Although lead ores are mined and smelted in only one state in the United States for lead alone, the treatment of lead ores is of much practical importance, since lead is used as a medium for extracting other metals. In smelting gold and silver ores, lead ores are used as a part of the flux, or the lead ores themselves often carry gold and silver. In this way the lead collects the precious metals carrying them into the bullion. The bullion is then worked up for the separate metals.

It is our intention in this article to discuss, first, the selection of a furnace site and the general arrangement of the plant, second, the principal methods of smelting lead ores and third, the matter of obtaining the pure metal from the furnace product.

In selecting a furnace site, all points of economy are sought for, technical consideration being of secondary recourse. The first question that presents itself is whether the plant is to be a permanent plant or a temporary structure. Naturally if it is to be merely a temporary one as little money as possible is expended but it is always better to build a small substantial building to start with, so planned that it may be enlarged as the output demands it.

The character of the ground is next an important consideration in the selection of a furnace site. A hillside is always chosen if possible, as by this means all costs of elevators and operating them is eliminated.

The question of water supply for the boilers and jackets must also be taken into account, if blast furnaces are to be used. The water when possible should be taken from a natural flow at some elevated point, thus saving the expense, of boring wells and requiring additional machinery for a pumping
plant. The character of the water will have some important consideration also and ought to be soft and clear.

In the laying out of a smelting plant the first object is to so arrange it that the materials will be handled as little as possible. In doing this the materials when transported from one place to another are discharged by gravity; then the run-ways are made as short as possible without crowding the apparatus, giving plenty of room to the workman and plenty of ventilation.

If the smelter is built on a hillside thus giving a natural fall a good general arrangement would be as follows:- Starting with the furnace floor, there will be on one side the slag dump with a fall of about twenty feet, on the other side the furnace reaching to the feed floor at an elevation of fifteen or twenty feet. The roasting furnace will be on the third floor, with the track, on which the crushed ore is discharged into the hopper, ten feet above it and below the discharge of the sampling mill through which most of the ore passes. On the same level with this will be the storage yard for the ore and fluxes. This arrangement is adapted especially to large plants, where both reverberatory and blast furnaces are used. It may be greatly modified to suit the character of the ground but the right fall for bringing in the ore and fluxes and carrying away the products by gravity is always the governing feature.

Lead ores are treated exclusively in the dry way and the processes are carried on in various forms of furnaces. These furnaces may be classed under two general heads, the Reverberatory and the Blast furnaces. It is our object here to give a short description of the furnaces themselves, the advantages acknowledged for each and some of the modifications met with.

In treating an ore in the reverberatory furnace it is subjected to the reaction process. Perhaps the most used of
any furnace coming under this head is the Flintshire, used in
the English method. The furnace has three doors opening on
either side of the hearth, the side on which the firing door
is situated being called the "laborers side" and the opposite
one the "working side". The bed consists of a slag from
previous operations and is spread over the hearth so that it
is level with the doors on the laborers side but on the working
side slopes so as to form a well eighteen or twenty inches
deep in front of the middle door. A tap hole connects with the
bottom of this through which the lead is drawn off, a hole above
this serves as an exit for the slag. At the top of the furnace
is a hopper from which ore is introduced into the furnace. The
ore is let into the furnace in charges of about a ton and
spread evenly over the hearth, at the same time being kept
clear of the well. The hearth should be still hot from a
previous charge when the next is added. The heat is then
raised to dull redness with the doors of the furnace open,
allowing free access of air; as the charge is constantly
stirred the oxidation of the lead sulphide to oxide and sul-
phate takes place. The doors are then closed and the tempera-
ture raised so the action between the sulphide, oxide and
sulphate gives rise to reduced lead which flows into the well.
The crust that forms on top of the molten lead is pushed back
into the hearth, a little lime added and the process repeated.
The lime serves two purposes, first to stiffen the charge and
second to reduce any silicate of lead to the oxide. The lead
after the second reduction is ready to be drawn off through the
first hole in the furnace and the slags are then drawn off after
the addition of more lime to make them pasty. The slags often
contain thirty or forty per cent. of lead as silicate which are
treated farther in the blast furnace. The flux varies with the
conditions of the ore and is adjusted to suit the particular
kind of ore to be treated.

Perhaps the furnace used in the Carinthian method is next
in importance under the consideration of reverberatory furnaces. In this the charges are made small and the roasting carried on very slowly so that most all the sulphide is oxidized to oxide and sulphate. The main object in the use of this furnace and in the method of the treatment of the ores is to obtain a complete extraction in the reverberatory, leaving a clean slag.

The charge of about four hundred pounds is introduced through the working door and spread over the hearth to a thickness of an inch and a half. The heat from a previous charge is sufficient to produce the first roasting so no new fire is made. The ore is constantly raked over until the blue sulphur flames cease to appear, then the doors are all closed and the heat is raised and kept at a high temperature as long as the heat continues to run. The doors are again opened, the slag raked up in a heap in the hearth of the furnace ashes thrown on and the heat again raised with the doors closed, thus extracting practically all the lead from the slag.

The Cornish process is used to some extent for the treatment of impure ores containing copper and antimony and also for the treatment of slags. The ore is first roasted in a separate furnace and then introduced into one very similar to the plintshire. The charge of about two tons is introduced and melted down, lime and anthracite culm are added and the whole well mixed. It is then spread over the hearth and subjected to a high heat the products separating in layers capable of being drawn off in sequence, the lead coming off first, the mixture of lead, iron and copper sulphides next and then the slag. The slag is thrown away while the second product is generally again in the ore hearth.

The reverberatory furnaces have many advantages although in many cases some of its products have to again be treated in the blast furnace. The ore is treated in the raw state and for the most part the apparatus is comparatively cheap. Any sort of long flame fuel may be used thus decreasing the expense in
many districts. The voltilization of the lead is very small and if any silver is present it is all extracted with the lead.

The reverberatory furnace however is greatly limited in its use as only high grade ore can be worked by means of it and the ore also must be of a limited character. The ore must be galena or carbonate assaying over fifty per cent. lead and must not contain over five per cent. silica with very little of the other common gangue minerals such as blende, pyrite, calcospar and barite. The process is also very slow compared with the blast furnace.

The ore-hearth furnace is sometimes treated as a class by itself but is properly classed with the reverberatory furnaces. The only point of difference is that oxidation and reduction take place simultaneously, the charge floating on a bath of lead. Its chief advantage is that it may be quickly stopped and started without much consumption of fuel and loss of heat. It is used to a great extent and has proven very successful in the treatment of ore of the Mississippi valley.

The blast furnaces used in lead smelting are various types but all essentially the same. The mechanism of them is very complicated compared with the reverberatory furnaces so we will only undertake here to describe them in a general way as space will not permit of a detailed description.

They are in cross section, square, polygonal, circular, elliptical and oblong and in vertical section prismatic in form or with sides tapering towards the bottom. The primary feature of them is a very sound foundation, so this is built on the bed rock if possible. The smelting zone is generally enclosed by water jackets and the crucible may be either external or internal or partly each. The lead may be tapped from the bottom or removed by means of Arent's automatic tap. The water jacket is an iron shell that encloses the smelting zone to protect it from corrosion by the slag, while Arent's
automatic tap is a siphon tap which forms part of the side wall, consisting of an inclined channel running from the lowest part of the crucible wall inside to the highest part outside, where it is enlarged into a dish shaped basin. From this basin the lead may be drawn off as fast as it is collected. The blast that forces the draught is of compressed air and furnished by machine of the class of rotary positive pressure blowers. Fans are seldom used.

The ore if a sulphide is first roasted in a reverberatory furnace to drive off the excess of sulphur and is then treated in the blast. The object of the process is to separate by fusion the lead in the metallic state from its ores. To do this the acid and bases have to be combined in certain proportions to form a slag. The acid constituent is invariably silica and the bases generally iron and lime, so if these do not occur in the ore in the proper proportion the deficient ones must be added. The fluxes are adjusted by the metallurgist to fit the conditions of the ore to be treated.

Smelting in the blast furnace is almost an entirely mechanical process and the success of the operation depends greatly on the experience of the men in charge. So with careful observation on the part of the workmen the plant may soon be bringing forth the best results. When a blast furnace is operating successfully a large amount of lead in the charge should flow freely into the well; the slag should be fluid and clean showing that a complete chemical reaction has taken place between the flux and ore; the furnace should be cool and quiet on top, thus keeping the lead from volitilizing; the furnace speed should be good and the furnace free from accretions and crusts.

The charge should be carefully prepared and mixed before coming to the furnace for without an intimate mixture the the process of smelting is greatly retarded. By thoroughly
mixing the charge there is no chance for any of the ore to be carried off mechanically in the slag. With the charge properly mixed next comes the feeding which though simple in theory is not so in practice. Suppose the pieces of ore to be of uniform size, then the ascending gases would follow the lines of least resistance, that being next to the wall, leaving the center of the shaft unmolested; this would necessitate a higher velocity of the blast which would overheat the easiest traversed portions and also give rise to some of the ore being carried off as flue dust. To eliminate this fault the charge should never be uniform but a mixture of coarse and fine, then by lodging the fine material close to the wall and placing the coarser in the center an adjustment may be made which will cause the gases to ascend uniformly through the smelting column. A furnace top smoking quietly and uniformly over its entire surface is the experienced workman's sign of a properly feed furnace.

From a metallurgical standpoint the reaction of the iron in the charge is the most essential feature. Just a sufficient amount of iron should be present in the reduced state to throw the lead out of the matte, the remainder being changed only to the ferrous state so it will enter the slag. Too much reduced iron will form a sow in the hearth. The iron is reduced from its oxides by carbon and carbon monoxide, the carbon monoxide being preferable in all cases, the chief advantage of it being to minimize the loss of lead in fumes and flue dust. This is true because in using carbon monoxide the zone of incandescence is kept low in the charge column leaving plenty of room above for the gases to yield up their heat to, and exercise their reducing power on, the descending charge so that by the time they escape they will be nearly all used up.

It is the prevailing opinion among most people that high temperature in the blast furnace should be avoided thus decreasing the volatilization but this is a misconception. A
high temperature means fast smelting, therefore it naturally follows that the lead will be subjected to aerorifying and volitilizing influences a shorter length of time. Then a rapidly descending charge with a constant supply of fresh ore, absorbs the heat of the gases and also acts as a most efficient fume and dust collector.

There are many devices such as bag-houses attached to the furnace to save the fumes and dust but after all it is acknowledged that the furnace itself ought to be the most efficient dust collector.

One thing that has been added to many large plants quite recently is the mechanical feeder. The argument in favor of it is:—since the work of the feeder is better the more it approaches the regularity of a machine then a mechanical feeder would be the ideal one. This device is used at present principally in lead smelters.

Whatever may be the description of the blast furnace, the general process is the same as we have described. The object is to flux the ore properly, then feed it to the furnace getting in return slag, matte, and bullion. The matte is generally subjected to the process a second time for the recovery of more of the lead and occasionally the slag is again treated being in some instances used as a flux.

When a lead-zinc ore is treated which is often the case as they so often occur associated in nature it is generally first concentrated thus separating the lead from the zinc owing to their different specific gravities. However if the ore does not average over twenty-five per cent, zinc it is smelted at once. One way of getting rid of the zinc is to flux the ore with a ferruginous slag, so the zinc will be taken up by the iron and enter the matte, the matte then being smelted separately for the recovery of the zinc. The ore may also be leached with sulphuric acid thus converting the zinc into
a soluble sulphate while the lead remains behind unaltered. If the zinc follows the lead through the entire process of smelting and enters the bullion with it, it is then separated out by one of the following methods. Zinc easily oxidizes when the lead is red hot, so the bullion is melted and a blast of air blown through, which cause the change of the metallic zinc to zinc oxide. In the above process steam may be used in place of air and often gives better results. The zinc may also be separated by the use of chlorides. Some chloride such as common salt is added to the molten mass causing the formation of zinc chloride while the lead is unchanged. This however is not a practical method since it becomes very expensive requiring a large quantity of the salt.

Silver when it is present in the ore always follows the lead through the entire process, so has to be separated from it in the bullion. The two methods used for this separation are the Pattinson and the Parkes.

The Pattinson process depends upon the fact that alloys of lead with silver containing less than six hundred and forty ounces per ton of silver, have a lower melting point than pure lead and also that lead in the molten state is denser than when molten. The lead bullion to be treated is put in a large iron pan and melted, then cooled slowly with constant stirring, the lead gradually crystallizing out. By removing the crystals with perforated laddles the fluid alloy obtained is richer in silver than the bullion started with. The removed crystals are again and again subjected to the same process until the lead is practically free from silver. The rich silver alloy is then treated by the Parkes process or subjected to cupellation.

The parkes process depends on the facts that zinc and lead do not alloy when melted together and that silver alloys with zinc more readily than with lead. The lead is melted and heated to the boiling point of zinc and then skimmed. The zinc
is gradually added as fast as it melts until a sufficient quantity has been added, all the time stirring the molten mass. The receptical is then covered over and the mixture allowed to stand for two or three hours. The zinc gradually rises to the top carrying with it the silver. This zinc silver alloy comes to the top as a crust and is skimmed off, then more zinc is added and the process repeated. The zinc crust is then distilled off in a large plumbago crucible, the zinc going off leaving the silver and lead which is moulded and cupelled leaving the pure metallic silver.