A Method of Studying the Motion of the Diaphragm of a Telephone Receiver.

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That, in a magneto telephone receiver the sound wave is mechanically reproduced by the transverse vibration of the diaphragm, is now virtually established. Some experimenters still dissent from this view; but later work including the very elaborate researches of M. Mercadier (Journal de Physique 1887) does not appear to confirm their position.

Many measurements of the amplitude of vibration of the diaphragm, have been taken, but few observers have attempted to study the form of the motion, or its relation to the sound emitted.

When we began the investigation of which this is a record, we were entirely unacquainted with the work of Frölich upon this subject, (La Lumière Electrique July 23, 1887, vol 25) and our method was developed independantly.

The difficulties of this subject lie in the exceeding smallness of the excursion of a telephone disc, and the consequently, extreme delicacy required in the apparatus and methods used.

As a preliminary to further work we first attempted to study the motion of the disc, by the method of sand figures. Three telephones were used; an ordinary Bell hand receiver; a similar instrument in which the permanent magnet was replaced by an electro-magnet; (the same instrument which we afterwards used with a capsule); a large two pole telephone with a permanent horse shoe magnet and a ferrotype disc about 3 inches in diameter clamped between two brass plates. The telephones were excited by an organ pipe, through a loud speaking transmitter, using a current of about 0.75 ampère in the primary circuit.

With all of the telephones above mentioned, the action was practically the same, save that in the double pole receiver, which is a more powerfull instrument, the action was more marked, than with the others.

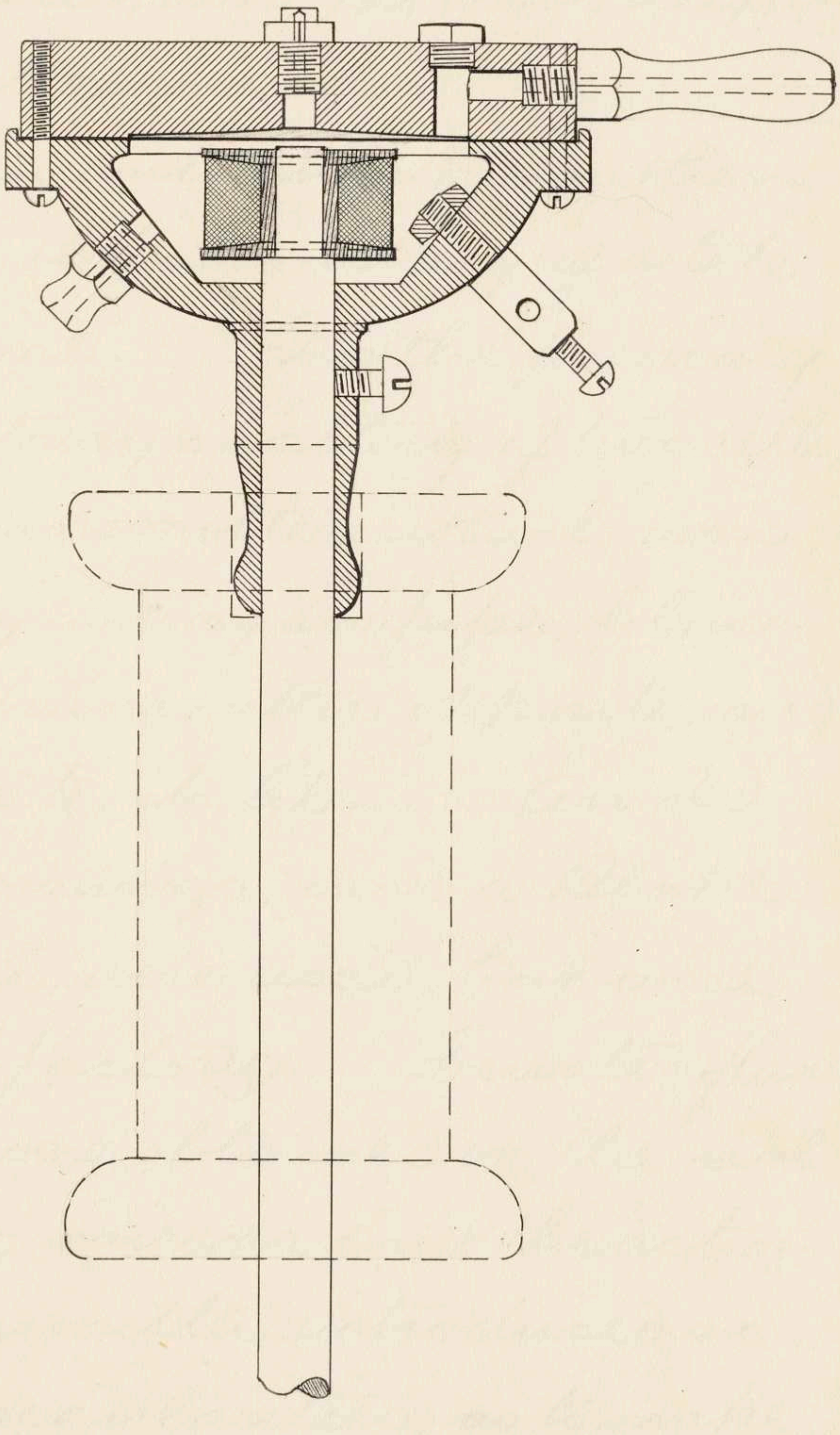
Sprinkling sand on the disc, it was strongly agitated, and very slowly drifted toward the edges. No other effect could be seen. Lycopodium, on the other hand, behaved very differently. The powder gathered in little heaps which were internaly in violent commotion, but which remained equally well on any portion of the disc as long as it was approximately level. Nothing was seen to indicate the presence of nodal points or lines.

We now turned our entire attention to the use of a manometric capsule, suggested by Prof. Cross.

A capsule of hard rubber was made, of the form used by König, having a diaphragm of ferrotype iron, below which were placed a magnet and coil, similar to those used in a telephone receiver. (See Fig 1.) The core of the magnet was continued downward for about eight (8) inches and a magnetizing coil excited by two Dolbear cells in series, was placed upon it.

To gain some idea of the results obtainable with such a capsule, it was put in secondary with the 110 volt alternating circuit, several lamps in series, forming a variable resistance with the primary of the induction coil. As it was not sensitive enough, a new top was made, in which the capacity of the space above the diaphragm was much

FIG. 1.



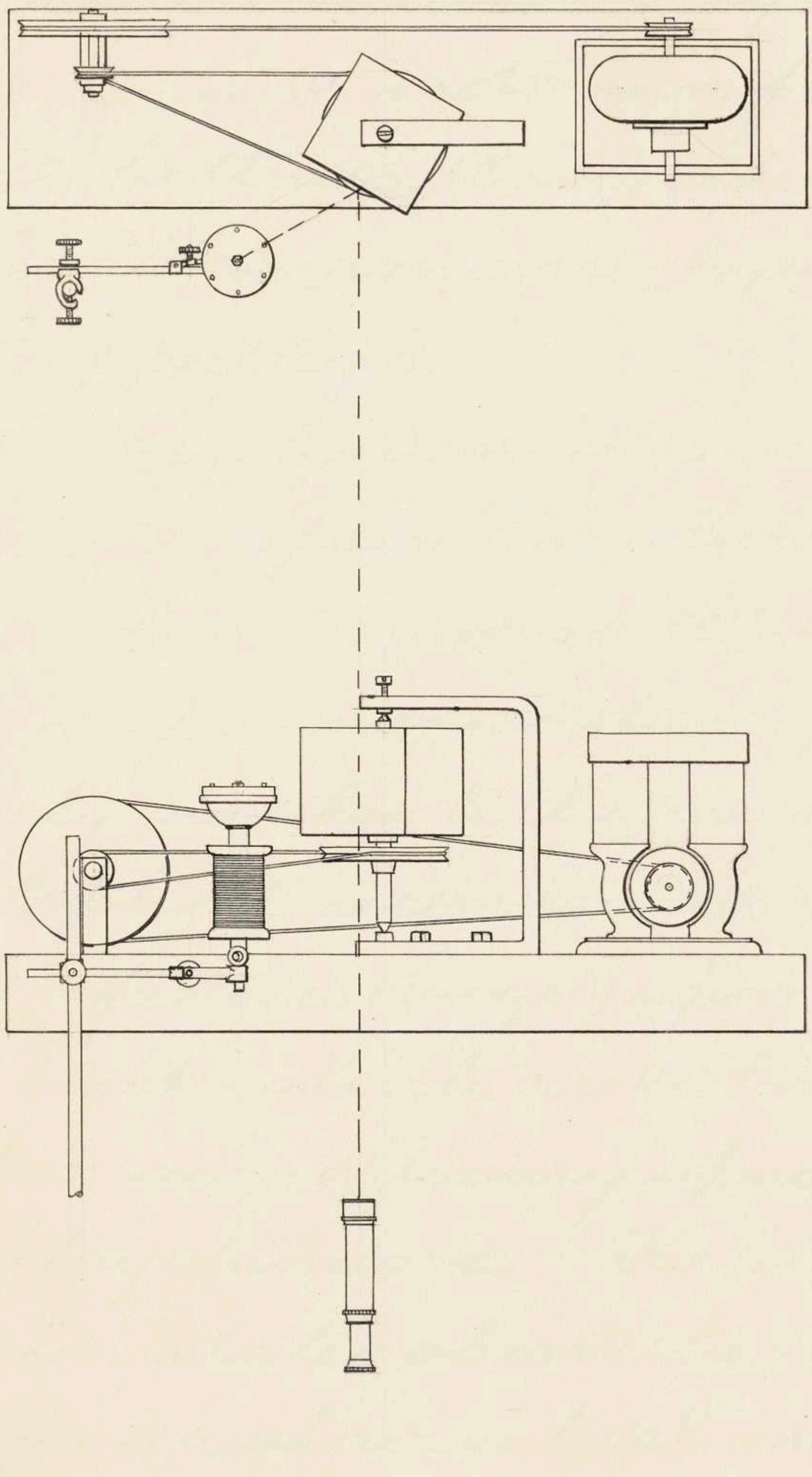
reduced. The chamber was now conical in form, 1.75 inches in diameter, and 1/32 inch deep in the middle.

This instrument was then placed in the secondary of a telephone line. In the primary were a storage battery of two cells, and a transmitter which was excited by an organ pipe, blown with the transmitter opposite, and very near ~~to~~, its lip. An old style Hunnings, and a Blake transmitter, were used, but were not satisfactory. Serrated flame bands were obtained in the ~~revol~~ revolving mirrors, but the action of the transmitter introduced so many irregularities, as to make them of quite uncertain form.

Later, two American long distance transmitters were placed at our disposal, and with these we got much better results.

Up to this time we had been using the four sided Hörnig mirror, of the laboratory, but it now became necessary to have one which could be revolved at a uniform rate, and apparatus was set up as in the accompanying sketch. As mirrors are required which reflect from the front surface only, and as such mirrors are not to be found in the market, we were obliged to make them.

For this purpose we used 4" x 5" photographic glass, which we coated with silver. (See process at end of thesis). They were then fastened by brass clamps upon a



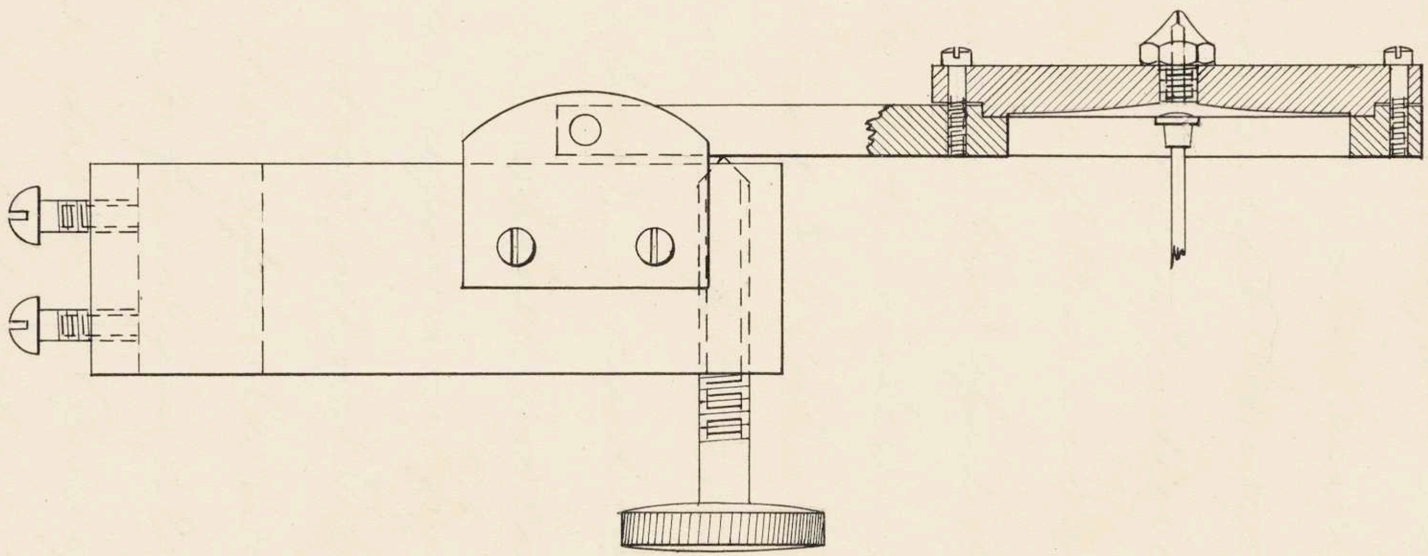
block of maple, carefully squared, and mounted on a vertical shaft.

The whole was revolved by a small C. and C. motor, run from storage batteries, the speed being reduced at convenience, by a system of pulleys.

We then had made, a modified Wheatstone explorer, in which the explorer disc, was made the diaphragm of a manometric capsule, precisely similar to the one on the telephone receiver. (Fig. 2)

It was fastened (hinged) upon a brass block which could be clamped on an ordinary upright laboratory standard. The block could be rotated about the standard, and a slow vertical motion was given to the capsule, by a

FIG. 2.



screw. (Fig. 2). The explorer rod was of light wood, sharpened at the lower end. We also used a rod of aluminium, but the wood seemed to maintain a steadier contact. The burners of this and all our other capsules had apertures about 0.01 inch in diameter.

The telephone to be studied and the explorer, were placed upon the same standard, in such a manner that the explorer rod could be made to rest upon any part of the telephone disc, at will. The weight of the capsule was trusted to keep it firmly in place on the telephone disc. An organ pipe was sounded before the transmitter, and the resulting flame band, was carefully noted.

This was in turn compared with the band obtained from the telephone capsule, using the same means of excitation, and with that given by the same capsule, when the pipe was blown into it directly.

The same telephones were used as in the method of sand figures. A number of organ pipes, in the second and third octaves, were blown, singly and in pairs. Closed pipes were preferred to open pipes on account of the clearer tone produced, as the presence of beats caused a progressive change in the flame band, rendering it difficult to note. When two pipes were used it was necessary to tune them to unison, and no more than two were used at once, as we could not bring the lips of any greater number, near enough to the transmitter. It was, in general, found easier to overblow a single pipe to bring out the first two harmonics strongly. The power blast running through a drip-bottle furnished a sufficiently steady source of wind.

The principal difficulties encountered were as follows.

I. We were obliged to observe the flame bands from different capsules, and different parts of the same telephone disc, in succession, rendering comparison, somewhat uncertain. This could be avoided by duplication of apparatus, which we had not time to make. In later work we however used two sim-

-ilar explorers at the same time.

II. The different degrees of damping in the various diaphragms, introduced some changes in the flame forms. The discs in the capsules, are quite effectually damped by the gas in the very small chamber above, while those of the open telephones, must be damped in some other manner. This was most easily done with the fingers, when possible. If care is taken not to jar the apparatus, the delicacy of the sense of touch, renders this a very good method.

III. The jar of the motor used to run the mirrors produced a regular rise and fall of flame, of short enough period, to distort the results obtained from the capsules. This was avoided by supporting the capsule and telephone on a separate and very heavy standard, resting on the floor. Any unusual jar in the building, however, would cause a very irregular motion.

IV. With the first explorer capsule used, the brass top conducted heat away from the flame so rapidly that water was condensed on the burner, causing the flame to flicker, and sometimes to go out altogether. In the other capsules, the tops were of vulcanite, and this difficulty was obviated.

V. The draft produced by the revolving mirrors, made the flame unsteady. This was easily remedied by setting the capsule at a greater distance, or by interposing a screen, pierced with a small hole.

The flame bands obtained by all three methods were virtually the same in appearance. Some minor differences exist, which may be stated as follows.

I. The band of the explorer capsule did not contain certain very small points which could be seen when the pipe was blown directly into a capsule. This might be due to unsteadiness at the point of contact of the explorer rod and telephone or to the loading of the telephone disc, by the weight of the explorer, or to both effects combined.

II. Some points appeared in the band of the telephone capsule used as a receiver, which were not visible when the pipe was blown into it directly. We have attributed this difference to the action of the telephone instruments.

A considerable amount of noise was always present in the tone from the receiver, which tone also differed somewhat in quality, from that given by the pipe. There was less noise, when the receiver diaphragm was heavily damped, but its sensitiveness was at the same time much diminished, so we tried to keep the damping as near uniform as possible.

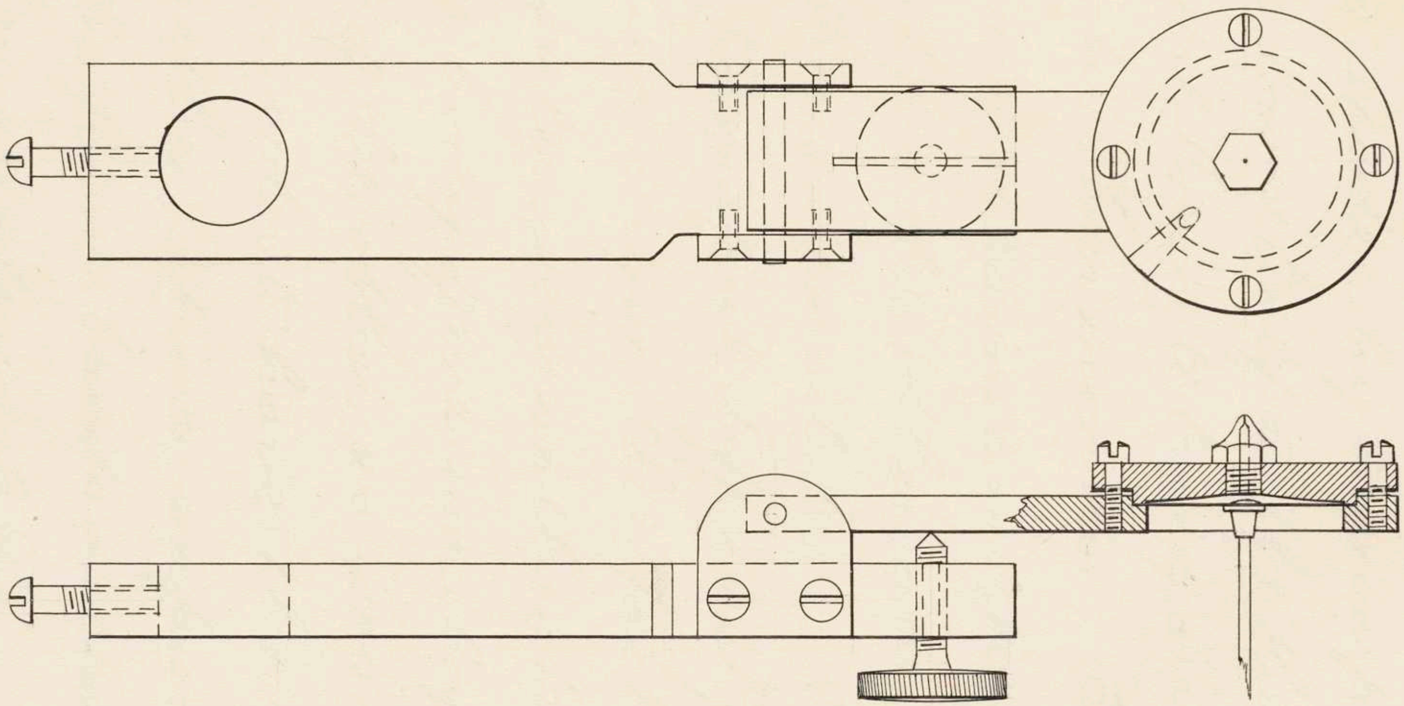
Analyses of both tones would of course determine this point.

Still all these differences were small and did not alter the character of the flames.

As far as could be seen the flame bands from different parts of the same disc were alike in form, but much trouble was caused by the different degrees of damping introduced, when the explorer rested on different portions of the disc.

In order to study the above more carefully, two smaller explorers were made, of such size that both could be used at once, on a telephone (See Fig. 3.) They were of the same form as the preceding one, and as nearly alike as possible. The diaphragms were of card-board (post card), as ferrotype iron

FIG. 3.



was found too stiff in such small discs. The same telephones were used, excited by organ pipes from the lower half of the third octave, overblown to bring out the first two harmonics. Two bands were obtained on the mirror, one above the other, and as near together as possible.

The principal difficulty in this method, lay in the fact, that the capsules were so thick that when the body of one was lapped over that of the other, as was necessary in order to have the rods near together, it was impossible to bring the flame bands as close to each other, as desirable.

A number of observations were taken in the above manner, and the results seemed to confirm those already found.

I. All portions of the disc give the same form of flame with the explorer, and from this we may infer that all points pass through the same cycle of motions. When, however, the explorer rests upon the middle of the telephone disc, the flame due to the fundamental of the tone transmitted predominates strongly, while near the edges the inequality is less marked. We are not, however, sure that this difference exists normally in the motion of the disc, for when the weight of the explorer is supported at its middle, it is most strongly damped (the telephone). A grad-

-ually increasing pressure will cause the flame points due to the partials to grow smaller, and disappear, apparantly more rapidly than the fundamental.

Local actions of this sort due to the weight of the two explorers might produce the difference noted. It is however, in this method, impossible to avoid loading the disc in some manner, and we made the pressure by the explorer rod, always the same, i.e. that due to the weight of the capsule.

II. The motion of the disc was always greatest in the middle, decreasing toward the edges, which were not quite at rest, as some motion seemed to be imparted to the clamping ring.

III. No appearance of nodes could be seen,

Now a disc may be conceived to vibrate in two different ways, each of which will fulfill the above conditions.

I. The disc may vibrate as a whole for each and every tone transmitted to it, posessing all these motions in every part, at the same time.

II. Each tone may be represented in the disc, by a circular wave traveling from centre to circumference, all waves with the same or nearly the same velocity.

In either case, every point in the diaphragm would pass through the same cycle of mo-

tions. Under the first supposition all points would be at the same phase at the same time.
Under the second there must be some two points, which would not be in the same phase, at a given time.

We proposed to study this in the following manner. The reflections in the mirror of the flames of two explorer capsules, are brought one vertically over the other. The adjustment of the explorers being quite independant, any two points of the telephone may be studied at once. The capsules and their flames should be as nearly alike as possible. If now a telescope with a vertical cross hair, be focussed upon the images, in such a manner, that the two flames are in line with the hair, and the mirrors are revolved, the cross hair will always mark simultaneous positions of the two flames.

Certain difficulties were met.

I. Any eccentricity of the mirrors with regard to the axis of revolution, will cause motions of the flame bands, rendering it difficult to compare them.

II. The flames must be screened, as any though very slight unequal blowing will produce an apparant difference in phase.

At this point we found that the block, carrying our rotating mirrors, had become so warped as to produce a considerable motion of the images. The silver mirrors were also badly tarnished. As there was not time to remedy these defects, we went on to take what observations we could.

No difference in phase between the two flame bands was found, though we were able to do but little work in this direction.

It then seems probable that in telephone receiving instruments of the types which we have examined, the diaphragm vibrates transversely, as a whole, for each and every tone which it emitts.

A much better method than the preceding, would be to photograph the flames directly upon a moving plate, or film, carried at a uniform rate, past an aperture, provided with a lens. A film wrapped about a vertical revolving cylinder, with apparatus to close the aperture automatically when it had been exposed for one revolution, might be used.

We believe the explorer capsule capable of other uses in this study. In any capsule, other conditions remaining the same, the difference in height between the maximum and minimum points of the flame, depends upon the amount of the excursion of the disc, and upon its period of vibration. If by any suitable means, as the action of an unequal armed lever, worked by a positive motion cam there could be given to the disc a vibra-

-tory motion of known amplitude and period, such a capsule might be calibrated, in terms of the flame measurements. In this way it could be used to measure the excursion of the disc of a telephone, and also by measuring the excursion at various points of the disc, to determine the manner in which the motion falls off, from the centre to the edges. Also to map the form which the disc assumes at the limits of its vibration.

Such a method would require,

I. Great rigidity in the frame and supports of the capsule.

II. Freedom from draughts and jars

III Some means of regulating

the flame to the same height at all times, as the sensitiveness varies at different heights.

The precision which might be attained, cannot be determined in advance. Should it become very considerable, it would probably be necessary to use some more constant source of excitation than an organ pipe blown by the power blast. This however we do not anticipate, as the upper portion of a gas flame, is not bounded by a very distinct line, so whether the flame were photographed, or measured by a spider line micrometer, it would be difficult or impossible to state its true height.

While the results which we have attained, in this study, are in no way commensurate with our expectations, we trust that we have put the matter in such form that some of the students who shall follow us may be able to take up the work where we have left it, and carry it to a definite end.

Directions for Silvering Mirrors.

Brashear's Formula

From Mr. Gerrish of the Harvard Observatory.

I. Reducing Solution

Dissolve 1/4 grain of Rochelle salts in 5 pints of water (distilled). Add slowly 1/4 oz. nitrate of silver and boil for 3 minutes. Filter through an ignited asbestos filter, and let stand for 12 hours, before using.

II. Silvering Solution

Disolve 1 oz of nitrate of silver in six (6) pints of water. Take out one quarter of this, and into the remainder, drop concentrated ammonia stirring, till the precipitate just clears. Then add the one quarter which was reserved, stirring slowly. Let stand for 12 hours, and filter through an ignited asbestos filter.

To silver, use equal quantities of the two solutions.

The utmost cleanliness must be observed, and all apparatus must be washed with dilute nitric acid, caustic potash, and distilled water. The plate to be silvered should be kept in a dish of distilled water till wanted, then quickly transferred to the solutions.

We obtained the best results by allowing the silver to deposit upward for about ten minutes, using about 200 c.c. of the mixed solutions to 20 sq. in. of glass surface. The coating thus deposited is not quite opaque, but is smooth and bright, requiring no further polishing. If the plate is allowed to remain too long in the solution, the silver deposit becomes milky in streaks.

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