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DESCRIPTION OF THE ZEEHAN-MONTANA CONCENTRATING PLANT.

By John Craze, *General Manager.*

As a rule, the ores of metalliferous minerals are not found in such a rich state as will permit of the mineral being at once sent to the market. Consequently, it is necessary that some system be adopted to get rid of worthless gangues and country-rocks which form part of the mineral veins, or may become mixed with the rich ores in the mining operations, thus increasing in quality the metallic contents of the ore, and avoiding the cost of freight on worthless rock to smelting furnaces, which are fequently at long distances from the mine.

Active mining operations are at present being carried on at the Zeehan-Montana Mine, of which I have had the honour of being Manager during the past eight years, on nine distinct lodes or veins, varying in size from two inches up to three feet in width. These veins or lodes are being worked simultaneously, at four levels, each level being 100 feet below the one above. The course of the veins varies from 30 degrees east of north to 30 degrees west of north, and in their strike they pass through various classes of country-rock, so that, while in one part the walls of the lodes or veins may be of slate, in another they may be of melaphyre, quartzite, or schist. The gangue of the lodes also changes as frequently as the country-rock. In parts of the mine quartz predominates as a lode gangue, while in another part the lode is composed of slate, with small veins of argentiferous galena intermixed; while again, in other parts, carbonate of iron composes the major part of the lode. Sometimes, veins and branches of pure galena are found in the carbonate of iron lodes, but often the galena found in these lodes is finely disseminated through the gangue or carbonate of iron in such a manner that without some system of reduction or concentration, it would be valueless. Various other minerals, such as zinc-blende and iron pyrites, are found in the lodes, and of the two named, zinc-blende predominates. As the smelting people who are purchasers of our argentiferous galena, have serious objections to zinc in lead-ores, and do not forget to exact heavy premiums from the seller when this mineral is found in the lead-ores, the duty of the mine-owners is to allow as little blende as possible to be sent away with the marketable product.

The system adopted in mining the lodes is practically the same, whether driving a drive or stoping. The country-rock is first mined and disposed of; the lode is then broken down on platforms, under which is spread a coarse canvas or sacking, so that any small particles of ore which may fall through the joints of the platform are recovered on the canvas. The lode-material being broken down, is now hand-picked by the miners, who select the clean galena from the inferior lode-stuff. The clean galena is sent to the surface and conveyed to the shed, and broken into a convenient size, and bagged for export. The remaining portion, which is practically refuse, composed of inferior lode-material, and containing quantities of country-rock which have formed a portion of the lode-filling, and unavoidably become mixed with the lode-material in the mining operations, and cannot, without loss, be separated in the mine, is sent to the surface and conveyed to the concentrating works, where it is concentrated, the principle of which will be explained later on. The reader can very well imagine from the foregoing that the material sent for concentrating is a very fair mixture of mineral and rocks generally. This material is known as second class ore, and is composed of the following:—quartzite, schist, slate, melaphyre, quartz, carbonate of iron, iron pyrites, zinc blende, and argentiferous galena. Each of these contain silver in more or less quantities, as instanced by numerous assays made from time to time. The quartzite gives from 1·30 to 3·2 ozs. silver per ton; slate, when forming the walls of the lode, from 2 to 3 ozs.; carbonate of iron, from 1·5 to 3 ozs.; zinc blende, 4 to 12·5 ozs; while each gives from a trace to 1·5 per cent. lead per ton. From numerous tests made from time to time, I am of opinion that the silver contained in these rocks is not in chemical combination with the lead, or, at least, not in the form of sulphide of lead, and, consequently, the system of concentration adopted is not calculated to recover these units. Our system is purely a silver-lead concentrating plant, so that any silver or lead not in the form of argentiferous galena is actually lost; and any silver or lead that may be associated with any of the rocks is also rejected as tailings, hence, they go to build up the loss sustained by concentration.

The total output of the mine averages about 1500 tons of lode-material per month, and, taking an average of our returns for some years past, one twelfth of this will represent hand-picked ore, while the remaining eleven-twelfths is second class ore, and is subjected to concentration. The first class ore averages about 100 ozs. silver and 63·5 per cent. lead, while the average assay value of the second class ore for the past two years, gives 12·71 ozs. silver and 7·20 per cent. lead per ton; and zinc, 5 per cent. The percentage of silver per unit of lead is here shown as equal to 1·76 in the second class ore, and 1·57 in the hand-picked ore, the difference being probably due to the silver contents of the rocks and zinc. I have shown that one twelfth of the output from the mine is actually marketable, while the remaining eleven-twelfths, assaying 7·20 per cent. lead and 12·71 ozs. silver, is worth, in actual money (taking present price of lead at £12 5*s.* per ton, and silver at 2*s.* 3*d.* per oz.), only £2 6*s.* 2*d.* per ton; and is thus unmarketable, and practically useless. Hence, the necessity of reducing the bulk and increasing the value in order that some revenue may be derived to assist in the profitable working of the mine. However much may be said in favour of smelting low-grade ores of the Zeehan field or in any other field with similar gangues, the fact must not be overlooked that first of all there must be sufficient mineral contents to defray the cost of smelting charges, and reduction for losses in smelting. If the contents of the ore are not sufficient to cover this cost and leave a further margin of profit over mining expenses, it would be useless to subject the ore to the smelting process. It is not the purpose of this paper to state that all ores, either auriferous or argentiferous, require the same process of concentration. On the contrary, the proper method of concentrating depends entirely on the class of ore to be treated. Hence, the system adapted to one class of ore may be entirely unsuited to another. The ores of the Zeehan-Montana Mine are being mined below the oxidised zone, and the particular system of concentration adopted is calculated to deal with the carbonated and rocky formations in which the argentiferous galena is found.

Concentrator.

The concentrating plant is situate about 230 feet from the main hoisting shaft and connected therewith by an overhead tramway, over which the ore is conveyed to an ore-bin attached to the concentrating plant. The capacity of ore-bin is 90 tons, the object being to keep a constant supply of ore for the steady running of the plant. The plant, which was erected in 1897, under the direct supervision of the writer, is erected on what is commonly known as the terrace system, *i.e.*, in benches. The total height from the floor on which the slime appliances are erected to the floor on which the ore enters the building is 40 ft., while the total length of building is 160 feet. The ore, therefore, after entering the building, continues downward through the various stages of breaking, crushing, and sizing, until its final exit as a clean marketable product or valueless tailings. The second and third products of the various jigs,

&c., which require fine crushing before re-treatment, are elevated to fine rolls, and again continue downward through the various systems of classification, finally passing out as clean products or tailings.

Water.

The water necessary for dressing purposes is pumped from the mine and carried direct to a large tank situate near the ore-bin, from which it is conveyed by a complete water service of cast-iron pipes, through the plant to the various machines. After having passed through the mill, it enters a large settling-pit at the lower end of the mill, where it becomes clarified. In the event of the water in the mine becoming less and the supply insufficient for dressing purposes, this water is pumped back and used over again, and in this way an ample supply is maintained. This system, however, has its drawbacks, and we are now constructing a dam situated above the mill, the area of which will be sufficient to allow proper settling and a continuous supply direct.

The ore is fed direct from the ore-bin on to a grizzle or barred screen, which is set at an angle of 50 degrees, and extends from the doors of the ore-bin to the rock-breaker, a distance of 10 feet. This grizzle is constructed of $\frac{5}{8}$ inch by $2\frac{1}{2}$ inches iron bars placed on edge, with distance pieces $\frac{7}{8}$-inch thick, placed between the bars at intervals of 2 feet. These are kept in position by bolts passed through the iron bars and distance pieces, holding together the screen, which forms a grating. The ore passing over this on its way to the rock-breaker becomes divided, the smalls up to $\frac{7}{8}$-inch diameter pass through the grizzle and are caught in a V-shaped shoot lined with $\frac{1}{4}$-inch steel plate, and carried downward, with the assistance of a small stream of water, to No. 1 trommel, while the coarse ore passes on to the rock-breaker.

Rock-breaker.

The rock-breaker is one of May Bros., Gawler, S.A., and is capable of crushing 7 tons per hour. It is set to break to 1-inch diameter. The ore thus broken falls on to a shaking-table, inclining $1\frac{1}{2}$ inches in 3 feet, and fitted with a perforated plate $\frac{7}{8}$-inch diameter. The fine ore passes through these holes into the V-shaped shoot, becomes mixed with the fine ore from the grizzle, and carried on to No. 1 trommel. The coarse ore which does not pass through the perforated plate is deposited on a circular revolving picking table, where any stray pieces of pure galena are picked out and bagged for export, and the purely waste rock discarded, while the second class ore is carried along by the revolving table to a shoot, where the table is automatically relieved of its contents, depositing them in the shoot which conveys the ore to coarse rolls.

Rolls.

These rolls are of the Cornish type, are 24 inches diameter by 14 inches across the face, and made of toughened steel. They are driven by belt and spur-gearing attached to one roll, while the other is driven by the friction of the other roll revolving. They make about eight revolutions per minute, and are adjusted by means of heavy set screws, with steel spiral springs to allow for the expansion of rolls. These rolls are set to crush the ore to 13 m/m. diameter, and the ore, after passing through the rolls, falls into the V-shaped shoot previously mentioned, and becomes mixed with the fine ore from the grizzle and shaking-table before described. It is at this point where all samples are taken of the crude ore being treated, before entering the No. 1 trommel.

Trommels.

A series of five trommels are here erected, each being driven by geared wheels attached to the trommel shafts, deriving their motion from a belt and spur-gearing arranged at the end of the series of trommels. The trommels are covered with steel perforated plates, having holes 13 m/m., 9 m/m., 5 m/m., 3 m/m., and 1½ m/m. respectively. The whole of the ore enters No. 1 trommel, which is situate below the rolls just described, and has holes 13 m/m. diameter; any particles too large to pass through the 13 m/m. holes, are thrown out at the end of trommel, and enter a shoot carrying them to a two-compartment jig. This jig is constructed after the pattern of the Hartz Jig, with side-pockets. The jig sieve has perforated holes, 3 m/m. diameter, and is supported and held down by two cast-iron frames. The bed of ore is about 6 inches deep, and the jig-boxes are kept full of water. The plungers, which are of solid pattern, derive their upward and downward motion from the usual eccentric, and runs at a speed of 90 revolutions per minute, with a 3-inch stroke. By this means, the bed of ore is kept in constant motion. The galena ore, owing to its specific gravity, finds its way to the bottom of the bed and travels forward over the cast-iron frame-work which supports the plates, until it reaches the side-pocket, where it is delivered. A small gate is placed in the open of the pocket, which, by raising or lowering, increases or decreases the value of the product. Any fine particles of ore that may find their way to this jig, pass through the jig-plate, and are drawn off at the bottom of the jig-box. The tailings from this jig pass into an elevator, and are carried back to the coarse rolls, where they become mixed with the other coarse ore from the picking-table, and after passing through the rolls, find their way to the trommels, as before, but being crushed finer, go on to the various jigs set apart for their respective sizes. This jig does excellent work, the assay value of the product being equal to that of first class ore in silver, while the lead increases, viz., 100 ozs. silver and 66·5 per cent. lead.

No. 2 Trommel.

This trommel is built on the same principle as No. 1, but is covered with a steel perforated plate, with 9 m/m. holes. The ore which passes through the 13 m/m. trommel enters No. 2 trommel, and all ore fine enough to pass through the 9 m/m. hole, is carried on to the next trommel, while the ore which is too large is thrown out at the end of the trommel, enters a shoot, and is conveyed to a two-compartment jig (No. 1). This jig makes two products. The first product is clean ore, while the second is somewhat inferior, but both are marketable, and go to the pile. The tailings are discharged into an elevator and carried upward to a set of fine rolls, recrushed, and afterwards treated in jigs on the fine side of the plant, explanation of which will be given below. The product of this jig gives an average assay of 65 per cent.lead and 80·80 ozs. silver, or equal to 1·23 ozs. silver per unit of lead.

No. 3 Trommel.

This trommel is of the same pattern as Nos. 1 and 2, and is situate at the end of trommel No. 2. The perforated plates covering this trommel have holes 5 m/m. diameter. The whole of the mineral which passes through the No. 2 trommel with 9 m/m. holes now enters this trommel, and the fine, up to 5 m/m., passes through the holes, and the coarse, *i.e.*, from 5 m/m. up to 9 m/m., is delivered at the end of the trommel, and carried by a shoot into No. 2 jig. This jig is a three-compartment jig, and is of the same pattern as No. 1 jig, with solid plunger. The first compartment produces clean concentrates, the average assay value of which is 69·50 per cent. lead and 84 ozs. silver, or equal to 1·21 ozs. silver per unit of lead. The second and third products are returned to the fine rolls for re-crushing.

No. 4 Trommel.

The steel plates covering this trommel have holes 3 m/m. diameter. The whole of the fine material which passes through No. 3 trommel now enters this trommel, and all material up to 3 m/m. passes through the holes, while the coarse, *i.e.*, from 3 to 5 m/m., is delivered out at the end of trommel and carried to No. 3 jig. The first compartment of this jig yields clean concentrates, the average assay of which is 66·50 per cent. and 84 ozs. silver, or equal to 1·20 ozs. silver per unit of lead. The second and third products of this jig are returned for recrushing.

No. 5 Trommel.

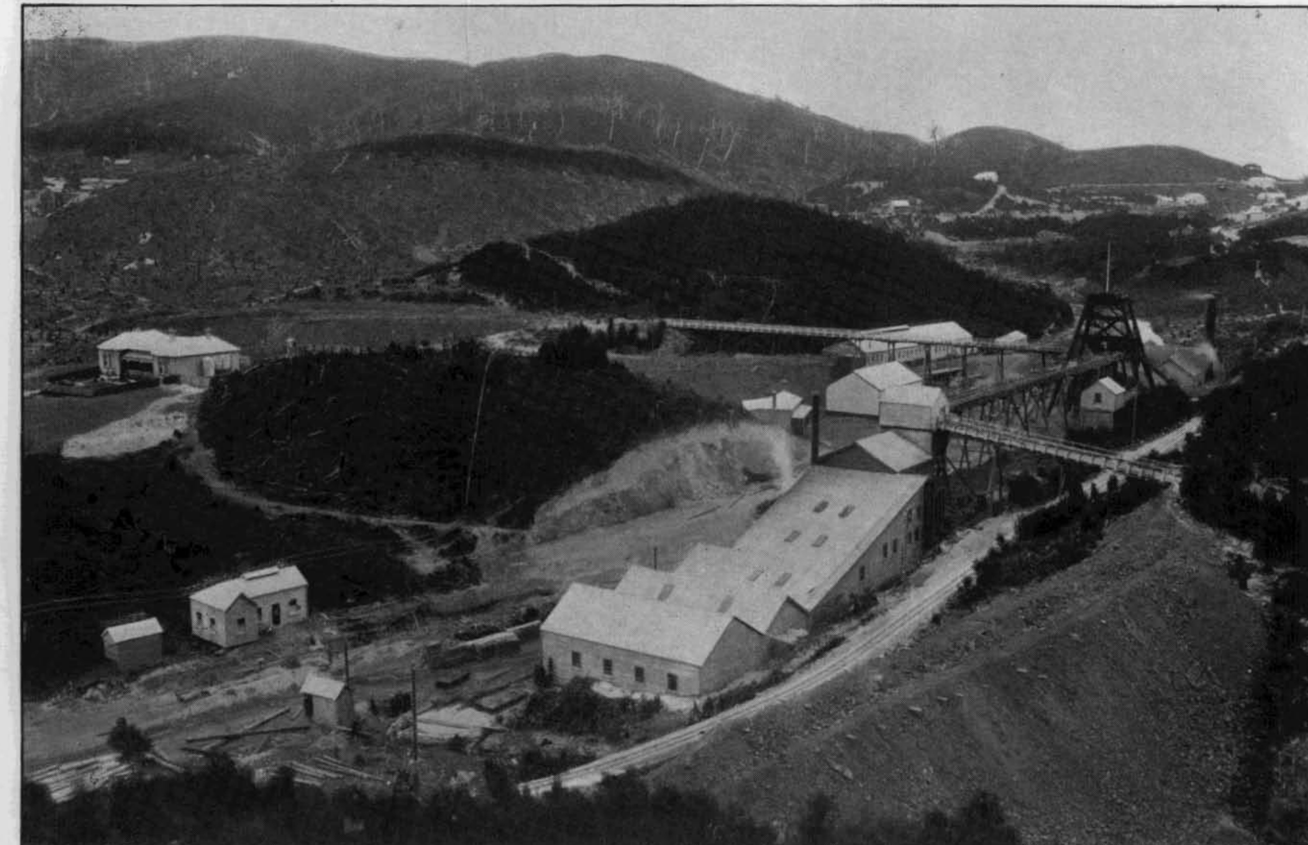
This trommel is covered with a steel plate with holes 1½ m/m. diameter, and is situate at the end of No. 4 trommel. All the material which passes through the 3 m/m. holes, now enters this trommel, and is again subjected to division, so that all fines up to 1½ m/m. pass through the holes, while the coarse, *i.e.*, from 1½ up to 3 m/m., is delivered out at the end of trommel and conveyed to No. 4 jig. This jig is of the same pattern as Nos. 1, 2, and 3. The first compartment produces clean concentrates, averaging 67·50 per cent. lead and 84·80 ozs. silver, or equal 1·27 ozs. silver per unit of lead. The second and third products from this jig are returned for finer crushing.

Water or Hydraulic Classification.

The ore that passes through the 1½ m/m. trommel now enters a V-shaped classifier, which is built of cast-iron. Clean water is conveyed to the bottom of this classifier by means of a one-inch diameter pipe, attached to the lower end or apex bottom. This water is conveyed under pressure, and regulated by a suitable valve, causing a spray of water to spread upward through the classifier. The water conveying this material from the No. 5 trommel into the classifier carries very fine slimes, together with particles of 1½ m/m., which here become separated, the coarser particles falling to the bottom, and are drawn off, and treated by a three-compartment jig, (No. 5), while the finer slimes are kept up by the upward flow of water and carried on for further treatment. The first compartment of this jig contains clean concentrates, assaying 62·50 per cent. lead and 70·40 ozs. silver, or equal to 1·13 ozs. silver per unit of lead. The second and third products are carried back to the fine rolls for recrushing.

Fine Crushing.

This part of the plant deals exclusively with the tail of No. 1 jig, and the second and third products, of Nos. 2, 3, 4, and 5, jigs, on the main side of plant, just described. The material consists of the heaviest particles of gangue with small pieces of argentiferous galena attached, and also, other minerals, such as zinc blende and pyrites. The clean products of each of the jigs described are practically free from either of the last two-named minerals. The object of the recrushing is to liberate



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the valuable galena from the gangues, which is accomplished by elevating the material to a height of 20 feet above the jig-floor, where it is delivered into a set of Fine Crushing Rolls. These rolls are of the same pattern and size as the coarse rolls previously described, but are driven slightly slower. The material, after passing through the rolls, is conveyed into a trommel, having a perforated plate of 4 m/m. holes, and the material which passes through these holes, enters a second trommel, with 3 m/m. holes. The material, which does not pass through the 4 m/m. holes, is delivered out at the end of that trommel, and conveyed again to the elevator and carried up to the rolls.

No. 2 Trommel.

This trommel has a perforated plate, with 3 m/m. diameter holes. The material which passes through these holes is carried on to No. 3 trommel, while the coarser stuff is delivered out at the end of trommel and into a three-compartment jig. The first product of this jig is put to pile as clean concentrates, while the second and third products are again returned to the fine rolls for re-crushing. Owing to the quantity of pyrites and zinc blende in the material treated on this side of the plant, the product of the No. 1 jig is of lower value than the average of first products. The average assay value of this product is 47·50 per cent. lead and 54·40 ozs. silver per ton, or equal to 1·14 ozs. silver per unit of lead.

No. 3 Trommel.

This trommel has holes 1½ m/m. diameter. The material which does not pass through these holes is delivered out at the end of trommel, and conveyed to a three-compartment jig. The first product is put to pile, and the second and third products are again returned to the fine rolls. The average assay value of first product from this jig is 52·50 per cent. lead and 58·40 ozs. silver per ton, or equal to 1·11 ozs. silver per unit of lead.

Hydraulic Classifier.

The material which passes through the 1½ m/m. trommel, enters an hydraulic classifier, the construction and arrangements of which are similar to the one described. It supplies a three-compartment jig, the products of which are similar to those of the No. 5 jig, before described.

Slimes.

At this point, the pulp-water which has passed through the trommels on both sides of the plant, meets, and is conveyed in one V-shaped shoot to a third hydraulic classifier of the same description, as those previously mentioned. The coarse material is fed into a four-compartment jig, while the fine continues on into an elevator. The first product of this jig is clean, and assays 42·00 per cent. lead and 46·40 ozs. silver per ton, or equal to 1·10 ozs. per unit of lead. The second, third, and fourth products, are conveyed into the same elevator, just described, to a series of settling-boxes or spitzkastens.

Slime Elevator.

The fine slimes rejected by the hydraulic classifier, together with the second, third, and fourth compartments of the fine jigs, and the overflows from all elevators throughout the plant, are conveyed into one common pit. This pit is about 3 ft. deep and 4 ft. by 4 ft., built around on the inside with brick and cement mortar. A double balata-belt elevator is placed in this pit, the buckets being attached to the belting with small bolts. This elevator raises the whole of the slime water to a height of 12 ft., where it is delivered into a shoot and conveyed into the spitzkastens.

Spitzkastens.

These consist of three funnel-shaped boxes or rectangular pyramids, with the base upwards; the first is 3 ft. deep, the second, 4 ft. 6 ins., and the third, 6 ft. The whole of the pulp-water flows into the first, where the coarse sands sink, and are drawn off at the bottom; the next size sinks into the second box, and the very fine, into the third. The first or coarse sands are drawn off at the bottom or apex of the box and fed on to a Wilfley table.

Wilfley Table.

This table is an American invention, but made in the States, N. Guthridge, Limited, 486 Collins-street, Melbourne, being the agents. The table consists of a flat surface 7 ft. wide by 16 ft. long, made of wood, and covered with linoleum, upon which are nailed a series of thin strips of wood which form riffles. These riffles extend nearly the full length of the table on the discharge side, but shorten as the feed corner of table is approached. The pulp is fed on to the table at the side near the end, while the discharge of the tailings is along the opposite side. The clean concentrates are carried forward and delivered at the end, while a second product is made by the moving forward or backward of a small flap situate on the side. This machine has also an elevator attached to the head which is intended to convey the second product again to the head of table for retreatment. This table is given a forward and backward movement by a particular joggle arrangement set at the end, and runs at a speed of from 230 to 240 revolutions per minute. The whole of the pulp is kept in constant agitation, the lighter gangues being carried over the side by a constant supply of water, while the heavier or clean concentrates are carried towards the end by the assistance of the riffles. The size of material fed onto the machine, is about 1 to 1½ m/m., or about the size of battery sand. Experience, however, has taught me that the table will do better work without elevating the second product, consequently, this is not returned to the table direct, but is treated by another machine. The clean concentrates from this machine give an average assay of 51·50 per cent. lead and 57·60 ozs. silver per ton, or equal to 1·11 ozs. silver per unit of lead.

Bartsch Tables.

The pulp from the second and third spitzkastens is drawn off at the bottom or apex, and fed on to two bartsch tables. These tables are circular in form, and are made of cast-iron; are 13 ft. diameter, and conical in form. The pulp is fed into a curved distributor, which spreads the feed over one half of the table at the time, while over the other half a curved spray-pipe is diffusing clean water; with the exception of a vibrating or shaking motion, the table is a fixture. The curved feed-distributor and spray pipe revolve over the surface of the table, the former distributing the pulp, and the later washing it, and finally washing it off into a delivery channel, which also revolves with the feed and water-spray arrangements. The clean product finally flows into the settling-pits, from which it is taken, dried, and bagged for export. These tables are excellent machines for the saving of fine slimes. They are, however, very expensive and slow, one costing £350, and will only treat from 4 to 5 tons in eight hours. The capacity is, therefore, too small to be considered a success on ores having a low-market value. The average assay value of the clean products from these tables, both depositing their product in the same receptacle, is 52·50 per cent. lead and 54·12 ozs. silver, or equal to 1·03 ozs. silver per unit of lead.

Bagging Floor.

The bagging floor is situate at the extreme end of the plant, and is 30 ft. by 60 ft. It is made of concrete, and has a dip of one inch in the foot towards the settling-pits of the bartsch tables. The concentrates are conveyed to the floor from the the various machines, and as the concentrates contain considerable moisture, this is allowed to drain off, the drainage flowing down the incline floor into the settling-pits.

Classification.

Much has been said and written on the matter of efficient classification. The writer's opinion, however, is that no hard and fast lines can be laid down whereby such efficiency can be secured for every class of ore. Efficient classification and sizing of the particles are, however, identical with efficient concentration, and the most accurate results can only be ascertained by experimenting on the particular class of ore to be treated. After long and severe experiments, the sizes and system of classification employed in this particular plant have been found most convenient.

Coarse side of Plant.

No. of Jig.	Size of Ore.	Lead Assay.	Silver Assay.	Silver per unit.
	millimetres.	per cent.	ozs.	ozs.
No. 1	21 to 13	66·50	100·20	1·52
No. 2	13 to 9	65·00	80·80	1·24
No. 3	9 to 5	69·50	84·00	1·21
No. 4	5 to 3	66·50	80·00	1·20
No. 5	3 to 1½	67·50	84·80	1·27
No. 6	1½ to 1	62·50	70·40	1·13
Fine side of Plant.				
No. 1	4 to 2	47·50	54·40	1·14
No. 2	2 to 1½	52·50	54·40	1·03
No. 3	1½ to 1	59·50	58·40	0·98
No. 4	1	42·00	46·40	1·10
Wilfley	1	51·50	57·60	1·11
Bartsch	Fine slimes	52·50	54·12	1·03
Crude ore	...	7·20	12·71	1·76
Coarse tailings	...	1·01	2·8	2·77

The average assay value of concentrates recovered during the last year is 63·22 per cent. lead and 77·69 ozs. silver, or equal to 1·22 ozs. silver per unit of lead. The assays of jigs and slimes given in the above table are the result of samples taken of one day's operations, especially taken for this paper, and must not be taken as averages for any long period. The assay values of second class ore and concentrates, and tailings, are the actual values of twelve months' operations, and on the treatment of 16,500 tons.

The figures given in the above table will be of interest, as they show the gradual decrease in the silver contents per unit of lead, according to the degree of fineness of concentrates. They also point out the advisability of avoiding as far as possible, fine crushing at the outset of concentration, and in recovering the valuable argentiferous galena in as large a state as possible. The result of fine crushing is forcibly shown by the values of products on the fine side of plant, of which a further enrichment in lead would involve greater loss of silver, and would be of no actual benefit as far as value is concerned. The principal object aimed at is to produce the most valuable product with a minimum of loss.
