LIGHT CURRENT SECTION: CHAIRMAN'S ADDRESS

THE PROGRESS OF TELEGRAPHY

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THE YEAR 1960 IS THE CENTENARY OF TELEGRAPHS in South Africa for in April, 1860, the first telegraph in the country was opened between Cape Town and Simonstown. It is thus perhaps appropriate to look back over the years to the birth of telegraphy and trace its progress to the present time.

About the first practical use of electricity was in its application to telegraphy. In fact the Institution of Electrical Engineers, which was founded in 1871, then had the title of The Society of Telegraph Engineers. In the early 1880's as electricity was then being applied in more and more spheres the scope of the Society was felt to be too restricted, so in 1888 it became the Institution of Electrical Engineers.

Telegraphy may be defined as the art, science or process of transmitting intelligible signals or signs between distant points. A more precise definition is: telegraphy is a branch of telecommunication which is concerned in any process providing the reproduction at a distance of documentary matter such as written, printed, or pictorial matter, or the reproduction at a distance of any kind of information in such a form.

The definition of a telegraph line has been variously given as: a piece of wire with a gentleman at this end and a complete idiot at the other!

From the days of the Persian Empire we hear of the use of signalling systems such as beacons and torches. In 1792, a semaphore system of signalling was introduced in France which was capable of making 86 different signals. Signalling posts were erected at intervals of 5 to 10 miles, depending upon the terrain, along lines radiating from Paris. By such lines having 534 stations, 29 cities in France were connected to the capital.

Now followed a period during which attempts were made to signal by electricity. One early method was to use static electricity. Two clocks — one at each end of the circuit — were run in absolute synchronism. The dials were divided into 20 sectors each labelled with a letter. Signalling was achieved by applying a charge of electricity to a line at the instant the hand of the clock at the sending end entered the sector marked with the desired letter. This charge caused two pith balls at the receiving end to repel one another thus indicating to the receiving operator the letter to be noted.

Oersted's discoveries opened up a new field and many proposals were made, some of which were impracticable and some remained just proposals.

In 1833, Gauss and Weber installed the world's first magnetic telegraph in Göttingen in Germany. The receiver consisted of a horizontally suspended magnetic rod which was able to rotate freely around its vertical axis which was enclosed in a wooden frame around which a number of turns of wire were wound. Current flowing in this coil then caused the magnet to rotate in one direction of the other and by means of a 4-position code signals could be sent.

Following this clumsy arrangement Wheatstone developed his five-, two- and single-needle telegraphs. In the 5-needle telegraph two needle movements, which represent each symbol, are produced simultaneously instead of consecutively as in the single needle instrument. One wire per needle is however necessary. Fig. 1 shows a genuine single-needle instrument and a model of a five-needle instrument.

While these events were taking place in Europe, Samuel Finlay B. Morse in America produced, in 1837, a telegraph system in which a code was formed of long and short impulses to form an alphabet. Morse started work on his ideas in 1832 but he was a poor man and had not time to develop his theories, so it was not until five years later that he produced the first true electromagnetic telegraph.

In his apparatus the armature of an electromagnet was moved horizontally to and fro by impulses transmitted from what later was known as a Morse key. The receiving armature carried a vertical pencil beneath the point of which a strip of paper was drawn, by means of clockwork, at a constant speed and at right angles to the direction of movement of the armature. Later he modified his receiver so as to move the pencil in a direction perpendicular to the surface of the paper and thus produce a series of marks of length depending upon the duration of the transmitted current.

This method of working was so successful that by 1847, it was adopted in Europe although a number of conservative administrations still pinned their faith on the needle and dial systems in spite of their much slower speed of operation.

In about 1840, Cooke and Wheatstone produced the dial or ABC telegraph. This was a device whereby a hand was advanced around a dial by impulses from the sending end (see fig. 2). These impulses were produced rather crudely by means of a hand-operated impulse generator but an important improvement was made to the transmitter of this instrument in about 1842 by Werner Siemens. Siemens' new transmitter also consisted of a dial surrounded by radially arranged keys but if one of the keys was depressed the pointer of the instrument was stepped around by a self interrupted drive until it reached the key depressed. These same drive impulses were passed over the line to the receiver which stepped in synchronism.

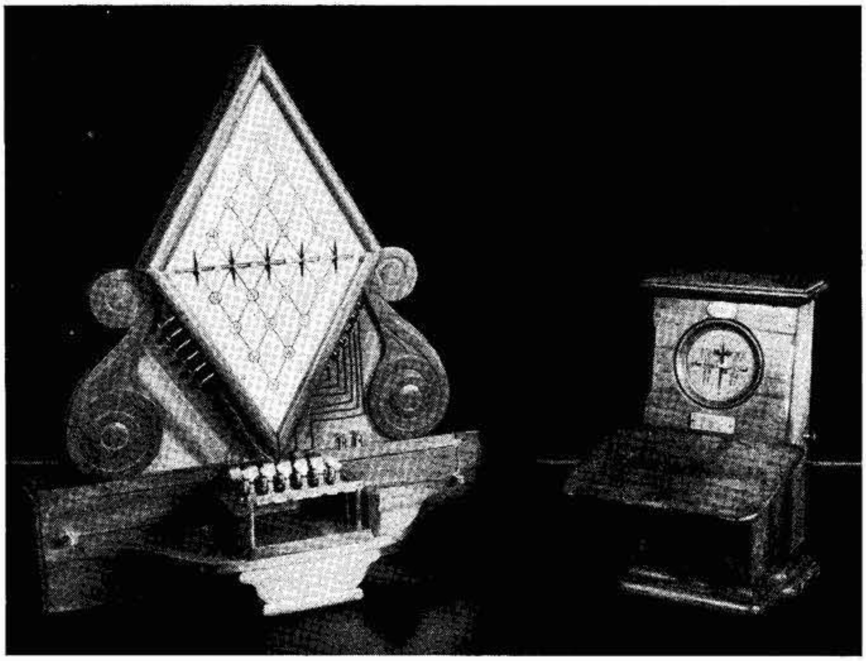
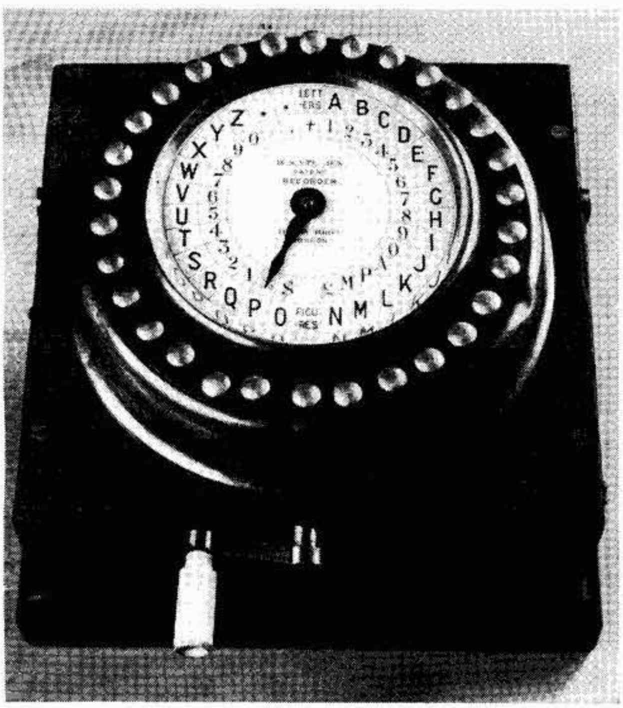


Fig. 1—Five-needle and single-needle instruments.

By the early 1860's a number of people in various parts of the world were busy trying to produce a printing telegraph. Even if these were slower than the Morse system it was considered that by dispensing with skilled Morse translators they would be an improvement. Siemens produced a workable machine which was an adaptation of the dial telegraph but at about the same time David Edward Hughes of America produced a printer that was reputed to be considerably faster than Siemens' device. Not only was Hughes' device able to



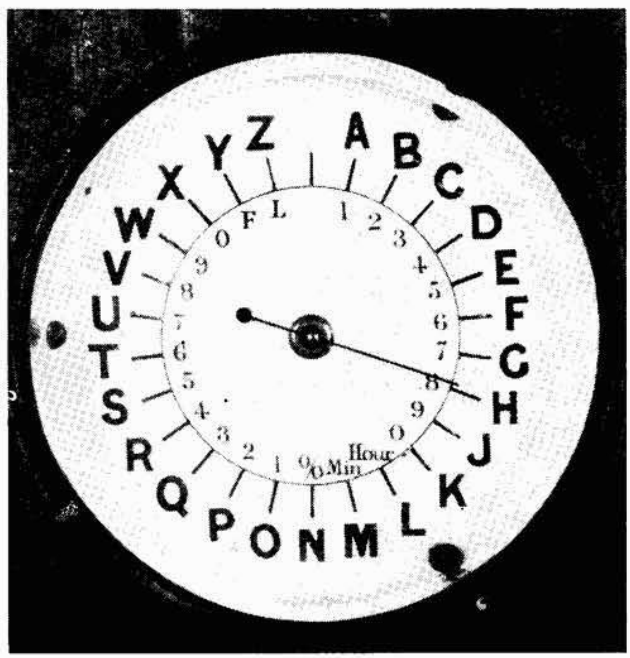


Fig. 2—Dial or ABC telegraph system.

(a) Transmitter. **(b) Receiver.**

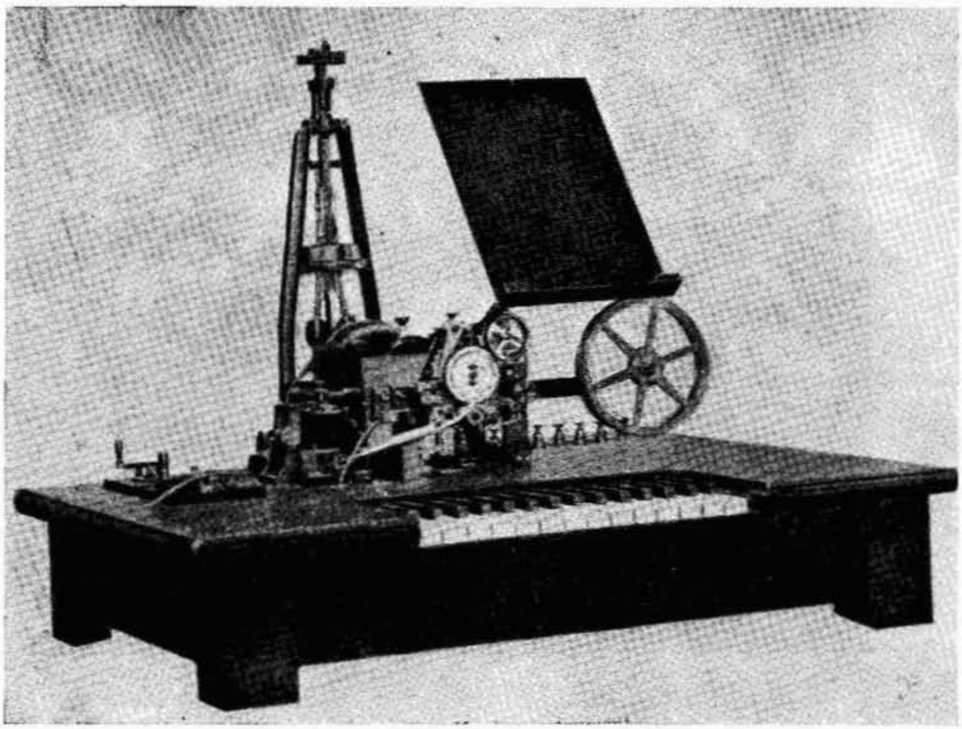


Fig. 3—Hughes printing telegraph system.

print messages directly thereby saving time and labour, but it also operated at a fairly high speed.

This machine was actually the forerunner of the teleprinter as we know it today. In fact the principle of printing, i.e. the use of the type-wheel, has survived many other systems and actually it is to be seen on the latest teleprinters. The keyboard had 32 keys like the keys of a piano — with black and white keys so arranged that by going from left to right on the black keys and coming back on the white keys, one covered the whole alphabet. Figures and punctuation marks were also marked as secondary characters and used in conjunction with a "figure blank" key — very similar again to the method in use today, 100 years later. Fig. 3 hows a reproduction of a photograph of a Hughes equipment. The piano-like keyboard is clearly shown.

The receiving portion of a Hughes equipment consists essentially of a continuously-revolving inked type-wheel and a paper tape. When an impulse of current is received the paper is raised into momentary contact with this wheel and the character printed. Each character consists of only one pulse of current, its separation in time from the previous one identifying it at the receiver. Thus synchronization of transmitter and receiver is extremely important. The speed of working (in words per minute) was low due to limitations of the keyboard where each character was transmitted by the depression of only one key. The Hughes machine was very successful and was used extensively in Europe where the manufacturing rights were purchased by a German firm.

The next important development in this field took place during the period 1870 to about 1880 when Emil Baudot — a quiet official of the French Telegraph Administration — observing certain shortcomings of the Hughes system, turned his attention to the development of what was known later as Baudot telegraphs.

In Baudot's machine we see the appearance of the 5-unit code for the first time. This was a code having the same length of signal for each character and, as explained later, Hughes had a start pulse at the beginning of each character. This code makes use of all 32 possible permutations of five elements and was the forerunner of the International Alphabet No. 2 which is the standard alphabet used today.

The transmitting mechanism and the receiving mechanism, as in the Hughes equipment, had to run in precise synchronism. Lack of synchronism would result in the receive mechanism being halted at the wrong instant and printing the wrong character. This system resulted in an operating speed of about 360 characters per minute which was 50 per cent faster than the Hughes speed.

One of the drawbacks of this scheme, however, was that the "keyboard" had only 5 keys — one for each element of the code (see fig. 4). The operator had, therefore, to memorise a rather difficult code and operate the 5 keys with his two hands — the first 3 elements with his right hand and the 4th and 5th with his left hand. Whereas in the Hughes keyboard the key could not be fully depressed until the transmitter was ready to send it, the Baudot operator had to get some kind of a signal that the next character should be selected. This was done by feeding a "start pulse" to the operator by means of headphones.

During this time, the automatic Morse system had also been developing, largely through the efforts of Wheat-

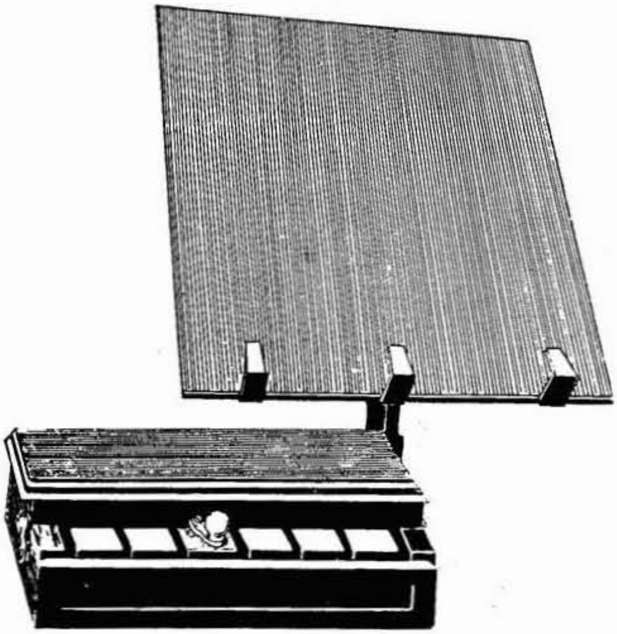


Fig. 4—Baudot transmitter keyboard.

stone. The system consisted firstly of a perforator, automatic transmitter and receiver. The early receiver was an inking device the tape of which had to be translated and then written out in longhand but, later, a receiver was developed which produced a perforated tape identical to that used at the transmitting end which was fed into a printer which in turn produced a printed tape. The perforator which was operated by three buttons — dot, dash, and space — was later superseded by a keyboard perforator which dispensed with the services of a skilled Morse telegraphist. By employing a number of "punchers" it was possible to feed a physical telegraph line at speeds of 400 and 500 words per minute. Fig. 5 shows the keyboard perforator and automatic transmitter whilst fig. 6 shows a receiver from which the perforated tape is fed into the printer.

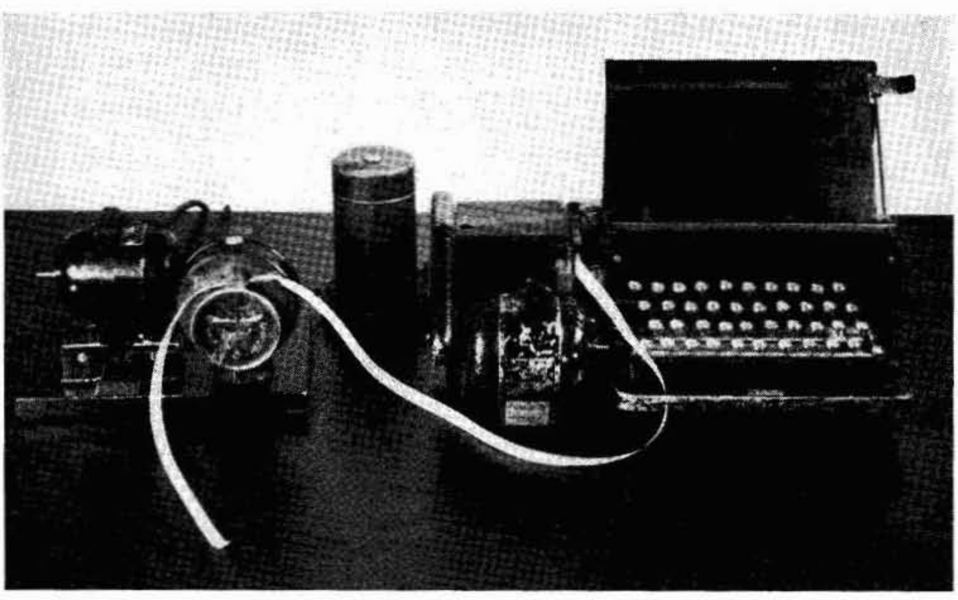
In 1900 tests were started with a Wheatstone Morse system between Cape Town and Bloemfontein and in 1901 Beaufort West was established as a repeater station — a position of importance it held until voice-frequency telegraph systems finally ousted it some 40 years later. As far as instruments are concerned, this was the position at the turn of the century.

So far very little has been said about the lines that were used in those early days. From information available it seems that in even the earliest days attempts were made to use cables. As far back as 1809 rubber covered wire had been produced while in 1837 Cooke and Wheatstone patented a cable consisting of insulated wires in lead pipes.

In 1838, however, the first electric telegraph in England — a 5-needle system — was operated over a "cable" laid between Euston and Camden Town — a distance of $1\frac{1}{4}$ miles. This cable consisted of 5 wires laid in grooves cut in baulks of oak about 2 in. square in cross-section, and secured by oak slips driven into the grooves. This line was workable so long as the ground was dry but once it became wet the system was useless.

In 1842 gutta-percha found its way from Singapore to London and thence to Germany where, in 1847, Siemens produced about 15 miles of cable which consisted of a copper conductor placed between two strips of gutta-percha and pressed to form two seams. This was not very durable but the following year he had produced a seamless covering which was hailed as the cable of the future. A further attempt to improve the cable by adding sulphur to the gutta-percha in an effort to increase its toughness, as had just then been done with rubber in

Fig. 5—Morse keyboard perforator and automatic transmitter.



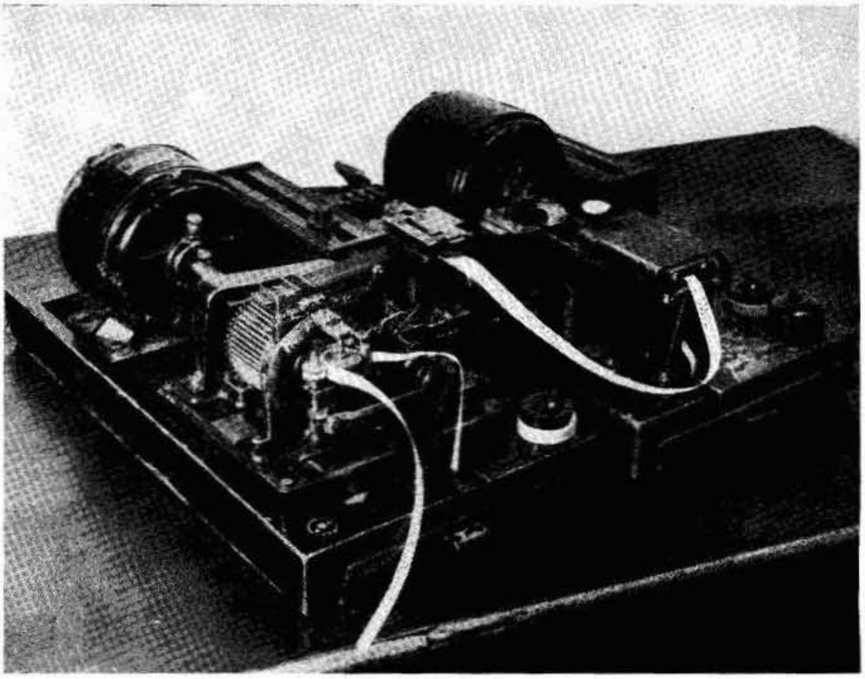


Fig. 6—A Morse receiver and printer.

the vulcanizing process, proved a failure since the sulphur combining with the copper completely destroyed the gutta-percha and left the conductor with no insulation. A somewhat more successful cable, however, consisting of a wooden trough with gutta-percha between the wires was laid in England in 1851, between Liverpool and Manchester and later was extended to London.

About this time, too, we find reference to porcelain and glass pin-type insulator routes in America and Europe.

By the late 1840's all the major cities in Europe were linked together and in America too, considerable expansion had taken place all over the continent. As early as 1837, Wheatstone had suggested a cable between Dover and Calais, but it was not until 1850 that the first unarmoured gutta-percha cable was laid. Its service life, however, was short because on the night after its opening it was fished up with a trawl and the fisherman, thinking it a sea-serpent, promptly cut it through!

The following year Jacob Brett, who had laid the first cross-channel cable, ordered a gutta-percha insulated stranded conductor armoured cable, which was much more successful and was still in service 50 years later.

This cable proved very successful and cable proposals became fashionable. Many difficulties in cable laying techniques had still to be overcome but these were dealt with gradually.

During the 1850's many cables were laid successfully around the shores of Europe, but in 1857 the first bold attempt to lay a cable between Europe and America was made by Brett and an American businessman Cyrus Field. The Atlantic crossing was to be made between Newfoundland and the Irish island of Valentia.

The first attempt failed however when the cable parted about 400 miles out in 1 800 fathoms of water. A second attempt was successful a year later. This cable, which operated at one word per minute, failed however after only 366 messages had been passed.

The signalling current was derived from a 10-cell battery of considerable capacity but in an attempt to raise the speed of working by increasing the current, the voltage was stepped up to 2 000 volts. The result was as would be expected. Tests were then conducted to determine the cause of the failure, but after a lengthy and fruitless search for the cable it was abandoned. A successful cable was laid in 1866, by Field, Brett and Pender, and almost immediately afterwards another cable which had parted during laying in 1865 was raised, repaired and put into service at a speed of about 15 words per minute. A third cable laid by a French company was completed in 1869. A fourth was laid in 1874 by a German firm.

Exactly 100 years ago, the first telegraph circuit in South Africa between Cape Town and Simonstown was brought into service. In 1864, a circuit had been pushed out as far as Grahamstown and it was possible to send messages to a number of places on the way and beyond. The charges were per 20 words and varied according to distance. For example, for a 20-word message to Mossel Bay the charge was 5/-, whilst to Port Elizabeth it was 10/-. By 1876, Kimberley was connected to Cape Town and the line reached Pretoria in 1889.

By 1879, a cable had been laid from London to Durban via Aden and thus, the landline linking Cape Town to Durban via Grahamstown having been completed the year before, Cape Town was able to send messages to London for the first time. A cable via the West Coast reached Cape Town in 1886, whilst the one worked at present via St. Helena and Ascension was completed in 1901.

It is interesting to note that many of the single-core submarine telegraph cables still in use today are almost identical in design to Brett's original cross-channel cable of 1838.

With the introduction of telephone cables of the new trans-Atlantic type, voice frequency telegraph techniques can be applied and so the landline network can be directly connected to the cable.

Having made and successfully laid submarine cables, it was found that it was not quite as easy to signal over them as over a landline. The cause as we know today was the huge capacity and resistance of the cable, the total effect being known as the retardation of the cable. It was, in fact, the complete misunderstanding of this factor that brought about the failure of Brett and Field's first cable in 1858.

The capacities and resistances of cables vary considerably but the lower these values are, the higher the speed of working will be. The 1869 French trans-Atlantic cable was 2 242 nautical miles long and had a capacity of 0.43 μF per nautical mile which gives a total capacity of 964.06 μF with a total resistance of 6 569 ohms.

Improvement in the speed of working of a cable can be achieved by reducing the signalling current to a minimum, but this unfortunately results in extremely low received currents and the need for extremely sensitive instruments. In fact, it was realized in 1858, when the first trans-Atlantic cable failed, that ordinary telegraph instruments were not usable on long high-capacity cables.

William Thomson, later Lord Kelvin, invented the mirror galvanometer which was the first device to enable operators to read the extremely weak signals received successfully at the end of a long submarine cable.

Unfortunately, mirror signals are fatiguing to read and require one operator to read and another to write, but this situation was overcome by the invention of the syphon recorder which could be made to be very sensitive by reducing the drag on the paper by either causing the pen to vibrate or by expelling the ink by electric repulsion and not allowing the pen to ride on the paper at all.

Now followed a period of slow steady progress in both cable design and terminating instruments. Considerable improvements can be achieved by the use of continuous loading and one such trans-Atlantic cable continuously loaded with permalloy tape laid in 1924 operates at a speed of 1 500 words per minute.

Recently a system has been devised whereby 5-unit apparatus can be applied to some of the old single-core cables with a consequent raising in speed. This system is to be introduced shortly between Cape Town and Ascension which will greatly simplify the cable office in Cape Town and allow cable and landline circuits to be freely interlinked.

During the early portion of the submarine cable laying era a cable was laid in 1859 between London and India — a country with which England did much trade — via the Red Sea, but it failed soon after completion. As a result attempts were soon made to reach India by an overland route. By utilizing various pieces of circuit it was possible to reach India via Russia or via Asia Minor and Persia thence to Karachi via Teheran and Bushire. There was however no through circuit and it was necessary to transcribe and re-transmit the messages many times. As, however, operators along the route were in many cases familiar with only their native tongue, each re-transmission was a source of possible error. It was not surprising therefore, that on reception after many days' delay telegrams were mutilated to the point of being unintelligible.

As no CCITT or I.T.U. existed in those days it was left to a private concern, the 'Indo-European Telegraph Company', to undertake the establishment of a through circuit operated throughout on the same technical system and under one management. It took nearly eight years to get this collosal project accepted, and wayleaves granted, by the various countries through which the line should pass. Of the 3 750 miles between London and Teheran via Berlin, Warsaw and Odessa, all but 750 miles had to be built by the Company. This route consisted of two 6mm diameter wires supported on 70 000 poles plus a section of cable across the Black Sea.

The story of the building of this route is an epic as within 2 years of the commencement of the actual erection, the line was in service. Could we equal this performance today?

Except for a 6 months' break in 1870, caused by the total loss of the Black Sea cable section due to an earthquake and a break of 7 years due to the first world war, this line was operated until 1931 with the reputation of being one of the speediest and most reliable of the world's great telegraph lines. Repeaters with monitor apparatus were inserted in the line at appropriate points and the circuit operated from end to end without manual retransmission.

Running parallel with the development of telegraph instruments and lines was the development of methods of line exploitation. Quadruplex was but a natural step from duplex but multiplex, attributed to a Frenchman, Meyer, represented a new idea in circuit sub-division.

In multiplex working one telegraph line is shared by up to six duplex channels. This is achieved by giving each channel brief but exclusive use of the line in turn. Each channel is connected to the line a number of times during even the shortest signal element but the inertia of the receiving equipment bridges the small gaps caused when the other channels are having their turn.

The method adopted is to apply each circuit to the line by means of a distributor which is basically a circle of insulated contacts, to which the sending and receiving apparatus is connected, which are swept by an arm, connected to the line, revolving at a regular speed. If now *identical* distributors are provided at each end of the line and these distributors are driven at exactly the same speed and pass over say, contact one at the same instant, the object of multiplex has been achieved.

Baudot adapted Meyer's multiplex to convert the simultaneous signal presentation of his transmitter to sequential signals on the line and at the receiving end

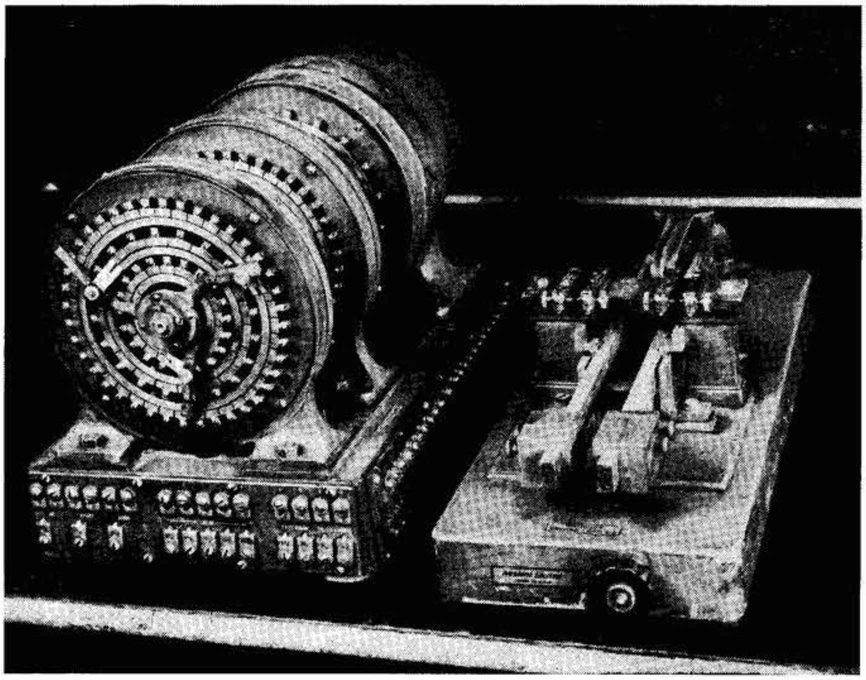


Fig. 7—Multiplex distributor and driving fork.

to distribute the impulses to the receive magnets of his printer. At the same time he arranged for four systems to be served by one line and one distributor.

There were many variations of multiplex and it enjoyed a long period of popularity but, as will be seen, it fell into disfavour when voice frequency telegraphs took over. Fig. 7 shows the distributor of a typical multiplex system introduced into South Africa in 1922 and used until the advent of voice-frequency telegraph systems and stop-start teleprinters.

These various methods of exploitation were all very well for use on open wire lines or on telegraph cables as the band-width available was adequate to handle total signalling speeds as high as the signalling apparatus of the day was able to produce. However, with the introduction of multi-core telephone cables and the economies obviously to be gained by using such cable for telegraph as well as for telephone purposes, the need for a means to transmit the telegraph signals over these cables without causing quite unacceptable cross-fire became pressing. Attention was thus directed to the idea of producing — at least so far as the cable was concerned — telegraph signals similar in nature and magnitude to telephone currents traversing the same cable.

Whilst no modification to the telegraph instruments would be required if a d.c. signal produced, for instance, by a Morse instrument was made to operate a relay which sent a small alternating current from some source along the line to be rectified and made to operate a relay at the distant end which now produced a d.c. signal again, the standard channelling equipment such as duplex multiplex was not usable. Here, the idea of channel subdivision by the use of a number of a.c. signals of different frequencies on the same line became attractive.

Early attempts by a Frenchman, Mercadier, to produce a multi-channel voice-frequency telegraph system were unsuccessful because at that time the 'filtering' properties of capacity-inductance networks had not yet been discovered. Work on filters in America and Europe resulted eventually in the production first of 6 then of 12 and later 18 and 24 channel voice-frequency telegraph systems as we know them today.

This now produced a frequency division multiplex in place of the old mechanical time division multiplex and as the system developed we got just as many channels per wire as the mechanical device could give. When a voice-frequency telegraph system is carried on a speech channel of a carrier system the economic advantages become considerable.

Due to band-width limitations the speed of operation on such a VF channel was restricted to speeds of 50 bauds or less so the conception of really high-speed single channel working was doomed especially as the demand for channels to meet Telex and leased circuit needs increased.

This reduction in channel working speeds may seem a retrograde step but as 24 channels can be accommodated in the spectrum normally occupied by one speech channel and the speed of a single vf channel is sufficient to allow one operator to work at his maximum speed we now have one telephone channel providing enough telegraph circuits to occupy 48 operators handling, theoretically, 1 440 words per minute.

In 1934, the first 18 channel voice-frequency telegraph system borne of a channel of an open-wire carrier system was installed between Cape Town and Johannesburg. The Union now has a total of 956 voice-frequency channels with a total length of 373 679 circuit miles.

In the years before the outbreak of the first world war a number of inventions were made all leading up to the development of the modern teleprinter.

An early development by Murray, a New Zealander, was a system consisting of a perforator with a typewriter like a keyboard which produced a 5-unit tape — not with the code across the tape as it is now, but in line on the tape. The receiver was a device that produced a punched tape which, in turn, was fed into a printer which, as a break-away from the now familiar type-wheel, used a type basket similar to a typewriter. As in previous automatic systems synchronization of receiver and transmitter was of paramount importance.

About this time we find the name Creed, who had devised a printer of the type-wheel variety, appearing in the telegraph world. For a time Creed and Murray worked together but they soon parted company, Murray going to America where he joined the Western Union Telegraph Co. whilst Creed, a native of Canada, remained in London.

In 1914, the Morkrum-Kleinschmidt Company of Chicago brought out a machine that was a development of Murray and Creed's work which dispensed with the use of a perforated tape at the receiving end and printed direct on page or tape.

By about 1913/14 it seemed that the telegraph had reached a stage where further expansion was limited as all the ordinary telegram handling equipment necessary to meet public needs was available. This was appreciated by telegraph companies who now set about 'selling' telegraphs to individual customers for private use or for what we now call Telex. This was not easy as there were many and various systems available but none suitable for customers' use.

In both Germany and America designers were looking for a simple solution to the problem — both realized that two major problems must first be solved. First, transmission must be direct from the keyboard and second, the extremely tricky business of synchronization had to be overcome.

Both problems were solved at the same time. The credit, it appears, will have to go to America for the invention of what we now know as the 'start-stop' system. This simply allows the rotating parts of the transmitter and receiver to leave their fixed starting positions at the same instant and come to rest after each complete character. Thus, provided that the speeds of the machines are approximately equal the effect is of almost perfect synchronization over the short duration of one character.

The first start-stop teleprinter was introduced into South Africa in 1924 and its use was gradually extended until by 1930 all the main offices and many of the smaller ones were equipped.

Now followed an era of development and consolidation. All the firms concerned with telegraph manufacture strove to improve their machines in both efficiency and reliability. Many and various forms have appeared but as can be seen from the examples of modern teleprinters shown in figs. 8, 9 and 10 no major revolutionary development has taken place.

The development of the voice frequency telegraph system has also been pushed forward steadily and today we are using systems employing frequency modulation instead of amplitude modulation as in the earlier systems.

The physical size of these systems had also undergone a radical change. When filters were still inductance-capacity arrangements they were many times larger than their modern crystal counterparts and by miniaturization still further significant reduction in size has been achieved.

During the last decade a number of special and interesting telegraph machines have also been developed for special applications, such as tape relay systems.

A fairly modern development which is having far-reaching effects on long distance telegraphy is the application of error correction — in particular — to radio circuits. Teleprinter on radio has long been the aim of telegraph and radio engineers, but as all 32 permutations of the 5 unit code are allocated to characters this lack of redundancy can result in the printing of apparently correct characters which are in fact wrong. Thus, by simply losing an element (due to a radio fade) or the insertion of an element (due to noise) undetectable errors could easily occur particularly in code traffic.

Many efforts have been made to overcome this disability, some clumsy and involved, but one arrangement

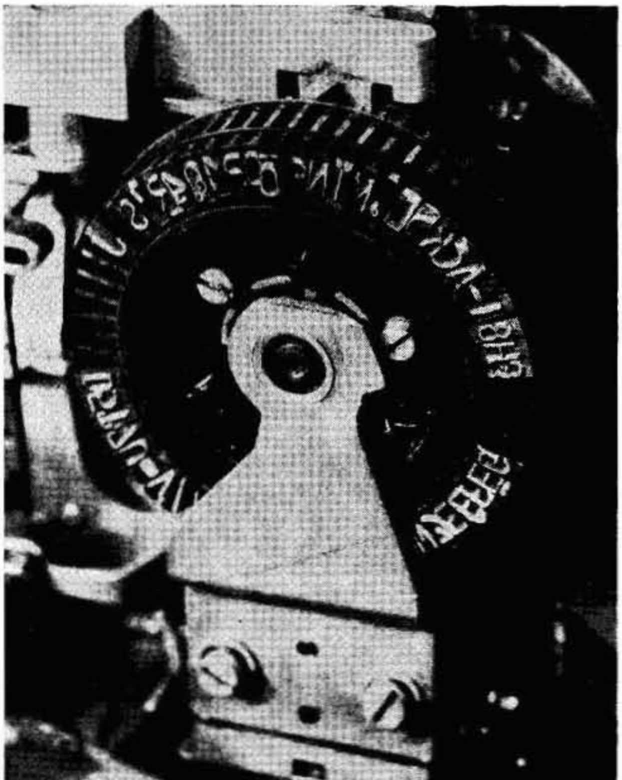


Fig. 8—Type-head printing mechanism.

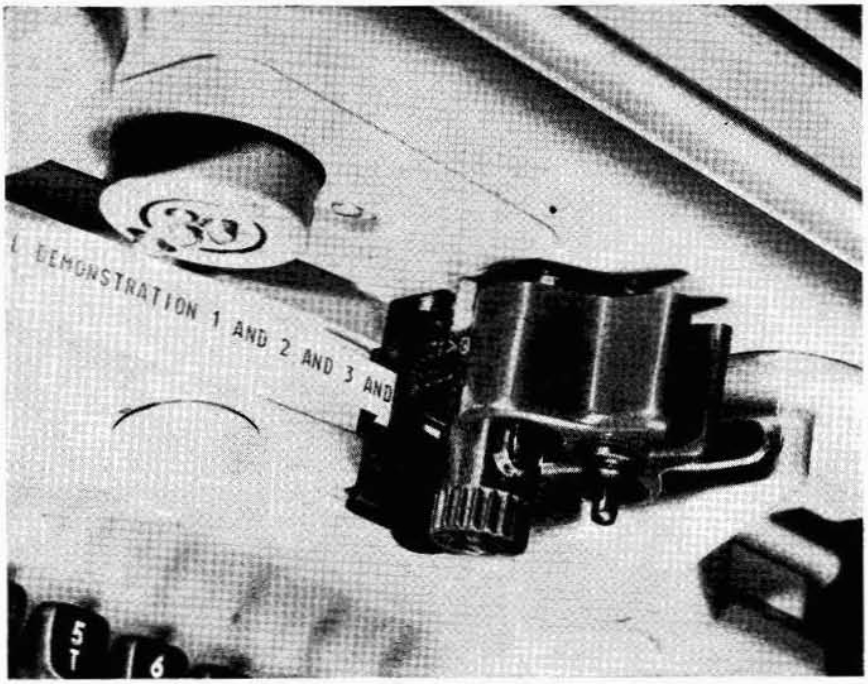


Fig. 9—Type-wheel printing mechanism.

was suggested by H. V. Higgett using the Morse code whereby a change from space to mark was read as a dot whilst a change from mark to space meant a dash. This arrangement produced a code that gave an indication of errors which then did not pass undetected. In recent years, however, an ingenious and relatively simple system has been devised by van Duuren in which 5-unit characters are automatically changed into 7-unit characters in which every used character has a 4 to 3 ratio of elements. It is thus possible to check this ratio in each received character and if this is not correct to automatically call for a repeat of the rejected character from the distant end.

It now becomes possible to connect a land line, operating with stnadard 5-unit equipment to a radio link and expect satisfactory error free service.

A very interesting device has been developed to interpose between the landline and the radio link. This is known as FRXD and is, in fact, a printing reperforator and automatic transmitter built as one unit. The two units can operate at different baud speeds if necessary to facilitate the interconnection of systems of different speeds. Obviously if each character on the radio link is subject to scrutiny and rejection if necessary at the receiving end it must be possible to stop transmission while repetition of a faulty character is being made. Thus, the transmitter of the FRXD can be made to transmit character by character under the control of the error correcting equipment. A feature of the FRXD is its ability to transmit up to the last character received on its reperforator.

The introduction of voice frequency telegraphs put an end to multiplex on landlines for the reasons mentioned previously. However, the band-width of a radio channel permits the application of this principle once more. Mechanical multiplex was used at first but the latest systems apply the method electronically. A further application has been to sub-divide 50 baud channels to give 4 quarter-speed, 2 half-speed, or 1 half-speed and 2 quarter-speed channels. Slow speed channels are used by private clients whose traffic does not require a full-time full-speed circuit but are better served by a full-time quarter-speed channel than a part-time full-speed channel.

As mentioned earlier it was in about 1914 that people began to think about the use of Telex, i.e., a subscriber service using teleprinters with manual switching. These systems have been fully discussed in an earlier address. The production of start-stop teleprinters gave this branch of telegraphy its greatest boost. Today this service is the one for which there is considerable demand and its application to business and industry is of great benefit.

The rather sudden development of computors has provided another application for telegraphy in the feeding of data to these interesting machines which in many instances use teleprinters for the ultimate presentation of the results.

A branch of telegraphy not mentioned hitherto is the transmission of pictures or documents by systems known as facsimile and photo-telegraphy. By definition this is telegraphy because the original document is reproduced in printed form.

Facsimile is the transmission of pictures or documents by non-photographic means whilst photo-telegraphy, as its name implies, produces what amounts to a photograph of the original.

In 1842 a facsimile system intended for the transmission of messages was patented by Alexander Bain in England. He synchronized his scanning and printing

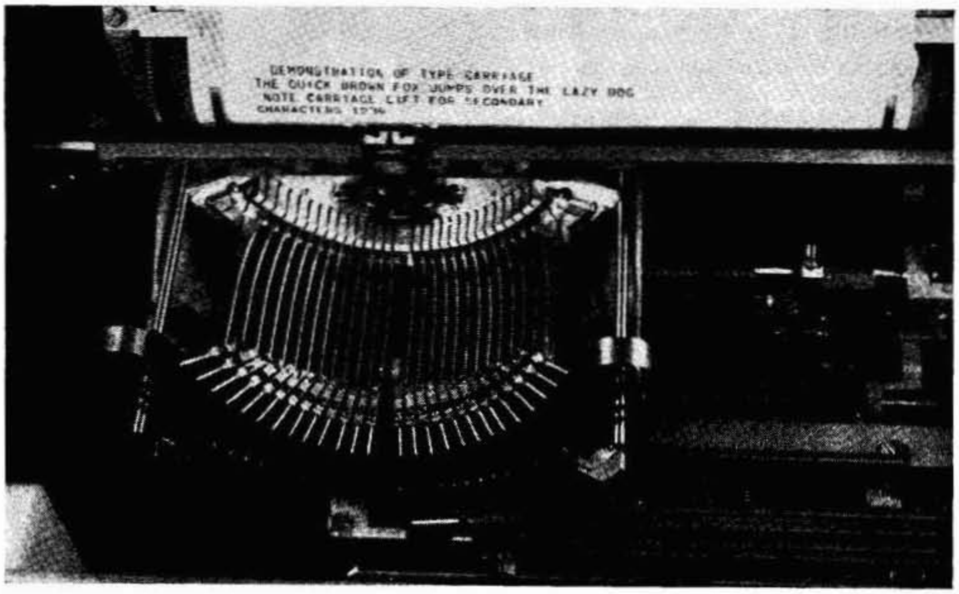


Fig. 10—Type-basket printing mechanism.

equipments by means of pendulums kept in step by pulses emitted from the sending end. The signal currents were derived from a light contact passing over the surface of raised metal type, a narrow line per swing of the pendulum. Printing was achieved by an electro-chemical process. There are no records to show that Bain's process was ever used commercially but many of the principles involved are still employed today.

The first recorded commercial system was introduced by Casselli who put an improved version of Bain's invention into service in France.

In 1907 Professor Korn, in Germany, devised the first truly photographic system of picture transmission. In this apparatus, as is still done today, the transmitted and received pictures are mounted on synchronously rotating drums. In Korn's transmitter the pictures were transparent. A light-beam passed through the picture to a prism in the centre of the drum which reflected the light on to a selenium cell. At the receiving end a shutter under the control of the line current controlled a light-beam which was focussed on a photographic film mounted on the receiver drum.

In the same year a Frenchman, Edouard Belin produced a picture by employing different principles. His transmitting and receiving drums, as in Korn's apparatus, ran in synchronism but here the similarity ends. Belin's transmitted picture was prepared on film coated with bichromated gelatin. This produces a surface which varies in thickness according to the light and shade of the original picture. A light-sensitive follower sensed this varying thickness and caused varying currents to flow in the line to operate a mirror galvanometer at the receiver which varied the amount of light passing through a mask and lens system to fall on the receiving film.

These systems, and variations of them, developed steadily but much labour went into the production of a system which would operate successfully on a radio circuit having no d.c. path and subject to fading.

The first pictures to be transmitted across the Atlantic were sent by cable using an equipment designed by Bartholomew and MacFarlane which used a 5-unit code, each 'character' consisting of up to 5 dots indicating a different picture tonal value.

Following a considerable amount of work by Ranger in America a workable system for radio circuits was produced. This system known as 'constant frequency variable dot' used a sub-carrier which was interrupted at a slow rate for the 'white' of a picture and at a much higher rate for the 'blacks'. This and a further development by Belin, producing a somewhat similar result, were the forerunners of the final development which made radio picture transmission reliable. This was the use of a frequency modulated sub-carrier which produces a signal unaffected by fading in the radio path. The transmitting principles of Korn and Belin form the basis of some of the modern equipments.

Parallel with these developments in later years has been the production of various forms of facsimile equipment. Most of these devices use a photo-electric system to transmit the signal and some form of mechanical or electro-chemical printing.

Photo-telegraphy is used mainly for the transmission of photographs and is used extensively for press purposes although some business concerns are finding it cheaper to send a closely typed sheet of information by this means rather than by normal telegraph methods.

Facsimile is used for the transmission of documents, telegrams, weather maps, etc., where such precise definition and shading as can be obtained with photo-telegraph equipment is not necessary.

Although equipment for picture transmission is classified as telegraph equipment it cannot be operated on normal narrow band telegraph channels. With a sub-carrier frequency of 1 900 cps the black on the picture produces a signal of 1 500 cps and white 2 300 cps, and for satisfactory reproduction a band of 800 to 3 000 cps is required or, in practice, a normal speech band.

Having reached this stage of reviewing the development of telegraphy, one asks—what now? We have seen the great milestones such as the Hughes telegraph system, the Wheatstone high-speed Morse system, the start-stop principle and teleprinters on cable, but when one remembers that Hughes and Baudot lived 100 years ago and we still use type-wheels, and 5-unit code, it seems that we must be waiting for some revolution in the printing of transmitted messages. What form this will take can only be guessed but already there are indications of electronic methods of printing which could well be the next step.

At some time in the not too distant future it will undoubtedly be possible to take the spoken word to pieces and re-assemble it at some remote point in a printed form for delivery.

While it continues to be necessary to process every message by hammering it out by hand or keyboard, whether direct on line or on a perforator the speed of the present equipment is high enough for even the above average operator.

Almost invariably a message to be transmitted is first either composed simply by writing it on a piece of paper like a telegram or by carefully copying information from one or more sources. If now the intelligence on this piece of paper could be transmitted without further ado, we might be able to benefit considerably by the use of much faster circuits and printing equipment.

ACKNOWLEDGEMENTS

I wish to thank the Postmaster-General for permission to publish this address and my colleagues for their help in its presentation.

VOTE OF THANKS

M. Hewitson (Past President): At the outset may I congratulate Mr Bennett on his election to the Chairmanship of the Light Current Section for a second term and convey to Mr Townsend our grateful thanks for the quiet and efficient manner in which the Light Current Section has functioned under his guidance. I am not sure why I was invited to propose the vote of thanks to Mr Bennett for his address but can only conclude that, among his friends and acquaintances, I was the only one old enough to confirm that some of the instruments he has described actually existed and did, in fact, work.

It is abundantly evident that considerable research has been necessary to unearth the details of the various stages of the development of the telegraph and to produce an address which is both valuable historically and of considerable interest. One must be impressed with the ingenuity shown by the pioneers in the art who turned their attention to printing mechanisms only thirty years after the invention of the electric telegraph. Their degree of success was truly amazing.

Practically all these inventions except, notably, the Hughes and Baudot systems found a place in the South African network which in the early days relied on Wheatstone working using the Morse code. Clockwork (spring and weight driven) Wheatstone transmitters and receivers became a familiar sight in all large telegraph offices (later these instruments were power driven). The highlight of the development was undoubtedly the Wheatstone (Creed) receiver and tape printer. The early models were operated by compressed air and did yeoman service, particularly in the JH-CT circuits, in spite of the fine limits necessary for the minute valves that operated the selectors. This equipment, first installed in 1913, continued in service until quite recently except that in later models (as illustrated in Mr Bennett's slide) the printer-receiver was operated electrically.

Another feature of note was, perhaps, the fact that although the telegraph started out as a visual system, Mr Sivewright was able to report in 1878 'another improvement has been the practice now becoming general amongst the best telegraphists of acoustic reading, i.e. reading from the Morse by sound in place of from the tape'. An old photograph of the Johannesburg C.T.O. taken in 1893 shows that sounders were in general use although the Morse inker was still much in evidence. Many years later the Morse inker was relegated to country offices and training schools. The performances of some of the early telegraphists, particularly during the South African war, has become legendary and many tales have been told of almost unbelievable performances under stress. The Morse sounder is fast disappearing although some short-haul Morse circuits still exist.

A point that strikes one was the apparent reluctance of the early telegraph engineer to take advantage of the developments on the telephone side. For example, they struck tenaciously to the elaborate (and inefficient) 'electro-magnetic switch' used on the fast speed s/c-d/c repeater even after it had been demonstrated that the ordinary 'B' relay used in automatic telephony could do the job more cheaply and better.

I was horrified in 1929, when I was shown the prototype of the 'new rack mounted equipment', to learn that it was the intention to retain the old brass-cased variable resistances and the equally clumsy $7\frac{1}{4}$ μF condenser box, mounted on shelves on the bays. The suggestion that radio type variable resistances and condensers might serve equally well was received in stunned silence. However, wiser counsels prevailed eventually and a much closer liaison between telegraphs and telephones exists today.

Mr Bennett has omitted to mention the ubiquitous phonopore; the telephone that was superimposed on telegraph wires and became the bane of all telephone men because of the high pitched calling note it spilled into all neighbouring circuits. The omission is doubtless due to Mr Bennett's comparative youth because had he experienced the banshee howl there is little doubt that he would have devoted a page to its ability to suppress all its competitors on the same pole route.

I must resist the temptation, however, to dig into the past and I now move that a hearty vote of thanks be accorded Mr Bennett for his excellent and absorbing address.

H. Korta: I would like to thank Mr Bennett for his interesting and illuminating paper on the progress of telegraphy up to the present day, and I am grateful for having been given this opportunity to make some additional comments.

In his address, Mr Bennett has given us a broad outline of telegraphy development experienced in this country. In closing, he voiced a statement which could be interpreted as somewhat pessimistic. He mentioned that the immediate future does not appear to hold any prospect of a major stride forward based on novel concepts if one disregards the fact that electronics will certainly find more and more adoption in telegraph equipment. Mr Bennett further pointed out that some of the principles discovered a century ago are still being applied in modern systems.

One must ask the question if the present state of affairs warrants this pessimistic outlook? In my opinion development during the last decades, once the start-stop teleprinter had come into being, was aimed at perfecting the equipment already existing, always bearing in mind that an increase in the operating speed would be of no importance because of the limits set by human reaction times. The CCITT have ruled that a teleprinter speed of 50 bauds be adopted and virtually the whole world — now that the United States and Canada have followed suit — has recognized this speed as the correct one and has accordingly developed and produced telegraph equipment for this speed. A uniform teleprinter operating speed throughout the world is of the greatest significance, especially now that large exchange networks have been constructed and interconnected by means of world-wide trunk line systems. Because of this uniform speed, it is possible, in many cases, for a subscriber of one country to dial directly the subscriber of another country and exchange information.

There is no doubt whatsoever that a teleprinter can operate at a speed of 100 bauds instead of at 50 bauds. Such machines, however, have no significance for general application or for operation in public networks because there will be no corresponding receiving machine and because normal machines cannot be allowed to dial these faster machines.

Moreover — and here we are again touching upon the human element — no operator would be able to operate such a machine at its maximum speed. It would, of course, be possible to prepare a perforated tape and to feed this tape through the machine. This is the only way of achieving a speed of 100 bauds. As mentioned before, this principle should not be adopted as uniformity of speed over the world would not be achieved.

Mr Bennett next referred to the facsimile transmission method with which a typed, handwritten or printed page is transmitted over a speech channel by means of facsimile equipment. This method will not result in any reduction in the overall transmission time as the document to be transmitted must first be prepared.

I would like to give an example at this stage, viz. the automobile. The automobile has hardly undergone any changes in its fundamental functional principles since its inception — it still runs on four wheels, is powered by a motor, has a gear box, brakes, steering wheel, etc. Despite this, nobody will deny that continuous development and improvement has taken place although these new advances are not so immediately apparent. Fundamental functional changes are not to be expected.

From this it is obvious that there is no reason to be pessimistic. The present aim should be to keep the already developed and existing equipment in operation. This equipment ensures the absolute correct transmission of all characters and can be maintained at relatively low costs. Where existing equipment does not exhibit these characteristics, development should be carried out to achieve them.

After the creation of operationally reliable teleprinter apparatus, the need arose for the provision of a rapid interconnection of 2 subscribers. As early as 1928 development began in Berlin, with the aim of producing automatic exchange equipment for the interconnection of teleprinter subscribers. This resulted in the first teleprinter network being taken into operation between Berlin and Hamburg, in October, 1933. The network grew rapidly because subscribers were quick to realize its advantages. Operator teleprinter trunk positions opened the door to international traffic. During the past years many operator controlled international teleprinter circuits have been adapted for international subscribers dialling. This could be realized because it is possible to transmit dial pulses over teleprinter circuits. Development in Europe has progressed today to the stage where nearly the whole of the Continent is equipped with teleprinter networks. These networks are interlinked, thereby allowing subscribers of any one country, in many cases, to directly dial subscribers of other countries, without the aid of an exchange operator.

The world's teleprinter networks have now reached the 100 000 subscriber mark of which as many as 30 000 in West Germany and 40 000 in America are connected to such networks.

At present a teleprinter network embodying latest circuit design principles and most modern viewpoints of organization, is being introduced in South Africa. This type of teleprinter network will, in time, replace the existing operator controlled network. This new network will provide direct dial facilities to Telex subscribers throughout the country and will, furthermore, have access to networks in other countries, thus permitting Telex connecions to be established in a short time and written intelligence to be conveyed. The establishment of such networks and direct communication between subscribers was possible only after the introduction of the teleprinter with the international 5-code telegraph alphabet. Therefore, in my opinion, there is no reason to view the future pessimistically.

Each of the many design principles conceived, for instance, the needle telegraph, the ABC telegraph, the Hughes telegraph and the Baudot telegraph systems are all excellent and well thought out. These various systems nevertheless are not suitable for subscriber-to-subscriber connections with untrained personnel who have no knowledge of the technical principles involved. The start-stop system is far superior to these previously mentioned sys-