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Pot roasting of lead ores

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P O T R O A S T I N G O F L E A D O R E S .

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THESIS FOR BACHELOR OF SCIENCE DEGREE IN MINING ENGINEERING.

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AND FOR BACHELOR OF SCIENCE DEGREE IN GENERAL SCIENCE.

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8287

June 10, 1908.

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ABBREVIATIONS USED:

Min. Ind. -----	MINERAL INDUSTRY.
U. S. P. -----	UNITED STATES PATENT.
Eng. & Mng. -----	ENGINEERING & MINING JOURNAL.

DESULFURIZING, OR POT ROASTING
OF
LEAD ORES.

- - - - -oo- - - - -

The dawn of the pot roasting era occurred in the year 1898 in one of the mining centers of Italy, and was known as "Desulfurization of Lead Ores," patented by Huntington & Heberlein.

Their scheme was to dilute the galena with lime and blow air through the charge, heat being given off by the oxidation of the sulfide.

The following year it had passed from its experimental stage into a practical method, and began to be adopted more or less generally by engineers, in Europe as well as in America. In America, however, the original name was soon lost sight of, or is beginning to be replaced with the name "Pot Roasting of Lead Ores," it being more expressive of the method used by the majority of American Engineers, they finding that the original idea governing the use of limestone was not a necessity, but that pyrites, ferrous oxide, manganous oxide, dolomite etc., could be used and as satisfactory results obtained.

In this thesis for a starting point, we attempted a roast of straight galena with no diluent. As anticipated the results were nil.

We next attempted the roast with a mixture of galena and silica, and obtained fair results.

Our next experiment was to use limestone with the galena, because of the large percentage of limestone present the results were not satisfactory.

Next pyrites and limestone were used with the galena, and excellent results were obtained. We made another run, using pyrites and limestone, but increasing the percentage of galena by 25%. This run was also very successful.

From these few runs, the data we are able to glean from periodicals, and the rational chemical analysis that we made on the roasted product, we base our thesis.

There are three modifications of the scheme for "desulfurizing" lead ores, i.e.-

1. Huntington - Heberlein.- The ore is given a partial roast in reverberatory furnace, roasting the sulfur contents down to 12% or 13%, with limestone to dilute the charge, and then transfer the partially roasted mass to pot for completion of roast.

2. Carmichael - Bradford.- Gypsum is used as a diluent instead of limestone, and the preliminary roast is not given.

3. Savelsburg.- Limestone is used as diluent, but the preliminary roast is not given.

In this thesis the general scheme as given by Savelsburg is followed.

H I S T O R I C A L.

In 1898 the general scheme for "lime roasting of lead ores" was first worked out and patented by Huntington & Heberlein. # A mixture of galena and lime was heated to about 700 degrees C. with an excess of air, cooled down to about 500 degrees C., when the PbS was rapidly oxidized to PbO and SO₂, the heat generated being sufficient to fuse the PbO.

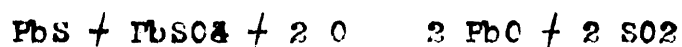
The next year description of the first roasting plant is printed, † giving the general scheme as worked out by Huntington & Heberlein at the lead works of Pertusola, Italy, in two steps: Sulphatizing and Finishing.

(1) Galena is mixed with 6% to 15% of burned lime, varying according to the per-centage of sulfur present, and given a partial roast in the reverberatory furnace at a temperature reaching 700 degrees C., and not falling below 450 degrees, so as to leave at least 5% sulfide-sulfur undecomposed, from 25% to 35% will be converted into sulfates, and only 2% into PbO, no metallic lead being set free, and the loss of lead by volatilization will be practically nothing. If however, the galena be treated without lime the sulfate and oxide will be formed in the proportion of 3 : ,4, and some metallic lead will be set free. Also loss by volatilization will be considerable. The formation of sulfates is thought to be caused either by the problematic dioxide of calcium, or by the catalytic effect of calcium oxide:-

Min. Ind. 1899. U.S.P. 600347 3/8/98.
 † " " 1899. p399.



(2) If this hot mass is then transferred to a pear shaped vessel, and the air under pressure of .75 to 1.25 inches of Hg, is forced through, the temperature will at first rise on account of the continued oxidation of the remaining sulfide. But now PbS will react on PbSO₄ in the presence of an abundance of air, the PbO resulting instead of Pb.-



The mass becomes pasty and gives off concentrated SO₂, and hardens when the reaction is finished. Most of the CaO is converted into CaSO₄. The process was also found to be successful in the presence of associated sulfide minerals, and the SO₂ can be utilized in the manufacture of sulfuric acid.

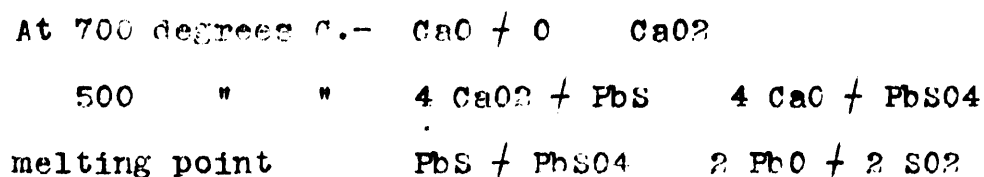
With this method these works require only a single blast furnace instead of three or four, and use 50% less fuel, labor, and cost of tools than with the former roasting and reduction method, and have a greater yield in lead as well as in silver.

The amount of substance added to the galena is regulated by the per centage of total sulfur, by the form in which the sulfur is present, by the quantity of gangue, by the specific heat of the gangue, and by the degree of preliminary heating or roasting.†

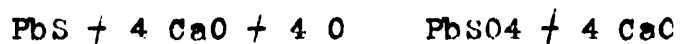
The inventors explain their process as follows:-

† Eng. & Min. Jnl. 10/20/04.

"At a bright red heat the CaO takes up oxygen from the air supplied, forming CaO₂, which later, in consequence of cooling down to a dark heat, again decomposes into the monoxide and oxygen. This nascent oxygen oxidizes a part of the PbS to PbSO₄, which then reacts with the further quantity of PbS with evolution of SO₂ and formation of PbO. Assuming the formation of CaO₂, the process leading to the desulfurization may therefore be represented as follows:-



Reaction 1. and 2. combine - assuming the presence of sufficient oxygen gives-



Now the invention consists in applying the observation described above to the working of galena and other ores containing PbS, for metallic lead and the essential of the process therefore consists in passing air through the mass cooled to a dark red heat - 500 C."

DESCRIPTION OF THE PROCESS AT BROKEN HILL

PROPRIETARY CO., N.S.W.

A mixture of PbSO₄ and PbO equalling 10% sulfur, mixed with the necessary CaO, is dropped from a mechanically roasting furnace into a converter. Seventeen ounces of air per cubic inch is forced through the ore from two to four hours. Converter is of a hopper shaped sheet iron cone 5'66" in diameter, 6' high and geared on to trunions. The converter

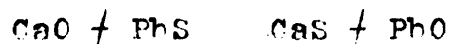
has a truncated apex, closed by a perforated plate forming the top of the wind box. Temperature rises at once, and the SO₂ goes off. The mixture soon softens and agglomerates, converter is turned down and contents dumped out. 1% sulfur remains, and the charge is in good condition for the blast furnace. The strongly oxidizing atmosphere in the converter is thought to eliminate all sulfur:



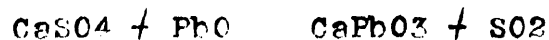
It is also believed that not only PbS but the sulfides of zinc, copper and iron will be oxidized when heated in contact with the CaO-O formed during the preliminary heating. Also evidence seems to show that ferrous and manganous oxides behave in a manner similar to that of the CaO.

More recent experimenting on the Huntington & Heberlein and Carmichael - Bradford processes has, however, contradicted the theory of the formation of CaO₂, as the CaO₂ is formed at low temperature, and splits again into CaO and O on gentle warming. Further, in preparing it, it is essential that all CO₂ and moisture be excluded, but both are present in the roasting of the ore. †

It is held that at first the reaction—



takes place. CaS is then oxidized to CaSO₄, which acts upon the PbO:



The CaSO₄ in addition has an oxidizing effect upon galena in

† Min. Ind. 1904, p. 292.

the presence of oxygen:



Also, that the oxidation of ZnS is due to the following equation:



Forcher found by laboratory experiment that the blowing of air through a charge of CaPbO_3 and PbS in a warm converter the process proceeded along lines similar to those of the Huntington & Heberlein process, and that the preliminary roasting of the PbS became superfluous. The theory that CaSO_4 is the leading oxidizing agent is substantiated by the Bradford - Carmichael process, in which air is blown thru the heated and dehydrated gypsum and galena, and the same phenomena occurs as in the Huntington & Heberlein process. Carmichael states that a mixture of PbS and CaSO_4 reacts at a dull red heat at 400 degrees C. forming PbSO_4 and CaS , according to the following equation:-



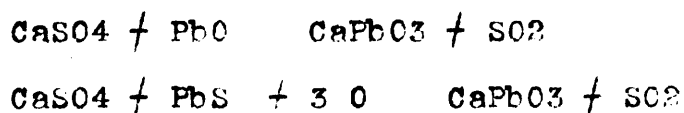
but according to Roberts-Austen the heat of formation (in kilogram calories) of the different compounds in this equation are as follows:-

PbS	-17.8
CaSO ₄	-318.4
PbSO ₄	+216.2
CaS	+92.0

hence we have the algebraic sum of -17.8, -318.4, +216.2, +92 = -28 calories, showing the endothermic reaction; and an endothermic reaction cannot take place in this reaction.

A. Savelsburg, of Germany, patents his process in United States, $\text{\textcircled{4}}$, patents describing it as follows:-

"The process consists of placing on the grate of the converter a bed of crushed limestone to protect the iron, charge some blowing coke or coal, add a thin layer of moistened galena concentrates in limestone and start the blast. When the mixture has attained a red heat it is followed by a second layer of moistened charge, and this is continued until the converter is filled - the blast being gradually increased. The operation is finished when the sulfurous fumes cease to be expelled, and the charge begins to harden. The limestone first acts as a diluent, keeping the temperature low, thus preventing the galena from cinderizing, and at the same time keeps the charge open. Heat is absorbed by the evaporation of the moisture and the decomposition of the CaCO_3 into CaO and CO_2 . The lime however, is quickly converted into CaSO_4 , which is again decomposed by the silica which sets free SO_2 with its powerful oxidizing influence. The gases issuing from the process contain 10% by volume of the SO_2 , and are utilized in the manufacture of sulfuric acid. It is thought strongly, but not proven analytically, that in these blowing processes the SO_3 of the CaSO_4 is the leading oxidizing agent, and that the reactions are as follows:-



which causes the elimination of the sulfur and the agglomeration of the charge."

Savelsburg explains the reactions of his process as follows:- †

"The particles of limestone act mechanically between the particles of the lead ore, separating them one from another. In this way a premature sintering is prevented, and the whole mass is rendered loose and porous.

The limestone moderates the reaction temperature produced in the combustion of sulfur, so that the fusion of galena, the formation of dust, and the separation of metallic lead are avoided, or at least kept within the limits permissible. The lowering of temperature reaction is due partly to the decomposition of the limestone into caustic lime and CO_2 in which heat is absorbed, and partly to the consumption of the quantity of heat which is necessary in the further process of the operation for the formation of a slag from the gangue of the ore and PbO produced.

The limestone gives rise to chemical reaction. By the decomposition it produces lime which, at the moment of its formation, is converted into CaSO_4 at the expense of the sulfur in the ore, which CaSO_4 , at the time of the slag formation, is converted into silicate by the SiO_2 present, sulfuric acid being evolved. The limestones, therefore, assists directly and forcibly in the desulfurization of the ore, causing the formation of sulfuric acid at the expense of the sulfur in the ore; the gaseous sulfuric acid then acts as a strong oxidizing agent towards the sulfur in the ore. If therefore, a mixture of raw lead ore and limestone (which mixture must of

† Eng. & Mining Jnl. 1905. p 1067.

course contain a certain amount of SiO₂ for the formation of a silicate) be introduced into a chamber, and a current of air be blown through the mixture, and at the same time that part of the mixture which is near to the blast inlet be ignited the combustion of the sulfur will give rise to very energetic reaction, and SO₂, SO₃ and PbO, sulfates and silicates are produced. The SO₂ and CO₂ escape while the SO₃ and sulfates act in turn as oxidizing agents on the undecomposed galena. Part of the sulfates is decomposed by the SiO₂, thereby liberating SO₃, which acts as an oxidizing agent:



The remaining PbO combines finally with the gangue of the ore, and the non-volatile constituents of the flux form the required slag.

The quantity of limestone required for the treatment of the ores vary according to the constituents of the ores. It should amount to 15% to 20%. For satisfactory working of the process the following precautions are to be observed:

In order that the blowing in of the air may not cause particles of the limestone to escape in the form of dust before the reaction begins, it is necessary to add to the charge before it is subjected to the action in the chamber a considerable amount of water, say 5% or more. This water prevents the escape of dust, and it also contributes considerably to the formation of SO₃, which, by its oxidizing action, promotes the reaction and consequently also the desulfurization. Also do not fill the chamber with the charge at once, but at first only partly fill, and add the remainder of the charge gradually while the chamber is at work, as by this means the reaction

will take place more smoothly. It is then advantageous to proceed as follows: The bottom part of a chamber of any suitable form is provided with a grate on which is laid and ignited a mixture of fuel and pieces of limestone. By mixing the fuel with the limestone the heating power of the fuel is reduced, and the grate is protected, while at the same time premature melting of the lower part of the charge is prevented. Or the grate may be first covered with limestone and the fuel laid thereon, and then another layer of limestone be placed on the fuel. On the material thus placed in the chamber a uniform charge of lead ore and limestone, say about one inch deep, is placed, this having been moistened as previously explained. Under the influence of air blast and heat the reactions hereinbefore described take place.

When the upper surface of the first layer becomes red hot a further charge is laid thereon, and further charges are introduced as the surface of the additional charge becomes red hot, until the chamber is full. So long as charge as still introduced a blast of air of low pressure is blown thru, but when the chamber is filled, a larger quantity of air at a higher pressure is blown thru. A scorification process then takes place, a very powerful desulfurization reaction having preceded it. During the scorification the desulfurization is completed."

TYPICAL METHODS OF OPERATION OF DESULFURIZATION
PLANTS IN DIFFERENT COMMUNITIES.

At the plant of the Sulfide Corporation Company, Cackle Creek, † N. S. W., galena concentrates are crushed thru 1.5 mm screen, furnishing material of which 60% was much finer than 1.5 mm. The limiting screen for the limestone is 10 to 16 mesh; SiO₂ is added in sufficient amount to furnish a blown ore containing 20% SiO₂. The mixture contains 20 to 25% lead, and 6 to 9% lime. The higher per centage of lime causes the blown ore to remain powdery. The roasted mixture may contain some sulfur - 6.5% to 12%, but the sulfur contents usually varies between 6% to 8%. It is important that the converted charge be well mixed, as otherwise the blast will form blow holes. In blowing small air pressure is used at the start, but is gradually raised, reaching 20 ounces at the end of the operation, which lasts 5 hours.

Another company in the same district uses converters 8' in diameter and 6' deep, holding 8 tons, and use a blast pressure of 24 ounces. Time of operation 4 hours. Blown charge contains 3% sulfur.

In Germany a typical charge is 100 parts of lead ore, 10 parts of quartzose silver ore, 10 parts of spathic iron ore, and 19 parts of limestone are used. Air blast is about 250 cubic feet per minute, beginning at a pressure of 2.75 to 4.50 ounces, and raised to 11.5 to 13.5 when the pot is completely filled. The desulfurization is complete in about 18

† Min. Ind. 1908. p 292.
‡ Eng. & Mng. Jnl. 1905. p 1067.

hours. A pot is attended by one man per shift of 12 hours. This is only the attention of the pot proper, the labor of conveying the material to it and breaking up the desulfurized product being extra. When the operation has been properly conducted the charge is reduced to about 2 to 3 % sulfur. As in the Huntington & Heberlein process, the greatest advantages of the Savelsburg process is the ability to effect a technically high degree of desulfurization with only a slight loss of lead and silver, which is due to the perfect control of the temperature of the process. The precise loss of lead has never been determined, but in the desulfurization of galena containing 60 to 78% of lead, the loss of lead is probably not more than 1%, and there appears to be no loss in silver.

The ore treated contains 60 to 78% and about 15% sulfur, but ore from New South Wales containing 10% Zinc has also been treated. A Zinc content, up to 7 or 8%, in the ore is no drawback; but ore carrying a higher percentage of Zinc requires a larger addition of SiO_2 , and about 5% more iron ore, in order to increase the fusibility of the charge. The charge ordinarily treated in Germany was made to contain 11% SiO_2 . The presence of pyrites in the ore is favorable to desulfurization.

Dolomite plays the same part in the process that limestone does, but is of course less desirable in view of subsequent smelting in the blast furnace. The ore is best crushed to 3 mm, but good results have been obtained with ores of coarser size. However, the proper size is somewhat attendant upon the character of the ore. Fine slimes are worked up with a mixture of coarser ore.

The proportion of limestone is not varied much, but the proportion of SiO_2 and iron must be carefully modified to suit the ore. Certain kinds of ore have a tendency to remain pulverent or to retain balls of unsintered powdered material. In such cases it is necessary to provide more fusible material in the charge, which is done by varying the per centage of iron and SiO_2 .

CHEMICAL PHENOMENA.

It was noticed in the English Smelting Practice[†] that when burnt lime is added to stiffen up the charge it seemed to glow for a time. In roasting a sample of the Broken Hill concentrates containing 50% lead, 3.6% iron, 14.6% sulfur, 3% silica in a muffle furnace alone, and with the addition of 10% pure lime, it was noticed the lime bearing charge ignited all over before the galena showed any change whatever, and that the temperature rose considerably with increase of bulk. The fully roasted lime bearing charge was found to contain 23% CaSO_4 , 20.2% being soluble in boiling water. Pure CaCO_3 gave the same results, except that it took longer to start the oxidation. It is not believed that the CO_2 has to be driven off in order to form lime, but that the oxidation once begun the SO_3 formed decomposes the carbonate, and the heat liberated by the oxidation suffices to carry on the process to the end. Experiment with CaSO_4 shows that the galena roasted more energetically when the dehydrated gypsum was present than when it was absent, in as much as experiments

[†] Min. Ind. 1905. p 403.

proved that the CaSO_4 does not act chemically upon the PbS . The effect of the CaSO_4 can only be physical, at least during the time that the charge does not sinter. The Huntington & Heberlein people state that the ore when charged into the furnace must still retain from 6 to 8% sulfur if the converting be successful. In such a charge the energetic oxidation of the sulfide goes on locally with the CaSO_4 as a carrier.

The investigations of the Imperial German Patent⁴ which preceded the issuance of the German patent on the Carnichael - Bradford process of desulfurization of lead, was extremely rigid, both from a technical standpoint and a legal one, and its discussion carries great weight.

It throws light on some of the reactions which are involved in the lime roasting process. Two views have been taken: one is that the oxidizing action is entirely atmospheric, while, according to the other, there is a reaction among the elements of the charge,

As a secondary phenomena, the German Patent Office called attention to the fact that the gas from the Carnichael-Bradford process is much richer in SO_2 than that from the Huntington & Heberlein process; therefore it is better adapted to the manufacture of sulfuric acid.

Huntington & Heberlein in their patent say that: ferric oxide may be used in their charge#. Charges of lead bearing sulfide ores, free from limestone, are being successfully desulfurized in pots with ferric oxide, thus making the name

"lime roasting" meaningless. L. S. Austin has proposed the name of "pot roasting." This implies nothing but atmospheric oxidization, the ferric oxide action as a diluent of the sulfide. It is not impossible that "pot roasting" and "lime roasting" may come to be regarded as distinct processes, the former as a simple modification of ordinary roasting, and the latter as a further modification in which lime or gypsum play some chemical part.

COMPARISON OF POT ROASTING WITH
REVERBERATORY ROASTING.

The results obtained by Huntington & Heberlein at Friedrichshutte, Germany [†] are very comprehensive, and is a sufficient example of the economic advantages the lime or pot roasting processes have over the reverberatory process. Mechanical Circular Roasters are used - six 19 feet and one 26 feet in diameter, and contain 27 and 55 tons of ore respectively. In the former practice the reverberatory smelting furnace treated five tons in 24 hours, and a hand reverberatory roasting furnace, with a sintering hearth, eight tons. For an annual output of 50,000 tons, fifteen reverberatory smelters and fifteen reverberatory roasting furnaces would be required as against eight Huntington & Heberlein roasters 19 feet in diameter, or four 26 feet in diameter.

COMPARATIVE DATA FOR LABOR.

One man per day will treat in a reverberatory smelting furnace .83 ton, and in a hand reverberatory 1 ton. In a 19 foot roaster of the Huntington & Heberlein Mechanical Circular type one man will treat 4.5 tons, and in the 26 foot roaster 11.8 tons per day.

Figures for fuel tell a similar story. Consumption per ton of ore in reverberatory smelting furnace is 50.3%; in the hand reverberatory 28.7%; while in the mechanical circular roaster, 7.3%. Flue dust is reduced from 9% to 1.8%. It is found that most of the zinc that is contained in the ore passes into the flue.

[†] Min. Ind. 1905. Vol. 14. p 405.

The new process permits the reduction of former floor space from 83,960 sq. ft. for an output of 50,000 tons to 11,776 sq. ft.- a reduction of 7 : 1. Cases of lead poisoning were reduced from 16.1% to 9.2%.

CHEMICAL ANALYSIS:

Analysis of original ore:-	Pb	77.27%
	S	11.94%
Analysis of Run #2:-	Pb	69.46%
	S	10.85%
Analysis of Run #3 :-	Pb	69.46%
	S	7.27%
Analysis of Run #4 :-	Pb	69.46%
	S	3.74%
Analysis of Pyrites:-	Fe	46.40%
	S	53.33%
Analysis of Limestone:-	CaO	52.56%

All the leads were determined by the Molybdate method, and the limestone and iron by the Permanganate method and the sulfur by the BaSO₄ method. ϕ

RATIONAL CHEMICAL ANALYSIS.

Our aim in this thesis was not only to know the ultimate composition of the ore, but also to determine in what condition as to compounds the ore existed after the roast. For this purpose we worked out the following scheme for rational analysis:-

5 gms. ore

100 cc of 10% sol acetic acid

Heat to almost boiling for 10 minutes

Filter

Wash with hot water

Filtrate of PbO		Residue of lead sulfate
5 cc H ₂ SO ₄		10 gms. NH ₄ Cl - 50cc water
Boil		Boil 10 minutes
Cool		Filter
Filter		Wash with hot water
Wash with cold acidified water	Filtrate	Residue
Dissolve sulfate in NH ₄ Cl & Am. acetate	Ammonia	Dried
Boil	Am. Carbonate	Roast
Titrate with Am. Molybdate and calculate to PbO	Boil	Treat same as original for PbO and PbSO ₄
	Settle	
	Filter	
	Wash with cold water	
	Decompose carbonate on paper with warm dil H ₂ SO ₄	
	Wash with acidified water	
	Dissolve in NH ₄ Cl and Ammonium acetate	
	Titrate with molybdate	

These results did not account for all the lead in the ore, so the residue in the re-roasted product was analysed for lead, with results as shown on page

In preparing the lead sulfate for titration it was necessary to precipitate with ammonium carbonate, and re-precipitate as lead sulfate, because of the solubility of the ferrous sulfate, it preventing the color test with tannic acid.

In burning off the paper from the residue, care was taken to prevent particles of the paper falling into the residue, which might cause the reduction of a small per cent. of metallic lead in the re-roast.

RATIONAL ANALYSIS.

#3	cc	%Pb	%PbO		
	2.65	1.55	1.67		
	2.68	1.61	1.73		
PbO	2.50	1.41	1.51		
	2.65	<u>1.55</u>	<u>1.67</u>		
	Average	<u>1.53</u>	1.53	<u>1.65</u>	1.65

RATIONAL ANALYSIS ON RE-ROASTED PRODUCT.

#3	4.10	1.75	1.88		
PbO	4.10	<u>1.75</u>	<u>1.88</u>		
	Average	1.75			1.88
#3	5.80	3.28	4.84		
	5.20	2.93	4.29		
PbSO4	5.30	2.99	4.37		
	5.25	<u>2.96</u>	<u>4.33</u>		
	Average	<u>3.04</u>	3.04		4.45

ANALYSIS ON RE-ROASTED PRODUCT.

#3	30.00	12.81	18.75		
	30.10	<u>12.85</u>	<u>18.81</u>		
	Average	<u>12.83</u>			<u>18.78</u>
	Total lead	19.15			
	Total PbO			3.53	
	Total PbSO4				23.23

After analysis was made on product, the residue from this analysis was given a complete roast, and rational analysis was made on this re-roasted product.

#4	cc	%Pb	%PbO	
	7.52	4.25	4.53	
	7.54	4.26	4.59	
	7.80	<u>4.40</u>	<u>4.74</u>	
	Average		4.30	4.64

ANALYSIS ON RE-ROASTED PRODUCT.

#4	28.20	10.89	11.72	
	28.20	<u>10.89</u>	<u>11.72</u>	
	Average		10.89	11.72

#4	11.25	6.37	9.32	
	11.40	6.44	9.42	
PbSO4	11.45	6.46	9.46	
	11.28	<u>6.38</u>	<u>9.33</u>	
	Average		6.41	9.38

ANALYSIS ON RE-ROASTED PRODUCT.

#4	34.32	13.26	19.41	
	34.32	<u>13.26</u>	<u>19.41</u>	
	Average		<u>13.26</u>	<u>19.41</u>
	Total lead	34.80		
	Total PbO		16.36	
	Total PbSO4			28.79

After analysis was made on product, the residue from this analysis was given a complete roast, and rational analysis was made on this re-roasted product.

MECHANICAL OPERATION.

The apparatus used in the roasting of the galena was comprised of an ordinary iron kettle, thru a hole in the bottom of which was conducted the air. A perforated iron plate about 16" in diameter rested on the sides of kettle, its holes were about $3/16$ " in diameter - small enough to prevent clogging, or sifting thru of the charge. The pot was covered with a cone shaped hood of galvanized iron, thru the side of which was a door for watching the roast, and from the top the fumes and dust were conducted to the flue chamber thru a 3" pipe, thence to the fire flue in the wall of the building, where they escaped to the air.

The dust chamber was an ordinary heavy white pine box, 2ft x 3ft, and lined with zinc. (This zinc had no importance, further than preventing the escape of the gases thru the interstices of the box. A tightly built box would have answered the purpose equally well).

Air for the roast was tapped directly from a storage tank, and entered the pot thru a 1" pipe.

The pressure guage consisted of a 6 mm. glass tube, bent in "U" shape and half filled with water, and supported by a wooden upright resting on a base. The scale was graduated in half inches, giving direct reading in inches. Pressure of air was regulated by an ordinary stop-cock.

Apparatus for the analysis of the escaping gas consisted of an 8mm. glass tube inserted in the flue between the pot and dust chamber, and bent at right angles, and connected to a 250 cc Wolff bottle containing 2 cc of a standard solution

of Iodine in 100 cc of water. This bottle was in turn connected to a 500 dropping funnel, held erect by clamp on iron stand. On regulating the flow of water from the dropping funnel the amount of gas passing thru the iodine solution can be easily measured, which was done with a 1000 cc cylinder. Barometric pressure and temperature of the water is necessary to calculate the results.

The Iodine solution was standardized against Arsenious acid in grams, and as the gas was measured by volume it ~~is~~ was necessary to calculate the SO₂ to grams.

CHARGING and OPERATION.

A brisk fire of pine was started in bottom of pot, and allowed to burn for some time. under low air pressure, heating the pot sufficiently to start ~~charge~~ reaction of the charge, care being taken not to allow any charcoal coming in contact with charge, which would likely reduce some galena to metallic lead. When the wood had burned down low enough to allow the perforated plate to fit snugly to sides of pot, a thin layer of the charge was dumped into the pot, more being added as reaction became brisker, until all was charged. The air pressure up to this point was kept low - not more than 2½" of water. As "chimneys" appeared they were covered with the loose charge. As the heat of ~~the~~ reaction decreased the air pressure was increased, until at the end of the roast pressure had attained 6" to 8". A sintered product was desired, so charge was not stirred or disturbed more than enough to cover the blow holes formed. The reaction was allowed to die of its own accord, doing so at the end of about four hours,

Air was turned off, pot allowed to cool, and charge dumped on the floor and sampled for analysis, then put aside for blast furnace run.

The size of the galena was 6 to 8 mesh, limestone 4 to 10, and pyrites 6 to 10. All was crushed thru breaker and rolls, sampled and assayed.

Loss in flue was not as great as we anticipated it would be, owing to the high pressure and arrangement of flue chamber.

BLAST FURNACE RUN.

Blast furnace run was made on the product of six pot-roast runs (the four as referred to in this thesis, and two by the Senior class), but owing to the high contents of sulfur, due to the large amount of fines, and the absence of lead oxide ores, we were unable to obtain a very large yield of metallic lead, the lead forming mostly matte.

CONCLUSIONS.

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An insufficient number of runs were made to draw definite conclusions. With this apparatus we were unable to make a run on galena alone; but by using and varying the amount of pyrites (partly for its sulfur contents, and partly for diluent) we were able to show that a very small amount, only, of pyrites is needed to start and maintain the oxidizing reaction.

These experiments were conducted on the same ore, and these results apply to this ore or one similar, but still they have a larger application, as they point to the following conclusions:

a. That to pot-roast a rich galena ore, or galena concentrates low in blende, charges containing a wide range of lime and little iron can be successfully used.

b. Low pressure blast is a better desulfurizer, and causes less loss than high pressure blast.

Irrespective of reactions, the Sayelshurg process has the great economic advantage of dispensing with the preliminary roast of the Huntington & Heberlein process, and is said to be cheaper both in first cost of plant and in operation.

	No. of charge	3	4
Charge			
Galena, pounds		93.3	150
Limestone, pounds		37.5	30
Pyrites, pounds		56.2	25
Galena, %		50	75
Limestone, %		20	15
Pyrites, %		30	10.5
Duration of run, hours		3.25	2.30

Blast			
Pressure while charging, inches of water		3	3
Maximum pressure	" " "	7	8

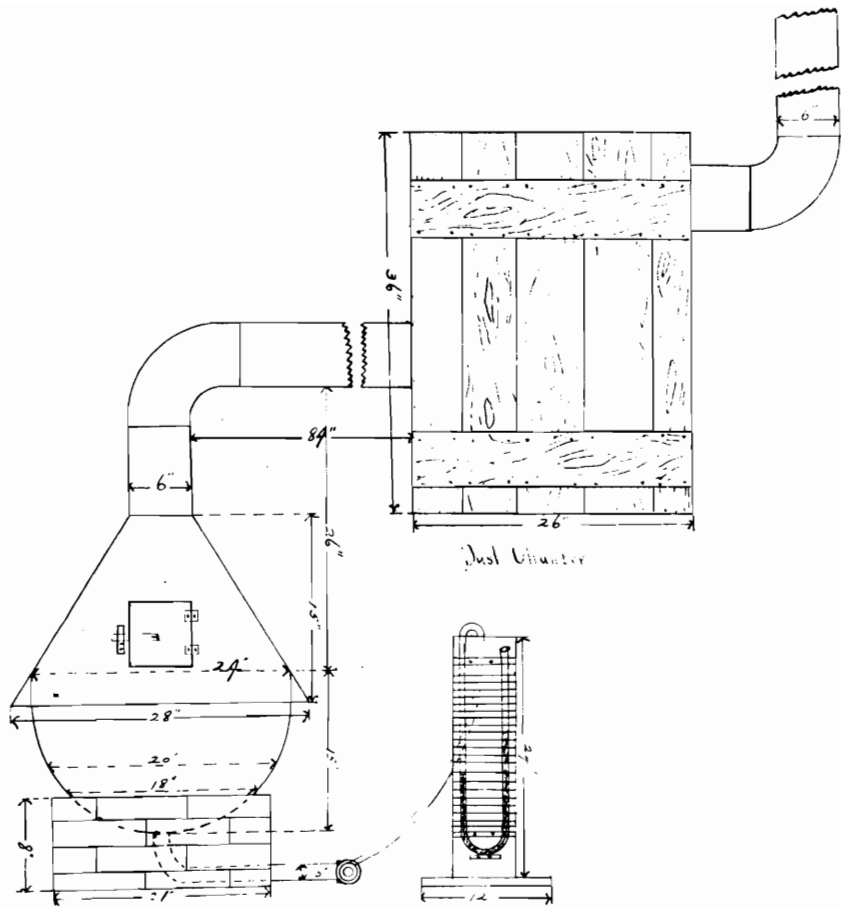
Weight of product in pounds		165	188

Sulfur			
Sulfur in ore charge, pounds		21.97	14.65
" " " "	%	11.8	7.31
" " product	%	7.27	3.74
" eliminated,	%	54.6	48.12

Lead			
Lead in charge, pounds		64.81	104.19
" " " "	%	34.65	50.82
" " product	%	38.03	52.72
" lost	%	3.17	4.87

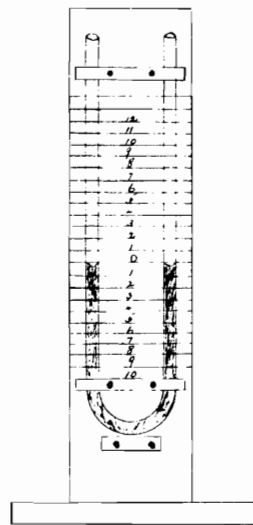
VIEW OF APPARATUS USED.



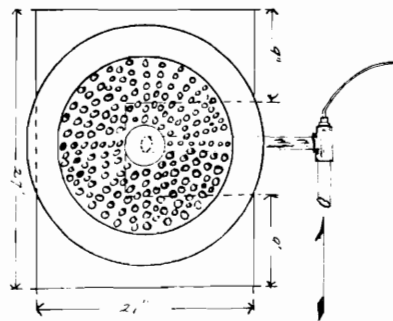


Moule.

Just Visimeter



Water Gauge



Perforated Plate