14TH JUNE, 1888.

NOTES ON SOME MECHANICAL ASPECTS OF METALLIFEROUS MINING IN AUSTRALIA.

By Dr. John Storer.

Whilst with nothing startling or novel to communicate to our Association, I think that some good will arise from my drawing the special attention of our practical engineers to the large field for work which is open for them in this colony, and in the direction indicated by the heading of this paper.

Mining has done much in Australia in the past, but it has not by any means had the mechanical attention given to it which, from its importance, it deserves. In the early days pick, shovel, and pan were the mechanical devices most in demand. Alluvial working of the old type is dead. We are entering upon an era where there are no poor man's mines, where capital, joined to mining, engineering and metallurgical skill, must produce the results.

In metals, gold production has taken the first place hitherto. There are not wanting signs that in the immediate future gold mining will receive a further impetus, and in a permanent direction.

Silver, so to speak, is a new metal for Australia. It too has a good future before it.

Lead is associated with silver, and as long as the one is worked so will the other be. With regard to this metal much could be said.

Tin has found a permanent home here, and I am of opinion that the production of tin from Australia will in the future rule the home market.

Copper is so widely spread throughout the Continent of Australia that it cannot avoid being more or less worked. I look upon it as being one of the most abundant metals here—iron of course excepted—and one, too, in which there is room for improved methods of production.

The general poverty of mechanical appliances in use on mining properties has often struck me during my many tours. My desire is to give in brief outline what machinery should do, leaving it then for the practical engineers to give the subject the attention which it deserves. The raw material is at our door. We know, or are supposed to know, what we wish taken out of it, and it is neither right nor proper for us to wait for improvements or suggestions to come from other lands.

In these present notes I shall confine myself chiefly to gold, looking, as I do, upon its production as the industry which will shew the largest development in the immediate future, leaving for some other time the question of what might be done industrially with the other metals which I have named.

That we have ample raw material that is gold-bearing, is beyond all doubt. The matter to which attention must be directed is to win the precious metal at the smallest cost. The day of economies and scientific working is at hand I hope.

Broadly stated, all metallic ores when brought out of the mine, are usually more or less intermixed with each other, or with the lode stuff, or gangue, in the midst of which they are found. These ores must undergo a varied manipulating, to separate the metals or minerals.

In the case of gold the metal is found in many varieties of lode stuff, such as quartz, granite, slate, serpentine, ironstone, and so forth, and it occurs either as free gold, or associated with iron or copper pyrites, or with zinc, arsenic, antimony, &c.

The present chief methods of winning the gold are:—1st. By amalgamating the free gold with mercury or quicksilver. 2nd. By washing the pyrites or other mineral carrying the combined gold, and thereafter, as the gold is then supposed to be free, either amalgamating with quicksilver or dissolving it out, in the shape of solution, by means of chlorine. There are also other methods to which I need not at present allude.

At the basis of all these operations the ore, as a start off, must be pulverized. It is here where practically the greatest poverty of invention has been shown, and where little in the way of innovation can be seen. The stamper battery has ruled supreme in Australia; other means of pulverizing are known, and numerous types of machinery capable of being worked are to be had; yet mine-owners here, and apparently engineers too, have been content to keep in the old rut. When machinery is spoken of for a goldmine, a battery is at once conjured up. It is the universal panacea. It is apt to remind one of those medicines which are warranted to cure all ailments, from baldness to a sprained ankle.

Until lately it never seemed to enter into the heads of mine owners that it would be a wise thing to have the exact nature of the ore they were working studied, to note its peculiarities, to learn exactly what was being lost, how it was being lost, and if, and how, it could be saved; and to know what constituent of the mineral carried the gold they sought; and then with all these points known, to call in the aid of the engineer and chemist to help him to solve the problem in a practical way.

It is common property to all how to-day in Australia, millions of pounds sterling of gold are lying in tailings heaps, the outcome of stamper batteries, yet with the increasing *heaps* of waste—not waste heaps—miners appeared content to let them grow.

With the stamper battery there is a considerable loss of power in addition to its being a cumbrous machine, and in very many cases its action on the mineral it is set to crush, reminds one of using a steam hammer to crack an egg.

A short extract here giving the ideas of others about stampers will illustrate my meaning—

"The loss of gold in stampers is great and a few facts will afford an intelligent understanding of this method. In gold-bearing quartz yielding 1oz. per ton there is an average of one halfpenny worth of gold to every pound of stone, and in ½oz. stone—2lbs. of stone to one half-penny worth of gold. This ½d worth of gold is nearly the size of an ordinary pin head, and the number of grains of sand of that size in a pound of ore is definitely determined by simple computation, and it is known to be a little over 98,000. In other words, there are nearly 100,000 grains of hard sharp quartz to one of soft yielding gold in one pound of stone containing 1oz. of gold per ton, and in ½oz. stone nearly 200,000 grains of sand to one of gold. The next step is to determine how many times this pin head of gold in ½oz. stone is crushed, pounded and ground with this mass of nearly 200,000 grains of sand before the whole is liberated. This problem is easily and simply solved. The stamp weighing 750lbs. and credited with crushing 2 tons in 24 hours, dropping 90 times or striking the quartz 90 blows in a minute, in one hour will strike 5,400 blows to crush $\frac{1}{12}$th of a ton, and in 12 hours will deliver 64,800 blows to reduce one ton. If the ore yields ½oz. gold per ton it takes something like 64 drops or blows to liberate ½d worth of gold, and it has been hammered, bruised, and ground 64 times before it can escape. It is not surprising that gold is lost."

I before stated, that all metallic ores when brought out of the mine are usually more or less intermixed with each other, or with the lode stuff or gangue, in the midst of which they are found. These ores must undergo a varied manipulating to separate the metals or minerals. That is the problem before the engineer. Let him produce the perfect machine—not a cure-all—but one, after he knows the mineral he is going to handle, which will effectually do its work.

He has many varying kinds and hardnesses of stone to pulverize. If the gold is present in the mass in a state fit to amalgamate, then the crushing mill, to be ideally perfect, must do nothing more nor less than simply free the gold from its matrix, so that the quicksilver can readily seize and retain it. No beating out of the metal to a state like gold-leaf, so that the power is produced to crush stuff that the gold therein may be put into a condition to float quietly away with the current of water which runs through the mill.

Then in cases where the gold is in a free state fit for amalgamating, there must, if possible, be means taken to prevent any contamination of the quicksilver from grease or oil, for these substances prevent the amalgamation and are in every way detrimental

If the gold is in combination with pyritic minerals, such as I before named, then the pulverizing must be done so that, whilst the matrix is separated, the pyrites shall not be too finely divided, and thus render its subsequent separation needlessly difficult.

Again, if we have the gold disseminated so finely throughout the mass so that chlorination must be the means of extraction, then a good method of dry crushing by which the ore is powdered to the finest possible condition is what is desired.

In all this we have work for more than one type of crushing machine, and a field is open for our engineers—with the raw material in abundance at their hands—to adapt themselves towards producing machines which will give the greatest mechanical results with the least expenditure of either power or cash.

Summarised, proper crushing machines for treating gold ores must not waste driving power; must be able to free the gold without altering its physical appearance to any extent; must not unduly pulverize the pyritic or other gold-bearing minerals, thus rendering their subsequent separation troublesome; must not grease or oil the quicksilver employed; must be simple in construction and easily kept in repair.

I would also draw attention to what is much needed for Australia as a crusher. It is a really portable, light, and effective prospector's crushing mill. One to crush a few cwts. thoroughly, be quickly erected, and, most important point of all, be so designed that it can easily be carried by pack horses.

Again, gold even and often, if free, occurs in such a fine state of division that after the ore is properly crushed, much of the gold floats away upon the surface of the water. Here is also a good subject for inventive ingenuity.

The traditional blanket has been and still is used with an uncertain amount of benefit, but there is yet room for improvement.

Incidentally I mentioned dry crushing—which involves the use of machinery of an essentially different type from what is required when quicksilver amalgamating is desired—as being necessary for gold-bearing ores suited for chlorination.

A brief outline of this process whilst showing the reason for dry crushing may not be uninteresting.

The basis of the chlorination process is the well-known chemical fact that free chlorine gas exerts a powerful action upon gold, combining with it and forming what is known as chloride of gold, which is very soluble in water.

Chlorine does not, however, confine its solvent action to gold. It acts powerfully upon many other metals—*e.g.*, copper, iron, etc., forming also with them chlorides soluble in water.

As a practical matter then it is desirable to bring about such conditions, where other metals, or their ores, are present, that if possible the chlorine will be able to dissolve little else, from out the mass operated upon, than the wished for gold.

For instance let us take the well-known Mount Morgan ores. Here the gold is present in a very finely divided condition, and accompanied with varying proportions of peroxide of iron and quartz. The chlorine would dissolve variable quantities of the iron peroxide. To prevent such a waste of chlorine recourse is had to roasting the ore. This roasting has the effect of rendering the iron practically insoluble in or unaffected by the chlorine.

To make the roasting effective, and to insure all the ore getting thoroughly heated and oxidized it must be in powder, hence the necessity of dry crushing.

Wet crushing would mean an additional operation, viz., that of drying the crushed ore; therefore the dry crushing is the proper method to adopt.

The dry powdered ore is roasted in long reverberating furnaces, and in which it is kept at cherry red heat. The style of these furnaces must be familiar to you all. Here the ore is heated and gradually worked by hand from the charging end of the furnace down to the discharging end; the ore being turned over thoroughly at regular intervals by the furnace-men to ensure the complete heating thereof.

Withdrawn from the furnace the ore is allowed to cool, when it is ready to be submitted to the action of chlorine gas. For this purpose the ore is filled, through a man-hole, into closed wooden cylinders, where it is mixed with certain quantities of water, bleaching-powder, which contains the necessary chlorine, and sulphuric acid, which last is added in sufficient quantity to set the chlorine free from the bleaching-powder containing it.

The wooden cylinder charged with ore, water, bleach, and sulphuric acid, is now closed and revolved slowly for several hours by means of a suitable gearing, thus giving the chlorine time to thoroughly penetrate the mass, and dissolve out such gold as is contained in the ore.

To heighten the action, air is pumped into the cylinder, thus permitting the chlorine to act under pressure, or the air may be exhausted from the cylinder leaving the pressure of the chlorine solely to act upon the gold. Both methods have been tried. After the chemical action is complete, the contents of the cylinder are emptied into leaching vats, or tubs with perforated bottoms, so arranged as to allow only the chloride of gold to drain away. The ore is washed with water till the last traces of dissolved gold are extracted. Thereafter the exhausted ore is cast aside.

We now have the gold by itself, dissolved in water in the form of chloride of gold. The solution is of a very pale yellow colour, clear and transparent.

The next operation is to get the gold into the solid form again. For this end the solution of chloride of gold is filtered through layers of common wood charcoal which has the peculiar property of seizing hold of the gold within its pores, permitting the chlorine to flow away in the water by itself as hydrochloric acid. After the charcoal has absorbed sufficient gold it is dried and burned, when all the gold is found in the ashes. These are collected, melted in suitable crucibles with the needful fluxes, and the gold finally cast into ingots. Sawdust, lignite, or other similar organic matter has the same action upon chloride of gold as the wood charcoal and may be used in place of it.

In these operations, which I trust I have made clear to you, there is scope for the engineer.

In the roasting furnace there is great improvement possible. A mechanical furnace capable of thoroughly roasting the ore in an automatic fashion is what should be used. There are no difficulties in the way of adopting such a furnace which cannot be easily overcome.

By running such a furnace the result would be that greater speed and regularity of roasting would ensue with a very considerable saving of labour and fuel as compared with the means now adopted.

Various types of mechanical roasting furnaces are known, but like the crushing machinery—adaptation for the special type of work is requisite.

There are some varieties of gold-bearing pyrites which are suited for treatment by the chlorination process as already described, the whole apparatus necessary is the same in both cases. The only difference in the working detail is, that a special attention to the roasting requires to be given, so that the sulphur and arsenic present in the pyrites are completely expelled.

In the matter of the cylinders used for the chlorinating operation, there is also much scope for both engineer and chemist to perfect a cylinder, better adapted for the work, and more lasting than the wooden cylinders now employed.

In the general arrangement of the plant for crushing, and in laying off working arrangements at mines, we see great lack of forethought. Much of it is due, I consider, to the irresponsible management of Boards of Directors, who do not make themselves sufficiently practically acquainted with the wants of their mines, do things in a piecemeal fashion, and not as part of a well considered scheme. Managers and overseers of mines often display great ingenuity in combating difficulties which ought never to exist, and which could easily have been provided for, had the adequate engineering knowledge been consulted in the first instance. How many heavy, cumbersome engines do we not see employed, running at a slow speed, and working with a low pressure of steam. Instead of that, there should be engines driven at higher speeds and greater steam pressure. This is easily done, and would result in an economy of engine costs, and also of fuel, matters of considerable moment.

Crushing mills are run continuously until cleaning up day, necessitating night work. With steam power always available, it is a matter of surprise to me that the electric light is not used for the night work.

Installations using the incandescent light are now to be had for, comparatively speaking, a few pounds, and would give a brilliant light where now darkness is just made visible. In many cases the mines themselves could be lighted up by incandescent lamps, thus effecting further economies. Such methods of lighting up mines are now in vogue in Great Britain, and I should like to see a similar system adopted here. Not only would a much better light be given for the miners to work by, but the workings would be kept cooler than is the case where candles are burnt.

Often when visiting properties, I hear of "grand reefs" just cut, but which I cannot see as the water has just come in, and so on. One would imagine that pumps were unknown or were a great luxury from the niggardly manner in which they are used, and when we see one we find a cumbersome affair working as a light pump. As yet there are no mines of any great depth here in New South Wales, and with steam always available, or nearly so, the proper course is to use a steam force pump; place it at the bottom of your shaft, carry the steam down to it, and force the water out. This method would be not only cheap and simple, but very effective.

I have still the question of treating the crushed mineral, after amalgamating, to touch on. It still carries in its grasp such gold-bearing minerals as the quicksilver will not, or rather cannot, touch. How can this best be separated and leave our tailings free from gold, or practically free?

The various minerals have various specific gravities, and it is by taking advantage of this fact that it is possible to separate the minerals and ores from the sand, quartz, or other matrix in which they are found after they are pulverized.

As each metallic ore is of a different weight compared with an equal bulk of water, each ore must naturally take a different portion of time in falling through a given space of water. This is the underlying principle governing all processes of separation or concentration.

In this part of the work much ingenuity has been displayed—outside of Australia—and many machines are to be had which will do their work; yet in this there is still much to be done, both in the way of increased speed of working, and in the cheapening of the means of so doing.

The free time presently at my disposal prevents me entering more into detail in this part of the work—indeed I have to crave your forbearance for presenting such crude notes before you at all.

In one way my end is gained if I draw active attention to a great industry, which will more than repay any attention given to it, and which only requires honesty of purpose and intelligence to be directed to it to yield a constant and profitable occupation to a large population.