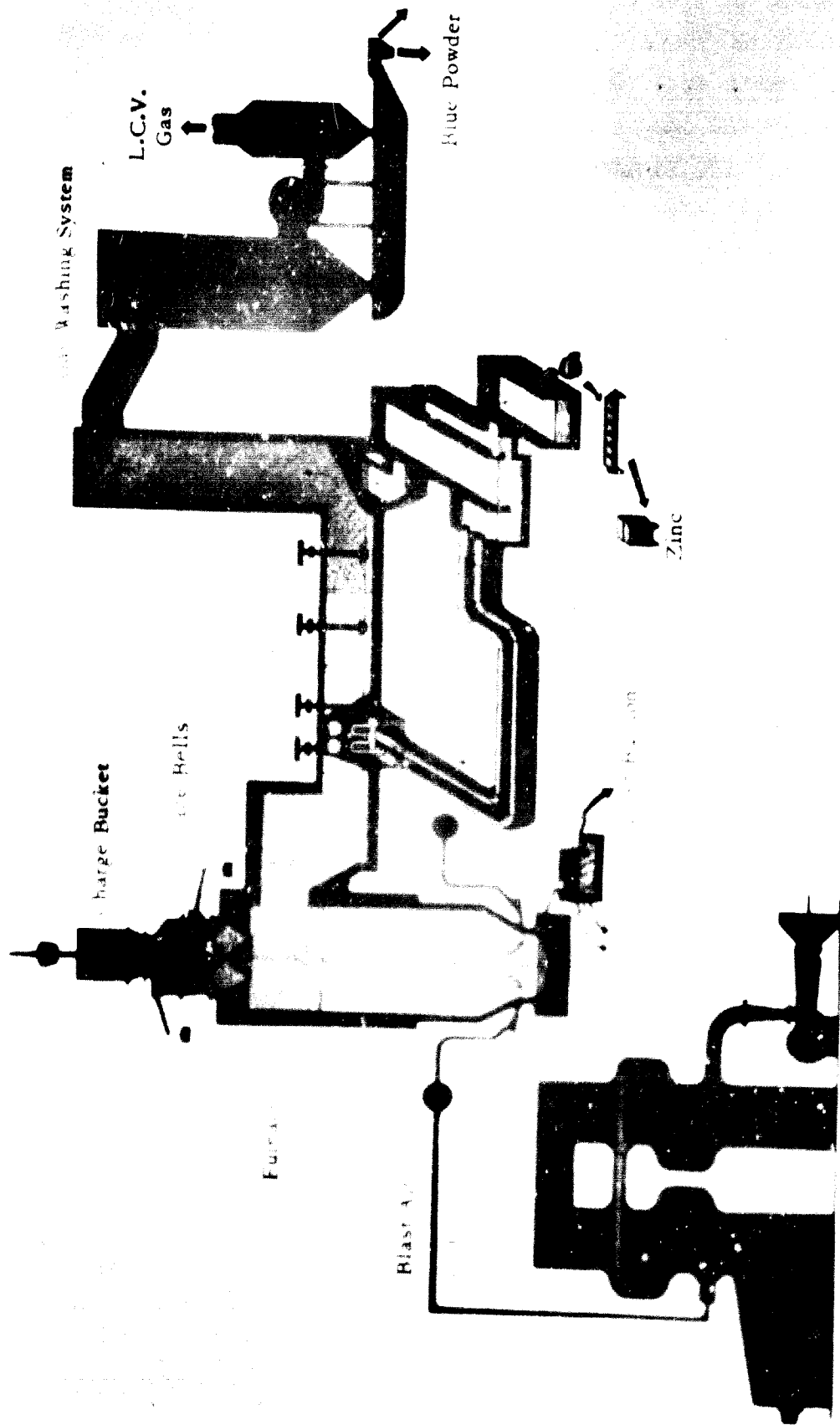
70. To produce all Grade 1 zinc it is necessary to have total recirculation of the bottom product of the column. The lead liquates from the zinc in the melting bath and is removed through a forewell, and a small proportion of the bottom product is bled off for batch distillation to recover copper, tin and other minor impurities which tend to concentrate here.

71. If it is desired to produce a proportion of Grade 4 metal the bottom product is removed and liquated in the normal way to reduce the lead content to below 1.5%. By adjusting the firing of the column it is possible to control the relative proportions of the zinc feed which eventually appear as the top and bottom products.

72. The top product of the lead columns is transferred to the cadmium column by feed launders. Grade 1 zinc now appears as the bottom product, while the top product is a zinc alloy containing five to ten per cent cadmium. The cadmium is recovered from this alloy by distillation in a small separate column producing pure zinc and crude cadmium metal.

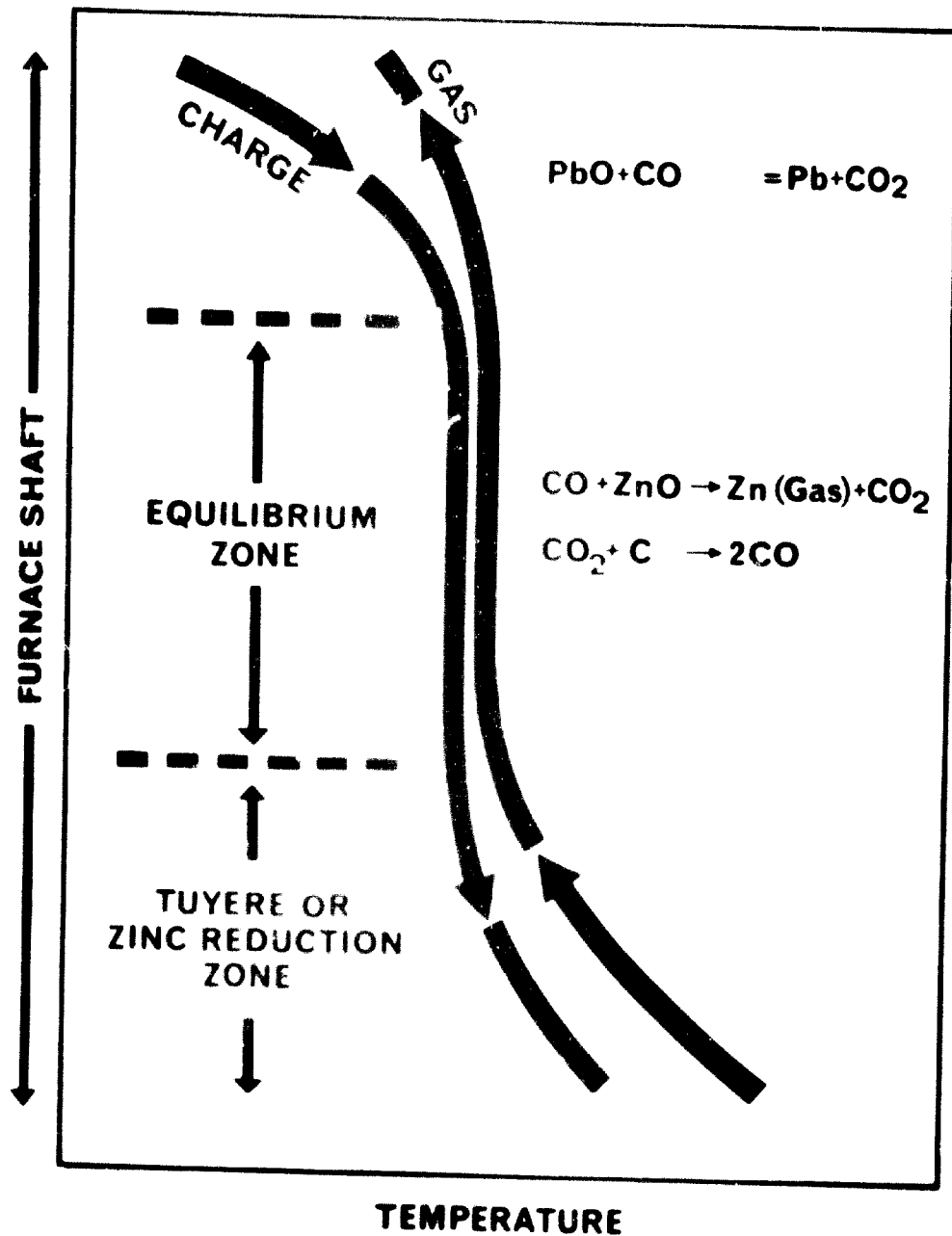
#### VI. Acknowledgement

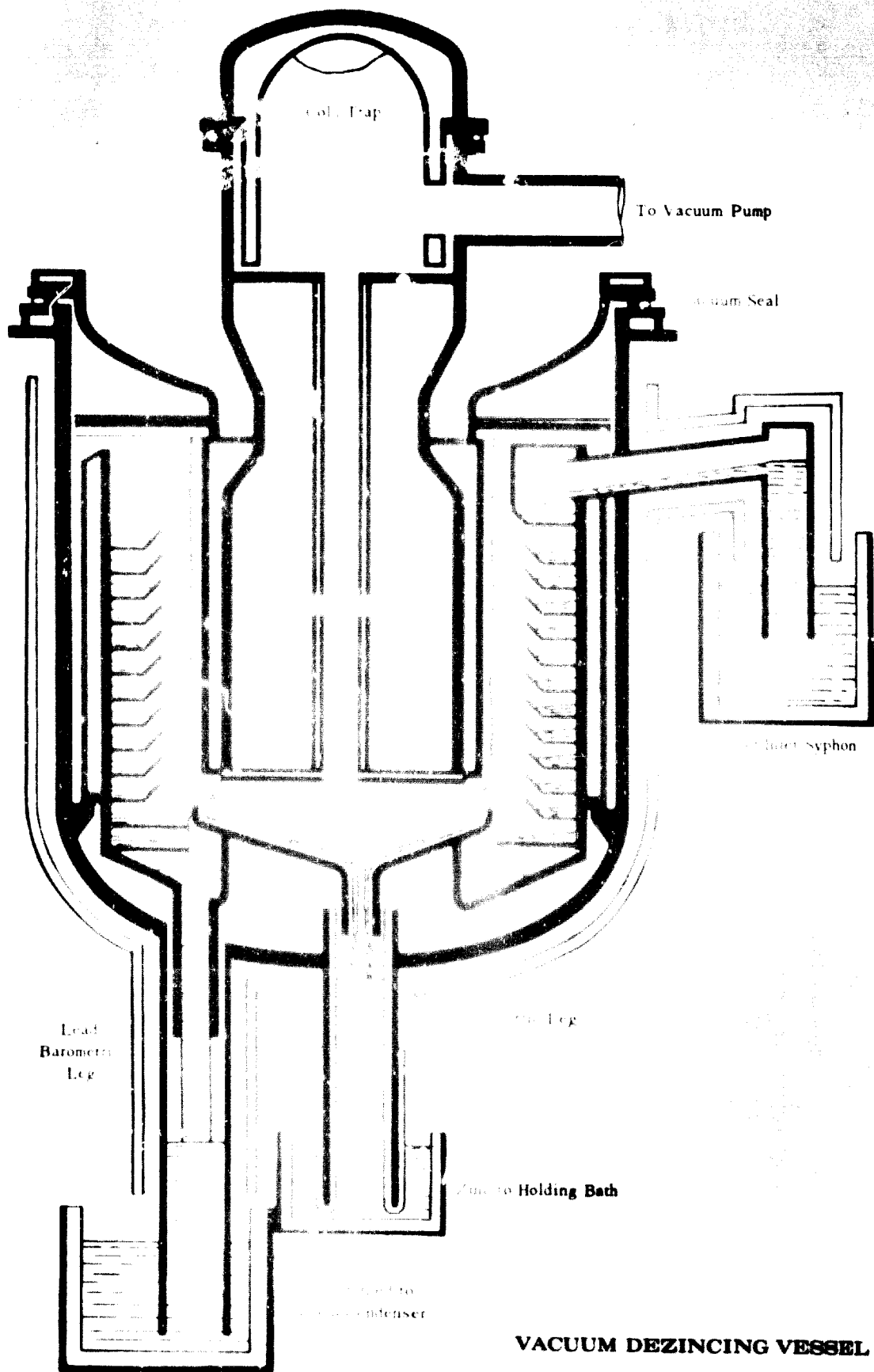
73. The author wishes to thank the Directors of Imperial Smelting Processes Ltd. for permission to publish this paper.



**THE IMPERIAL SMELTING FURNACE**

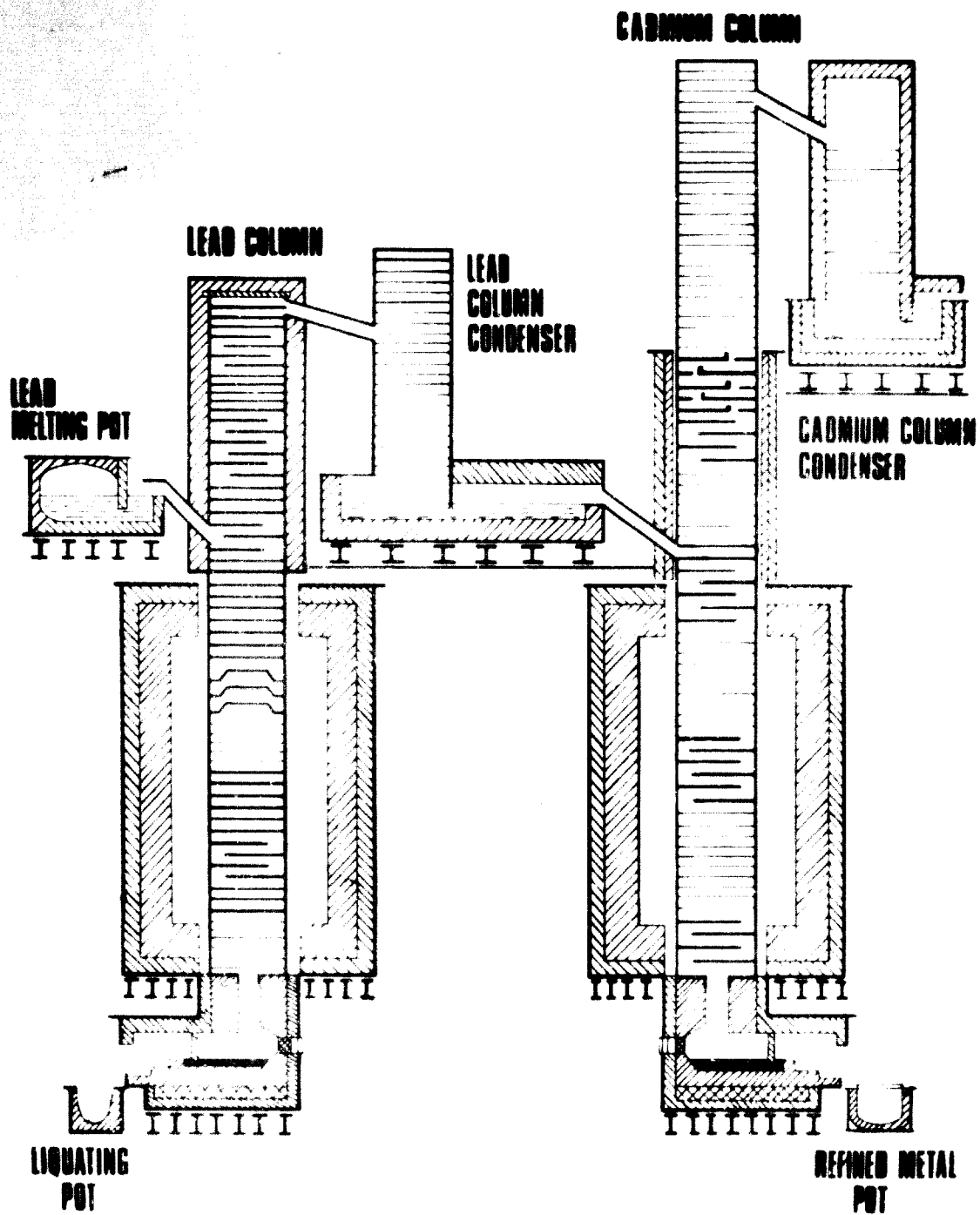
## THE EQUILIBRIUM ZONE IN AN IMPERIAL SMELTING FURNACE







**DIAGRAM OF LEAD AND CADMIUM COLUMN  
ZINC REFLOXER PLANT**





**20. 1. 72**