an experimental art, conducted for the scientist and inventor rather than for the home user.

How Television is Now Conducted.

THE television signals, now being radiated, are obtained by setting a subject before a bank of flood lights. A scanning disc is used at the transmission point which reflects light from the subject point by point in a regular predetermined order to a photoelectric cell. The photoelectric cell may first "look" at the upper right hand corner of the subject as impression number one. Light is reflected on a photoelectric cell through a tiny aperture from that point in the image. As a result, an electric current, proportionate to the intensity of light reflected from that point, flows through the photoelectric cell. The disc scanning hole then moves slightly to the right, making a second impression, and so on, point by point, an electrical impression is made of the top line of the picture. Where the subject is black, little light is reflected, and little photoelectric current flows; where it is white, such as in a white background, much photoelectric current flows, producing maximum modulation.

Having swept across the upper line of the subject, the second hole of the scanning disc falls into line and makes a series of impressions immediately underneath the first. This is continued for as many "sweeps" of the subject as the scanning system contemplates. For example. WGY is radiating signals for a 36-hole disc so that there are 36 sweeps of the subject for one complete impression: the Jenkins system, using short waves, is making 48 lines.

Fundamental Limitation to the Entertainment Vale of Television.

Inasmuch as all of these systems (there are no exceptions to this rule) depend upon reflecting a beam of light from the subject to a photoelectric cell, the range of the "eye" of television is necessarily limited. The subject must be sufficiently close so that a beam of light reflected from it will cause a change of electric current through the photoelectric cell. For a standard potassium photo cell, this range is limited to about one foot, and this fact is the reason that so far only faces have been "televised" with its aid. The public imagines football games and prize fights coming before its eyes through television scanning discs, but the most we can hope for, at the present time, is profiles and full front views of single faces. If we attempt to crowd two faces before a television scanning disc, the number of images gathered is so few that the faces become unrecognisable.

A FEW weeks ago, the Bell Laboratories showed an improved photoelectric cell which permitted, for the first time, the scanning of a full-size human figure. This was used in connection with the same television transmitter and receiver which had been shown with such acclaim to the world nearly a year and a half previously. Among the elements of the reproducer are synchronising devices, a neon tube with 2500 pairs of elements and a room full of control instruments. At the recent demonstration, the statement of Walter S. Gifford, president of the American Telephone and Telegraph Company, which was originally made nearly two years before, was again given out stressing the fact that television is far from the point where it may be introduced into homes. "The elaborateness of the equipment required," says Mr. Gifford, "by the very nature of the undertaking, precludes any present possibility of television being available in homes and offices generally." All of the limitations of channel shortage and lack of detail, more fully described in subsequent paragraphs, apply to television transmission with the more sensitive cell.

One by one these problems may be overcome, but to the engineer who understands them it looks like a matter of many years.

At the receiving end, we obtain an electric current similar to that flowing through the photoelectric cell at the transmitting point, through the usual transmission and reception processes. When these currents are sufficiently amplified, they are applied to a neon tube. The intensity of the light of the neon tube then varies exactly as the light reflected on the photoelectric cell through the scanning system. Considerable amplification is required to cause the neon tube's light output to fluctuate visibly in this manner, and no system has yet been demonstrated which does not need at least a five-stage audio amplifier to make even a powerful television signal cause the neon tube to fluctuate sufficiently to make a visible image reproduction.

But this is not the most important problem. Experimenters can make five-stage audio amplifiers work. The image is reconstructed at the receiving point by watching the neon tube through a series of pinhole apertures in a revolving scanning disc. The receiving scanning disc must be precisely similar to that used at the transmitter to set up the image. If an attempt is being made to reproduce the face at the transmitting end in 1 x 1 size at the receiving end, the scanning disc consists of a spiral of holes an inch apart. The neon tube at the receiving end should have a plate of at least 1 x 1 size so that the image can be reproduced.

> **". . . for the present, universal television consists merely of moving shadows, at best. However, backed up by sufficient broadcasting, even moving shadows can be merchandised . . . provided they are merchandised as such . . ."**

At the precise instant that the upper left-hand corner of the subject at the transmitter is being "examined" through the hole in the scanning disc by the photoelectric cell, the scanning disc at the receiving end must also be "looking at" the upper left-hand corner of the plate of the neon tube. Both discs must then sweep across the top line of the picture in exact synchrony, the receiving disc completing its one-inch trip across the plate of the neon tube at the same rate that the scanning disc at the transmitting end makes its sweep of the top subject. The neon tube at the receiving end fluctuates in intensity with the shading of the picture. This perfection of synchrony must obtain while 24, 36, or 48 apertures pass over the subject at the transmitting end and over the plate of the neon tube at the receiving end each sixteenth of a second.

THE importance of perfect synchronisation cannot be over-estimated. The most advanced public demonstration of television, so far given, was that made by the Bell System two years ago. This made a picture of 50 screen, one inch square, or a total of 2500 image points per picture. The impression was enlarged to motion-picture screen size by means of a neon tube consisting of 2500 pairs of elements. Each of these was mechanically switched in, one at a time, sixteen times per second, by a rotary contact switch. This amounted to a total of 40,000 contacts per second, and each contact had to be accurate within a forty-thousandth of a second so far as time is concerned. This remarkable result was obtained by using two separate synchronising signals sent on short wave channels.

The difficulties of manual synchronisation which is being attempted by television systems having no specific means of synchronisation, can best be appreciated by imagining what the result would be if the motor used at the Bell System demonstrations were slightly off speed. At correct cynchrony, let us suppose, the motor operating the 2500 contacts revolves at 2000 revolutions per minute. It makes 2,400,000 contacts per minute, each at the correct instant. Suppose the motor ran off speed five parts in ten thousand, which would make the motor turn 2001 r.p.m. instead of 2000. Every sixteenth of a second, then, 2512 contacts would be closed instead of 2500, and the second picture would already be 33 1-3 per cent. off synchrony, so that the image would not be recognisable for more than one sixteenth of a second. Those now experiencing difficulty in the hand operation of a d.c. motor by means of a rheostat, must appreciate they are attempting manually to stabilise the speed of a motor within ten thousandths of a per cent.

SOME systems contemplate the employment of sixty cycle alternating current with power lines as the means of synchronising. This may be satisfactory when the listener is on the same power line as the broadcasting station radiating the television signal. In that case, both the transmitter and receiver use synchronous motors, operating from the same power source. Where there are rural and d.c. districts involved, or non-interconnected and non-synchronised power lines, synchronisation by this method is uncertain. The claim is made by some, however, that current from independent power systems is sufficiently close to rated frequency to permit the synchronisation of television from any sixty-cycle line.

Electric clocks are simply small synchronous motors operating from sixty-cycle a.c. It is the practice of power houses to check the time with Western Union each hour and to speed up or slow down the alternators so as to make up for the loss or gain in cycles experienced. Since we require accuracy of one part in 10,000 to hold a reasonable image for a fraction of a second, it is obvious that there is considerable variation in "60" cycles. Only if special arrangements were made among alternating current power systems to maintain absolute synchrony, a condition not yet obtaining, can there be any widespread use of a.c. synchronization for television.

In the New York area, for example, there are, within twenty miles of the metropolitan district, at least six unsynchronized alternating power systems and two important direct current areas, each of which would require special broadcast transmission which would not be interchangeable with the other districts. Practical and widespread television is not attainable until synchronizing signals are radiated with the television transmissions or crystal oscillators of sufficient stability to be accurate to one part in a million are available at low cost.

THE next point to consider is the availability of channels for television reception. The ideal would be to transmit television occasionally through ordinary broadcasting stations so that the ordinary receiver could be used and so that the television programme could be associated with musical entertainment. Our broadcasting structure has been designed for a maximum modulation of 5,000 cycles, making possible the arrangement of a spectrum with ten kilocycle separation. Most of the television promised in the broadcast band does not fit within these channel limitations.

It is easy to calculate the frequency band required by a television transmission using the usual scanning disc having a single spiral of apertures. These discs usually rotate at 960 r.p.m., that is, one revolution each sixteenth of a second. The maximum number of impressions made by a single sweep of the subject is usually equal to the total number of holes in the disc. Thus, with a 24 hole scanning disc, which is the fewest number of sweeps of the subject to which even the simplest profile can be reduced, each sweep of the subject makes 24 image impressions on the photo-electric cell and the entire subject therefore consists of 24 x 24, or 576 impressions. With the meagre illumination afforded in the five hundredth of a second or less that the subject is illuminated at the receiving point, eighteen or twenty images per second should be used rather than the usual sixteen used in motion picture practice, where every detail of the reproduction remains illuminated on the screen for at least one thirtieth of a second. The total number of impressions per second is the product of the number of holes on the disc and the number of revolutions per second. In the case of a 24 hole disc making sixteen revolutions, 9216 images per second are sent. Since there are upper and lower side bands in transmission, a frequency space of twenty kilocycles is required for modulation, infringing upon at least three broadcast channels. With a 48 hole disc, revolving at 16 r.p.s., about seven broadcasting channels are used.

SEVERAL attempts to circumvent the carrier channel difficulties have been made by ingenious inventors. Senabria, co-operating with WCFL of Chicago, uses a scanning disc with three sets of spiral apertures so that his disc revolves at one-third the usual speed. He makes a fifteen line picture, each picture consisting of a scanning, of only one-third of the subject, but, by slightly displacing each image, covers the area of a 45 line picture. The same effect would be secured with a 45 hole disc operating as follows:—During the first rotation of the disc, the first, fourth, seventh, tenth, etc., holes would sweep the disc, the others being for the time closed; during the next revolution, the second, fifth, eighth, eleventh, etc., would sweep the disc; and in the third revolution, the third, sixth, ninth, and