plasma (indicating approximately the level of free haemoglobin in the plasma: see above) reached about 3% of the total amount of haemoglobin injected in the form of intact red cells (Fig. 9).

Apparently the proportion of haemoglobin liberated into the plasma depends upon the amount of red cells injected. Thus, Jandl *et al.* (1957) found that when

FIG. 9.—An example of predominantly extravascular destruction. 0.4 ml. of Rh-positive red cells was labelled with ^{51}Cr , then sensitized *in vitro* with Rh antibody and reinjected into the donor. The red cells were removed from the circulation with a half-time of approximately 20 minutes; the amount of radioactivity in the plasma never exceeded 3% of the total amount injected in the form of labelled red cells.

amounts of Rh-positive red cells equivalent to 3 g. of haemoglobin were injected into subjects whose serum contained anti-Rh the maximal level of plasma haemoglobin was usually equivalent to about 5% of the total dose injected, but when the amount of red cells was equivalent to about 7 g.—that is, about 50 ml. of blood—the maximal plasma haemoglobin level was equivalent to about 10% of the injected dose. Presumably when larger doses, of the order of 500 ml. of incompatible blood, are transfused an even higher proportion of the haemoglobin from destroyed red cells is likely to spill into the circulation, since haemoglobinuria does occasionally occur after haemolytic transfusion reactions due to anti-Rh (Vogel *et al.*, 1943).

When destruction is predominantly extravascular, the localization of the ^{51}Cr -labelled cells can be determined by surface counting—that is, counting over the surface of the body with a scintillation counter.

Surface Counting.—The gamma rays emitted by ^{51}Cr are very readily absorbed by tissues, and thus, owing to differences in bodily configuration, it is not possible to make precise quantitative estimates of the distribution of ^{51}Cr in different organs. However, it is possible to make rough quantitative estimates, and it is often possible to conclude that the greater part of the activity is localized in some particular organ—for example, the spleen. Interpretation of the findings is made easier by calibrating the particular scintillation

counter used with models of the liver and spleen containing known amounts of radioactive chromium. Thus, Mollison and Hughes Jones (1958) made models out of agar, incorporating known amounts of ^{51}Cr , placed the models in a dead body, and then carried out surface counting. They found that when the liver and spleen were of a normal size a given amount of radioactivity in the spleen gave a counting rate which was three times higher than that for the same amount of radioactivity in the liver. By counting different models in different bodies they arrived at average figures expressed as counts per second per microcurie for ^{51}Cr in the normal liver and normal spleen, and they used these figures to make estimates of the amount of red cells trapped in the liver and spleen after injecting incompatible red cells. These estimates are referred to below.

Summary of the Capabilities of ^{51}Cr

Radioactive chromium is thus an extremely useful label for incompatible red cells. Volumes of less than 1 ml. can be easily and rapidly labelled *in vitro*. If the red cells are destroyed intravascularly the amount of haemoglobin set free in the plasma can be estimated. If they are destroyed extravascularly their main sites of destruction can be identified, and an approximate estimate made of the proportion of red cells destroyed there. Finally, ^{51}Cr can easily be counted in the presence of ^{32}P , which can be used to label a control sample of compatible red cells. This makes it possible to detect the destruction of even 5% of incompatible red cells.

With such a test system the effects of different antibodies on the destruction of injected red cells can be accurately determined.

[The second lecture, with a list of references, will appear in our next issue.]

MAXIMUM FORCED EXPIRATORY FLOW RATE AS A MEASURE OF VENTILATORY CAPACITY

WITH A DESCRIPTION OF A NEW PORTABLE
INSTRUMENT FOR MEASURING IT

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The use of a single forced expiration as a method of assessing ventilatory capacity is becoming increasingly popular, mainly because, as pointed out by Kennedy (1953), it is a much simpler and less tiring procedure than the maximum voluntary ventilation (M.V.V.).

The basis of most of the various single-breath methods is the same: the volume of air expired is measured against time by means of a spirometer with either a recording drum or a timing device. There are some differences of opinion about the most suitable interval of time over which to measure the volume and about the relative merits of a recording drum or a timing device, but it is generally agreed that methods of this kind are clinically valuable and give results which are comparable

with those of the M.V.V. All the methods, however, suffer from the disadvantage that the necessary apparatus is cumbersome and normally requires connexion to an electric supply. Attention has therefore been directed to the possibility of using the maximum forced expiratory flow rate (or "peak flow rate"), instead of what is in effect the average for a limited time, as a measure of ventilatory capacity; such a measurement seemed likely to lend itself to the use of a simpler instrument, consisting merely of a flowmeter with a device for recording the maximum.

According to Donald (1953) the empirical use of a measurement of this kind is very old. "The physician of the last century who asked a patient with respiratory disease to whistle or blow a candle out was crudely assessing the maximum respiratory velocities" (*sic*). Donald suggested that a "simple, whistle-like instrument" might be developed and might become a standard clinical tool.

In this paper an instrument of this kind is described, but first it may be useful to give an account of the maximum forced expiratory flow rate as a physiological measurement.

Historical

Apart from the rather vague reference quoted by Donald the earliest systematic attempt to use the peak flow rate as a physiological index was that of Hadorn (1942), who measured the flow rate on expiration by means of an aneroid manometer connected across a simple orifice. The resistance of the system was high, as much as 32 cm. of water at a flow of 500 l./min., and no provision was made for recording the maximum deflection of the manometer pointer except judging it by eye. The highest flow rates he recorded were about 500 l./min. Wyss (1950) used the same type of orifice as Hadorn, but recorded the pressures photographically, using a membrane manometer and an optical lever. This gave a permanent record and a higher frequency response. He registered flow rates as high as 720 l./min.

The basic method used by both these workers has the disadvantage that the pressure drop across a simple orifice varies as the square of the flow rate, with the result that the higher flows are considerably reduced, thus cramping the scale of the measurement. In addition the sensitivity of the method at low flow rates is low, giving an unsatisfactory logarithmic scale. Nevertheless, an instrument of this kind has been produced commercially and has been the basis of a number of studies of the relationship between the maximum forced expiratory flow rate and the vital capacity (Hildebrandt and Hanke, 1956). The instrument, called a "pneumometer," incorporates an aneroid manometer fitted with a device for recording the maximum flow rate. Rates up to about 700 l./min. can be recorded.

Of recent years the use of improved forms of pneumotachograph (Silverman and Whittenberger, 1950; Lilly, 1950) has led to many observations of the expiratory flow pattern, but no systematic attempt to use the peak flow rate as a physiological measurement in its own right appears to have been made. Moreover, although the pneumotachographs themselves have had very low resistances (of the order of 2 mm. H₂O/100 l./min.) which gave a linear relationship between flow and pressure, for some reason which is not clear they seem to have sometimes produced a considerable reduction in peak flow rate in healthy normal men. For

instance, Shephard (1955), measuring peak flow rates during a forced expiration in "healthy young adults," recorded none higher than 427 l./min., and one of only 183 l./min. in an apparently healthy man of 25. Similarly, Leuallen and Fowler (1955) found no flows higher than 660 l./min. in a group of normal males; and Comroe, Forster, Dubois, Briscoe, and Carlsen (1955) quote 500 l./min. as a "typical figure" for a "maximum expiratory flow rate." In their table of "normal values," however, they quote a figure of 400 l./min. and make it clear that this is averaged over a volume of one litre. In contrast, as will be seen, we have found that peak flow rates over 700 l./min. are common in adult males and flows up to nearly 1,000 l./min. by no means rare. To measure such flows it has been necessary to make use of an enlarged version of the Lilly pneumotachograph with connexions of very wide bore. Details of this instrument are given later.

For two reasons it is desirable to measure the peak flow rate in such a way as to get the maximum possible figure. In the first place, the higher the figures given by normals the more clearly they are differentiated from the abnormals, whose relatively low flow rates are less affected by resistance, especially if it is non-linear in type. Secondly, one important advantage of the peak flow rate as a physiological index is that it is relatively easily understood and defined. Respiratory physiology is beset with measurements which are peculiar to the instrument and the laboratory where it is made (Comroe *et al.*, 1955), and therefore it is highly desirable that, if possible, a measurement should be absolute, and clearly defined, so that it will be the same however and wherever it is measured.

Both the earlier and the latest forms of pneumotachograph suffer from the disadvantage of being fairly complicated and not easily portable. A much simpler and more robust and portable instrument, designed specifically for measuring the peak flow rate, has been described by Goldsmith and Young (1956) and called by them the "puffmeter." It is of basically the same design as the Lilly and Silverman pneumotachographs, but uses a robust ceramic grinding wheel as a linear resistance and an aneroid manometer to measure pressure.

It appears to suffer from two disadvantages; the pressure drop across the resistance is relatively high, about 1 cm. H₂O/100 l./min., and the maximum reading has to be read off from a presumably rapidly moving hand on a dial. Nevertheless, Goldsmith (1958) has used it extensively, and by calibrating it empirically against a pneumotachograph he has obtained a considerable body of data about peak flow rates. Unfortunately, his results are all given in "puffmeter" units, which are admitted to be much lower than the actual flow measured with a pneumotachograph. He calibrated the puffmeter by connecting it to the outlet of a Lilly pneumotachograph, using peak flows varying from 100 to 700 l./min. produced voluntarily by one individual; from this he claimed to be able to estimate the true figures. His mean values for a "normal reference population" aged 40-65 and free of all apparent respiratory disability, translated into absolute units in this way, were about 600 l./min. for men and 450 l./min. for women. These results are difficult to compare with our own because of the very wide age group for which they are given, but they appear to be compatible with them.

Before we became aware of the pneumometer or of Goldsmith's work with the puffmeter, a quite different

type of instrument was developed for the same purpose. It seems to have some advantages over the pneumometer and the puffmeter in that it is simpler and more easily portable, and has a lower resistance at high flow rates.

The Peak Flow Meter (P.F.M.)

This instrument operates on different principles from any used hitherto for this purpose, being of the class of flowmeter known as a "variable area orifice meter," of which the best-known example is the rotameter (see Linford, 1949).

This type of meter has a number of advantages for respiratory measurements. It can make use of the fact that, although only a small resistance can be tolerated, an expiration has large volume, so that a very simple and robust instrument can measure rapidly changing flows with quite sufficient accuracy. Although the pressure drop at low flow rates is higher than that of plain orifice-type instruments it rises only ten times over the whole range from 100 to 1,000 l./min., so that at high flow rates the resistance is comparable to that of Goldsmith's puffmeter.

The principle of operation of the instrument is illustrated diagrammatically in Fig. 1. A cylindrical cavity about 5 in. (12.7 cm.) in diameter and 1½ in. (3.6 cm.) deep has a radial inlet nozzle (1), and contains a movable vane (2) pivoted in the centre of the cylinder and fitted closely without touching. A fixed partition (3) extends from one side of the inlet orifice to within a short distance of the boss of the vane, but again does not touch it. A spiral spring (4) attached to one end of the spindle of the vane tends to rotate it towards the

FIG. 1.—Diagram of peak flow meter. For key see text.

inlet orifice, a stop (5) preventing it from passing the orifice. A pointer (6) on the other end of the spindle indicates the position of the vane on a dial (not shown) and also serves to counterbalance it. An annular orifice (7) extends round the periphery of the cylinder at the back, from one side of the inlet orifice to the other.

It can be seen that when air is blown into the instrument it cannot escape (except for a small amount which leaks past the vane) until the vane has moved and uncovered part of the annular orifice. When the area of orifice uncovered is such that the pressure behind the vane is just sufficient to balance the force of the spring, the vane will come to rest in a position which will depend on the flow rate. Since for a given pressure the rate of flow is proportional to the area of the orifice, the deflection of the vane would be proportional to the air flow if the tension of the spring were constant. In practice, the tension of the spring increases with the deflection, so that the deflection is proportionately less at high flows than at low. This has the effect of

increasing the range of the instrument without loss of sensitivity at the lower end of the range, so that flows from 50 to 1,000 l./min. can be covered in one instrument.

The instrument is fitted with a ratchet which holds the vane and pointer in the position of maximum deflection. They can be returned to zero by pressing a release button.

The general appearance of the instrument, which weighs about 2 lb. (900 g.), and its method of use are shown in Fig. 2. The subject is asked to take a deep breath, as for a vital capacity, to place the mouthpiece in his mouth, and then to blow into the instrument as hard as he can. It is not necessary to try to empty the lungs, and it is undesirable to do so, because it is unpleasant and tiring, but a certain amount of "follow through" is required. After a couple of practice blows, three attempts in succession are recorded and the average is taken. This is statistically a more satisfactory procedure than

FIG. 2.—Peak flow meter, showing method of use.

simply taking the highest reading, although logically the latter would be preferable, since a maximum is being measured. Most subjects will give three readings which agree within 10% after the practice tries, but the observer must ensure that the subject is really trying his hardest. As with all ventilatory tests of this kind, including the M.V.V., failure to produce reasonably concordant readings usually indicates lack of co-operation.

The instrument is supplied with a plastic mouthpiece, which can be easily removed for washing and sterilization. Disposable cardboard mouthpieces are also available. A removable coarse-mesh gauze in the inlet nozzle prevents the ingress of large particles of sputum, etc.

Performance Tests

The P.F.M. was originally developed as a largely empirical device, and it has only recently been possible to arrange for satisfactory physical and physiological testing. Two forms of calibration have been used—with steady and with transient flows.

Steady-flow Calibration

Because of its low resistance the instrument can be easily calibrated by simply blowing air through it in series with a rotameter. Calibration in this way of an instrument with a dial graduated in degrees gives a curve of the form shown in Fig. 3. The curve does not pass through the origin, because even when the annular orifice is completely shut off there is some leakage round the vane; a certain minimum flow is therefore needed to deflect the vane against the spring. The exact

calibration of the instrument in this range is thus liable to be much affected by the accuracy of construction, so that steady-flow calibration is a convenient method of checking this point. Fig. 3 also shows the relationship between flow rate and pressure

FIG. 3.—Steady flow calibration curve of peak flow meter and pressure/flow curves with and without inlet gauze and mouthpiece.

drop through the instrument. At low flow rates the pressure drop is relatively high, but it rises only slowly with increasing flow rate. At high flow rates the fixed orifice component of the resistance comes more and more into play and the pressure drop increases more steeply. The additional resistance of the mouthpiece and gauze, of which the latter is the main component, is also more important at higher flow rates; this additional resistance has been found to be an advantage in practice, as it makes the instrument more comfortable to blow into, and it does not appreciably affect even high peak flows.

Transient-flow Calibration

The only instrument which can be used to test the ability of the P.F.M. to measure very transient flows is a pneumotachograph. As already noted, the one we have used is an enlarged version of that described by Lilly (*loc. cit.*), and gives an approximately linear response to flows up to 1,000 l./min. It has a resistance of 400-mesh gauze, 4 in. (10.2 cm.) in diameter, giving a pressure drop of 1 mm. H_2O /100 l./min. The entry and exit cones connect to tubes $1\frac{1}{4}$ in. (3.2 cm.) internal diameter, and the subject blows through a mouthpiece connected to the instrument by 10 in. (25.4 cm.) of hose of $1\frac{1}{4}$ in. (3.8 cm.) internal diameter. The overall pressure drop through the complete instrument, including the mouthpiece, is 1.5 cm. H_2O at 700 l./min.

A capacitance manometer is used to convert the pressure into an electric signal, which is suitably amplified and recorded by a "mingograf" spray writing pen. This instrument has a high-frequency response which sometimes makes its records difficult to interpret owing to the amount of "noise" recorded. It is therefore used with a 1 μF condenser connected across its input.

For technical reasons it is not convenient to connect the P.F.M. in series with the pneumotachograph. It has

also proved impossible so far to produce artificial peak flows of sufficiently smooth wave form for satisfactory recording by the pneumotachograph. The procedure, therefore, has been to ask a series of subjects to blow alternately into the P.F.M. and the pneumotachograph. Usually three blows into each instrument are used and the instrument to be blown into first is alternated between subjects.

Although this procedure is rather laborious and time-consuming it has the two great advantages that the calibration is carried out on actual human peak flows, and that the question of whether the resistance of the P.F.M. modifies the peak flow does not arise. On the other hand, the scatter of readings is increased because the two instruments are in fact measuring different peak flows; this scatter can be reduced by taking a large number of readings and averaging them, but with any practicable design of experiment the scatter from this cause is inevitably considerable.

Another difficulty that arises when an attempt is made to use pneumotachograph recordings to measure the peak flow rate is the practical definition of the term "maximum expiratory flow rate." Fig. 4 shows a drawing of a pneumotachograph recording of a typical normal forced expiration. It will be seen that in this case the definition and measurement of the maximum expiratory flow rate present no difficulty. Fig. 5, on the other hand, shows a type of record that is sometimes obtained from abnormal subjects, where the maximum

FIG. 4.—Normal type of forced expiratory curve.

FIG. 5.—Abnormal type of forced expiratory curve, showing method of deciding level of peak.

is in the form of a sharp "peak" which is sustained for only a very short time.

To take the top of a peak of this kind as the maximum is unsatisfactory for two reasons. First, the actual height of the peak is critically dependent on the characteristics of the recording instrument. Secondly, the volume of air represented by quite a large change in peak level is very small, so that it is likely to have little physiological significance. On both instrumental and physiological grounds, therefore, it has seemed to us better to ignore the top of the peak and to take a level of flow which is sustained for a definite time as being what we call the "peak flow rate" (P.F.R.). An interval of 10 millisees was chosen as being the shortest which lent itself to reasonably accurate measurement of the peak on a pneumotachograph record. The P.F.R. is therefore defined as the highest flow rate sustained for at least 10 millisees (cf. McKerrow *et al.*, 1958).

As can be seen from Fig. 5, although this definition is fairly easy to understand, the actual measurement of peak levels defined in this way sometimes presented some difficulty, owing to the steepness of the sides of the peak, even when recorded on paper moving as fast as 10 cm./sec. There was thus room for considerable observer error in making the measurement, but by averaging the results of a number of recordings fairly stable figures could be obtained.

A number of calibrations of different models of P.F.M.s were carried out in the way described, using a variety of subjects ranging from children of 4 years to healthy male adults capable of peak flows up to nearly 1,000 l./min. and also including many seriously disabled patients. It soon became apparent that, although the P.F.M. tended to underestimate the P.F.R. as recorded by the pneumotachograph, the relationship between its reading and that of the pneumotachograph was remarkably consistent.

The reason for the underreading of the P.F.M. is rather obscure. It is probably due chiefly to the fact that the instrument is highly damped and therefore fails to reach equilibrium in the short time available.

In view, however, of the high correlation obtainable between the P.F.M. and the pneumotachograph it seemed legitimate to aim at producing an instrument with a dial graduated in litres/min. peak expiratory flow rate. This would conceal to some extent the fact that the relationship between the P.F.R. recorded by the P.F.M. and that recorded by the pneumotachograph was not perfectly constant, and in particular the fact that it was liable to vary at different levels of flow and with different patterns of expiration, but such a loss of information seemed amply compensated by the simplification in the use of the instrument that would result. To have an instrument with a dial calibrated in degrees, or in "peak flow units," and supply various calibration curves to the user did not seem reasonable in view of the relatively small differences involved, especially for an instrument intended primarily for clinical use.

When carrying out the final calibration of the prototype production instrument, therefore, the procedure was as follows: A group of 20 normal subjects (male and female; ranging in age from 15 to 69), 10 children (male and female, ranging in age from 5 to 11), and 20 male patients (mostly suffering from pneumoconiosis, ranging in age from 30 to 70) was used. A much larger

and more heterogeneous group would obviously have been desirable, but the time and labour available for carrying out the calibration were unfortunately limited. Each subject made two practice blows, and then three blows into the P.F.M. and the pneumotachograph alternately, the order of starting being reversed after each subject. The calibration of the pneumotachograph was checked against a rotameter after each subject, and also by integrating some of the curves and comparing them with the forced expiratory volume (F.E.V.) recorded with a Gaensler (1951) type of apparatus. The overall accuracy of the instrument was considered to be $\pm 5\%$.

The steady-flow calibration of the P.F.M. was also checked at intervals, and was found to be constant within the limits of accuracy with which it could be determined—that is, about $\pm 2\%$.

Fig. 6 shows the result of the P.F.M./pneumotachograph calibration. The P.F.M. results are recorded in degrees, and each point is the average of the three readings. It can be seen that there is considerable scatter in the results, which for the reasons given above is inevitable, but a simple curve cutting the abscissa at 50 l./min., the point at which the P.F.M. ceases to record, can be quite easily fitted. The equation of this curve, for which we are indebted to Miss S. Findley, is $y = -20.6 + 0.39x - 0.000068x^2$, and the 5% confidence

FIG. 6.—Calibration curve of prototype peak flow meter, using human subjects.

limits are as shown on the graph. It will be noted that the points for the different types of subject tend to be grouped together, but the error resulting from assuming that the points are homogeneous is not large.

A curve of this form was used to prepare a dial reading directly in litres per minute peak expiratory flow rate, as shown in Fig. 2.

The instrument has now been in commercial production in various forms for about two years. When the final design incorporating the new dial had been in production for about three months, two instruments were taken from stock and rechecked against the pneumotachograph, using exactly the same procedure as before, except that a rather smaller number of subjects were used and the patients were different. Fig. 7 shows the results for one instrument, and it can be seen that the agreement is satisfactory. The results for the other

instrument were so similar that they have been omitted for the sake of clarity.

A batch of 100 instruments were made at an early stage for a nation-wide survey of bronchitis organized

FIG. 7.—Recheck calibration on production instrument.

by the College of General Practitioners. Many of these were rather unsatisfactory, owing to "teething troubles," but the faults were mainly mechanical and did not affect their calibration. The stability of this is illustrated in the Table, which shows single readings taken on 17 subjects with six instruments which had been in use for a year. (We are indebted to Dr. C. M. Fletcher for these figures.)

Peak-Flow-Meter Readings in Litres per Minute

Subject	Instrument Number					
	107	125	135	158	173	217
1	780	780	770	760	740	780
2	820	750	780	760	760	740
3	730	690	720	700	690	670
4	730	640	680	620	640	610
5	490	470	450	420	440	440
6	440	430	430	380	420	420
7	750	740	720	700	700	680
8	620	600	660	600	600	560
9	490	460	440	400	440	430
10	530	530	550	500	530	550
11	740	690	680	700	650	640
12	590	600	570	560	550	520
13	152	136	140	140	112	120
14	190	164	170	180	147	140
15	450	420	460	430	440	400
16	320	300	290	320	310	310
17	120	140	130	130	100	120
Mean	526	501	508	488	486	478

Clinical Value of P.F.R. and Relation to Other Tests

It is not the purpose of this paper to enter into a detailed account of the clinical use of the instrument, because our experience of its use in this way has been rather limited.

The prototype instrument was constructed in 1954, and since that time has been used continuously by Dr. C. M. Fletcher, of the Postgraduate Medical School, London, for clinical and survey work. Another early model of the instrument has been used in several surveys conducted by the Pneumoconiosis Research Unit; an account of one of these has been given by Higgins (1957).

Using an early but quite satisfactory model of the instrument, Higgins carried out some extensive studies amongst a normal population in an agricultural district. In a restricted group of males aged 55 to 64 he found that the correlation coefficient between the P.F.R. and the F.E.V. (0.75 sec.) was 0.86, and he also obtained figures for the distribution of normal values for men and women aged from 25 to over 65 years. These figures are of interest for comparison with those quoted earlier which were given by other workers using other methods, but two points must be borne in mind. (1) As the instrument he used was an early model it had not been calibrated against actual peak flows. The figures he quotes were obtained by using the steady-flow calibration, which was quite consistently 17% too low. His figures, therefore, have all been multiplied by 1.17 to convert them to true peak flows. (2) The population he studied was a sample of a complete population and so included a number of disabled persons. Even so, the average value for males aged 25 to 34 with no history of exposure to dust was over 700 l./min. About 25% have P.F.R.s over 800 and about 3% over 900 l./min. At the other end of the scale, he recorded flows below 50 l./min. in very disabled elderly women, but otherwise flows below 100 l./min. were uncommon.

The only data at present available for children (given in Fig. 6) suggest that they can produce flows over 100 l./min. as soon as they will co-operate sufficiently to give reproducible results—that is, usually at about 4 years of age.

Initially, the P.F.M. was looked upon as a more convenient but substandard method of measuring the F.E.V., which in turn is usually regarded as bearing the same sort of relationship to the M.V.V.

An attempt was made to study directly the relationship between the peak expiratory flow rate and the M.V.V., but the results were not very satisfactory. Since then the use of the M.V.V. has been practically abandoned by the Pneumoconiosis Research Unit, so no further opportunity of carrying out a direct correlation study has occurred.

Meanwhile, however, it has become apparent that the P.F.R. is quite a stable and reproducible measurement—so much so that it has been customary to check both the P.F.M. and the pneumotachograph by using the known values of subjects who have had a reasonable amount of practice.

As a result, the relationship of the test to others such as the M.V.V. or the F.E.V. has become of less interest. It is obvious that no single factor can be used to translate the P.F.R. into the M.V.V., any more than the same can be done for the F.E.V., although numerous attempts have been made to do so.

In this paper, therefore, the P.F.M. is put forward as a simple and reliable device for measuring the maximum expiratory flow rate during a forced expiration, which in turn is put forward as a stable and useful measure of ventilatory capacity. Only clinical experience can eventually decide whether it is as generally useful as the M.V.V. or F.E.V., or whether, if it is not, its lesser usefulness is to some extent compensated for by the greater simplicity and portability of the instrument used for measuring it.

Summary

The advantages of the maximum forced expiratory flow rate as a measure of ventilatory capacity are

considered and the history of the use of the measurement is reviewed.

A new instrument, the peak flow meter, for making the measurement is described, and an account given of the method of calibration.

The available figures for the range of normal values are reviewed, and it is noted that the figures obtained with the peak flow meter are much higher than those recorded by most previous observers using other methods.

It is suggested that the maximum forced expiratory flow rate ("peak flow rate") measured with the peak flow meter may be found to be a convenient and reliable way of estimating ventilatory capacity.

This instrument has been developed over a period of several years, and it is impossible to acknowledge the help of all those who have assisted us. We should, however, specially like to thank the following: Dr. J. C. Gilson and the staff of the Pneumoconiosis Research Unit who have assisted in innumerable ways, including offering themselves and their children as subjects on a number of occasions; Mr. V. Gubb, who made two of the early models; and Messrs. Fred Ferraris, who started commercial manufacture and contributed a number of useful features to the design. Mrs. M. McDermott gave much valuable advice and assistance on the physical problems involved in the testing of the apparatus. The calibrations against the pneumotachograph were carried out by Miss M. Collins and Miss P. Edwards, and the drawings were made by Mr. C. W. Couling, Miss M. B. Wilson, and Miss M. Jenkins. Finally, we thank Dr. C. M. Fletcher for arranging numerous clinical trials of the instrument and for his constant help and encouragement. The instrument is distributed by Messrs. Airmed Ltd., of 16, Wigmore Street, London, W.1, who also supplied the photograph.

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Ten scholarships have been awarded this year by the British Commonwealth Nurses War Memorial Fund, bringing the total awarded since the Fund was founded in 1946 to 94. Four of this year's scholarships go to nurses of the United Kingdom, and six to Commonwealth countries: Canada, New Zealand (two), India, Rhodesia and Nyasaland, and Malta. The four United Kingdom awards go to Miss ANNIE ALTSCHUL (principal sister tutor, Bethlem Royal and Maudsley Hospitals, London), Miss CHARLOTTE BENTLEY (general secretary, National Association of State Enrolled Assistant Nurses), Mr. C. SCOWCROFT (principal tutor, Pinderfields General Hospital, Wakefield), and Mr. O. HUGHES (deputy chief male nurse, Bexley Hospital, Kent).

CASE OF CONN'S SYNDROME

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The syndrome of potassium depletion and hypertension due to adrenocortical adenoma was first described by Conn (1955a, 1955b). It is characterized clinically by episodes of severe muscle weakness and paralysis, intermittent tetany, and paraesthesiae. Hypertension is the rule, polyuria and polydipsia generally occur, but there is no oedema. The principal biochemical features are hypokalaemia and a varying degree of alkalosis and hypernatraemia. An increased secretion of aldosterone can often be demonstrated, and Conn named the syndrome primary aldosteronism. There is selective impairment of urinary concentration and acidification, and histologically a distinctive tubular vacuolation results from hypokalaemia. An increased liability to urinary infection often leads to progressive renal damage.

About 20 cases have been reported in which an adenoma was found either at operation or at necropsy (Conn and Louis, 1956; Mader and Iseri, 1955; Eales and Linder, 1956; Chalmers *et al.*, 1956; Hellem, 1956; Campbell *et al.*, 1956; Milne *et al.*, 1957; Skanse *et al.*, 1957; Hewlett *et al.*, 1957; Russell *et al.*, 1956, 1957; Fine *et al.*, 1957; Brooks *et al.*, 1957; Kretchmer *et al.*, 1957; Crane *et al.*, 1956, 1958). In two other cases the syndrome was produced by adrenocortical hyperplasia (Wyngaarden *et al.*, 1954; van Buchem *et al.*, 1956) and in two patients a malignant adrenocortical tumour was found (Foye and Feichtmeir, 1955; Brooks *et al.*, 1957). In the following case of Conn's syndrome no increase in aldosterone production could be demonstrated and a firm diagnosis could not be made before operation.

Case History

A spinster aged 47 had several attacks of urinary infection at the ages of 20 and 33. Thereafter she remained well until February, 1955, when at the age of 45 she noted increasing lethargy and nocturnal frequency of micturition. In September, 1955, she developed severe weakness, affecting the legs particularly, with lumbar pain and paraesthesiae in the arms.

She was thought to have poliomyelitis, and was admitted to a fever hospital, where she showed photophobia, and tenderness and paralysis of the leg muscles with absent reflexes. Her blood pressure was 180/100. The illness proved atypical, with normal cerebrospinal fluid and negative virological investigations. She made a spontaneous recovery after six weeks and was discharged. Her lethargy, however, continued and she remained liable to recurrent episodes of weakness in the legs, and in May, 1957, a severe exacerbation occurred after a respiratory infection. She was admitted to the Bolingbroke Hospital, where the hypokalaemia was discovered. Serum electrolyte levels on admission were: potassium, 2.6 mEq/l.; sodium 142 mEq/l.; chlorides, 102 mEq/l.; alkali reserve, 32 mEq/l. She was very anaemic, with an Hb of 31%