Proceedings
at
One Hundred and Nineteenth
Ordinary General Meeting
15th December, 1921.

The One Hundred and Nineteenth
Ordinary General Meeting of the South
African Institute of Electrical Engineers
was held in the Assembly Hall, Scientific
and Technical Club, 100, Fox Street,
Johannesburg, on Thursday, 15th December,
1921, at 8 p.m., Mr. L. B. Woodworth
(President) in the chair.

There were present :— 44 members; 11
visitors, and the Secretary.

MINUTES.

It was proposed, seconded and agreed that
the Minutes of the Ordinary General Meeting
held on the 17th November, as printed in
the November Journal, be confirmed.

FERREIRA DEEP DISASTER.

The President: I telephoned through
just before the meeting to the Ferreira Deep,
and was told that Mr. Johnston had died at
five o'clock, and that they had been unable
to recover the bodies. Well, gentlemen, you
know how it affects us all. They were
fellow-workers engaged in the industry in
which we are concerned. I feel you agree
that all honour and admiration is due to
those who have risked their lives in the
rescue work. We had all hoped that life
would be saved, but unfortunately the worst
has happened. I ask you gentlemen to
stand just for a moment to express your
sympathies with the relatives of those who
have lost their lives.

[All members present rose to their feet].

ELECTION OF NEW MEMBERS.

Messrs. A. L. Ballard and G. K. Nowlan
were elected as scrutineers of the ballot for
the election of new members, and after
their scrutiny, the following candidates were
declared duly elected :—

AS MEMBERS.

ERIKSSON, CHARLES THEODORE, Electrical
Engineer, P.O. Box 318, Bulawayo.
HILYER, WILLIAM JOHN, Projects Engineer,
Telegraphs and Telegraphs, Egyptian State
Telegraphs, Cairo, Egypt.
KELLEY, CEDRIC, Electrical Engineer, c/o.
Messrs. Hubert Davies & Co., Ltd.
Johannesburg.

AS AN ASSOCIATE MEMBER.

MENDES, JOHN HENRY, Instrument Repairer,
Electric Supply, Johannesburg Municipality.
(Re-admission).

The Council has admitted :—

AS TECHNICAL ASSOCIATES.

BREEN, FLETCHER, Electrician, Mossop's Garage
and Engineering Works, Box 22, Vrede, Orange
Free State.
MILELLA, OLYMPIO, Electrician, Consolidated
Main Reef and Estate, Ltd., Box 13, Florida.
(Transfer from Student).

ANNUAL BALLOT FOR ELECTION OF VICE-
PRESIDENT AND MEMBERS OF COUNCIL.

The President: The next item is the elec-
tion of not less than four scrutineers for
the annual ballot of officers and members of
Council, in terms of the Rules, each nomina-
tion to be seconded, and taken in turn.
The following gentlemen were then proposed, seconded and declared elected:—

**GENERAL BUSINESS.**

**DECLARATION OF PRESIDENT FOR 1922.**

**The President:** Gentlemen, it gives me great pleasure to announce that the Council has unanimously elected Mr. E. V. Perrow as President of the Institute for 1922. (Loud applause.) You all know what a worker he is. We want workers in the Institute. Since I have been a member of Council, and in office, I have known just how hard Mr. Perrow works, and I do not think in all my experience I have seen a better worker, and, as I said at the last meeting, what we want is a man who gives us the goods. I think Mr. Perrow will. He is one of the hardest workers, and has the interests of the Institute very much at heart. I am very pleased that the Council has seen fit to elect him as our future President. (Applause.) I think one of our Past Presidents has something to say. I might say there is a telegram from Mr. Perrow, who is in Capetown, to the Institute, expressing his thanks to the members for his election as President. He apologises for his absence, and also regrets his inability to meet Mr. Mordelay. (Applause.)

**Mr. W. Elsdon-Dew (Past President):** Mr. President and Gentlemen, I think on an occasion like this, when an election of President has been made, one likes to review the position and look back to see what work that member has done for the Institute. In this instance I think every member of the Institute of Electrical Engineers of South Africa recognises that the Council's decision has been made with a full knowledge of how much the interests of the Institute are to Mr. Perrow. I think it speaks very strongly for what the family of Perrows has done, when we remember that not four years ago we had the pleasure of having Mr. Will Perrow, his father, as our President, and now we welcome his son, who is following in his footsteps. His son is one who has any amount of energy and good intentions, which he carries out, not only for the benefit of his fellow-men, but of the electrical profession as a whole. I feel that the choice of the Council has been a happy one, because it shows, in the Institute's Council deciding to have a resident electrical engineer from one of the mines, how the honours can be spread to all workers who are electrical engineers at heart. I think the Institute is to be congratulated on having made this choice. (Applause.)

**Mr. J. W. Kirkland (Past President):** Mr. President, I would like also to add my voice in appreciation of Mr. Perrow's work for our Institute. He has done a great deal; he has attended Committee meetings, and he has put his back into the work of this Institute. I am very glad that the Committee and members have decided that he should follow in his father's footsteps. (Applause.)

**The President:** Well, Gentlemen, I certainly endorse the sentiments expressed by the speakers, and I would like on your behalf to ask the Secretary to send Mr. Perrow a telegram of congratulation from the members. (Applause.)—Agreed.

**NOMINATIONS FOR COUNCIL.**

**The President:** I believe nominations have to be in by the 19th, and I trust members will fill up their nomination forms, and, as I mentioned at the last meeting, nominate the workers.

**HISTORY OF S.A. ELECTRICAL ENGINEERING.**

**The President:** We want to try and get as much information as possible, so that the Committee can start work; and, as I pointed out before, some of the subjects are:

- **Power,** from water, gas and steam.
- **Pumping.**
- **Winding,** and all classes of mining work.
- **Traction.**
- **Railways.**
- **Lighting and Heating.**
- **Telegraphy and Telephony:** Ordinary and wireless.
- **X-Rays and Medical.**

Any member who has any information dealing with these, also their early history, is requested to compile it and get it ready to forward to the Committee, as it will aid them in the work they are about to undertake.
A PAPER CONCERNED MAINLY WITH CERTAIN PHYSICAL PHENOMENA—NOT WITH DEVELOPED PRACTICAL PROCESSES. IT IS BASED ON AN EXPERIMENTAL STUDY WHICH WAS INTERRUPTED AT THE END OF 1921, WHEN THE AUTHOR'S WORK CALLED HIM TO PORTUGUESE EAST AFRICA, WHERE THE PAPER HAS RECENTLY BEEN PUT TOGETHER, IN ORDER TO KEEP A PROMISE TO READ A PAPER BEFORE THIS INSTITUTE. THERE HAS BEEN NO OPPORTUNITY OF MAKING CHECK TESTS ON A NUMBER OF POINTS THAT HAVE ARISEN DURING THE WRITING OF THE PAPER, NOR OF REFERRING TO WORKS OF REFERENCE OR OTHER SOURCES OF INFORMATION, AND IT HAS BEEN NECESSARY TO Rely A GOOD DEAL ON MEMORY.

By W. M. Mordey, Past President I.E.E., M.Inst.C.E.

An ordinary laminated alternate-current electro-magnet behaves more or less like a permanent magnet, or a direct-current electro-magnet, when presented to a mass of iron filings or crushed magnetite, tufts of these materials adhering strongly to the poles and joining them by lines of force if they are not too far apart.

These effects of alternating magnetism in themselves do not offer any advantage over uni-directional magnetism for the concentration of minerals; on the contrary, they involve a greater expenditure of energy—and at a low power factor—for the production of a given field.
Thus this mineral, which is paramagnetic with uni-directional magnetism, appears to be diamagnetic with alternating magnetism.

In seeking for explanations of this effect, we have three properties to consider: electrical conductivity, magnetic susceptibility or permeability, and magnetic hysteresis. Having dismissed conductivity as inadequate—it would cause repulsion if appreciable—we turn to permeability and hysteresis, and ultimately realise that with alternating magnetism these two properties will play active but opposed parts: the relative importance of the forces exerted—that of attraction due to permeability and of repulsion due to hysteresis—determining which shall prevail—that is, whether the substance will act as a paramagnetic or as a diamagnetic material; in the present instance hysteresis prevailed.

But we must not conclude that there will always be this dual action—that specular haematite will always act in the manner described with alternating magnetism. That will depend on the frequency; by decreasing or increasing the frequency hysteresis may be reduced or, in the latter case, eliminated—as will be shown presently—when repulsion will cease, the apparently diamagnetic changing to paramagnetic.
In studying this subject we naturally recall Faraday's original researches on diamagnetism; all his results were obtained with uni-directional magnetism, and all his explanations and definitions had reference to that.

There was only one partial and accidental exception, the record of which is characteristic and interesting. When he suspended a pellet of silver, by a silk fibre, near the poles of his electro-magnet he noticed that when he made or broke the circuit of the magnet the pellet was momentarily repelled from the magnet. He investigated that, and proved that the repulsion was not due to diamagnetism—like the repulsion of a pellet of bismuth—but to eddy currents.

As Faraday would not apply the term diamagnetic to an effect other than that for which he had introduced that term, it will probably be agreed that it ought not to be applied to still another kind of repulsion.

In this address that other effect is attributed to hysteretic repulsion.

So far, we have used an ordinary laminated horse-shoe electro-magnet, excited by a 1-phase current at fifty periods a second.

The induction used was low, probably about 2,000B in the core, and yet the poles exerted an appreciable repulsion through a distance of several inches.

These results encourage us to proceed a little further with our experiments.

**Multiphase Magnets.**—Let us now try a multiphase magnet—e.g., a multipolar magnet (M), made like a narrow portion of a toothed armature or field, laid out flat with the poles or teeth pointing upwards as in Figures 2 and 3.

In the space above the poles (p.p.) of such a magnet, when magnetised by multiphase currents, waves of an alternating magnetic field will sweep along continuously—in one direction or the other according to the connections of the windings—at a speed depending on the frequency and on the spacing of the poles.

Resting on the poles of this magnet place a non-conducting dish (A), in which put a heap (B) of the material to be tried, such as crushed specular haematite ore.

On exciting one phase at any usual frequency, such as 50, the magnet will act very much like the 1-phase magnet previously used, the particles of haematite being feebly repelled in every direction from the poles.

But on exciting the second phase a different and stronger action takes place, the haematite streaming from the heap (B) towards the end (C) of the dish, avoiding the poles and curving out towards the sides of the dish, as shown in Fig. 3, collecting mostly at the two right-hand corners of C, the middle space at the end being left bare.

This migration of the particles is slow but steady—from one to three inches per second in this experiment—the rate being the same whether passing over the poles, or over the spaces between or at the sides of the poles; there is no visible polar action and no deflection towards the poles. If the heap (B) consist of a mixture of silver sand or crushed quartz and specular haematite the particles of the latter will be clearly seen emerging on the upper surface of the heap, and then moving away horizontally, as described above, showing that these particles are repelled upwards from the magnet—with sufficient force to penetrate a light covering of dry sand—before being propelled along from end to end of the row of poles. Shaking the tray or stirring the heap greatly facilitates the action—not by increasing the speed, but by enabling the particles the better to free themselves.

If a small heap of sand is placed in the path of the moving particles they will climb over it.

We see in this action the repulsion of this feebly magnetic substance from the poles as with 1-phase, accompanied by a migratory movement, due no doubt to the continuously advancing alternating magnetic waves, as if a succession of 1-phase magnets was being mechanically moved along under the dish.
repulsion, there is no doubt a vertical repulsion, which will aid mobility and have other effects to which reference will be made later.

With such a magnet we can make many experiments and tests.

Attraction and Repulsion.—It will be observed that if the material be placed a little beyond one end of the row of poles, as in Figs. 2 and 3, it—even specular haematite—will be attracted into the field, propelled along it, and repelled or expelled out of it at the other end of the row of poles.

These end effects are, of course, due to spreading or extension of the multiphase field beyond the ends of the line of poles; the apparent attraction may be regarded as a repulsion from the extended field.

The whole action is directed to the repulsion of the material from the magnetic field in a certain direction—in line with the movement of the so-called "rotating field." As the ultimate result is repulsion it is probably not incorrect and is certainly convenient to apply the term hysteretic repulsion to the whole series.

Planes or Plates of Force.—If any iron filings or particles of magnetite are present they will stay over, or be drawn to, the poles (dancing over the poles), only moving on if the dish is raised several inches or the field weakened; they will then advance rapidly over the line of the poles—very much more rapidly than the specular haematite—and will not be repelled to the sides.

This narrow magnet brings out certain differences. For example, with specular haematite the lateral repulsion is from the line or row of poles—not from the individual poles—and the lengthwise repulsion or propulsion or migration is parallel with, but not over, the line of poles.

Whereas with more filings or magnetite there is attraction to the line of poles, followed, if the field be not too strong, by lengthwise repulsion, propulsion or migration along and over the line of poles—not to the sides of that line.

Instead of a long narrow magnet, let us use a magnet that is roughly square in plan, as shown in Figs. 4 and 5, the winding not being shown. This can be wound with a coil round each tooth, the connection being 2-phase. Such a magnet may be made of stampings with teeth and spaces, each about one inch wide and three inches long. A wave winding would require seven teeth for balanced phases; it would not be so convenient for our present purpose.

The outside or end poles or teeth must have a winding external to them, otherwise there will be no repulsion beyond the iron.

With the magnet somewhat as shown in the figures, and using a dish that is not greater in width than the magnet, the material—e.g., specular haematite—will not tend to escape sideways, and as the lateral repulsion will be balanced, will pass over the poles in a steady and nearly uniform stream of particles—from a to b or vice versa. Although there is no evident lateral repulsion, there is no doubt a vertical repulsion, which will aid mobility and have other effects to which reference will be made later.

With such a magnet we can make many experiments and tests.

Attraction and Repulsion.—It will be observed that if the material be placed a little beyond one end of the row of poles, as in Figs. 2 and 3, it—even specular haematite—will be attracted into the field, propelled along it, and repelled or expelled out of it at the other end of the row of poles.

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Planes or Plates of Force.—If we try crushed magnetite in a dish over such a magnet we find that there is no migration of the material if the dish is resting on the poles or near them, the material standing up over and joining the poles forming thin high distinct planes, plates or laminæ, separated from each other by clear parallel spaces of an eighth of an inch or more wide. These planes are apparently mutually repellant. Towards the sides of the magnet, they tend to lean over radially, no doubt in accord with the disposition of the field and the unbalanced repulsion.

This formation is quite different from the lines of force in the field of a uni-directional magnet, or the tufting of filings or magnetite on or near the poles of either a uni-directional or a 1-phase magnet.
If the dish is moved backward and forward on the surface of the magnet, the planes sway flexibly to and fro, but do not break up unless the dish is raised.

These planes are parallel with the core-plates of the magnet, but there seems no reason for supposing there is any numerical relation between them.

The lower portions of these planes tremble a little with the alternations, otherwise they stand erect and steady. If they are more than about three-quarter or one inch high the upper portions become unsteady, and seem to be in a state of unstable equilibrium.

Small portions of the top of one or other of these planes then become detached and dart rapidly forward horizontally through the air to another part of the same plane or to the extremity of the dish, indicating that at a certain height the force of repulsion or propulsion is strong enough to overcome that of attraction and of gravitation.

The sudden change from the stationary to the migratory condition, as the field is weakened or the dish raised, can be clearly shown by raising the dish slowly and carefully, when the material will first get unsteady, and then suddenly move forward.

In water, magnetite or iron filings tend to form rudimentary plates, closer together than when dry. The tendency to remain stationary over the poles is much less in water than dry, no doubt because of the partial flotation and consequent greater mobility assisting the force of repulsion.*

Perhaps we should not leave this subject without at least an attempt at an explanation. These planes of force seem to be formed in a multiphase field by a material in which magnetic attraction is approaching the condition of being overcome by hysteretic repulsion, the attraction holding the material in place, its particles tending to arrange themselves with their longest dimensions in the lines of force. The moving field accentuates this tendency, marshalling the particles in line and preventing those in one plane from setting themselves across the space to either side of that plane.

*At the time of writing it is not clear whether iron filings formed plates or planes as magnetite did—from memory it is thought they did, but only in a weakened field. A note on this point will be furnished on the author's return to England.

The vertical hysteretic repulsion already referred to prevents the planes exceeding a certain height in a field of given strength and frequency. Through the successive changes of the field, all points facing one another on the sides of adjacent planes are magnetically equi-potential, and therefore mutually repellant, this lateral repulsion separating, compressing and flattening the planes. As the planes grow in height, the magnetic adhesion at their upper parts lessens, and hysteretic repulsion increases, till finally the tops of the planes are torn off and thrown forward by the moving field, the vertical repulsion supporting them in their horizontal flight.

In experimenting with filings it is well to remember that the "hysteretic constant" varies from 0.02 with very soft iron to about 0.16 with cast iron, and 0.25 with hardened cast steel, so the experimenter should be prepared for some irregularity in his results unless his "iron filings" are chosen with some care.

As an example of differences in the action of materials, mention may be made of the behaviour of some iron kindly sent me by Professor Truscott, from the Museum of the Royal School of Mines. It was labelled, "Iron separated from Blende, after calcination, by Magnetic Separator." It was black, in coarse grains and lumps up to about 3/8th inch in diameter, with slightly conchoidal surface. It was very violently
observe the time particles took to travel across a dish placed over a multiphase magnet.

Tests were made at 25, 50, 75, 150 and 350 periods per second, the excitation in amperes being constant.

From 25 to 75 periods the speed of the specular hematite increased approximately as the square of the frequency. It is perhaps allowable to assume that if still lower frequencies had been used the movement of the material would have stopped as zero was approached—it was very slow even at 25 periods—and that magnetic attraction would then assert itself almost unopposed by hysteretic repulsion.

But our object was to get greater repulsion, not less, so a higher frequency was tried. At 150 and at 350 periods there was no movement, or only a very feeble movement of a few particles (which were possibly iron)—that is, no repulsion and presumably little or no hysteresis—but at both 150 and 350 periods magnetic attraction was very evident, although at 75 periods and less there had been no sign of it.

It should be mentioned that in order to have the same exciting current throughout this series of tests it was necessary to use a low core induction—this was about 560 B.

The Note-book entry on the experiments at the two higher frequencies was as follows:

**Bessemer Laboratory.**

"At 350 ~ magnetite stood up over poles, there was a strong orientation, but no movement, except a little to the edges of the poles in either direction from the middle of a pole"—this is an effect well known with uni-directional magnetism, it is due to the greater density at the edges—

"With 1-phase the action was the same as with 2—orientation, but no movement."

"With black specular hematite a very slight movement of a few particles and orientation."

"At 150 ~ no practical difference from last experiment with either magnetite or hematite—the latter perhaps a little more movement."

Thus it appears that, in these oxides of iron, hysteretic repulsion in a multiphase field reaches a maximum somewhere between 75 and 150 periods per second—probably not far from 100 periods; that it is
practically nonexistent at 150 and at 350 periods, the materials then reasserting themselves as paramagnetics.

It will be understood that the cessation of any migratory movement is not strictly a proof that there is no hysteresis, but that it is so reduced as to be unable to overcome the force of attraction.

These experiments seem to support the view previously expressed as to the dual action in an alternating field. With hysteresis eliminated alternating magnetic attraction manifests itself alone, the particles even of so feebly magnetic a substance as specular haematite standing motionless over the poles, and oriented to them, and this, be it noted, either in a 1-phase or a 2-phase field—that is to say, there is no repulsion in a 1-phase field or migration in a multiphase field if there is no hysteresis.*

**Repulsion and Distance.** When the field of a multiphase magnet is weakened by reducing the excitation, or when the distance from the poles is increased, iron filings or magnetite, in a dish over the poles—subject to exceptions as already mentioned—become migratory, although in a stronger field they remain stationary, showing strong attraction. This is what might be expected from a consideration of uni-directional attraction, which decreases very rapidly with distance, and from the Steinmetz coefficient for hysteresis, 3.1-6.

But with specular haematite repulsion in a multiphase field always prevails—except at the higher frequencies—there is no laminar structure, no standing over the poles, the material moving slowly and steadily forward, much more slowly than magnetite.

As the action is simple, a test was made at 50 to find the effect of distance on the movement of specular haematite by observing the time taken by a certain amount of the material to travel across a dish supported at various distances above the poles of a multiphase magnet. The result was as follows:

Distance in inches: ½ to ¾ ... 2 seconds
  1¾ ... 2⅝
  1⅛ ... 3

* It is hardly necessary to point out that the question of minimum energy for a given result may be of more importance than the precise choice of frequency, and it should not be forgotten that the energy is approximately proportional to the square of the frequency.

Thus throughout a considerable distance above the poles the rate of travel was sensibly constant, and even beyond that region the decrease was not very great.

As it is difficult to believe that the induction was constant through the region of constant speed, some other explanation seems to be called for. It is perhaps possible that as the induction falls off it may be counterbalanced by an increase in what, for lack of a better term, may be called the meshing of the phases; it is not difficult to form a mental picture of such an effect.

The minimum distance of ¾th inch referred to above represents the thickness of the dish resting on the poles. Speaking from memory only, the result of reducing the distance to much less than ¼th inch by placing the material on a piece of note-paper resting on the poles was that the rate of travel was appreciably reduced. If this is correct it affords another point of difference between magnetic attraction and hysteretic repulsion, and is perhaps not inconsistent with the explanation suggested above.

The foregoing test throws some light on the behavior of the upper parts of the "planes of force" referred to elsewhere.

A brief reference may be made to a few general experiments:

If the dish is open on one side, the concentrate may be driven several inches beyond the magnet, as in Fig. 6; or it may be driven over the side or corner of the dish, as in Fig. 7.

If the dish is tilted at an incline of about 1 in 4, as in Fig. 8, and some specular haematite is placed at A, it will climb up several inches, and be maintained there till the excitation is switched off, when it will run back to A. This action through a considerable air space is significant.

**Wet Tests.**—With materials in water the effects are the same in kind as dry, but generally stronger—often much stronger—as is to be expected from the partial flotation of the particles and their greater mobility. Gravitational concentration is, of course reversed, as the heavier "value" acts as if lighter than the gangue. This is the case wet or dry.

For example, if in a slightly tilted dish, as in Fig. 9, we place a thin "pulp" or slime of specular haematite ore, over the magnet (M), the gangue gravitates to a and
the heavier haematite collects at b. Shaking or stirring in this, as in other cases, helps the action. The sensitiveness of very fine material to the action of the magnet is clearly shown. On closing the circuit this fine material is at once seen moving rapidly forward like a cloud of ink, even without any stirring or agitation.

**Figure 6.**

**Double-action Magnet.**—By winding or connecting a multiphase magnet suitably the phases may be reversed in direction from the middle to each side, as indicated by the lower arrows on M in Fig. 11. The result of this will be that the concentrate will then move from the middle to each side, as shown by the upper arrows, and the gangue will collect in the middle of the dish, especially if the latter is slightly concave.

**Rotating Test Tube Experiments.**—If a small quantity of a susceptible substance is placed in a test-tube, which is then filled with water or thin, clear oil, and rotated on its axis over a magnet (M), to ensure freedom of movement, as in Fig. 12, the concentrate will move along to one end of the tube, and if the tube be suitably inclined the gangue will pass to the lower end.

**Eddy Currents.**—On finding—as mentioned earlier in the paper—that aluminium powder or grains did not show any inclination to move, either wet or dry, in a flat dish, some of it was tried in a test-tube, as in Fig. 12. On slowly rotating the tube aluminium particles were made to fall in a continuous rain across the diameter of the tube. This rain was vertical, showing that there was no appreciable eddy current effect, and there was no change in the disposition of the particles—no sign of any gradual longitudinal movement.

No doubt with a very strong field there would be some movement, but the experiment shows that in a field easily capable of causing movement by hysteretic repulsion, however finely divided the material, there is no observable eddy current effect, and there was no change in the disposition of the particles—no sign of any gradual longitudinal movement.

**Water Flowing Up-hill.**—If a slime or fine pulp of suitable material is placed in a tilted dish open on one side, as in Fig. 10, filling it up to the line a, it will be found on energising the magnet (M) that the concentrate and some of the water will be driven up-hill somewhat, as shown by the line b, overflowing at c, the gangue gravitating to G.

As with Fig. 8, this action will take place with M horizontal; if M is tilted to the same slope as the dish the action will, of course, be stronger.

The upward flow is not due to any direct action on the water, but to surface tension between the water and the concentrate. It does not occur with the gangue and water only.

**Figure 7.**

**Figure 8.**

**2-Phase or 3-Phase?**—With the same excitation, in amperes per pole, of a multipolar magnet, the speed of the material was nearly 50 per cent. more with 2-phase than with 3-phase. Although rather surprising at first, this is what should be expected from the disposition of the magnetic circuit.
Practical Applications.—The results described provide material for the study of possible applications to practical ore dressing. We should begin this study by recognising that many very good magnetic separators are in successful use, and that it would be difficult to improve on them for the kinds of work for which they have been found suitable.

It will therefore be wise, for our present purpose, to confine ourselves to what we are told by the authorities is an unsolved problem—the magnetic concentration of finely divided, wet, feebly magnetic materials. Let us take such a mixture, slime or pulp, as before, of crushed specular hematite ore in water. Let it flow down a non-conducting launder or channel at such a speed that it will not settle or form banks. And let this launder rest on a long narrow multiphase magnet with longitudinal poles and windings—the arrangement in section, resembling that having the field of force moving in both directions from the middle—the “double-action” magnet indicated in Fig. 11, or better still, in Fig. 13. Then, as the pulp flows down the launder, the hematite will move to the sides in both directions—to right and to left—and if the field is strong enough, will be discharged over the sides with some of the water, or it may be assisted over the sides by small jets of water, the gangue gravitating to the middle being discharged at the end as tailings containing most of any phosphorus (apatite) that may be present. Or, the concentrates may be allowed to flow down the two sides of the launder, the middle of the stream as before being the tailings.

Another arrangement of magnet and launder is as indicated in Fig. 9—reading that figure as a sectional view of a long launder. The magnet and launder have a slight traverse inclination to allow the

![Fig 9.](image1)

![Fig 10.](image2)

![Fig 11.](image3)
gangue to gravitate to one side of the stream, while the concentrate, under the influence of the magnet migrates to the other side of the stream—thus the two materials will follow diagonal lines that cross one another—the stream arriving at the end of the launder with the concentrates on one side and the tailings on the other, the only moving thing being the stream itself.

For a number of launderers—to treat a large quantity of material—one wide magnet and launder would be used, the latter being divided longitudinally into a number of channels in order that the transverse migration in each channel shall not be more in distance than sufficient for the purposes of concentration, the small channels discharging their concentrates and tailings into appropriate receptacles.

![Fig 12.](image)

There should be no difficulty in constructing a magnet to withstand the conditions inseparable from wet treatment, or even to work in water, as the voltage could be limited by transformation and suitably insulated cables used.

**EXPERIMENTS AT THE ROYAL SCHOOL OF MINES.**—By the kindness of Professor Truscott, some tests were made in the Bessemer Laboratory with a very short magnet and launder arranged on the last-mentioned plan. The magnet was 3 ft. long and about 5 ins. wide. A wooden launder about 5 ft. long and about 11 ins. wide was used.

On the occasion of the first trial of this apparatus a pulp of a synthetic ore consisting of one part of specular haematite and three of quartz, crushed to 60 mesh, in water, was sent down the launder which was set at a slope of 1 in 20 with a traverse inclination of rather less than 1 in 20.

On sending the pulp down the launder without exciting the magnet the solid matter in the pulp followed the lower side of the stream almost entirely. But on exciting the magnet there was an immediate effect which was described as follows in the note made at the time.

"... at the upper end of the launder, before reaching the magnet, the haematite gravitated quickly to the lower side; on reaching the magnet it at once began to move transversely upward across the launder. At the lower end beyond the magnet it swerved downwards at once."

This action is illustrated in plan by Fig. 14. The portion of the launder b to c 3 ft. long, was over the magnet—the upper and lower portions, a to b and c to d, each 1 ft. long, extended beyond the magnet—there was a slight traverse downward slope from e to f and the launder as a whole sloped from a to d, as explained above.

With the black haematite and the white quartz the movements of the materials were clearly seen.

Between b and c one side or edge of the stream became black with haematite, while the other side was nearly white with the quartz powder.

The dotted lines indicate approximately the flow of the haematite as described above.

The result justified the experiment, if only because it showed the transverse migration of the concentrate towards one side of the stream without any other agitation or assistance than that provided by the flow of the pulp itself.

Many experiments were made with this apparatus. Although it served its main object, it was too short to enable any reliable tests to be made. With a slow stream the concentrate often formed banks or deposits which tended to imprison streaks of gangue and to deflect the stream, while with a stream quick enough to entirely prevent banking, the traverse movements of the materials were not sufficient in the short distance to give an appreciable concentration. Attempts were made, by passing the products several times down the launder, to improve the concentration, and this was effected, but...
there was difficulty in collecting the products and no reliable results were obtained.

These tests on the whole supported the view that with a launder of reasonable length, and with certain modifications—mostly the outcome of these tests—satisfactory practical results might be looked for.

This magnet was designed for a core induction of about 3,600 B, which was occasionally considerably exceeded with marked improvement in the effect. Quantitative tests were of necessity postponed, but it was realised that for refractory materials like specular haematite a higher induction was desirable, and that in practice it would not increase the cost very much as it would enable a shorter launder and magnet to be used for a given effect.

For magnetite a much lower induction would suffice—certainly under 1,000 B.

The model at the Royal School of Mines was, unfortunately, so made that the side discharge of concentrates referred to above could not be applied. The arrangement was a 5-pole magnet with a balanced two-phase winding, consisting of two coils only—a useful and simple arrangement, but open to the objection mentioned. The magnet did not comply with the condition previously mentioned as necessary for that purpose that there should be a winding outside of the side teeth or poles.

The side discharge is, however, easily demonstrated otherwise.

**Variations in Susceptibility.**—The launder experiments confirmed the Dish tests in showing considerable differences in the susceptibility of different parts of the same ores to concentration by this method. Most of the “value” migrates freely and quickly, but there is generally a residue that only moves slowly and unwillingly, and no doubt some that does not respond at all to a field amply powerful for the bulk of the material. This residue requires a stronger excitation.

**Probable the cleanest and most complete concentrate would be obtained by graduating the strength of the magnet—either in one passage or successive passages—beginning with a weak magnet—or a low excitation—and ending with a strong one. With a magnet of uniform strength throughout, a certain amount of gangue would be entrained and carried over with the more susceptible part of the concentrate at the upper end. Even with so short a magnet as three feet, there was often a very considerable concentration within half that length.

It should be mentioned that the less susceptible residue of specular haematite is usually slightly brown in colour, no doubt due to the crystalline formation having to some extent broken down.

**As an example of a Dish test, the table on page 228 is an assay of wet and dry results for which thanks are due to Mr. F. W. Harbord, of some Dunderland Specular Haematite ore from which it was stated some magnetite had been previously removed by a permanent magnet.**

Later experiments showed that if a stronger field had been used, the recovery of iron would have been greater.

**Apparent Change of Weight.**—In considering possible practical applications emphasis may be placed on a phenomenon which has been mentioned more than once—the effect of vertical hysteretic repulsion in appearing to modify gravitational conditions. For example, although the specific gravity of specular haematite and of magnetite is nearly twice as great as that of quartz, over a multiphase magnet these iron oxides act as if they were much lighter than quartz.

Or take another mineral, tinstone containing Wolframite. There is so little difference in the specific gravity of cassiterite and Wolframite that ordinary gravitational separation is difficult or impracticable. But a multiphase magnet, in addition to causing a transverse migration of the Wolframite...
DUnderland ORE.

<table>
<thead>
<tr>
<th>80 Mesh Ore as Received.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet. Dry. Magnetite Removed.</td>
</tr>
<tr>
<td>Iron content of Crude Ore ...</td>
</tr>
<tr>
<td>Phosphorus ...</td>
</tr>
<tr>
<td>Iron content of Concentrate ...</td>
</tr>
<tr>
<td>Phosphorus ...</td>
</tr>
<tr>
<td>Recovery of Iron ...</td>
</tr>
<tr>
<td>Yield of Concentrate ...</td>
</tr>
<tr>
<td>=} 1 ton of Concentrate ...</td>
</tr>
</tbody>
</table>

Some early dish tests were made with chalcopyrite from various sources—e.g., a sample described as average Cordoba ore, lightly roasted, gave the following results, wet:
Migrated ... 48% containing 6.3% Cu.
Did not move ... 52% ... 1.14%
Recovery of Cu ... 83.7%.

This result is also probably due to the iron present—in this case oxidised by roasting.

A few negative results may be mentioned, especially as some of them refer to materials that are successfully treated by unidirectional magnetic separators.

Red haematite—the purest found in Cumberland—no response dry—wet, the reddest particles migrated—a small proportion of the whole. Red haematite from Lancashire—no response wet or dry.

Monazite sand—ilmenite impurity, no response; Ilmenite, no response; Franklinito, no response.

From memory it is thought the last three were separated products from an Ulrich separator.

It has only been possible to touch the fringe of this subject.

Some of the substances which do not respond to weak fields may respond to stronger fields and the use of small air-gaps, but limits are likely to be imposed by hysteresis in the apparatus itself. With unidirectional magnets very intense fields are often used—20,000 to 25,000 B in the core and not much less in the air-gap. With alternating magnetism such high densities are probably impracticable,

makes it in effect much the lighter of the two and renders "gravitational separation" easy.

SUNDAY—Tests.—In these experiments, specular haematite was generally used for reasons already sufficiently indicated, but other substances were tried mostly in a tentative way, some with promise of useful results, others with no effect.

At an early stage in the experiments a good many tests were made on the separation of Wolframite from cassiterite in certain tin ores, as already mentioned. Wolframite behaves very much like specular haematite—in fact, all the qualitative tests made with the latter may equally well be made with the former, the Wolframite separating freely from the cassiterite and gangue—but the concentration was not as good as with specular haematite, possibly in part because no amount of crushing will sufficiently separate the components mechanically, and possibly in part because the concentration does not seem to be due to any action on the Wolframite, as such, but to iron associated with it. This is illustrated by the following test of the "Final Wolfram product" from a unidirectional magnetic separator at a Cornish tin mine. On submitting this product, dry, to a multiphase field of about 2,000 B, it separated into two portions as follows:

| % WO₃ Sn Fe | Migrated ... 10.8 7.25 11.4 48.15 | Did not move ... 83.2 71.25 1.75 12.8 |

It was found by another test that neither pure Wolfram crystals nor pure Cassiterite made any response to a multiphase field of the above strength.
although no doubt inductions of 8,000 or 10,000 B could be reached without much difficulty—if it should be worth while.

But as these alternating methods with low inductions and open fields can, with certain materials, give effects which cannot be got even with the highest unidirectional fields, there may be a prospect of useful results in that direction.

The author wishes to express his thanks to Mr. Lancelet Wilde and Mr. Roland Wilde for valuable laboratory facilities and help, to Prof. Truscott and the Royal School of Mines for permission to work in the Bessema Laboratory, to Prof. Mather, F.R.S., for a supply of electrical energy from the adjoining laboratory of the Central Institution, to Mr. R. Holman, O.B.E., of the R.S.M. for help in the experimental work, and to Sir Thomas Rose and Mr. F. W. Harbord for their interest and encouragement.

The President: Well, Gentlemen, on your behalf I would like to thank Mr. Mordey most heartily for his interesting paper. I know, as far as I am concerned, and I have been mixed up myself a little bit with the separation of minerals, I came here with my mind practically fixed on separation by direct current, because one of the best authorities, one of the highest in the world, has stated that separation cannot be effected by alternate current. It has opened new ideas to me. One can see possibilities. I think we owe a deep debt of gratitude to Mr. Mordey for helping us and showing us possible methods whereby new metallurgical processes will be available, and certain reduced working costs will result. It is a difficult thing to discuss this paper right off, because, as Mr. Mordey pointed out, some of the points mentioned are in the experimental stage; but I know you will all agree with me that it opens up a very wide field, and I think we ought to be deeply grateful to Mr. Mordey for his paper this evening. On your behalf, Gentlemen, I would like to propose a very hearty vote of thanks to Mr. Mordey for his most valuable and interesting paper. (Loud applause.)

Mr. J. W. Kirkland (Past President): I would like to second the vote of thanks, Sir, that you have proposed. I think we have listened to a most delightful and inspiring paper from Mr. Mordey. The suggestions that he made, and the experiments he has performed, show a line by which larger trials may be made possible, to the great advantage of the separation of such ores as we have here. I have particular pleasure in seconding this vote of thanks, because I think I may claim, with pleasure, that mine is one of the oldest acquaintances with Mr. Mordey of anybody in this room. It dates back to 1890, when Mr. Mordey went as a very young and successful engineer to America, to see the Thomson-Houston Company. At that time I was a young fellow there. Mr. Mordey came over and was acclaimed as one of the leading electrical engineers in England. I have very great pleasure in seconding your vote of thanks. (Loud applause.)

The President: Gentlemen, the paper is now open for discussion. I hope some of our metallurgical friends will come forward.

Mr. F. Wartenweiler (Visitor): Mr. President and Gentlemen, your President has kindly asked me to be present to-night, as he expected a very interesting paper to be read, which would have a direct bearing on metallurgy, and, as a metallurgist, I am pleased to state that I have been fascinated by the exposition of the line of research shown to-night by Mr. Mordey. I have had a certain amount of experience, but not very much, with magnetic separation, principally with the precious metals. I am not quite clear, from Mr. Mordey's address, whether he has been successful in separating pyritic material, such as, for instance, the simple iron pyrite. If he has, I dare say that his research and his invention may prove of great value on these fields. We have at present a method well known for separating pyrites cleanly from the banket ore—the flotation method. I might preface this remark, though, by saying it has been fairly well established that a very large proportion of the precious value in our banket ore is contained or associated with iron pyrites. Therefore a separation of the iron pyrites and of the metallic gold from the gangue would be a practical and, let us hope, a commercial process. The method I have mentioned—the flotation method—deals with the wet pulp, but it requires considerable mechanical contrivance and auxiliary apparatus. If by means of the alternate currents, such as Mr. Mordey has shown, he can separate the pyrite in the banket ore by such simple methods as are indicated by him to-night, he may help us to solve the treatment of our low-grade ores; I think we are all fully aware of the significance of that. I have great pleasure in
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Mr. Bernard Price (Past President): While I note with regret that Mr. Mordey's invention does not require any large amount of power, I desire to add my thanks to him for a charming address upon a most fascinating piece of research. We all hope, I am sure, that his discoveries will prove of high commercial value, and, speaking as one who cannot claim any expert knowledge on metallurgical questions, the process would seem to justify such a hope. What pleased me most, however, was the way in which Mr. Mordey developed his investigation stage by stage. Surely this piece of work is an excellent example of how research should be carried out, and it might well serve as an object-lesson to our younger members.

I was disappointed that Mr. Mordey did not deal more fully with the theoretical side of the problem. It is not altogether clear to me why the presence of hysteresis should cause the desired movement of the particles of ore. There seems no doubt that the phenomena is the result of two opposing forces, either of which might preponderate, but there may be members present who, like myself, lack a clear physical concept of the manner in which these forces are produced. We should therefore appreciate very much a more detailed explanation of the elementary principles which underlie the phenomena if Mr. Mordey would be so kind as to enlighten us. (Applause.)

Professor W. Buchanan (Past President): I just take this opportunity of thanking Mr. Mordey for coming here this evening and giving us such a very interesting and instructive address. I have to confess that the subject is one of which I am very ignorant, and feel the paper wants careful study before attempting any criticism or discussion upon it; but while the author is with us I would ask him to make clear one point which appears to be at variance with preconceived opinions. We who have been mainly interested in electrical machinery have always understood that the value of the hysteresis was directly proportional to the frequency and to about the 1.6 power of the magnetic induction, so it appears strange to find experiments indicating a variation as the square of the frequency. Of course the induction density will be affected by frequency, unless the applied voltage is altered to keep it constant, and any electrical conductivity of the particles reduces the amount of alternating magnetic flux which can pass through such particle; this would be very marked in the case of aluminium filings, particularly at high frequencies. We have to bear in mind that no alternating magnetism can pass through a perfect electrical conductor. In conclusion, I must say that it has given me much pleasure listening to this address, which takes our thoughts away from ordinary business problems back to a study of forgotten first principles.

The President: Does any other member wish to discuss the paper? Well, Gentlemen, I feel like voicing the opinion of the last speaker. The paper is very original, and is difficult to discuss. To me it seems to open out quite new ideas. As you know, we have "magnetic separation" by direct current; we will call this A. We have "static separation," where the energy is generated by static machines, and also by means of special generators used in combination with other apparatus; we will call this method B. We also have another method, which we will call C, whereby mineral separation is effected by means of electrodes insulated or otherwise from the pulp, and a field is set up upon the application of direct current; the said field causes divergent stream flow and certain separation results are possible. Again the introduction of certain solutions containing iron have the effect that in some cases certain minerals so treated are sooner susceptible to magnetic treatment than others, and separation is possible. Other methods are also possible, all in each case being subject to electrical laws. And when you think that now another method has been placed before you, you can see how immensely it increases the field of electrical separation as regards ore concentration. With one or other of the methods stated used singly or in combination our knowledge of the art is wonderfully increased.

One method of separation may take you so far, and then it may be that the suggestions put forward by Mr. Mordey this evening solve certain problems just at the point past which further progress had been found impossible.

The meeting then terminated.
WIRELESS SECTION.

The third meeting of this Section was held on Thursday, 1st December, at 8 p.m.

Mr. S. C. Pleass (Telegraph Associate) was in the chair.

Mr. L. C. Watkins (Student) read his paper on “Transmitting Apparatus,” dealing with the efficiency of suitable Spark Gaps, and Make and Breaks, which was followed by an interesting discussion. Members giving their experiences with their sets, the Quenched Gap, The Fixed Electrode, and the Rotary Gap, having all been tried with good results.

A vote of thanks was passed to Mr. Watkins for his interesting paper.

Mr. D. W. Pugh who was present, kindly promised a paper on “Facts on Astronomy,” dealing mainly with the Solar System. Mr. Pugh also made an interesting contribute relating to Meteorites and Sunspots, for which the thanks of the meeting were tendered to him.

The usual Round Table talk followed, starting with the Wireless Transmission of Speech from Braamfontein to Pretoria. Several members had heard this distinctly with their sets. The gramophone music transmitted was also heard. This caused some enthusiasm being the first experience members had had of picking up speech.

The meeting terminated at 9.50 p.m.

TELEGRAPH AND TELEPHONE SECTION.

The Annual General Meeting of the Section, which had been called for Thursday, 8th December, was adjourned till the 12th January.

STUDENTS’ SECTION.

The December meeting was held on the 19th, when Mr. Opperman read his paper on “Rectifiers.” This paper will again be read in January at the General Meeting, at which the retiring chairman will deliver an address.

The Committee are awarding no prize for discussion this year, as the terms of the award are that it be given for the best contributions to discussions by Student members outside of the Committee—there was not any.

NOTES ON ALUMINIUM.

Ever since aluminium was produced in a commercial form, the greatest interest has been taken in its application to various engineering structures where lightness with strength is desirable. It was soon found that when aluminium was alloyed with other metals its strength was greatly increased without any great change in weight. Various alloys of aluminium have been used in the structure of airships and aeroplanes, and the results have been so promising that a special Committee was formed in Great Britain to undertake systematic research of the properties of aluminium alloys. A report recently issued by this committee embodies the results of seven years of research conducted in the National Physical Laboratory, which is subsidised by the British Government. This research has resulted in the discovery of many alloys which are of great promise for practically all kinds of engineering, particularly motor-car manufacture, railway rolling stock, internal combustion engines, and steam engineering. The only problem awaiting solution is the production of these alloys on a commercial scale. Already a beginning has been made in this direction by a British Government factory; and British manufacturers are looking closely into the possibility of producing some of these wonderful substances for regular use in place of steel.

ELECTRIC RAILWAY PROPOSALS IN GREAT BRITAIN.

Remarkable activity is being shown by British railways in connection with the conversion of lines, especially in the neighbourhood of London, from steam to electric traction. The Great Eastern Railway
The number of types of oil fuel burner is legion, and the engineer who has to choose among them often finds it extremely difficult to decide among so many closely competing claims. It is interesting therefore to come across a new type which is radically different in its design from all the others. The purpose of an oil burner is to reduce the oil to a fine spray and to mix that spray so thoroughly with air that the oil will be completely burned. As a rule the oil is forced through fine orifices or some other fixed contrivance to "atomise" the oil. In the new form a rotating cone is employed. This cone is fitted at the end of the oil pipe and is rotated at a high speed by means of a small fan operated by the system of air in which the oil is ultimately burned. The oil, in emerging from the pipe, trickles down to the inner surface of the spinning cone and spreads out under centrifugal action into a thin film, which travels forward to the outer edge of the cone. This edge is finely serrated and breaks up the oil film into an extraordinarily fine spray, which is carried into the furnace by the stream of air already mentioned. By a simple adjustment, the form of the flame can be altered to suit any purpose, so that the burner can be employed for ordinary boiler work or for forges and special furnaces, in addition to domestic and central heating. This burner has been fully tested under working conditions, and has proved most satisfactory and economical in every way.