lines, which in most cases does not require to be attended to in ordinary telegraph circuits, is the induction from one line to an­other (see Electricity, vol. viii. p. 76 *sq.* ). When two lines having, as in ordinary telegraphy, an earth connexion at each end run for any great distance, say a mile or more, parallel to each other on the same supports, a conversation which is being carried on through one of them can be overheard by means of the telephones on the other. This is due to the fact that, when a current is suddenly set up in one closed circuit, it induces an instantaneous current in any other closed circuit which is near to it. This induced current not only destroys the privacy of the circuit in question but also lowers its efficiency. The mischief is even greater when telegraph and telephone lines run along the same route supported on the same poles, because the strong intermittent currents sent through telegraph wires, and the irregular manner in which the intermit­tences follow each other, induce a series of such powerful secondary currents in the telephone lines that the noise heard in the tele­phone is often sufficient, when the line is a mile or two long, to drown all speech. In the case of parallel telephone lines the best, if not the only, cure is to use return wires, and arrange them so that the currents induced in the outgoing wire shall be neutralized by the corresponding current induced in the incoming wire. For mixed telegraph and telephone circuits various methods have been pro­posed ; but the most generally approved plan is to have return wires. For circuits worked wholly on the return principle the main thing to be attended to is the symmetrical arrangement of the wires, so that the outgoing and incoming wires may be subjected to the same influence. This is nearly provided for by running them in such a way that they may be all supposed to lie on the surface of a cylinder in lines parallel to its axis, the two wires at the opposite ends of a diameter being always used for the same circuit. When more than four wires form the group complete compensation is not obtained in this way, because the current is always stronger near the transmitting end of the line than near the receiving end, on account of the very sensible effect of the capacity and the leakage of the line. It is therefore best to arrange the wires in groups of four —that is, in pairs of circuits—and run them so as to form spiral lines round an axial line equidistant from each of the four wires. Any pair of wires forming a circuit which runs parallel to other wires can be arranged so as to be very nearly free from induction by interchanging their position relatively to the other wires at short distances along the line. Care must, however, be taken, when more than one group of four or when more than one pair are run, that the compensation produced by the twisted arrangement of one set, or of the interchanges of the wires in the different pairs, is not spoiled by the twisting or interchanging of another set or pair. Telephone lines running parallel to telegraph lines should be formed into one or more groups, each being run on the twist plan so as to eliminate as completely as possible the effect of the telegraph signals ; the small residual effect of the telephone signals is of comparatively little importance in such a case. A twisted cable of telephone wire may, when each circuit is formed by diametrically opposite wires, be placed in the same tube with similar cables employed for telegraph purposes. The central wire of the cable may be used either as a telegraph line or as a telephone line having an earth return. Another method is to use powerful telephone transmitters and insensitive receivers ; that is to say, make the telephone currents so powerful that the telegraphic induced currents will be small in comparison, and use receivers so insensitive as to suit such currents. One of the main obstacles in the way of this method at present is the difficulty of getting strong telephonic currents, for even the best transmitters are not yet sufficiently powerful, and there is, besides, a decided tendency towards a loss of quality in the sound when the transmitter is made powerful. A third method is to render the telegraphic current comparatively harmless by taking away the suddenness of the intermittences. This is quite possible because the number of currents sent per second, even on fast working circuits, is not such as to produce a high musical note. If, then, the currents be made in some way to rise slowly to their full strength and fall again slowly to zero the diaphragm of the receiving instrument, instead of showing the sudden rise and sudden fall as at present, would move so slowly backwards and forwards that the ear would not be disturbed by the sound. Perhaps the simplest way to accom­plish this is to place an electromagnet in the circuit of the tele­graph line at the sending station, for the self-induction of the magnet coil prevents the current assuming its strength suddenly. But on telegraph circuits where speed is of great importance this method cannot be followed owing to the retardation of the telegraph signals and the consequent loss of speed thereby occasioned.

An ingenious application of the method of compensation just indicated has been made by Rysselberg, who has used not only wires carried on the same poles as the telegraph but even the telegraph lines themselves for telephone purposes. The arrangement of his system is shown in fig. 14, where L and L1 represent two telegraph lines. Between these, at each end, are inserted two condensers C1, C2 and a telephone T, together with transmitters, &c., so that, supposing the telegraph instruments removed, the two wires would

be an ordinary telephone circuit worked through condensers. The telegraph apparatus consists of an ordinary receiver R, sending battery B, and key K, together with a con­denser C, inserted be­tween the earth and the line terminal of the key, and two electromag­netic. inductors E, E'.

When the key is de- pressed the current is

retarded by the electro- magnet E and the con­denser C, which has to be charged, giving in

fact additional electro- static capacity at the

sending end of the line. The current is still

further retarded by the electromagnet E' ;

hence the condenser C1 becomes charged so gradually that very little disturbance is noticeable in the telephone T. The condensers C1, C2 prevent leakage from one line to the other, but have suffi­cient capacity to allow the telephone to act as if it were in a metallic circuit.

*The* *Working of Telephone Circuits.*

The method first employed for working a telephone line was extremely simple. A single line of wire, like an ordinary telegraph line, had a Bell telephone included in it at each end and the ends were put to earth. Words spoken to the telephone at one end could be heard by holding the telephone to the ear at the other. To obviate the inconvenience of placing the telephone to the mouth and the ear alternately, two telephones were commonly used at each end, joined either parallel to each other or in series. The con­trivance most generally adopted for calling attention is the call bell, rung either by a small magneto-electric machine or by a battery. The telephone was switched out of circuit when not in use and the bell put in its place, an ordinary key being used for putting the battery in circuit to make the signal. This arrangement is still employed, a hook being attached to the switch lever so that the mere hanging up of the telephone puts the bell in circuit. In some cases, when the bell is rung by a magneto machine, the coil of the machine is automatically cut out of circuit when it is not in action, but the turning of the handle moves a centrifugal arrangement by which it is thrown in.

At first it was usual to employ the same instrument both as trans­mitter and as receiver, and to join it in the direct circuit. But it was soon found that the microphone transmitter could only be used to advantage in this way when the total resistance of the circuit, exclusive of the microphone, was small compared with the resistance of the microphone,—that is, on very short lines worked with low resistance telephones. The transmitter on long and high resistance lines worked better by joining indirectly in a local circuit, in the manner shown in fig. 13, the microphone, a battery, and the primary of an induction coil, and putting the line in circuit with the second­ary of the induction coil, which acted as the transmitter. The resistance of the microphone can thus be made a large fraction of the total resistance of the circuit in which it is placed ; hence, by using considerable currents, small variations in its resistance can be made to induce somewhat powerful currents in the line wire. The requisite energy is derived from the battery. If there are other resistances in the circuit it is, in some cases, better to join it as a shunt to the primary circuit of the induction coil. It may even prove advantageous to insert resistances in the circuit, increase the battery power, and join the microphone as here indicated, because in this way powerful currents can be obtained in the line without the harshness which is apt to be produced by the variations of a strong current passing through the microphone.

Translation from one line to another, or from one section to another of the same line, is effected by putting the primary of an induction coil in the place of the receiving telephone, the secondary being in circuit with the second line or section. This plan is use­ful where the same message is to be sent to different places at once (distributed), and is sometimes used for translating from a double wire to a single wire system. Probably a better plan is to work a microphone by the membrane of the receiving telephone, and re­transmit the message, taking new energy from a second battery.@@1 When the induction coil arrangement is used for translating from a double to a single wire circuit, or *vice versa,* it is necessary to make the induction coil suit the circuits, so that either coil may be used as primary, according to the end from which the message is sent. Everything else being similar, the resistances of the coils should be in nearly the same ratio as the resistances of the lines in which they are placed.

In a large town it is neither practicable nor desirable to connect each subscriber directly with all the other subscribers, hence a system of “ exchanges ” has been adopted. An exchange is a central station to which wires are brought from the different subscribers, any two of whom can be put in telephonic communication with each other when the proper pairs of wires are joined together in the ex-

@@@1 See Thomson and Houston, *Tel. Journ.,* 15th August 1878.