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PRELIMINARY CONSTRUCTION OF A PHOTO-ELECTRIC CELL CONCENTRATOR

By

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June 5, 1931
Butte, Montana
Preliminary Construction of a Photo-Electric Cell Concentrator

Thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Metallurgical Engineering at the Montana School of Mines

by Stanley S. Williams of Brooklyn, New York Butte, Montana June 5, 1931
THE PRELIMINARY CONSTRUCTION OF A PHOTO-ELECTRIC
CELL CONCENTRATOR

INTRODUCTION.

The separation of the valuable portion from the waste
portion of an ore is an individual problem for every ore.
However, the various methods for accomplishing this end, more
or less classify themselves by the physical properties of the
constituents of the ore. Most of the properties of minerals
have been utilized in some way or other to affect the separation
of the valuable from the invaluable parts. Practically nothing
has been done so far with color and luster to attain this purpose.
Certain industries have used the photo-electric cell as the eye
of a picking device. Cigars are graded by this means as to the
depth of color. Bad fruit is sorted from good with this
ingenious little device. It is believed that the photo-
electric cell could also be used in concentrating a certain
class of ores which are not well suited to other methods.
Again, it should replace hand sorting in a great many instances
and be carried on down to sizes below the economic limit of
hand picking. It is with these ideas in mind that this work
was started. Mr Roy W. Drier of the Michigan College of Mining
and Technology under the supervision of Prof. A. T. Sweet, did
some very excellent work along these lines. This was of
considerable value in organizing an attack of the problem.
His work which he called "Photo-Electro Metallurgy" was the only one found of this nature, and was published in the February 1930 issue of Industrial and Engineering Chemistry.

The principle used by Mr. Drier was to pick the particles wanted from a travelling belt, by means of a pneumatic tube. The main difficulty here was the slowness of operation and the expense of creating the suction. It was believed, after many methods were considered, that the best and simplest was to get at the particles and remove the desired portion of them was to have them drop one by one in front of a light sensitive cell and the ones reflecting the most light would activate the cell. This current from the cell thus set up could then be amplified sufficiently to operate a relay which would in turn control some device such as a solenoid which would be the motive power for a splitter of some kind. In this way the particle could be made to fall into either of two storage receptacles simply by its degree of luster. By this system, it was thought that the limiting speed would be the speed with which the splitter could be operated through a relay. To make such an arrangement as this possible it would be necessary to develop a feeder which would drop the particles one at a time past the photo-electric cell.

Such was method of attack.

THE APPARATUS AS DEVELOPED.

Feeder--

Various types of feeders were considered such as the
conveyor belt, pulley and revolving slate feeders, but none of these seemed to be adapted for the one particle delivery. About the only plan that seemed feasible was to design a feeder by which the particles could be made to slide along a V-shaped trough. Feeding them at one end from a hopper, they would arrange themselves in a single row, one particle deep, if the trough were of the proper length. This idea was worked out in the feeder constructed. The motion was imparted to the feed by giving the trough an oscillatory motion at the delivery end by means of a very small eccentric. This was driven by a 1/8 H. P. motor. The feed end was supported by a shaft which passed through slots in the trough to allow the lateral motion. This system worked very well with sized feed which would be absolutely necessary for the selective part of the apparatus. The accompanying picture shows the feeder as developed.
Separator Unit—

The separator unit may be divided into several parts to simplify its description, namely: — The light and cell, the splitter, the amplifier and the relays.

The first part, the light source and the cell— the brains of the apparatus, — gave considerable trouble. A photo-voltaic cell was first tried which met with an accident and a second had to be ordered, before this type of cell was given a fair trial. The liquid cell did not work out at all satisfactorily, since it cannot readily be amplified by radio tubes. The reason for this is because amplification by this means depends on a change in potential at the grid and the liquid cell does not give this to a large enough extent. The cell is very sensitive in as much as the current passing through it varies greatly with a change in light intensity. It then became necessary to order a standard gas filled cell which was much more satisfactory.

The arrangement of the light, reflector and cell may be readily understood from the following sketch and picture.

Looking down on separating unit:

A- Photo-electric cell
B- Parabolic mirror with a hole in the center
C- Shield with hole about the size of the reflector. A small disc is held at the center by means of a wire.
D- Solenoid
E- Splitter
F- Light source; thru a hole, not shown.
The splitter is shown in both the sketch and the picture and is merely an inverted V-shaped piece of tin soldered to a pivoted arm. As this moves from one side of the little hopper to the other, the direction of the stream of particles is changed. The chute just below the splitter passes through the bottom to two receptacles. The solenoid, also shown in the picture operates the splitter. After being moved, the splitter is returned to its normal position by means of a small spring.

All the above mentioned apparatus of the separator is enclosed in a box, the inside of which is painted black. This is to keep the cell as close to totally dark as is possible when
no particle is in front of the mirror. It will be noticed that there are two other shields in the box which have not been mentioned. The first is just to one side of the cell which helps to keep out any light that might be reflected from the box. The other is on the side of the box and is set at an angle. It was found that in spite of the fact that the side was black that it reflected a considerable amount of light into the cell. This passed the small disk as the source was too far to one side. The shield remedied this trouble and cut out only a very small portion of the light to the reflector.

Outside of the box is an amplifier unit, consisting of two tubes and two relays. The hook-up of these is shown by the following schematic diagram.
The tubes are arranged in parallel to give a strong
deflection to the small relay. Only one tube was used at first,
but two were believed to be more satisfactory. The first relay
is sensitive to $\frac{1}{2}$ milli-amp., and works easily with the mentioned
amplification. The secondary of this relay is connected in series
with a single dry cell and the primary of a telegraphic relay.
In turn, the secondary of the telegraphic relay is connected in
series with the solenoid and a bank of dry cells in series, which
gave an E. M. F. of 30 volts. This much voltage was necessary
to operate solenoid with the desired speed as the resistance and
inductance were quite high.

RESULTS AND THEIR INTERPRETATION.

The results from the apparatus as set up were negative: it
would not work. Many things were at fault, but there was not time
to correct them. These will be discussed further on in the report.
The problem had been attacked from the standpoint of setting a
speed with which the apparatus must function to be practical. It
was here that it fell down. When any small shiny object was
passed fairly slowly in front of the reflector, everything
operated as it should. However, when a particle was dropped past
the mirror, only the small relay functioned, but the contact was
too light and for too short a time to make the rest work. Since
there is evidently still a great deal to be done to make this
experiment successful, this report is being written with as much
the idea of aiding a successor to the work as in describing that
DIFFICULTIES EXPERIENCED AND THE VARIOUS CHANGES WHICH WOULD APPEAR TO REMEDY THESE.

Although the feeder did not have a fair trial, it is believed that it is, in the main, satisfactory. However, the chances are that it will have to handle larger feed than it was designed for; so the following changes are suggested. The mouth of the hopper should be made larger in order to handle the larger feed without blocking. If this is done, it will be necessary to lower the feed end of the trough and set the stop in the trough further ahead. It would also be advisable to use a resistance on the motor to facilitate the control of speed with which the particles are to be delivered.

The arrangement of the light and cell as it is now set up is fairly satisfactory. A larger lamp could be used to some advantage. With a reflector behind the lamp and the proper lenses to cause the rays to be parallel the intensity would be increased and the efficiency also. An arc lamp was tried, but this flickered and varied too much, so the Mazda lamp still seems the best.

As far as the splitter is concerned, it would be much better if it were lighter and designed somewhat differently. As it is, it requires a very powerful solenoid to operate it at the desired rate of speed. This, it itself, is quite a disadvantage as will be explained later.
The above sketch illustrates a simple means of constructing a splitter of much less mass.

If the particles fall too fast, it may be necessary to reverse the direction of their path just below the focal point of the reflector by means of a small inclined plane or platform.

In this way, it would be possible to have the particle in the path of the light several times as long. It would also increase the period between the time of activation of the photo-electric cell and the time when it would reach the splitter. As there is
bound to be some lag in any arrangement where a solenoid and coils are used, this would be a distinct advantage. The small hopper just above the splitter would probably have to be extended upward somewhat if the particles are to be bounced on a small platform. Otherwise they might not go into either of the receptacles. If this is done, it will have to be painted black as it would reflect too much light in this position.

With the change in the construction of the splitter and a different relay (discussed later) it would be advisable to change the solenoid to some extent. The way it is there are about 3000 turns of #28 wire on it. This could be cut down to about half without seriously affecting its efficiency. It might also aid in increasing the speed to bore the center of the moving core of the solenoid.

The relay or relays were probably the main cause for the failure of the apparatus to function as it should. In the proper design of the relay for the particular work that it has to do, lies the crux of the whole problem. At first, only one very sensitive relay was tried, but the secondary could not handle the current necessary to operate the solenoid. In fact the relay was not designed to handle more than about a tenth of an amper with a potential of one volt. This was not stated in the catalogue and no directions were sent with it. The only way that could be done, was to try it, and see what would happen. This was the procedure carried out, not only with the relay, but almost all the way through, since there had been no detailed description of any work done along those lines before. The relay really failed for two reasons,
namely; First, because a relatively small current in the secondary affects the deflection of the contact arm. This is due to the fact that the current has to go through the hair-spring that gives the tension to moving part of the relay. This spring is in the field of a strong permanent magnet. When a current passes through this spring, it tends to distort the shape of it, and thereby change the tension of the spring. This causes the contact arm to be thrown back and the circuit to be broken almost as soon as it is made. The effect is an action similar to that in a buzzer. Even were this not the case, the current through the secondary might have some effect on the primary since one of the contacts of the primary is also one, and the same for the secondary. In other words, the two circuits are connected. Unless the wiring were done very carefully, it is easy to conceive of enough current being induced from the secondary to the primary circuit and thus cause a change in deflection of the contact arm as soon as the secondary circuit was completed. The second difficulty with the relay was in the contact points. Only a very small current could be passed through them or they would fuse and stick together. With such a sensitive relay the spring was not strong enough to break them again. Then if it did function the make and break is practically instantaneous, and does not allow time enough to overcome the hysteresis of the coil. With these various troubles outlined, it should not be difficult to design a relay, that would take care of all these. A relay sensitive to about five milli-ampere, instead of one-half
milli-amperes, with the primary absolutely independent of the secondary, and the contact being a point going into a well of mercury would probably remedy the difficulties. The mercury contact idea would serve three purposes. A good contact could be made without having too strong a relay, it would not stick, and there would be a longer period of contact as it takes time for the point to go into and come out of the mercury. Such a relay as this could handle the solenoid directly instead of having the second telegraphic relay. Not only that, with the changes for the solenoid, a lower potential could be used, and this would help get away from the sparking at the contact.

As far as the amplification unit goes, it would probably be necessary to have tubes in series to get enough power to operate the less sensitive relay. Either a power tube or two tubes in parallel for the second stage would be advantageous. The whole idea of the changes is to get more power to a less sensitive relay by means of more amplification. In this way the time lag is cut down to a minimum.

To get greater amplification, and still not put too large a load on the photo-electric cell, it is advisable to use an independent battery of from 20 - 50 volts for the cell, and then use about 90 volts on the tubes. It might be well to state here that the greater the grid resistance, the greater the amplification factor. However, when this becomes too great the system becomes unstable due to leakages. Also a greater negative bias has to be
used. About 5 - 10 megohms is about right. The following arrangement as shown by the diagram would probably give sufficient amplification for a relay sensitive to five milli-amperes.

CONCLUSION

I sincerely believe that the principle outlined for a photo-electric separator is theoretically sound, and that it also will have many practical applications. It is hoped that the work will be continued and that my successor will derive some value from the suggestions offered.
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