motor, properly governed. Lines of light are recorded at definite intervals, *e.g.* two seconds.

(b) Air-speed recorder, simply a Pitot-Venturi nozzle attached to suitable pressure-recording capsules.

(c) Single component accelerometer, consisting in the main of a damped steel spring, one end of which is free.

FIG. 3.—Showing the curves of pressure on the entire surface of the rudder at various intervals during a left turn.

(d) Three-component accelerometer, a combination of three of the previous instruments. The sensitiveness of the three is adjusted corresponding to the amount of the acceleration to be expected.

(e) Angular velocity recorder, making use of a high speed electric motor as a gyroscope. The curves obtained by this give, when integrated, angular displacement, and when differentiated, angular acceleration.

(f) Three-component angular velocity recorder, a combination of three of the previous instruments.

(g) Control position recorder, consisting essentially of three spring-controlled spools threaded on an axial screw, each spool actuated by a wire leading to the horn of the control surface.

(h) Force recorder, using a carbon pile resistance method.

Of course all these instruments are not used at the same time, but only as many as are needed for the study of each particular question.

From a practical point of view these instruments allow the performance of an aeroplane to be recorded accurately, in a manner quite free from the personal impressions of the test-pilot; and, further, the records taken in any manœuvre tell a story which is perfectly plain. Numerous questions, often raised by pilots,

have already been answered, and pupil pilots have received great assistance.

The last research to be mentioned is one which is only beginning, but the apparatus has been carefully tested, and a few preliminary readings have been made. This refers to a new method of investigating the "scale effect." In the ordinary wind tunnel the forces and moments on a model of about one-twentieth the full scale are observed, and from these measurements deductions are made as to the promised performance of the full-sized aeroplane, or part thereof. It has been known for many years that in order for these deductions to be justified it would be necessary to have in the tunnel and in the flight of the actual aeroplane the same Reynolds's number, as it is called. This number is the fraction $\rho VL/\mu$, in which ρ is the density of the air, V is the relative velocity of the air-stream, L is a linear dimension of the aeroplane (or part), and μ is the coefficient of viscosity. It is clear that the Reynolds's number in the tunnel is about one-twentieth, or less, that of the aeroplane in flight. To obviate this, a complete wind tunnel has been installed inside an elongated steel tank—35 feet long, 15 feet in diameter—in which the air is kept compressed to 20 or 30 atmospheres (Fig. 4). The walls of the tunnel proper are hollow, and in this space the balances are installed, so as to, be out of the air-stream. The attitude of the model in the tunnel may be varied, and the balancing weights may be shifted, etc., by small

FIG. 4.—Compressed air wind-tunnel.

electric motors, controlled from outside the tank. Readings consist in viewing through suitable small windows a number of Veeder counters. The importance of this apparatus from the point of view of aerodynamics is sufficiently obvious, and from that of the aeroplane designer even more so.

Radiography and Physics.¹

By Dr. G. W. C. KAYE.

THE frail, untrustworthy X-ray tube of 1895 and the more robust and dependable tube of the present day do not differ in principle. The X-ray tube still remains a device for generating high-velocity electrons and suddenly depriving them of that velocity

by hurtling them against a target. In fact, the tube possesses all the characteristics of a battlefield, except that as yet we lack the ability to give our shells speeds of the order of 50,000 miles a second. Then, just as a flash of flame accompanies the sudden stopping of the shell, so do the X-rays set out in all directions from the target, travelling in straight lines just as

¹ Abstracted from the opening address to the Society of Radiographers, October 31, 1922.

light rays radiate from a lamp. The X-ray tube is, indeed, an X-ray lamp in which the applied voltage is analogous to the temperature of a luminous lamp. If we raise the temperature of the latter, we shorten the average wave-length; so with the X-ray bulb, if we raise the voltage the average wave-length is diminished.

In the light of present-day knowledge, what do we know to be the factors which control output from an X-ray tube? The radiographer is concerned more with the general or continuous spectrum of X-rays than with the superposed rays characteristic of the target. In regard to the former the factors are three: (a) The number of the cathode rays or electrons which strike the target; (b) the speed of the electrons; (c) the massiveness of the atom of the target. (a) is represented by the current through the tube, (b) by the voltage across the tube, (c) by the atomic weight or, more precisely, the atomic number of the metal of the target.

To what extent do these several features come in? To settle these points let us call in the aid of the X-ray spectrometer and vary each of the factors one by one. The spectrometer spreads out into a continuous fan of rays all the various wave-lengths present, and tells us, moreover, the amount or intensity of each wave-length. So that if we plot wave-length against intensity, we get a curve which clearly reveals the composition of the beam. Furthermore, the area of the curve is a measure of the output. If we do this, we find that the several spectral curves show that the X-ray output is proportional to the current, to the atomic number of the target, and to the square of the voltage.

We notice that the voltage comes in as a second-power term, and the importance of measuring voltage by the radiographer not sporadically but as a routine procedure day in and day out should be stressed. For the applied voltage has a dual importance: it not only dominantly affects the output, but it is the sole arbiter of quality or penetrability or wave-length.

The time is approaching when we must gradually relinquish the use of the terms "hard" and "soft" X-rays and accustom ourselves to speak of wave-lengths. For example, in deep therapy we can say that the spectrum of rays employed lies between 0.06 and 0.2 Å.U., the mean effective wave-length being about 0.15 Å.U. or less. The radiographer who uses point spark-gaps up to, say, 6 inches long employs a spectrum of rays ranging from about 0.12 to 0.4 Å.U., the mean effective wave-length generally lying between 0.2 and 0.3 according to the filter and nature of the high potential generator. We might make a beginning by agreeing, for example, that "hard" rays refer to rays with wave-lengths shorter than 0.1 Å.U., and that "soft" rays have wave-lengths longer than 0.3 Å.U., the intervening rays being of "medium" hardness.

Let us consider the career of an electron in an X-ray tube impelled towards the target with a velocity which it owes to the applied voltage V . The chances that that electron will ultimately come into suitable conflict with one or more atoms in the target and so generate X-rays are slight—about 1000 to 1. The energy of the electron is, in fact, much more likely

to be frittered away as heat. Assuming that the unlikely happens, one of two things may occur: the electron may lose all its energy at one encounter or it may do so by instalments in a succession of encounters. In other words, if we agree to think of its energy in terms of the original driving voltage (V), then it may lose the whole of V in one step or do so in a number of steps.

Now Planck's quantum relation tells us that whenever an electron has its speed altered the wave-length of the X-ray produced is inversely proportional to the energy given up by the electron; that is, to the equivalent loss of propelling voltage. It will be noted that no question arises of the nature of the target. To put it another way:

$$\left(\begin{array}{c} \text{Loss of propelling} \\ \text{voltage on electron} \end{array} \right) \times \left(\begin{array}{c} \text{Wave-length of} \\ \text{resulting X-ray} \end{array} \right) = \text{const.}$$

In those encounters where the whole of the energy of the electron is transferred in one fell swoop, the shortest-waved X-rays possible to that voltage will be generated. They will be accompanied by a variety of longer waves depending on the varied experience of other electrons, but always a short-waved limit is set by the magnitude of the full exciting voltage.

We are led to appreciate a number of other results. It is seen at once why we do not get (as was once imagined) homogeneous X-rays when a tube is excited by constant potential, and where all the electrons reach the target with the same velocity. Nevertheless, we should expect that the proportion of short waves would be greater with constant potential than it would be with fluctuating potential, the peak value of which is equal to that of the constant potential. Furthermore, from what is known of the effect of voltage on output, we should anticipate a greater X-ray output (and less heating of the target) with a constant voltage than when that voltage is diluted with lower voltages. Both these surmises as to the superior efficacy of constant potential are confirmed by the X-ray spectrometer.

With reference to the existence of a minimum wave-length or boundary to every spectrum of general X-rays, this is fully borne out by spectrometer measurements and photographs. Numerically, Planck's relation becomes:

$$\left(\begin{array}{c} \text{Minimum wave-} \\ \text{length in Å.U.} \end{array} \right) \times \left(\begin{array}{c} \text{Maximum} \\ \text{voltage} \end{array} \right) = 12,350.$$

This very simple relation provides us with a scale of quality which, if not perfect, is more exact than any which the radiologist has been in the habit of using. If we glance at typical spectral curves of X-ray emission, we see that they are not symmetrical—the centre of gravity of the curve is well towards the quantum limit—the shortest waves are the dominating ones, and still more so if the rays are subjected to normal type filtering. The mean effective wave-length of a spectrum of rays is seen to approximate to the wave-length of the peak of the curve; that is, the wave-length of maximum intensity. Now, there is some evidence that the "peak" wave-length is proportional to the limiting or quantum wave-length, and this fact enables us so to identify very fairly the quality of a mixed bundle of X-rays. No doubt something depends on the wave-form of the exciting potential, but the

effect of this is probably less important as the voltage is raised. The precision of the method would be enhanced if steps were taken to standardise apparatus and technique, so that all work could be done by the use of, say, three or four spectra the distinctive features of which, including energy distribution, could be determined and specified.

Among the other interesting aspects of the X-ray tube is the distribution of the rays in different directions from the target. With the usual 45° target the rays are most intense at right angles to the cathode ray beam. For radiographical purposes it is often better to mount the target face more nearly at right angles to the cathode beam and thus employ a pencil of rays which leaves the target face at a relatively small angle. The width of the focal spot is thus foreshortened and definition enhanced.

If penetrating power is the important factor, then we may well endeavour to utilise the X-rays leaving the tube in the direction of the cathode rays, which X-rays are of appreciably shorter wave-length than in other directions. Thus a tube in which the target also served as a metal window would offer advantages on this score.

The proper choice of filter may do much to increase the effectiveness of a tube. For example, it is known that, weight for weight, silver is relatively more transparent than lead to short waves, but is relatively less transparent to longer waves. Again, copper is relatively superior to aluminium in letting through short waves, but relatively inferior as a filter if long waves are required.

What has the future in store for us as regards X-ray tubes? Higher voltages are coming—one hears rumours of 500,000 volt tubes in Germany; and both the United States and Germany have, I understand, developed transformers giving 1 million volts. The life of 200,000 volt tubes is none too long; there will be many difficulties to overcome before a 500,000 volt tube will become a practical proposition.

A crying need is more robustness in the X-ray tube, which must become more of an engineering job. The portable Coolidge tube with lead-glass walls $\frac{1}{4}$ inch

thick and a window of soda-glass for letting out the rays is to be commended on this score. Equally robust is the new miniature dental tube of similar design which measures only 4 to 5 inches long and has a diameter of about $1\frac{1}{2}$ inch. It is operated at 45,000 volts and 10 milliamperes, is mounted in the same oil-tank as the transformer, and gives excellent definition. It also contributes substantially to the protection which the radiographer has a right to demand. In this connexion we may confidently look forward to a time at no very distant date when, in the interests of the operator, all protective material and apparatus shall be certified by the National Physical Laboratory. This will be realised when I mention that different makes of lead-glass on the market differ by 100 per cent. in protective value. The same remark applies to lead-rubber.

What should be our ideal in radiography? To make the process as simple and noiseless as taking an ordinary photograph. The patient should hear nothing untoward, the apparatus should look no more formidable than a camera. Spark and brush discharges should be taboo; the rumble of rotating machinery anathema. Standardised technique must be the order of the day for much of the radiographer's work. The number of variables must be cut down.

It is possible that the future may witness the fuller development of the metal X-ray bulb of a design radically different from the present. Much work is being done on them at the present time. But in almost every section of a radiographer's X-ray equipment there is room for great improvement. How low the efficiency is may be gathered from the following. We may take it that the efficiency of the high-tension generator is of the order of 50 per cent., that of the X-ray bulb $1/1000$. We may assume that half the rays emitted by the bulb are utilised, that half these useful rays are arrested by the object, and that 1 per cent. of the remainder is recorded by the photographic plate or screen (rather more, say 5 per cent., if an intensifying screen is used). Thus the overall efficiency of an X-ray equipment is of the order of 1 in 800,000.

An Inquiry into Dog Distemper.

FOR some considerable time it has been felt in this country that an investigation might be undertaken with advantage on the mystery of dog distemper, and the matter has recently been brought to a head by an appeal from the editor of the *Field* to dog lovers. A considerable sum of money has been promised, and the Medical Research Council has undertaken to organise an experimental inquiry with a view of finding out the causal agent of the disease and possibly a prophylactic. As announced in *NATURE* of March 10, a committee has been appointed under the chairmanship of Sir William Leishman, the other members being J. B. Buxton, S. R. Douglas, F. Hobday, and C. J. Martin. Other workers, it is suggested, will be co-opted for special investigations later on.

Distemper is an acute highly contagious disease, presenting symptoms somewhat analogous to measles in man. While some have regarded it as specific for the

dog, others consider that it occurs in cats, young foxes, wolves, jackals, hyænas, and even monkeys. From its contagiousity it is certain that the cause is a microbe of some kind, which, however, has hitherto remained unmasked. Indeed, there is very little real scientific knowledge extant on the disease. This is in part, at any rate, due to the fact that what veterinary surgeons and the laity call distemper is almost certainly not one but several different diseases. That one of these is the specific disease distemper is, however, very probable.

At present the concept of "distemper" is entirely clinical. Thus, one finds descriptions in the literature of catarrhal, gastric, nervous, and exanthematic types of the disease. There is a great body of evidence to show that one attack of the malady confers a durable immunity on the survivor. The disease occurs in all countries and was apparently known in antiquity. On the other hand, there is a tradition—it is little more—