change. The arrangement is illustrated in fig. 15, where C represents an exchange from which wires radiate to the points *a*, *b, c, d, ...* Suppose *a* wishes to speak to *d* ; he communicates his wish to an attendant at C, who first calls *d,* and then con­nects 6 to 1, making the circuit continuous from *a* to *d.* The ar­rangements at the ex­change for facilitating connexions vary con­siderably, but are simi­lar in principle to the switch boards used in telegraphy. Each of the

wires is first brought to an indicator and then to a set of terminals arranged in an orderly manner on a board, the number of the terminal for any one wire being the same as the number under the shutter of the indicator in that wire circuit. In many cases the terminals take the form of spring clips, which connect the line to earth, and under which a thin piece of metal, covered with insulat­ing material on one side and called a “jack,” can be readily inserted for connecting that circuit with any other. A piece of flexible wire cord, carrying a jack at each end, forms a ready and common medium of connexion ; but in many cases the switch board is arranged with cross strips of metal so that by inserting a jack into the terminals of the two wires they can be both connected to the same strip of metal and therefore together. In large exchanges one switch board of moderate size is not sufficient, and so a number are fitted, being connected together by several conductors, in order that no interrup­tion may ensue in consequence of these being all occupied. A line on one board is connected with one on another board by joining the terminal of the first to one of the conductors connecting the two boards by a jack-cord, and then by another jack-cord connecting that conductor to the terminal of the other line. Thus different switch boards may be looked upon as separate exchanges, connected together by a number of trunk wires after the manner described below.

In a large system it is much more convenient and economical to have exchanges in the various districts, and connect these with a central exchange by a sufficient number of trunk lines. A sub­scriber in one district wishing to speak to a subscriber in another calls the exchange in his own district and is put in communication by the attendant stationed there with the central exchange. The attendant at the central exchange puts the subscriber in communi­cation with the district he requires, and the attendant there calls the other subscriber and joins the two subscribers’ lines together. In some cases neighbouring district exchanges have, besides a com­mon means of communication through the central exchange, an independent connexion. These arrangements are diagrammatically

illustrated in fig. 16, where 1, 2, 3, 4, 5, 6 represent district ex­changes and C the central exchange ; districts 3 and 4 and 4 and 5 are supposed to have independent connexions.

An arrangement was proposed about two years ago by Mr D. Sinclair of the Glasgow telephone exchange for allowing small dis­trict exchanges to be worked by the attendants at the central ex­change.@@1 The two exchanges are connected by a trunk line and from the district exchange wires are led to the different subscribers. These wires are in the normal state of matters connected with con­tact plates, over which an arm joined to the trunk wire can be made to travel. Suppose the central exchange wishes to speak to any one of the subscribers, the arm is made to travel round, by currents sent from the exchange through an electromagnetic step by step arrangement, until it comes in contact with the proper plate, after which the subscriber is called in the ordinary way. When one subscriber belonging to the district exchange wishes to speak to another in the same district, he rings the bell in the ordi­nary way, and this operation disconnects all other subscribers and puts him in connexion through the trunk line with the central ex­

change. The attendant there ascertains to whom it is that he wishes to speak, and by moving round the contact arm puts tho two subscribers’ lines in contact.

The indicator, or annunciator as it is sometimes called, is shown in fig. 17. It consists of an electromagnet M, which on a current being sent through it pulls down the armature *a,* relieves the catch *c,* and allows the shutter *d* to fall down, exposing a plate *p,* on the front of which the number of the subscriber is printed. When the exchange is called, the shutter *d* is dropped, the attendant connects the line leading to the exchange table with the ter­minal corresponding to the indicator, and finds who is wanted ; then he calls that subscriber, makes the through connexion, and puts up the shutter. When the subscribers have finished, both call the exchange or, as it is commonly put, “ring off”; this drops both shutters and serves as the signal that they have finished speaking.

The principle of transmitting sound by the radiophone will be understood from fig. 18. M represents a mirror, from which a beam of light is reflected through the lens *l* to a second mirror *m,* and *m* forms a diaphragm against the back of which the sound vibrations sent through the tube *t* are made to impinge. The beam of light, after being reflected from *m,* passes through the lower lens Z, and thence as a nearly parallel beam to the parabolic reflector R. A photophonic receiver P, sup­posed in this case to be a spiral of selenium wire wound on the surface of a cylinder, is placed at the focus of the reflector so that the beam of light from *m* is concentrated on it. In circuit with the receiver P a battery B and a telephone T are included and through the circuit a feeble electric current flows continuously. The photophonic receiver should be placed so as to receive as little light as possible from any other source than the mirror *m.* Words spoken through the tube *t* make the mirror *m* vibrate, so that the beam of light reflected from it becomes more or less spread. The lens *l* is then unable to bring the beam into parallelism, and the intensity of the reflexions from R to P is varied, therefore also the current through the coil of the telephone, which in consequence gives out a sound. The amount of spreading of the beam being proportional to the intensity of the vibrations of *m,* and this again proportional to the intensity of the sounds, the sounds heard in the telephone are similar to those pro­duced at the end of *t*. Theoretically the receiver may be at any distance from the transmitter, but considerable difficulty arises if the distance is great.

One of the simplest forms of the phonograph is shown in fig. 19. It consists of a rigid spindle S screwed for about one-third of its length, and fitted to work smoothly but tightly in the frame *f, f,* which is se­curely attached to a sole plate P. On the spindle a drum D is fixed, the axis of which coincides ac­curately with that of the spindle. On the surface of the drum a screw is cut of precisely the same pitch as that on the spindle. A fly-wheel W is fixed to one end of the spindle, and is provided with a handle H, by which the spindle and drum can be conveniently turned. One of the bearings has either a screw thread cut along it, or is fitted with one or more studs which work easily, but without shake, in the screw thread. When the spindle is turned, it receives a trans­verse motion, and a point fixed relatively to the sole plate P and touching the drum traces out a spiral on its surface, exactly coin­ciding with the screw thread cut on it. A mouthpiece M, like that of a telephone transmitter, provided with a diaphragm of parch­ment or similar substance, is mounted on a lever, which is pivoted at *h* and provided with a set screw *b.* A blunt needle point is either fixed to the centre of the diaphragm or carried by a light spring in such a way as to press on the centre of the diaphragm with the needle point projecting outwards. To use the instrument, the drum D is covered with a sheet of somewhat stiff tinfoil, and the mouthpiece is adjusted as shown in the figure, with the needle point over the hollow part of the tinfoil, and fixed by the set screw to make a slight indentation in it. The drum is then turned and words spoken in a somewhat loud and clear tone in front of the

@@@1 See *Proc. Phil. Soc. of Glasgow,* vol. xvii. p. 39.