united by suture to the coracoid. The inter-clavicle had the slender T-shaped form of the bone in *Ichthyosaurus*.

*Procolophon* has teeth on the vomera and pterygoid bones, and the structure of the palate and the post-orbital region show that the Procolophonia forms a distinct division of the Anomodontia. Observations are made on the relations of the European and South African Anomodonts, and on the relation of the Anomodontia to the Pelycosauria and to Cotylosauria. Comparison is made with *Placodus*, which genus has two exoccipital condyles, comparable to those of mammals, and appears to have lost the basi-occipital condyle. Comparisons are made with other extinct reptilia to show the relation of the Anomodonts to the Saurischia, and other reptilian types. Observations are offered on the theory of the Anomodont skull, and on the effect of the articulation of the lower jaw with the squamosal in causing a diminished growth of the malleus and quadrate, converting them into the malleus and tympanic.

The larger groups included in the Anomodont alliance are regarded as the Pareiasauria and Procolophonia; Dicynodontia, Gennetotheria, and Pelycosauria; the Theriodontia, Cotylosauria, and Placodontia are regarded as coming under the same sub-class, which at one end of the series exhibits characters which link reptiles with amphibians, and at the other end of the series link reptiles with mammals.

## XII. "A new Form of Eudiometer." By WILLIAM MARCET, M.D., F.R.S. Received June 20, 1888.

[PLATE 14.]

The quantitative determination of oxygen, simple as it appears at first sight, is found in practice beset with many difficulties. Liebig's method with pyrogallic acid and potassium hydrate, though considered as yielding correct results, takes too much time, and is unsatisfactory in some respects, so that the eudiometer has become of general use for the estimation of oxygen. I shall not attempt to describe the various forms of eudiometer, but it may be assumed that Regnault, so well known for the care he bestowed on his investigations, had adopted a very correct kind of eudiometer in the researches he undertook with Reiset on the chemical phenomena of respiration.* Other eudiometers have been made since then, such as the ingenious instrument of Dr. Frankland for gas analysis, which has proved most serviceable. I claim for the present form of eudiometer that it is correct and reliable in its working, simple in construction, and easy of manipulation. The main objects of an eudiometer must be the easy introduction of the air to be analysed, the ready mixture of that air with a known volume of pure hydrogen gas, and the correct reading

* 'Annales de Chimie et de Physique,' 3rd Series, vol. 26, 1849.

of the volume after explosion. It will be seen that these conditions are entirely fulfilled in the present instrument; and it has, moreover, the advantage of being available in conjunction with Pettenkofer's method for the determination of carbonic acid in atmospheric air.

The eudiometer as figured in the accompanying Plate has the form of a T-piece, the vertical limb of which is a straight tube about 60 cm. in length and 12 cm. in diameter; it is divided into 50 or 60 c.c. and tenths of c.c., like a common burette. The upper end of this tube is closed air-tight with a steel cap, from which lateral tubes project right and left; these tubes are bent V-shaped, or rather in the form of a lyre. At the junction of the lateral tubes with the cap, there is a three-way stop-cock allowing of the passage of air or gas in four different directions, viz., first through the tubes cut off from the body of the eudiometer; secondly, into the eudiometer, which is done by raising it in the mercury trough; thirdly, out of the eudiometer, on the side opposite that from which it was introduced, which is effected by depressing the tube in the mercury; fourthly, through the tubes and eudiometer simultaneously. The eudiometer is held tightly by two claws projecting at different heights from a vertical iron rod connected with a rack and pinion movement. The iron rod, together with the eudiometer, is immersed in mercury contained in a straight cylindrical glass vessel.

The hydrogen used for the explosion is prepared for that special object from zinc and sulphuric acid in the ordinary way, and washed through an alkaline solution, rather than obtained condensed in iron bottles from the manufacturers, and it is collected in a bell-jar suspended over water. The bell-jar I use holds 11 litres of gas; it is balanced by a counterpoise, and its weight, as it moves up and down in water, is regulated by another counterpoise hanging from a cycloid, so that the gas in the holder is always under atmospheric pressure; an oil-gauge fixed to the holder shows at any time the pressure in the bell-jar. Should the gas fail to be absolutely under atmospheric pressure, the equality of pressures may be ensured by the use of the adjusting instrument I have described in a former communication. It consists of a clamp fixed to the rim of the tank, and made to grasp at will the cord holding the counterpoise; a screw in connexion with the clamp enables the cord, and consequently the bell-jar, to be drawn up or down. For the actual requirements of the analysis, a receiver for the hydrogen holding only one litre of gas would suffice, but it is better to have a larger gas-holder in which to store up the hydrogen for future determinations.

Moreover, the cycloid arrangement for regulating the weight of the bell-jar, though very convenient, may be dispensed with, as the gas in the receiver can be brought approximately under atmospheric pressure

by means of weights, while the adjusting screw will enable its being accurately placed under atmospheric pressure.

The analysis is made as follows:—

We suppose that air for analysis has been shaken with barium hydrate in a glass jar of a capacity of about 10 litres, and made according to the form adopted by Dr. Angus Smith* for the determination of carbonic acid in air by Pettenkofer's method. This jar is closed by a tight-fitting india-rubber cap, which I cover with several coats of copal varnish; from this cap two short india-rubber tubes project, each of these tubes being clamped by a pinch-cock. After the agitation is over, and when all the carbonic acid is taken up by the alkaline solution, the fluid is poured out from the jar into a glass-stoppered bottle holding about 100 c.c. This can be done easily without letting any air into the jar, as the india-rubber cap will collapse somewhat while the fluid is allowed to run out through one of the india-rubber tubes in the cap, a very small quantity of fluid only being left in the jar. The india-rubber tube is again clamped, and the bottle holding the barium hydrate is sealed with paraffine and left undisturbed for the precipitation of the carbonate and subsequent analysis.

The glass jar full of air free from carbonic acid, and absolutely saturated with moisture, is placed under a funnel supported on a filter stand, and the funnel is connected with one of the india-rubber tubes projecting from the cap, while the other tube has a short piece of glass tubing inserted into it, to which a longer india-rubber tube is fixed.

Everything is now ready for the determination of the oxygen of the air contained in the glass jar. After turning the stop-cock in the cap of the eudiometer, so as to allow the hydrogen gas to wash out the steel tubes and top of the eudiometer, the latter is lowered in the cylinder until the mercury is in contact with the cap, and therefore very near to the stop-cock. The eudiometer is next connected by narrow india-rubber tubing with the hydrogen receiver on which a weight has been placed, and on opening the receiver hydrogen rushes out, washing thoroughly the passage through which it will have to reach the eudiometer, and driving out the very small quantity of air contained in the steel cap between the mercury and the stop-cock. I found it convenient to stop the end of the V-shaped tube letting out the gas with short india-rubber tubing and a pinch-cock. When a few hundred cubic centimetres of gas have gone through, the three-way tap is turned by one-quarter of a turn, so as to place the tube in communication with the hydrogen; it is now easy to rinse the eudiometer with that gas, by raising the eudiometer, and then giving the three-way cock half a turn, so as to bring the instrument in communi-

* 'Air and Rain,' 1872.

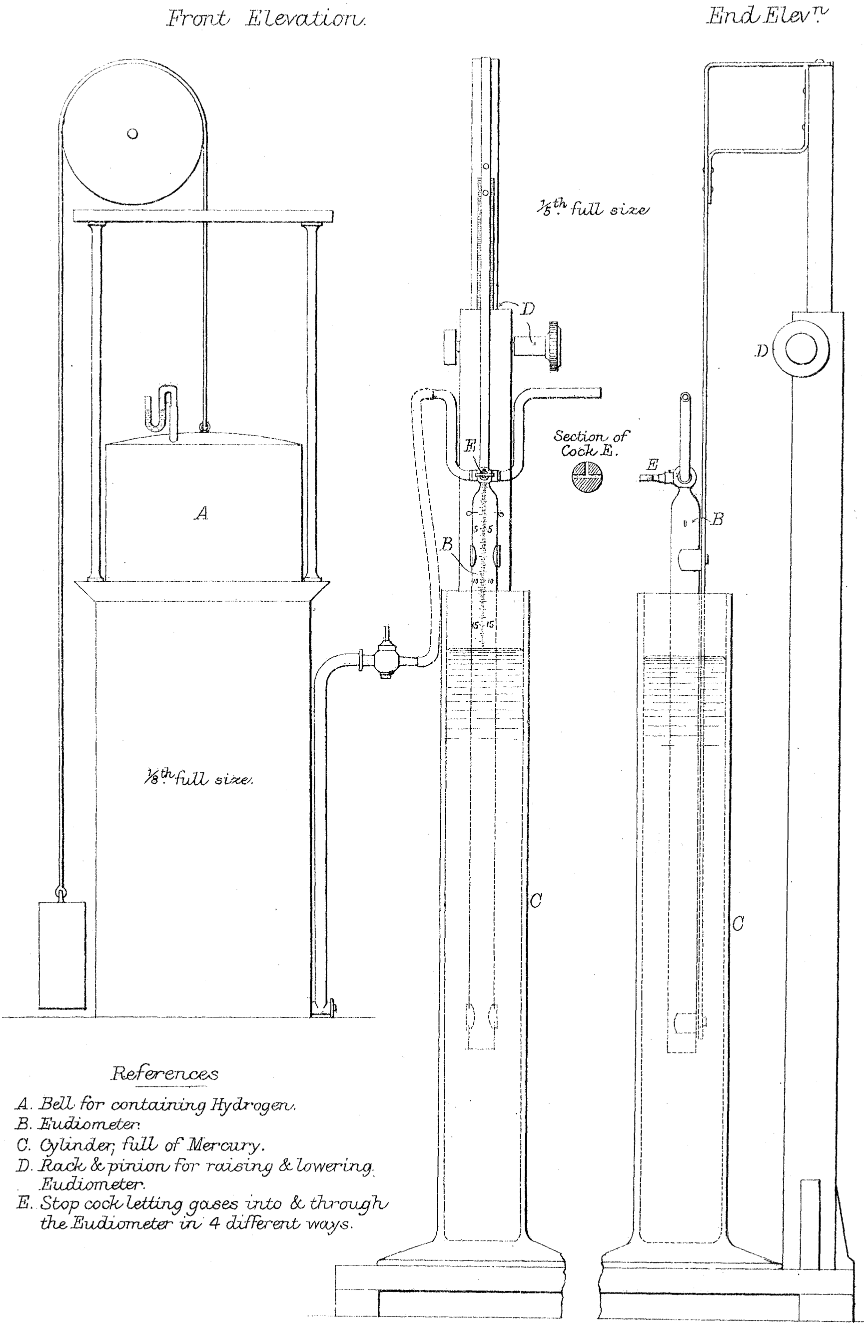
cation with the external air; the eudiometer is then rapidly depressed and closed. In this position the tube from the hydrogen can be rinsed again, independently of the eudiometer, so that the washing may be considered as complete and thorough.

The eudiometer being brought into connexion with the hydrogen is again raised, and 18 c.c. of hydrogen gas are taken in under atmospheric pressure.

The hydrogen kept over water is saturated, and a thermometer with its bulb in the bell-jar gives the temperature of the gas, which is very nearly that of the laboratory; so that by the time the gas is ready to be measured in the eudiometer it shows no tendency either to contract or dilate. The eudiometer now contains the volume of hydrogen required for the analysis, and the stop-cock is turned shutting off the gas from the holder, and opening the V-shaped tubes through and through in readiness for washing out with the air to be analysed.

The air from the large glass jar is introduced into the eudiometer in the following way. Having filled the funnel referred to above with water, the latter is let into the jar by opening slightly the pinch-cock closing the funnel; at the same time the glass jar having been connected with the V-shaped tube of the eudiometer by india-rubber tubing, is opened towards the instrument, when the air displaced by the water added rinses out the india-rubber and steel tubings. There is plenty of air in the jar, so that no necessity occurs to be saving; when the tubes are rinsed the eudiometer is raised in the mercury up to about 45 c.c., carrying a column of mercury with it; then the two-way stop-cock is very carefully turned so as to admit the air to be analysed, which is aspired by the mercury as it subsides. Thus some 27 c.c. of air are introduced. The aspiration must be fairly rapid, and the fall of mercury in the tube should be stopped by turning the stop-cock before the mercury has quite reached its level in the trough, otherwise there is a risk of a recoil of the mercury, and a "pumping" which it is important to avoid. The mixed gases are left undisturbed for two or three minutes, and their volume is read off under atmospheric pressure, the eudiometer being next moved up and down in the mercury by a few centimetres, so as to effect the perfect mixture of the gases. The instrument is now slightly raised, carrying with it a short column of mercury, and the gases are ignited by the electric spark under reduced atmospheric pressure. This mode of proceeding, recommended by McLeod,* weakens considerably the violence of the explosion, and ensures perfect safety. Immediately after the explosion the gas in the eudiometer is brought approximately under atmospheric pressure.

* McLeod, "On a new Form of Apparatus for Gas Analysis," 'Chem. Soc. Journ.,' 1869.




References

A. Bell for containing Hydrogen.
B. Eudiometer.
C. Cylinder, full of Mercury.
D. Rack & pinion for raising & lowering Eudiometer.
E. Stop cock letting gases into & through the Eudiometer in 4 different ways.

West, Newman & Co. lith.

A slow contraction now takes place as the heat produced by the explosion is radiated from the instrument; it is advisable to wait about twenty minutes, until the contraction is complete, and the volume of the gas is read off under atmospheric pressure.

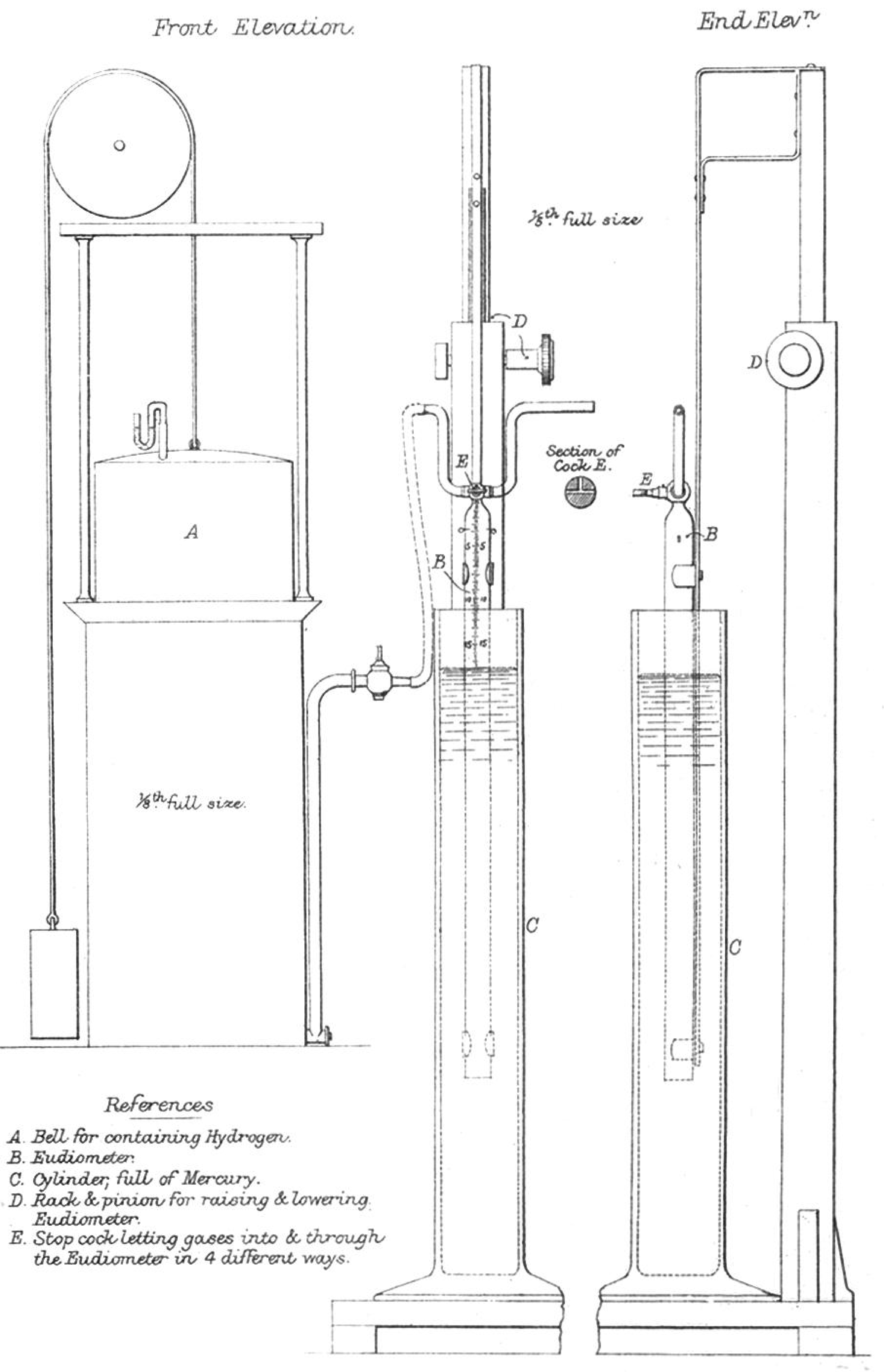
The instrument should be sheltered from any draught, or from the direct radiation of a fire, and indeed be kept from any change of temperature, and with that object I find it advisable to shelter it with a cardboard tubular shield sliding up and down the mercury trough.

If air taken directly from the atmosphere is to be analysed, in order to ensure its being saturated it will be advisable to pass it through a tube full of wet horse-hair, and obtain it directly from the tube into the eudiometer. In the above account of the manipulation required, the hydrogen is introduced before the air into the eudiometer. I have tried to let in the air first, but this plan was not successful apparently because the mixture of air and hydrogen was incomplete before the explosion. The hydrogen being collected first in the eudiometer will rise from its comparative lightness as the air is drawn in and mix with it perfectly, while the stream is sufficiently rapid to prevent any of the mixture from diffusing out of the tube. It should be borne in mind that after a number of analyses the water resulting from the explosions accumulates on the surface of the mercury in the eudiometer, and the mercury meniscus is no longer clearly seen. This can be easily avoided by drying the tube with filtering paper after a certain number of analyses. The following are a few determinations of oxygen in atmospheric air made with the form of eudiometer described above. They are not selected, but given in succession in the order in which they were made. And I must here beg to record the valuable aid of my assistant, Mr. Charles F. Townsend, F.C.S., in the present inquiry.

Oxygen per cent. in Atmospheric Air.

| First Series. | Second Series.* |
|---|---|
| 21·01 | 20·94 |
| 20·98 | 20·93 |
| 21·00 | 20·96 |
| 20·97 | 20·95 |
| 20·97 | 20·93 |
| | 20·95 |
| Mean .. 20·99 | 20·96 |
| Greatest difference, 0·2 per cent. | |
| | Mean .. 20·946 |
| | Greatest difference, 0·14 per cent. |

* One analysis omitted: obviously too high from insufficient rinsing.



Front Elevation.
End Elevn.
1/8th full size
A
B
C
D
E
Section of Cock E.
1/8th full size.
References
A. Bell for containing Hydrogen.
B. Eudiometer.
C. Cylinder, full of Mercury.
D. Rack & pinion for raising & lowering Eudiometer.
E. Stop cock letting gases into & through the Eudiometer in 4 different ways.