lines. This arrangement permits particulars of calls to be passed over lines while conversations arc in progress.

*Automatic Systems.—*The idea of automatic telephony is to substitute for the operator of the manual exchange an electro­mechanical or other switching system, which, controlled in its movement by the action of the subscriber, will automatically select, connect and disconnect circuits as desired. Several schemes em­bodying this idea have been developed, and one of them has been put into extensive operation. Each subscriber’s circuit on this system terminates upon the incoming portion of a selector switch, called a first selector, and is multipled upon the outgoing portions of a number of similar switches called connector switches. Only calls originated by a subscriber pass through the selector switch (first selector) provided for his sole use; the calls incoming to him pass through one or other of the various connector switches upon which his circuit is multipled. Each connexion involves the use of three switches, viz., a first selector, a connector switch, and a second selector which is brought into operation between the other two.

The subscribers’ lines in an exchange are arranged in groups of 1000, which are divided in turn into sub-groups of too each. By means of his first selector the circuit of a calling subscriber is connected to the outgoing end of a junction whose other end terminates upon the incoming portion of a second selector in the thousand group to which the wanted subscriber belongs. The second selector in turn extends the connexion by means of another junction circuit to one of the connector switches in the hundred group wanted, while finally the connector switch completes the connexion. One hundred circuits arc connected to the outgoing portion of each switch, and the contacts upon which they terminate are arranged in a number of horizontal rows upon the face of a curved surface, at whose axis a vertical shaft is placed. This shaft, which carries a set of “ wipers ” connected to the incoming circuit, is susceptible of a vertical and a rotational movement, so that the wipers may be brought, first opposite any particular horizontal series of contacts, and then into actual contact with any particular set in the series. The movements of the shaft arc con­trolled by relays and electro-magnets which operate in response to the action of the subscriber whose telephone is fitted with a calling mechanism which, when the subscriber calls, earths the line a certain number of times for each figure in the number of the wanted subscriber.

*Wire Plant.—*In suburban and rural districts subscribers are usually served by means of bare wires erected upon wooden or iron poles. As subscribers’ lines are invariably short, the smallest gauge of wire possessing the mechanical strength necessary to with­stand the stresses to which it may be subjected can be employed, and bronze wire weighing 40 lb per mile is commonly used. In large towns telephone distribution by means of open wires is prac­tically impossible, and the employment of cables either laid in the ground or suspended from poles or other overhead supports is necessary.

In the types of cable that were first used, the wires, usually with a cotton insulation, were drawn into lead tubes, and the tubes filled with paraffin or other similar compound, which kept the wires from the injurious effects of any moisture which might penetrate the lead tube. This form of cable has been superseded by a type with paper insulation. The separate wires are surrounded only with a loose covering of specially prepared paper, which furnishes abundant insulation. In the manufacture of the cable the wires are first enclosed in the paper, which is applied sometimes longitudinally and sometimes spirally. The conductors are then twisted in pairs with definite lays. These pairs are laid up symmetrically into cables, each layer being protected with an additional covering of paper and all adjacent layers revolving with an opposite twist. The cable is then placed in an oven, and, after all moisture has been driven off, it is passed through a lead press whence it emerges protected by a continuous lead pipe. The electrostatic capacity of a cable of this type is low, and its dimensions are small, the external diameter of a cable containing 1600 ten-lb conductors being only 2¾ in. The conductors used for subscribers’ circuits are of copper weighing from 10 to 20 lb per mile. Junction circuits are usually made up of 20 or 40 lb conductors.

When a number of cables follow the same route, they are gene­rally laid in conduits made up of earthenware or cement ducts; iron pipes are used when the number of cables is small. Manholes are placed at intervals in the line of ducts to facilitate the drawing in and jointing of the cables, and surface boxes are placed in the footways for distributing purposes. Various methods of making the connexions between the large main cables and the subscribers are in use. In one system the main cables terminate in large air­tight iron boxes placed in the manholes.. There, the large cables divide into a number of small cables, which are carried along the footways in pipes and are tapped at suitable points to serve sub­scribers Another method of distribution, largely adopted, is to run the lead cables into the interior of blocks of buildings, and to terminate them there in iron boxes from which the circuits are distributed to the surrounding buildings by means of rubber-covered wires run along the walls. Aerial distribution from distributing poles is a method frequently adopted. In this case the cables terminate upon the poles, the connexions between the cable wires and the open wires being made with rubber-covered leads.

The introduction in 1883 of the hard-drawn copper wire of high conductivity invented in 1877 by T. B. Doolittle was of the greatest importance in rendering the use of long lines practicable, and it is universally employed for such service. Wire weighing between 150 and 400 lb per mile is generally used. The New York-Chicago line, built in 1892, is of wire 165 millimetres in diameter (No. 8 Birmingham), weighing 435 lb per mile and having a resistance of 2∙05 ohms per mile. Speech has been habitually transmitted for business purposes over a distance of 1542∙3 m., viz., over the lines of the American Telegraph and Telephone Company from Omaha to Boston. Conversation has been carried on over 2200 rn. of No. 8 line.

As no practical process of telephone relaying has been devised, it is extremely important that the character of the line should be such as to favour the preservation of the strength and form of the telephone current. In circuits possessing high resistance and capacity and low inductance per mile, telephonic currents are rapidly attenuated, and the higher the frequency the more rapid is the attenuation. Moreover, as the velocity of propagation is a function of the frequency, there is distortion of the complex waves. Oliver Heaviside showed mathematically that uniformly-distributed inductance in a telephone line would diminish both attenuation and distortion, and that if the inductance were great enough and the insulation resistance not too high the circuit would be dis­tortionless, while currents of all frequencies would be equally attenuated. Following up this idea, Professor Μ. I. Pupin showed that by placing inductance coils in circuit, at distances apart of less than half the length of the shortest component wave to be transmitted, a non-uniform conductor could be made approxi­mately equal to a uniform conductor. Many circuits have been “ loaded ” in the manner proposed by Pupin during recent years, especially in underground cables, and it has been found in practice that the transmission value of these when loaded is approximately from three to four times their value unloaded. Open aerial long­distance lines have also been loaded, but not to the same extent. The introduction of inductance coils into such circuits renders them more susceptible to trouble from atmospheric electricity and more sensitive to leakage variations.

In consequence of their high capacity, the attenuation constant of submarine cables is high, and only a small number of cables, of comparatively short length, are in use for telephonic purposes. Attempts have been made to improve submarine cables in this respect, and in 1906 a short cable “ loaded ” with Pupin coils was laid across Lake Constance. The problem, however, of construct­ing a deep-sea cable satisfactorily, with suitable inductance coils inserted at short distances apart, is a difficult one, and one which it cannot be said has been solved. (H. R. K.)

*Commercial Aspects.—*The records of the telephone industry in Great Britain during the thirty years from 1877 to 1907 form an instructive chapter in the industrial history of the country. The aspects which stand out most prominently in this history are: (0) The vacillation of successive governments due to the conflicting policies adopted from time to time to protect the telegraph revenues of the Post Office and to avoid the suppression of an enterprise which was becoming a public necessity and yielding substantial royalties to the Postmaster- General. (*b*) The obstructive use made by the local authorities of their power to veto underground wayleaves. (c) The remark­able success achieved by the National Telephone Company, despite these obstacles, in developing an extensive organization and a profitable business.

The chief events in chronological order are:—

1876. Graham Bell’s telephone patent was granted for the United Kingdom.

1877. Edison’s telephone patent was granted for the United Kingdom.

1878. Professor D. E. Hughes invented the microphone, but did not apply for letters patent. The Telephone Company, Limited, was formed to acquire Bell’s patent. During the passage of the Telegraph Bill 1878 through parliament the Postmaster-General endeavoured, without success, to insert a clause declaring that the term “ telegraph ” included “ any apparatus for transmitting messages or other communications with the aid of electricity, magnetism, or any other like agency.”

1879. The Edison Telephone Company of London was formed. Both the Bell and the Edison Companies opened negotiations with the Post Office for the sale of their patents to the govern­ment, but without success. The Edison Company announced its intention to start telephone business in London, and the Postmaster-General instituted proceedings against the company