tains any impurity which affects the permanganate it should be constant, and thus be eliminated with the indigo. The titration is finished when the pure yellow liquid shows a faint pinkish rim. This end-reaction, which is of extraordinary delicacy, is due to Kathreiner, and is quite different to the pink caused by excess of permanganate, being an effect common to all pure yellow liquids. I do not find it needful to make the titration so slowly as has been advised—the permanganate may be dropped in rapidly, with vigorous stirring, so long as there is large excess of indigo, but as soon as the bottom of the basin can be seen through the solution it must be added very cautiously, and with occasional pauses, to allow time for its complete mixture through so large a mass of fluid. I make my infusion of such a strength that I can employ 5c.c. of the original liquid for each titration. This is repeated twice, and the results added together and denoted by a. I then take 50c.c. of the infusion, and add 28·6c.c. of a freshly-made solution of Nelson's gelatin of 2grms. to 100c.c. After shaking the mixture is saturated with salt, which brings the volume up to 90c.c., and 10c.c. of dilute sulphuric acid (containing 1 vol. of concentrated acid in 10) and a teaspoonful of pure kaolin are added. It is best to do this in a flask in which it can be well shaken, after which, filtration may be at once proceeded with (the flasks may be cleansed with caustic soda solution). 10c.c. of this filtrate (= 5c.c. of the original infusion) are employed for a second pair of titrations, which are added as before, and the result denoted b. If, further, c, be the quantity of permanganate required to oxidise 10c.c. of decinormal oxalic acid, and 10grms. of substance have been employed to 1 litre of infusion, $c : (a-b) :: 6{\cdot}3 : x$, where x is the percentage of tannin expressed in terms of crystallised oxalic acid. For the present I invariably calculate my results in this way, since we do not actually know the relation of any single tannin to permanganate, even Neubauer's number for gallotannic acid being probably too high, and Oser's for quercitannic being only a fair approximation. It happens, moreover, that this last equivalent (62·36) does not differ from that of oxalic acid (63) more than the ordinary limits of error of such estimation, and the substitution is therefore of no commercial importance, while it is surely better to employ a standard which is easily and exactly verified than one which is certain to be modified by further research, and so to run the risk either of having our results made useless for future comparison, or of establishing a false and arbitrary equivalent. What is wanted for practical purposes is not the absolute weight of tannins in the various materials, but only a means for the relative comparison of two samples of the same material; cross comparisons of different tannins being simply delusive. If, however, it is necessary at any time to give actual percentages of gallotannic acid, it is probably best to stick to Neubauer's number for the present, as it is in general use and as likely to be correct as any other. I think when this is done the equivalent used should be definitely stated, or it will certainly lead to confusion. Neubauer's equivalent is only properly applicable to gall nuts, and possibly to sumac and myrabolans. For oak bark Oser's number or that of oxalic acid is most likely nearly correct; and this may also be approximately true of oak wood and valonia, but as respects all other materials we have no information whatever, and the oxalic equivalent is as likely to be right as any other.

I have been unable from lack of time to make so complete an examination of the results of the process with various materials as I should have liked, and as I hope to do later; but in every case in which I have tried it, the results have been sharp and concordant, and there has been no difficulty in filtration, even with those tannins which before were most apt to give trouble. I give below a few results, not as showing the relative values of the materials, which, of course, cannot be directly compared by any analytical process, but for comparison with those obtained by other methods and modes of calculation :—

	Tannin (as oxalic acid).	Other bodies oxidised (as oxalic acid).
Spent Liquor	0·12	1·0
Valonia (good Smyrna). Sample 1	29·1	2·3
Valonia (good Smyrna). Sample 2	30·7	2·1
Valonia (good Smyrna). Sample 3	30·5	1·9
Hungarian Larch Extract. Sample 1	11·78	1·95
Hungarian Larch Extract. Sample 2	18·03	2·33
Chestnut-wood Extract, 25° B.	25·53	3·68
Pegu Cutch	63·59	2·15

I have proved by experiment that kaolin removes nothing which is oxidised by permanganate, but simply facilitates the precipitation and filtration; and I have often found it useful in clarifying the original infusions and liquors before the first titration. On the other hand, there is no doubt that the salt and acid of Löwenthal's method precipitate of themselves a large proportion of certain tannins. In the case of cutch this amounted to 67 per cent. of the whole. I think, however, there is good reason to believe that these bodies would also have been absorbed, or at least removed from solution by hide in the process of tanning. This is shown by the analysis of spent liquor, which originally contained the tannins of oak bark, valonia, myrabolans, gambier, hemlock, and oak-wood extracts, etc., to the extent of 10 to 15 per cent., but which was reduced by contact with hide to 0·12 per cent. That a portion had not been absorbed but decomposed is proved by the large accumulation of oxidisable impurities (equal to 11 per cent. of oxalic acid); at the same time this example shows that the method is capable of estimating a very small portion of tannin in presence of much gallic acid and other analogous substances. It is worth remark that such spent liquors become very pale in colour, and also that the filtrates, freed from tannin by precipitation, are nearly colourless, thus proving that the colouring matters present in tanning materials are of the nature of tannins, at least as regards their precipitability by hide and gelatin.

It would be out of place here to enter upon the methods of sampling and grinding tanning materials for analysis, though I believe this to be frequently one of the most difficult parts of the process. With regard to extraction, I may mention that I have found brisk boiling in a large flask with a litre of water for half an hour to be more effective as well as less troublesome than repeated exhaustion with smaller quantities. In dissolving extracts it is well to pour them into water actually boiling, as in this way uniformity is attained, many extracts becoming permanently insoluble if mixed at first with water at too low a temperature.

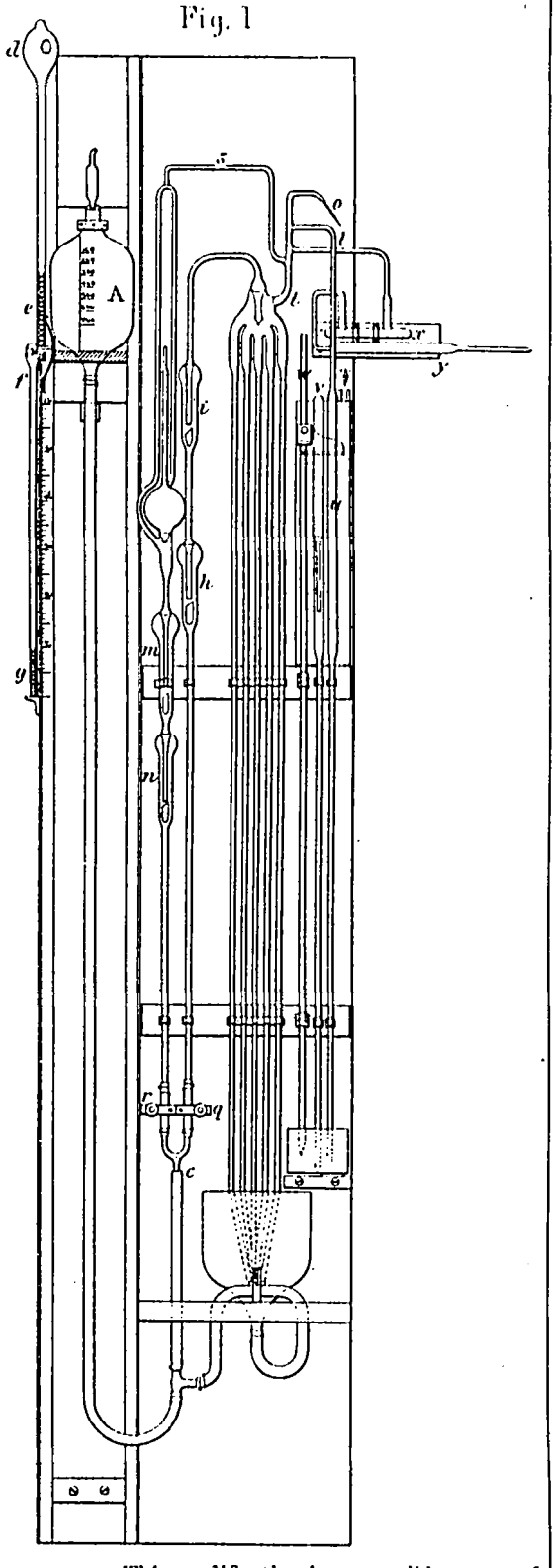
CONTRIBUTIONS TO THE DEVELOPMENT OF THE SPRENGEL AIR PUMP.

BY CHARLES H. GIMINGHAM, F.C.S.

At the close of the year 1876 I wrote a short paper, which was published in the Proceedings of the Royal Society, on a modification of the Sprengel air pump, and showed that the slowness of the process of exhaustion, which had always been a drawback to

the employment of that air pump, might be to a great extent overcome by the adaption described in

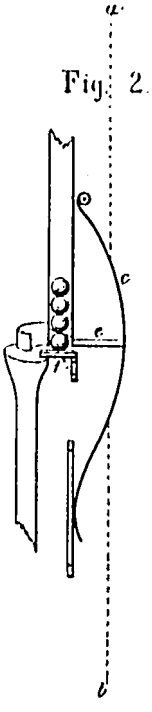
Fig. 1



my paper. This modification is now well known, and has come into pretty general use. The result of continued experiments directed towards a similar end has been so far successful that I think I am justified in inviting for a second time the attention of the scientific public to the subject. I will now endeavour to point out, as briefly as the subject will permit, what the alterations are which I have to suggest, what results they will effect, and by what means and from what causes those results are produced; and I shall further add a few observations relating to the working of the instrument, which may be useful to those who have but small practical acquaintance with it.

The principal objects kept in view in my later efforts were those of accelerating the process of exhaustion, and of rendering that exhaustion more complete; but in addition to this it seemed to me exceedingly desirable to construct some form of jet which could be adapted in a simple way to a multiple fall tube, and before proceeding to discuss the rate of exhaustion with fall tubes of various diameters it will be well to give my reasons for adopting the par-

Fig. 2.



ticular form of jet that I use. From time to time various jets have been devised, mostly with the idea that the mercury should fall regularly and in long pistons down the fall tube. To my mind this is by no means necessary to the successful working of a pump, and it prevents all possibility of obtaining a rapid exhaustion. The advantages possessed by my form may be briefly stated as follows: The simple way in which it can be adapted to a multiple fall tube pump. In producing high exhaustions the great variation in the speed of the mercury flowing down the fall tubes that it affords is exceedingly useful, as it is often good at the higher exhaustions to pass the mercury through alternately slow and then fast. The mercury running slowly collects bubbles of air just below the point where the hammering takes place, and then a fast stream will generally carry them out, or far down the tube, to await the arrival of other bubbles until they are swelled sufficiently to be carried out.

Before proceeding further it will also be well to glance at and dismiss an addition to the instrument

of minor importance, but whose usefulness and simplicity of construction demand a few words of explanation. In experimenting I often found it necessary to count the number of times the mercury reservoir was raised, in order to calculate the amount of mercury passed through the pump, and for this purpose the shot counter shown on the left-hand side of the reservoir A in Fig. 1, and enlarged in Fig. 2, was constructed for automatically registering each bottle of mercury. Two tubes, *d e* and *f g* (Fig. 1), are placed one above the other. The upper one has a small bulb at the top with an opening in it through which shot may be inserted. The shot should be picked all of one size, and just loosely fit the tubes. The lower tube is closed at the bottom and blown into a funnel

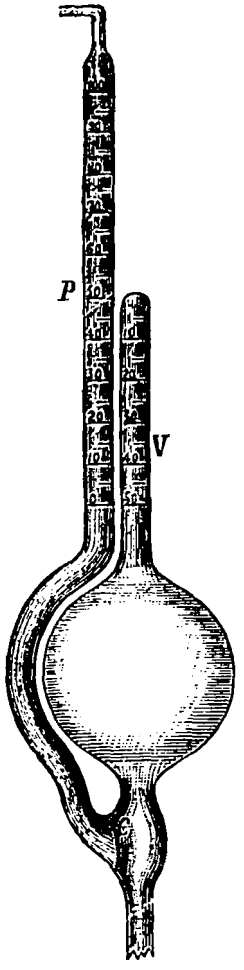


Fig. 3.

shape at the top to receive the shot as they are transferred from the upper tube, one by one, each time the reservoir A is raised. The shot being all of one size a scale may be made to indicate without counting the number of times the reservoir has been raised. The tube *f g* when filled can be removed, and the shot poured back into the opening in *d*. The arrangement for transferring the shot one at a time from the upper to the lower tube will be easily seen by reference to Fig. 2. The position that the slide carrying the reservoir A takes when raised is shown by the dotted line *a b*. It will be seen that the spring *c* will be pressed inwards, which will force, by means of the projecting piece *e*, one shot over the little brass support *f* and *e*, remaining in its new position as long as the reservoir is raised, thus preventing the next shot from falling down. As soon, however, as the slide is lowered the spring draws *c* out, and a new shot comes down ready to be forced out the next time the slide comes up. The one I have counts to 100, which is more than I have ever required. In order to divide the mercury into smaller portions than the total contents of the bottle it is graduated at every 100c.c., the whole contents being 800c.c.

I shall now consider a more important branch of my subject, and ask you to follow me through a series of experiments all pointing to the conclusion that perfection of the instrument is only to be

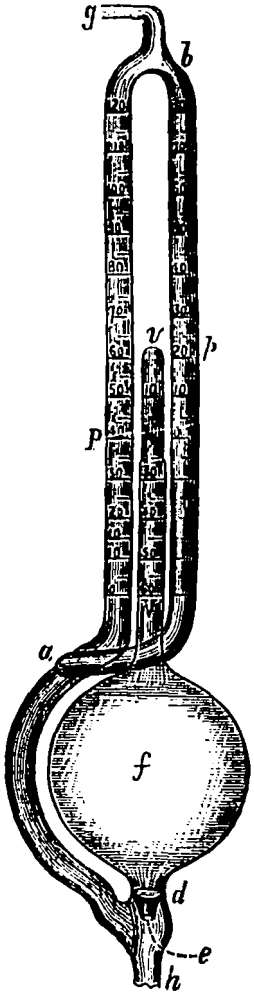


Fig. 4.

attained by a careful regulation of diameter and length of the fall tubes employed.

It will perhaps be the more explanatory as it is the more natural plan that I should narrate the experiments in about the order in which they took place, premising that the tabular statistics appended, and to which I must often refer you, are extracted from notes carefully recorded at the time of the respective experiments.

In order to accelerate exhaustion I increased the number of fall tubes from 3 to 5, and in one pump that I used in my own laboratory for a long time, to 7. Although the results with the seven-tube pump were quite satisfactory, yet I found that for general use

a three or five tube pump was preferable. In the case of the seven fall tubes I used four of comparatively large diameter for rapidity, and three smaller ones to get the higher exhaustions not easily accomplished with fall tubes of large diameter. The rate of exhaustion with this pump was very great for one constructed on the Sprengel principle, but the supply of mercury also had to be very large, a bottle containing 800c.c. only serving for three or four minutes, which necessitated so much lifting and waste of time (the transference of the mercury from the lower reservoir into the movable one occupying almost as much time as its passage through the pump) that I afterwards used two small fixed reservoirs and transferred the mercury from the lower one to the upper by means of a small force pump, which was constructed out of a stout glass tube, using boxwood and leather for the plunger and valves. The pump could then be worked by the circulation of a few pounds of mercury, and had one sufficient work to keep a gas engine going on the force pump a great advantage would be gained. For laboratory work, however, I came to the conclusion that I had done too much in the direction of rapidity, as it will be seen further on that exhaustions cannot be produced

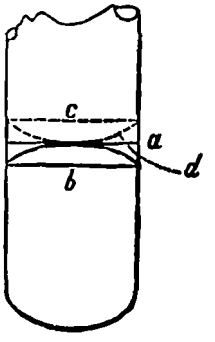


Fig. 5.

at any desired rate unless the connection between the pump and the apparatus to be exhausted is very short and open, two conditions very often impossible to obtain. To ascertain the best length and diameter for the fall tubes a single fall tube was arranged in front of my five-tube pump, a general view of which is given in Fig. 1. The single fall is not shown, as it was only temporarily arranged. It, however, was supplied from the reservoir A by making an extra joint in the glass YY-piece at *c*, and arranging a third pinch-cock there similar to *r* and *q*. The mercury passed from the reservoir through the supposed joint at *c* (Fig. 1) and two ordinary air-traps exactly similar to *h i*, which have been already described in my previous paper, but in which I have since introduced a slight improvement, consisting of a piece of twisted iron wire placed in the inner tube of the trap, which prevents the mercury forming pistons, and thus facilitates the emptying of the traps into the vacuum, when it is desired to re-exhaust them. The fall tube was attached to the jet by means of a stopper which was fixed by vacuum cement.* An arm from the upper wide part of the fall tube was connected to the five-tube pump at *l*, thus connecting the two pumps together and avoiding the necessity for separate drying tubes and measuring apparatus.

The first point—viz., the best length for the fall tubes—was decided some time back to be 39in., measured from the average height of the mercury in the lower reservoir. This length has been arrived at from practical experience and making careful notes on the working of each pump that I have from time to time fitted up. If the fall tubes be too short the pump works very slowly, owing to the column of mercury (deducting the air spaces) not being of sufficient length to run quickly down the tube, thereby occasioning a constant filling up at the top end and consequent waste of mercury power. An experiment recorded in my note-book with a five fall tube pump whose tubes were at first made 33in. long, and then were lengthened to 39in. by sealing pieces to their lower ends, shows that by passing the same quantity of mercury through at the same rate, a certain globe was exhausted in the first case to 50mm. pressure, and in the second to 1mm., showing a great increase in the rate of exhaustion, due to the extra 6in. of fall tube. On the other hand, if they be made a greater length than 39in., the fall of the mercury at the high exhaustion causes such severe hammering that the tubes are liable to be fractured. In testing the different sized fall tubes the same length was adopted in each case, and also the same cubical contents to be exhausted. The latter was ascertained by collecting the gas at the end of the fall tube and carefully measuring it, the result being 136c.c. The first fall tube experimented with was a very wide one, in which the mercury was only just able to form pistons.

The following experiments were tried with the double object of finding the best size, and also the most economical rate for the mercury to flow through the jet. It will be seen from table 1 that it took 2,500c.c. of mercury, running at the rate of 100c.c. in 1·2 minute, to accomplish the same work that was done by 1,600c.c. of mercury running at the rate of 100c.c. in 5 minutes. On the other hand, we have the time saved by using the mercury at the quick rate, equal to 50 minutes.

FALL TUBE No. 1. 2·1mm. DIAMETER.

c.c. of Mercury.	Pressures in millimetres recorded with mercury running at the rate of	
	100c.c. in 1·2 minute.	100c.c. in 5 minutes.
100	329	368
200	236	212
300	186	187
400	146	133
500		108
600	106	85
700	85	72
800	73	55
900	69	46
1000	57	33
1100	50	21
1200	41	16
1300	38	10
1400	29	6
1500	21	3
1600	20	1
2500	1	—

This tube being too large for ordinary use, further experiments were not tried with it, except at higher exhaustions, of which I shall speak presently. It will perhaps be noticed that the exhaustions produced by the slow rate at first are less than those by the fast rate. This discrepancy is due to loss by the mercury running down the tube without properly forming pistons, owing to the large diameter of the tube. The amount of this loss will be seen by referring to the table giving the results with fall tube No. 2, which is of smaller diameter, yet we have the same

* A mixture of beeswax and resin: 3oz. beeswax, 3oz. resin.

amount of work done by 700c.c. of mercury that it took 1,600c.c. of mercury to do with the large tube No.1, the rate of flow and contents to be exhausted being the same in both cases.

FALL TUBE No. 2, 1·8mm. DIAMETER.

c.c. of Hg.	Pressures recorded with mercury running at rate of	
	100c.c. in 5 mins.	100c.c. in 2 mins.
100	232	219
200	128	119
300	79	87
400	39	61
500	20	36
600	8	22
700	1	16
800	—	8
900	—	6
1000	—	4
1100	—	2·5
1200	—	1

This table also shows a gain in time by allowing the mercury to flow fast, but not bearing anything like the proportion to the amount of mercury expended which was shown with No. 1 tube. In both cases, however, extremes have been taken, and the most economical rate will be between the two experimental times taken. The experiments with No. 3 fall tube show how largely the rate of exhaustion of different pumps may vary by having differences in the diameter of the fall tubes, which from the outside would be scarcely visible.

FALL TUBE No. 3, 1·1mm. DIAMETER.

c.c. of Hg.	Pressures recorded with Mercury flowing at rate of	
	100c.c. in 10 mins.	100c.c. in 4 mins.
100	170	582
200	311	461
300	258	358
400	197	295
500	155	249
600	119	208
700	93	178
800	80	153
900	66	132
1000	50	116
1100	38	102
1200	29	86
1300	23	73
1100	15	65
1500	10	56
1600	5	48
1700	3	42
1800	1	33
1900	—	25
2000	—	21
2100	—	17
2200	—	13
2300	—	10
2400	—	6
2500	—	4
2600	—	2·5
2700	—	1

This tube, it will be seen, took 108 mins. to produce the same exhaustion that was done in 24 mins. by the previous tube, with a far less expenditure of mercury power. In this table we have the same thing shown as in No. 1, viz., a large increase of time saved at the expense of mercury power. With this tube No. 3 an experiment was tried with the mercury running at the rate of 100c.c. in 30 mins., and producing an exhaustion of 1mm. pressure with 1,500c.c., whereas by using 1,800c.c. of mercury the same work was done in 3 hours, and 2,700c.c. accomplished the same exhaustion in 1 hour 48 mins. Although I considered this tube small, and there was a good deal of mercury power wasted by the filling up of the top part of the fall tube, I thought it would be well to try a still smaller tube, more especially for the sake of the results at higher exhaustions.

FALL TUBE No. 4, 1·1mm. DIAMETER.

c.c. of Hg.	Pressure recorded with mercury running at rate of 100c.c. in 5 mins.
300	361
600	263
900	195
1200	145
1500	110
1800	86
2100	67
2400	52
2700	32
3100	4
4000	1

Table 4 shows the result up to 1mm. pressure. The maximum speed at which the mercury could be run with this tube was 100c.c. in 15 mins., and it will be seen that 10 hours were occupied and 4,000c.c. of mercury. This enormous increase of mercury used is caused entirely by waste, on account of the incessant filling up of the wide part of the fall tube, the direct cause of which is the friction due to the small bore of the tube.

Owing to the very limited time that I have had at my disposal for original work, I have not been able to carry out the experiments at higher exhaustions with these single fall tubes to the same detailed extent as those at the lower exhaustions. However, I have arrived at very definite conclusions with regard to the sized tubes that should be adopted for producing high exhaustions. At one time I had an idea that if a pump could be so constructed that as soon as the rarefaction had reached the barometric height by exhaustion through large fall tubes, the mercury could be turned so as to exhaust through a set of fine bore tubes, I should be able to get a high vacuum easily, because the pistons of mercury, being of small diameter, would enclose bubbles of rarefied air which would escape in a larger tube. On experimenting with pumps constructed on this principle, I soon found that I could produce as good an exhaustion with the large tubes alone as I could by using the finer ones at higher stages. It is therefore not a case of producing pistons at the higher exhaustions, the last portions of gas being taken out by a process of entanglement. The contents being exhausted remaining at 136c.c. the maximum rarefaction obtained with tube No. 4, 1·1mm. diameter, was ·66M.* with an expenditure of 7,200c.c. of mercury at 15 mins. per 100c.c. = 18 hours. Going to the other extreme I next tried tube No. 1, 2·4mm. diameter, for high exhaustions. This gave, with 2,700c.c. of mercury, an exhaustion of ·1m. in 2·5 hours. In the case of fall tubes Nos. 2 and 3 I have unfortunately not recorded sufficient data to get the quantity of mercury and time occupied as in the other cases, but practically I know that with these sized tubes the high exhaustions are most readily produced, and with them I have several times recorded ·01m., and three or four times with my five tube pump, which contains three tubes in the centre, of 1·5mm. diameter, and one on each side of 1·8mm. I have measured exhaustions up to ·000006mm. equal to ·008M. Such exhaustions as these are, however, only produced under the most favourable circumstances.

* M is now generally used to stand for a millionth of an atmosphere.

THE MEASUREMENT OF THE VACUUM.

Moderate exhaustions, viz., to within 1mm. or so of the barometric height, are generally and most readily measured by means of a barometer gauge which forms a part of every air pump. Great care is, however, necessary in reading, in order to obtain trustworthy observations at pressures within two or three millimetres of the height of the barometer. A few remarks will therefore not be out of place on the methods used to obtain the necessary precision. The position of the barometer gauge in my arrangement is shown at *a* (Fig. 1), and to facilitate comparative measurements I place on the right of it a good barometer *v* and a glass rod *w* divided into millimetres measured from the extreme lower end, which is pointed in order that contact with the surface of the mercury may be seen by the point of the rod just meeting its reflection on the bright surface of the metal. As this operation had to be repeated for every reading taken, owing to the constant and considerable variation of the height of the mercury in the gauge reservoir, I devised the following method of obviating the necessity for constantly keeping the surface of the mercury bright, as well as stooping to see that the exact contact was obtained. A stout piece of platinum wire was sealed to the lower end of the measuring rod and filed to a sharp point, from which the millimetre divisions up the rod were measured. A thin wire was attached to this platinum point, which, after being twisted into a spiral to allow of the up and down motion of the rod, proceeded to a small galvanometer, which could be placed in any convenient position on the stand of the pump. Another wire from the mercury in the gauge reservoir passes through a small battery to the other terminal of the galvanometer.

Now it is only necessary before reading the height of the gauge to lower the rod till the first movement of the galvanometer needle is seen, which shows that the surface of the mercury has been reached. I must here mention that on visiting Prof. Barrett's laboratory at Dublin, I found that he had independently devised and was using the same arrangement for one of his barometers. In the absence of a cathetometer I still use a mirror placed vertically behind the top part of the barometer and gauge, in order that the reflected image may be used to prevent errors arising from parallax. The best method of reading the difference between the heights of barometer and gauge is to have a slide running smoothly on the measuring rod, carrying a piece of clear mica with fine lines, a millimetre apart, scratched upon it, which lines must move up and down at right angles to the gauge. Even if every precaution be taken, and the finest possible adjustments be used, it is still impracticable to obtain any approach to accuracy in the measurement of exhaustion above 1mm. or so by means of the barometer gauge. We therefore have recourse to the now well-known low-tension gauge of Professor McLeod, a slight modification of which I have used in my experiments. The modification consists merely in giving it a greater range and increasing the accuracy with which it can be calibrated. In Fig. 3 is shown an ordinary gauge, of which V is the volume, and P the pressure tube. In Fig. 4 it will be seen that on the top of V is blown a small volume tube *v* which is about 1in. long and 5mm. internal diameter, made of a piece of thermometer tubing, with white enamel back, the latter greatly assisting one to read quickly the position of the mercury in the tube. To avoid correction for capillary depression when using the small volume tube, I have placed a second pressure tube, made of the thermometer tubing, by its side. This second pressure tube communicates with the large pressure tube P at *a* and *b*, so that mercury always rises in both at the same time.

In the calibration of the McLeod gauge it has always been difficult to obtain the total contents of the bulb and volume tube—that is, to the point where the gas is enclosed by the rising mercury passing the junction of the pressure tube at *c* (Fig. 3). Professor McLeod in his original paper, recommended pouring in mercury while the apparatus was held in an inverted position, till it runs down the pressure tube. It will readily be seen by reference to Fig. 3 that this method would only give approximate results. In calibrating several gauges I have overcome the difficulty by the introduction of what is technically called an improved joint *d* (Fig. 4), which is similar to the joint forming the air-trap of a barometer, the only difference being that the inner projecting part, *e*, is very short and has a smooth round opening of 3mm. or 4mm. diameter instead of being drawn to a fine tapering point. In this case the mercury, rising upwards, cuts the communication between the bulb and the pressure tube quite sharply at the smooth aperture *e*. It will also be seen that the introduction of this joint enables one to determine accurately the contents of the bulb and volume tube to the exact point where the rising mercury encloses the amount of residual gas to be compressed. The working of the gauge is in no way altered by these slight improvements. I might therefore refer those who are not familiar with its use to Prof. McLeod's original paper in the *Phil. Mag.* for 1874; but as this is not easily accessible to all, I will briefly describe the *modus operandi*. Let it be granted that the volumetric contents *v* to *e* is accurately known, and also that from *v* to division 60 in V. Although in working, the values of other divisions are taken in the volume tube, these two values are sufficient for the present description. On dividing the contents of the bulb and volume tube, viz., *v* to *e*, by the contents of the volume tube *v* to V, we have the ratio R existing between the two. Now let the whole apparatus be exhausted from *g* to *h*, and then allow mercury to rise from *h* upwards, as soon as it arrives at *e* the residual gas in *f* will be cut off from the pressure tubes P *p*, and gradually compressed into the volume tube by the rising mercury filling up the bulb *f*, the increase of rise in the pressure tube P showing the pressure in millimetres P^1 of mercury necessary to accomplish this condensation, then

$$\frac{P^1}{R}$$

gives approximately the degree of exhaustion that existed in the bulb *f* before condensation. In order to find the exact original pressure, a slight correction is necessary, on account of the depression of P^1 by the tension of the residual gas in the pump with which the gauge is connected. To apply this correction the number

$$\frac{P^1}{R}$$

must be added to P^1, and the result again divided by R. The difference between the number thus obtained and the approximate presssure is, however, so slight in the high exhaustions for which the McLeod gauge is generally used, that it comes considerably within the limits of experimental errors. For example, we will take a pressure of ·113mm. approximate pressure, which is represented in the particular gauge I am now mostly using by $\frac{10}{88}$, that is, the residual gas requires 10mm. pressure to condense it to the division 60 of the volume tube. This approximate pressure added to the 10mm. in the pressure tube equals 10·113, which, when again

divided by the ratio, viz., 88·42, in this case equals ·114—that is, a difference of 1 in the third place of decimals. This, perhaps, might be considered appreciable, but as most of the pressures measured by the McLeod gauge are far lower than this, I think it will suffice to show that the correction is scarcely necessary, especially as it involves considerable extra calculation.

CALIBRATION OF THE GAUGE.

The calibration of the McLeod gauge has always been a matter of some little difficulty, and the method I use being to the best of my belief new, and at the same time exceedingly simple and accurate, I will give it in detail, thinking it may be useful to those who, like myself, would not trust to a gauge unless they had personally verified its calibration. Fig. 5 represents the top part of an inverted volume tube *a*, the division on it to which we want to find, from the weight of the mercury with the meniscus in position *b*, what weight of mercury would fill the space to division *a*, when we are reading with the meniscus in the dotted position *c*. Make a wooden plunger to fit rather loosely in the volume tube to be graduated, and rub the end on a piece of fine glass paper till it is perfectly flat, then place mercury in the volume tube rather above the division which it is desired to calibrate, and slowly pass the plunger down to the division. All the excess of mercury will pass the plunger, and on withdrawing the latter this excess will be removed, the exact weight of mercury to the division selected being left in the tube. In this way I proceed to obtain the values of four or five different portions of the volume tube. To correct for the meniscus when reading with it in position (Fig. 4) I have only to find the value of the annular space *d* and add it to each of the values found by the above plunger method, since the meniscus will be of the same shape in all parts of the tube. The weight of mercury that would occupy the annular space *d* is found by taking accurately the weight of mercury to a certain division with the meniscus in position *b*, and subtracting this weight from that obtained by means of the plunger to the same division. The accuracy which may be obtained by the use of a plunger in calibration is shown by the following four weights obtained while calibrating a volume tube of 4mm. internal diameter to a certain division, 115·07 grains, 115·01 grains, 115·04 grains, 115·09 grains. In calibrating a McLeod gauge, it is advisable to select three or four of the most useful divisions and accurately determine the weight of mercury for each by the method described, calculate a table for various pressures on each of these divisions, and take all observations from one or other of them. The points in an ordinary gauge with the volume tube 60mm. long, which will serve for all pressures, are (1) the topmost division, (2) 5mm., (3) 20mm., (4) 60mm.

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MEETING, *Wednesday, February* 6, 1884.

GASEOUS FUEL APPLIED TO THE HEATING OF GAS RETORTS.

BY CHAS. HUNT.

IF it were at all incumbent upon the writer of a technical paper to introduce his subject with a history of the art to which it relates that necessity does not devolve upon me to-night; for at the last meeting of the Section our attention was largely occupied by the able survey of the rise and progress of illuminating gas with which Mr. George E. Davis appropriately ushered in his description of a proposed new departure in the economy of coal distillation. By so much, therefore, my task is a less formidable one; and if, of what remains, my subject be less generally interesting than those that have preceded it, I am not without hope that in practical importance it will compare not unfavourably with them, or indeed with any that may be brought under the notice of the Section.

Heating gas retorts by fuel in the gaseous form, as a substitute for its common application in the solid state, dates almost as far back as the introduction of the regenerative system by the late Sir William (then Dr.) Siemens, more than twenty years ago. The success that attended the latter in its applications to other industries led to its being applied experimentally in at least two gasworks in this country—namely, the Brick Lane station of the then Chartered Gas Company, and the Windsor Street works, at that time belonging to the late Birmingham Gaslight and Coke Company. In neither case, however, were the results such as to secure for it a more extended use, although, almost simultaneously, it obtained a firm and (as it proved) enduring footing at the works of the Paris Gas Company, where, with sundry modifications of detail, it has ever since been very largely employed. Here is a drawing showing substantially the arrangement which down to the year 1875 (when it was finally abandoned) was used in Birmingham for heating six beds of retorts. It is that of the familiar alternating system, with regenerators for both air and gas, worked by means of reversing valves, the producers (not shown upon the drawing) being of the ordinary kind, with sloping grate, placed at a convenient distance outside the retort-house, to which the gas was conveyed by the usual wrought-iron condensing tubes.

It is only natural to inquire how it came to pass that *a system which, in its most important applications*, has proved so advantageous, failed (in this country, at any rate) to displace, even in the smallest degree, the less scientific method of direct firing when applied to gas retorts. From personal experience I am able to reply that the small fuel economy and greater regularity of heating, which constituted the chief merits of the system, were too dearly purchased at the expense of simplicity, convenience, and certainty of action, the sacrifice of so much additional ground space as was required for the producers, and the employment of capital altogether disproportioned to the service performed. It may be only fair to assume that, under more favourable conditions, successive modifications might, as at the Paris Gasworks, have led to better results; but so far as the experiment (extending over several years) was pursued, the advantage remained with the *more primitive system*.

Other methods, however, for the attainment of the same object were, in the meantime, in process of development. It is very probable that the stimulus to further inquiry was furnished by the scarcity and consequent high prices of fuel that prevailed about ten years ago; and it may not be far wrong to conjecture that the clue to the direction which has since been followed by our German brethren with such assiduity and success was furnished by the Ponsard gas furnace—the first attempt, apparently, at continuous recuperation. I ought to qualify this observation by saying that it has special reference to recuperators built of fire-brick, because only within the last few days it has come to my knowledge that a patent was taken out as long ago as 1847, by