Transatlantic Telephone Cable

Supplement to the Post Office Telecommunications Journal

International Achievement

Sir Gordon Radley, K.C.B., C.B.E., Ph.D.(Eng)., M.I.E.E.

Director General, United Kingdom Post Office

IT is difficult for me to write objectively about this project because I have shared with Dr. Kelly, President of the Bell Telephone Laboratories, responsibility for recommending that a transatlantic telephone cable was a feasible technical proposition. Together, we were also responsible for the choice of cable and repeaters to be used.

During the past two years we have watched our plans taking shape. But perhaps just because of this, I am in a better position than most to point out just how much has gone into the design, manufacture and laying of the cable. Engineers and scientists on both sides of the Atlantic have put their best into it. They had to. With over 100 repeaters between Newfoundland and Scotland, many of them two miles below the surface of the ocean, the project far exceeds in scope anything of the kind that had been attempted before.

In every phase of this combined operation use has been made of the best that was available for the job, irrespective of its country or origin—of the results of a quarter of a century of American research looking forward to the possibility of a transatlantic telephone cable, of their development of a flexible housing for the repeaters so that they could be laid more readily, of British experience in manufacturing submarine cables, and of our cable ship *Monarch* to undertake an entirely new essay in cable laying.

Manufacture of the cable and repeaters demanded new standards of precision and care. The cable had to be made to an accuracy of dimensions never attempted before. Construction of the repeaters, on both sides of the Atlantic, aimed at achieving as near perfection as humanly possible; if one of them fails communication will stop.

The engineers and scientists, the factory workers and seamen, who have turned long-cherished plans into a reality have done a great job.

"Monument to Co-operation"

CLEO F. CRAIG
President, American Telephone and Telegraph Company

IT'S a special privilege to add a word here to what others are writing about the first transatlantic telephone cable. I'd like to mention three elements which to me have been essential to this great undertaking.

The first is imagination. The cable has come into being only because there were men who dared to imagine it. Before they knew how it could be created, they dared to try. Everything else has followed from that.

The second element I am thinking of is precision, and of course the patience and skill needed to achieve it. We have been a long time at this job. We have had to be, because it has taken prolonged and patient effort to gain the precision the cable demands. To me these new ocean-going voiceways are a dramatic reminder that progress in communications will always depend on our doing just the very tip-top utmost that it is in our power to do.

And finally, the cable is a living monument to co-operation. Co-operation in the laboratories—in discovering, designing, testing and measuring. Co-operation in our business arrangements, in the factories, and in all manner of crafts on land and at sea. Co-operation among sovereign states.

The inventor of the telephone crossed the sea from Scotland, and came to Canada and then to the United States. All our countries shared him. Now it seems to me that this new cable symbolizes our common heritage from the past. May it also serve our common interests for years to come.

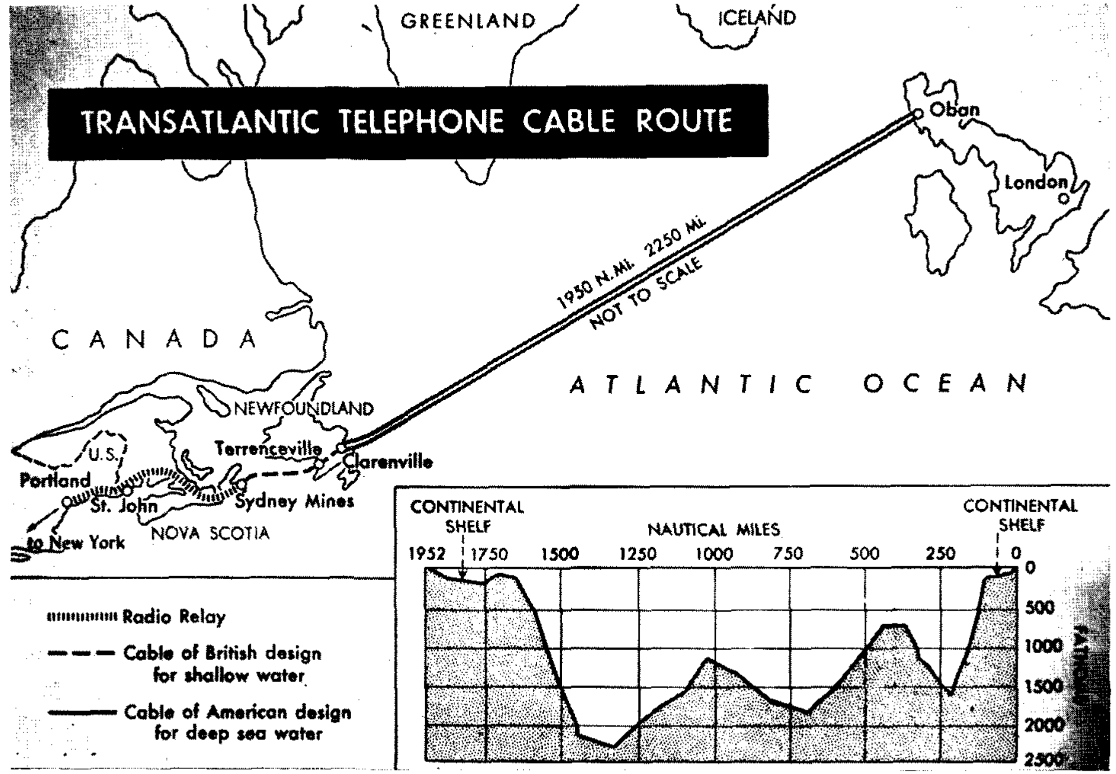
"Tribute to the Engineers"

D. F. BOWIE
President, Canadian Overseas Telecommunication Corporation

AS President of the Canadian Overseas Telecommunication Corporation I may say that we regard the completion of this new transatlantic medium of telecommunications as a tremendous achievement of engineering and planning and of extraordinary international co-operation. Failure in any one sphere would have been disastrous to the project. The fact that I am able to write these words means that any and all problems have been met and overcome.

I should like to refer especially and pay tribute to the engineers on both sides of the Atlantic whose vision and skill devised and produced this system which is going to be of outstanding benefit to the users of transatlantic services. The customer has the right to expect to be provided with the latest and best in telecommunications equipment and facilities and we believe that the Transatlantic Telephone Cable will give him precisely that. Improved service, keeping pace with the rapid as well as steady growth of Canada and her Commonwealth and foreign relations are regarded here as being a vital element in the development of the nation and this cable system, in our view, is without doubt the most important item in our programme of improvements.

It has been a great pleasure as well as a privilege to have collaborated with our British and American friends in a project of such vast significance in the field of international telecommunications and, in greeting the inauguration of this new and exceptional facility of which we are all so justly proud, my colleagues in Canadian Overseas Telecommunication Corporation join with me in cordial wishes to those in all three countries who have contributed to this project.



The Joint Undertaking

C. J. Gill

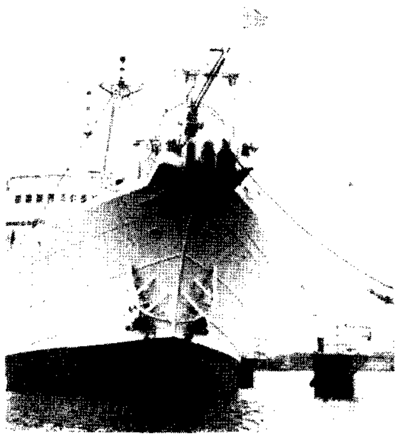
"AND WHEREAS it is desired to provide a submarine telephone cable system between the United States and Canada on the west, and the United Kingdom on the east..."

SO runs the second recital in the Transatlantic Cable Construction and Maintenance Contract, executed on behalf of the Post Office in November, 1953, by Lord de la Warr, then Postmaster General.

Behind that recital lay many months of negotiation between the Post Office and the three other parties to the Contract, the American Telephone and Telegraph Company and the Canadian Overseas Telecommunication Corporation (with which the Post Office had for some years operated radio-telephone services to the United States and Canada respectively), and the Eastern Telephone and Telegraph Company, a Canadian subsidiary of the A. T. and T.

Inherent in it, and in all the detailed conditions of contract which followed, was an act of faith in the ability of the designers and manufacturers on both sides of the Atlantic to create, in the short space of three years, an entirely novel medium of trans-ocean communication : to link North America and Europe for the first time by telephone cable, and to build the cable to a standard of accuracy and with an expectation of life never before attempted.

Within those three years the system had to be planned and the whole vast interconnected system of submarine and land cables and radio links, had to be manufactured and constructed. The final



Symbol of co-operation: H.M.T.S. "Monarch" flies the Blue Ensign and Stars and Stripes when loading cable in America

system designs had to be completed and interlocked without delay, so that manufacture could be put in hand. New machinery and techniques had to be developed for placing the cable in deep waters. The route had to be surveyed and established.

Nearly 4,500 miles of cable had to be made to the most exacting specification ever devised, most of it in a factory which had still to be completed, and 146 repeaters had to be built to withstand the rigours of laying and water pressures at depths of up to 2½ miles under the Atlantic, with components of such fidelity as to last for 20 years at least without attention.

The act of faith now stands justified by events. The achievement owes much to the research and practical work by the Post Office and the American Telephone and Telegraph Company over the past 30 years in submarine cable and repeater development. But of the highest significance has been the way in which all the problems—and these have been many and serious in this great undertaking—have been approached and resolved as common problems by the experts on each side, working as a team with a common objective. The Contract provided in cold legal terms for a joint undertaking; the warm spirit of international goodwill and co-operation in which it has been carried out has given it a true human meaning.

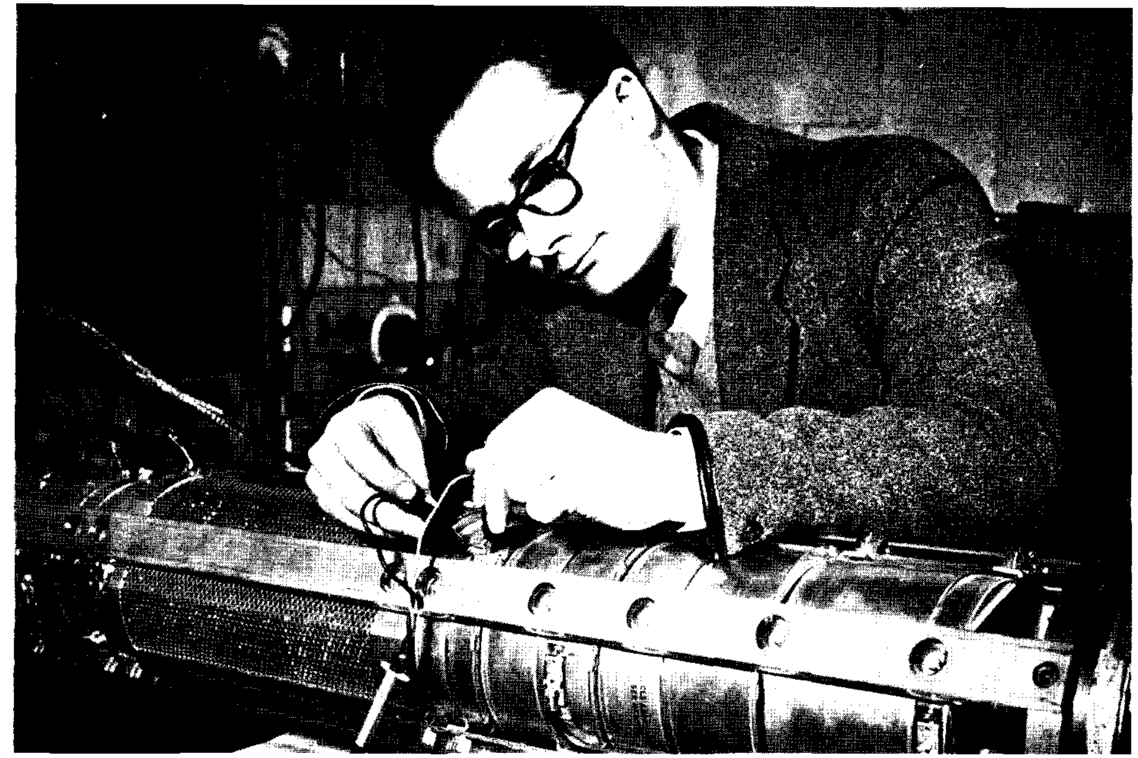
Contracts are necessary, and this one has stood well the practical test of completion. From it has sprung a jointly owned and constructed system extending from the Scottish coast, near Oban, to the Canada-United States border near St. John, New Brunswick. The main Atlantic crossing consists of two cables (one for each direction of transmission) of American design, embodying one-way flexible repeaters at 37-mile intervals. From Clarenville, in Newfoundland, to the Canadian mainland, the Post Office two-way repeater system is used, enabling transmission in both directions over a single cable. From Sydney Mines to the United States border a line-of-sight micro-wave radio link completes the jointly owned system.

Each of the parties concerned with operating the system has, in accordance with the Contract, provided the necessary connexion from the ends of the cable system to the operating terminals in London, New York and Montreal. The 35 high quality telephone circuits foreseen in the Contract are now available—29 to New York and six to Montreal as are the additional telegraph circuits to Canada which will strengthen the Commonwealth telegraph network.

The joint system is owned in indivisible shares: 50 per cent. by the American Companies, 41 per cent. by the Post Office and 9 per cent. by the Canadian Overseas Telecommunication Corporation. But the cost, about £15,000,000, has been shared in proportion to use, the Post Office share of 50 per cent. having been met entirely in kind by the supply of cable, repeaters and terminal equipment and by the services of H.M.T.S. *Monarch*, which has laid all the sea cable; the difference in value between the shares of ownership and cost establishing the indefeasible right of user of circuits in excess of those actually owned.

The Contract provides for the joint maintenance of the completed system and for anything else necessary in a joint undertaking: for exchanges of patent rights, for consultation and agreement about the term of specifications and contracts, for keeping accounts, for settlements, and so on. It runs for an initial period of 25 years and may be added to and altered from time to time by agreement; it is perhaps significant of the care and forethought that went into its drafting that only one addition, and that a minor one, has so far been found necessary.

The Atlantic has ever been a proving ground for long-distance overseas communications. The first successful transatlantic telegraph cable, opened in 1866, and Marconi's transatlantic radio experiments in 1901 established patterns for the development of world-wide telecommunications as we know them to-day. The successful completion of this Contract marks a fresh major conquest of the Atlantic, providing trans-ocean telephony by cable for the first time. This unique development will undoubtedly in its turn set the new pattern, and from now on the telecommunication system of the world can be expected to share in an increasing degree the benefits of submarine cable telephony.



Prototype of British repeater under test

The Plan of the System

R. J. Halsey, B.Sc. (Eng.), A.C.G.I., D.I.C., M.I.E.E.

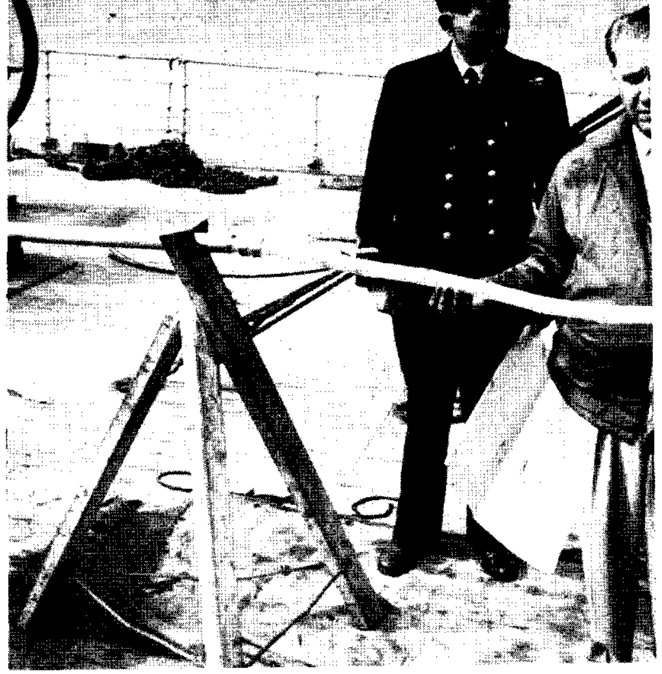
In September 1952, about a year before the Agreement was signed, representatives of the Bell Telephone Laboratories, New York, and the Post Office Engineering Department began technical discussions. Both sides thoroughly examined the techniques developed in each organization for amplifying signals in under-water repeaters. These techniques proved to be very different, although they had some common features in the development of components and manufacturing and testing methods, designed to ensure a very high order of reliability over a long period, and in the supply of power to the repeaters from both shore ends from constant-current d.c. generators at voltages up to about 2,000.

In America, development initiated by Dr. Buckley as long ago as 1919 had led to the design of a thin flexible repeater unit primarily for inclusion in co-axial cables* in deep water and capable of passing round the normal paying-out gear of a cable ship. This repeater was fairly simple electrically, partly because of the small internal diameter of the housing—less than 1.5 inch—and was based on a valve of very conservative design unaltered since 1941. The repeaters amplified signals in one direction only and separate cables were therefore required for the two directions of transmission. Repeaters and components had been subjected to exhaustive tests over a period of 10 years and in 1950 two cables had been laid between Key West, Florida, and Havana, Cuba, each about 120 nautical miles† (n.m.) long and including three repeaters, at a maximum depth of about 900 fathoms.‡ This system provided 24

* *A coaxial cable is one in which the electric signals pass along two copper conductors, one conductor in the form of a wire being placed inside the other, which consists of a flexible tube. The wire has the same axis or centre as the tube—hence "coaxial".*

† *1 nautical mile = 1.15 statute miles. (In this article a mile is a statute mile unless otherwise stated).*

‡ *1 fathom = 6 feet.*



American flexible repeater with armour and housing removed

telephone circuits and was regarded as a prototype for a transatlantic system.

Great Britain, having a considerable network of coaxial cables to Europe and between the Islands, all in shallow water, had directed development primarily towards increasing the number of circuits on such cables, and a number of systems, mainly providing 60 two-way circuits over a single cable, were in operation. Under the conditions encountered, Britain had been able to lay large rigid repeaters without difficulty and this had facilitated two-way amplification, since adequate space was available for the necessary filters. However, the Post Office had not overlooked the problem of long distance transmission and a new design of rigid repeater which, it was hoped, would prove suitable for deep water, was due to be installed for the first time, between Aberdeen and Bergen (Norway) in 1954. This cable, 300 n.m. in length, would then be the longest submarine telephone cable in the world.

With the laying gear available, only the American repeaters could be laid in a continuous operation without stopping the cable ship, as would be essential in the deep waters of the Atlantic. Clearly therefore, if work on a transatlantic project was to proceed quickly, the American system must be used in deep water; development of laying methods suited to the British rigid repeaters would involve several years' delay. On the other hand, the British system was admirably suited to shallow waters.

As a result of the technical discussions, therefore, Sir Gordon Radley, for the Post Office Engineering Department, and Dr. M. J. Kelly, for the Bell Telephone Laboratories recommended that a submarine cable link between Great Britain and Nova Scotia should be provided as follows:—

(a) the section between Great Britain and Newfoundland, nearly 2,000 n.m. in length and up to 2,400 fathoms (2.7 miles) in depth, by two cables equipped with American repeaters of the Key-West Havana type, modified to provide as many circuits as possible with a 2,000 volt terminal voltage limitation; the number of circuits was subsequently agreed as 36.

(b) the section between Newfoundland and Nova Scotia, involving much shallower water, by a single cable equipped with British repeaters of the Aberdeen-Bergen type, also providing 36 circuits. As a result of representations from the Canadian Overseas Telecommunication Corporation for additional facilities between Newfoundland and the mainland of of Canada, it was later decided to increase the number of circuits to 60 as in earlier British repeaters. The route selected is 324 n.m. long, including an overland section in Newfoundland, and up to 260 fathoms deep.

It was subsequently agreed that the three cable terminals should be at Oban (Scotland), Clarenville (Newfoundland) and Sydney Mines (Nova Scotia) and that a radio-relay link would be built west of Sydney Mines to carry the New York circuits to the United States-Canadian border and thence beyond it to link with the existing carrier network at Portland (Maine); it would also carry the Montreal circuits to a suitable junction point for connexion to the Canadian telephone network.

When the Agreement was made in November, 1953, it specified that, of the 36 transatlantic telephone circuits, six, plus a half-circuit for telegraph purposes, would be allocated for London-Montreal. The ink was hardly dry before detailed considerations of the system planning were undertaken in New York in the first of a series of joint technical discussions. From the start there was remarkable unanimity of technical opinion and some basic principles were quickly agreed:

(a) that sound engineering should be the first consideration, drawing on the best resources of all parties at all times, within the framework of the Agreement;

(b) that there should be nothing in the design within the agreed bandwidth limitations to restrict the type of transmission which could be used later;

(c) that where standard equipment was required it should be British on the eastern side of the Atlantic and American on the western side;

(d) that common basic power equipment at each station should be used for British and American equipment;

(e) that, because the American system transmits the frequency range 20-164 kilocycles per second (kc/s) the British system should be modified to transmit a lowest frequency of 20 kc/s, instead of 24 as previously, to simplify arrangements at Clarenville;

(f) that the circuits should be transmitted as 12-channel groups throughout the entire system with channel equipment at London, New York and Montreal only; the requirement to provide 6½ circuits between London and Montreal would be met by splitting 12-channel groups at the break-out point on the radio-relay route between Sydney Mines and the United States border (subsequently designated as Spruce Lake, near St. John, New Brunswick);

(g) that standard 4 kc/s spaced channel equipment should be used at first, though band-economy systems might be introduced later to provide additional circuits if and when required;

(h) that the circuits should be switched 4-wire. (It is to be noted that London becomes an international switching centre for the first time and, as such, is required by the Comité Consultatif International Téléphonique (C.C.I.F.) to switch on a 4-wire basis).

International circuits in Europe are expected to conform with C.C.I.F. recommendations, but in the Bell System—which is twice the size of the whole European network—somewhat different standards are adopted. The two requirements, therefore, had to be examined and correlated, and as a result the following objectives were agreed:—

1. the circuits to operate at a very low overall transmission loss (0.5 decibels*) in a transit connexion, this being increased to 6 decibels in a terminal connexion;
2. a very high standard to be set for the gain stability of the circuits, higher indeed than is normally achieved on long inland circuits in this country;
3. the frequency response of the circuits to be better than the C.C.I.F. standard for 2,500 km. circuits;
4. the total circuit noise to be less than the Bell "4,000-mile circuit" standard and hoped to be less than the C.C.I.F. standard for 2,500 kilometres.

Further, it was agreed to open service with ring-down signalling and to make arrangements later for operator dialling into nominated centres on both sides of the Atlantic.

The routes, which are shown on the map on page 3, can be conveniently divided into the following sections:

1. *London-Oban* (561 *miles*)

The decision to limit channel equipment to the terminal stations requires facilities for transmitting three 12-circuit groups, which are normally transmitted over two routes in parallel, selected at the receiving ends. The routing is: London-Glasgow (450 miles), 12- and 24-circuit carrier cable; Glasgow-Oban (111 miles), coaxial cable.

2. *Oban-Clarenville* (2,240 *miles*)

Two submarine cables are used for the two directions of transmission, each including 51 flexible repeaters and transmitting three 12-channel groups; the American Telephone and Telegraph Company (A.T. & T.) was primarily responsible.

3. *Clarenville-Sydney Mines* (376 *miles*)

One submarine cable, including 16 rigid repeaters transmits five 12-channel groups (that is, one super-group) in each direction; the British Post Office was primarily responsible.

4. *Sydney Mines-Portland* (575 *miles*)

This is a 4,000 megacycles per second (Mc/s) radio-relay system with 17 intermediate stations. From the relay tower at Spruce Lake (328 miles), the break-out point for the Canadian circuits, a separate micro-wave system operates over the intervening 10 miles to St. John, New Brunswick.

5. *Portland-White Plains* (326 *miles*)

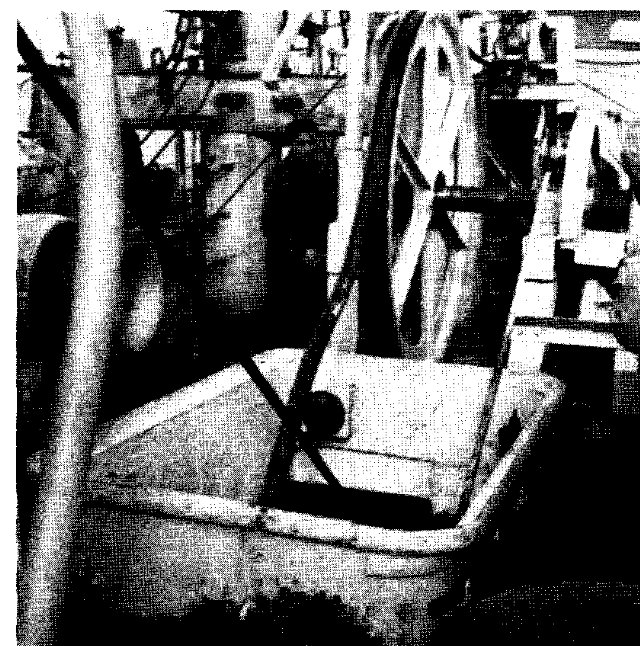
This section uses groups in the A.T. & T. Long Lines network: Portland-West Haven (271 miles) 12-circuit carrier cable; West Haven-White Plains (55 miles), coaxial cable.

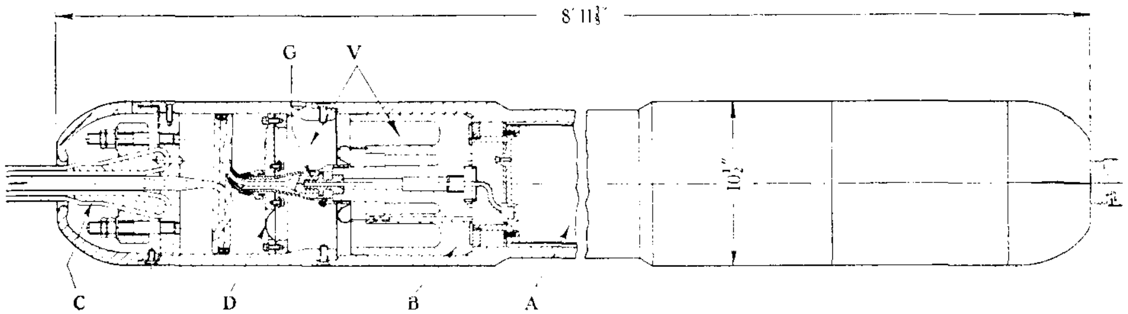
6. *Spruce Lake-Montreal* (652 *miles*)

This section is the responsibility of the Canadian

** A decibel is a unit of change of the strength of a signal; 3 decibels corresponds to a change of 2 : 1.*

American flexible repeater entering cable machinery, H.M.T.S. "Monarch"





Housing of the British repeater: Clarenville-Sydney Mines section
A. Inner unit enclosing electrical apparatus
B. Bulkhead brazed in
C. Armour clamp
D. Flexible diaphragm enclosing Vistac V
G. Castellated gland

Overseas Telecommunication Corporation, who rent the necessary facilities between St. John and Montreal from the operating companies. The routing is: Spruce Lake-St. John (10 miles), radio-relay; St. John-Quebec (450 miles), 12-circuit open-wire carrier; Quebec-Montreal (192 miles), 12-circuit carrier cable.

Thus, the overall lengths of the London-New York and London-Montreal circuits are 4,078 and 4,157 miles respectively.

Some 20 telegraph cables already span the North Atlantic and those from the British Isles extend from the south-west corners of England and Ireland to the south-east coast of Newfoundland. The route selected for the telephone cables runs well north of the telegraph cables until it enters Trinity Bay, Newfoundland; here the cables land at Clarenville without crossing any existing cable, although the routes run close together. The design limitations of the American repeaters require that no more than about 2,000 volts can be applied at each end of the cable. For a given type of cable, this sets an upper limit to the frequencies which can be transmitted and hence to the number of circuits which can be provided. The design for 36 circuits just fits the route distance and cable involved.

The choice of the route between Clarenville and Sydney Mines was the subject of considerable discussion and on-the-spot investigation. A sea route would be mainly across the Newfoundland Banks with extensive trawling activity and the cable would need to cross and recross many existing telegraph cables; this would produce hazards when grappling for the other cables. Several alternative routes involving land crossings were examined and the route described in a later article was ultimately selected; it makes use of numerous water sections in the sea rivers and lakes, involves no cable crossings and is well in-shore of the main trawling areas.

The diagram opposite shows how the frequencies are allocated in the submarine cable sections. Each 12-channel group appears in the basic group frequency range (60-108 kc/s) at Oban, Clarenville, Sydney Mines, Portland and West Haven, except that the group containing the 6½ Canadian circuits is split west of Sydney Mines, the two partial groups being subsequently treated as separate groups.

The transmission losses in land and submarine cables at the frequencies employed on the trans-atlantic system are enormous and the system is practicable only because these losses can be compensated with amplifiers at regular intervals. For example, the loss in transmission in each Oban-Clarenville cable alone, at the highest working frequency, is over 3,200 decibels and is compensated by 51 intermediate repeaters, each of which multiplies the signal power by over one million. Some idea of the losses involved can be given by saying that, if power could be fed into the cable at Oban equal to the combined output of all the generating stations in the world, it would only just be possible to obtain an indication on the most sensitive galvanometer, without the repeaters, at a point one-tenth of the way to Clarenville.

The means to amplify signals have, of course, been available for many years but it is only within the past decade or so that it has been possible to build up the techniques of design, construction and testing of components—including valves—to the point where there is sufficient confidence in their reliability to place repeaters on the ocean bed.

The objectives in respect of stability of transmission loss on the overall circuits—only one or two decibels variation—must be considered in relation to the enormous total losses and gains involved. To facilitate maintenance of transmission levels the loss in each 12-channel group is monitored by two pilot frequencies, one isolated in each section and one overall.

The same basic design of submarine cable is used in both sections; it is described in the article on making the cable, where the differences between the main cable and the cable across Newfoundland are also outlined.

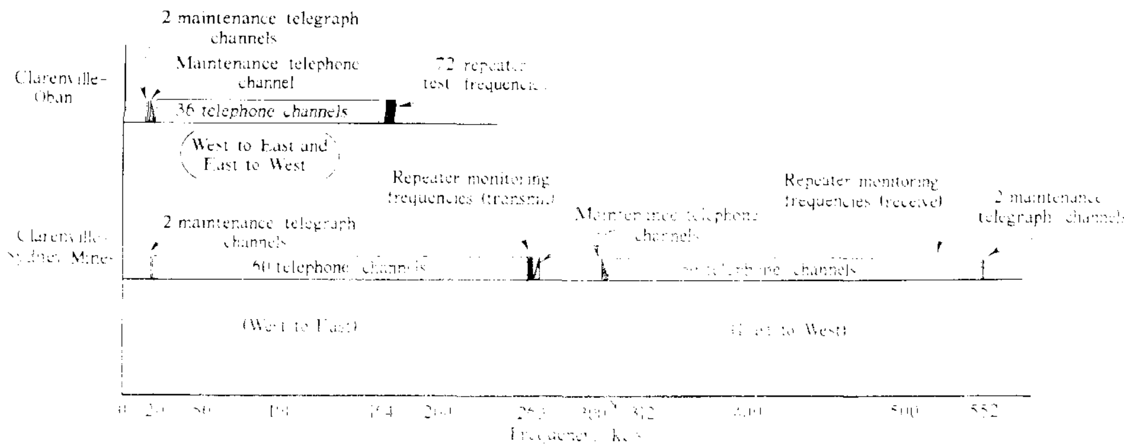
Because of the small amount of apparatus space available in the American repeater, a one-directional amplifier with comparatively simple circuitry and unduplicated components was essential. The structure is a flexible bulge in the cable 8 feet long and 2⅞ inches in diameter, tapering for a distance of about 20 feet at each end down to the cable diameter. The armour of the cable itself is carried over the repeater housing, with additional wires to give complete coverage; over this is a second layer of wires with opposite lay. The electrical equipment, consisting of a three-valve amplifier arranged to match the cable losses and the power filters, is enclosed within an 8 foot series of articulated cylindrical units inside the housing, as illustrated. The structure has to withstand a water pressure of 3 tons per square inch in service.

The rigid housing of the British repeaters allows more apparatus space and this includes, in addition to corresponding items in the American unit, the directional filters necessary for both-way amplification and dual amplifiers so arranged that any component may fail in one amplifier without affecting the other.

The power circuit in each repeater is in series with the centre conductor, without a connexion to earth and, because of this and the extremely high insulation resistance of the cable and repeaters, direct current can be fed right through the cable between shore stations without sensible loss. Constant-current d.c. power units feed the appropriate line current from each end and so distribute the applied voltage. Thus, between Oban and Clarenville, the line current is 225 milliamperes and the requisite driving voltage is about 2,000 at each end. This supplies the valve heaters and provides 55 volts anode supply.

For the American repeaters, operating at a maximum frequency of 164 kc/s, the spacing is about 38 n.m., thus requiring 51 repeaters in each cable. The British repeaters, operating at a maximum frequency of 552 kc/s, are spaced at about 20 n.m., which means 16 repeaters, of which two are in the land section in Newfoundland; these, being located in ponds, are unlikely ever to become dry.

The expectation is that the repeaters will operate undisturbed for very long periods with possibly only 10 per cent. failures in the first 20 years; this requires an average life of perhaps 30 years for the complete repeaters and a very much greater average life for the individual components.



Allocation of the frequency bands

The radio-relay system between Sydney Mines and Portland is designed to provide up to 12 broad-band channels, six in each direction, spaced 40 Mc/s apart in the 3,700-4,200 Mc/s range. Each broad-band channel will handle more than 600 telephone channels but for the present purpose we are concerned only with two supergroups (each with a capacity of 60 channels) in one broad-band in each direction. The working broad-band channel is associated with a reserve to which the circuits are switched automatically in the event of failure or fading. The relay stations are optically spaced at an average distance of about 32 miles and are equipped with horn-reflectors of a new type.

At Spruce Lake, separate reflectors link up with the C.O.T.C. station at St. John, the supergroup carrying the Canadian circuits being filtered out for this purpose.

The primary purpose of the system is, of course, to provide telephone facilities across the Atlantic. All six Canadian circuits terminate in London (Kingsway) and Montreal. Of the 29 New York circuits, 22 terminate in London and seven are permanently extended to Paris, Frankfurt (2), Amsterdam, Brussels, Copenhagen and Berne.

In each group, two telephone channels in the range 68-76 kc/s or three in the range 64-76 kc/s can be replaced, as required, by a music channel; this provides two music channels each way between London and New York and one each way between London and Montreal.

The Agreement foresaw that the half-circuit London-Montreal would provide at least six telegraph channels each way; in fact eleven are provided.

For maintenance purposes two low-grade telephone (speaker) circuits and two teleprinter (printer) circuits are provided. One speaker circuit provides point-to-point communication between the principal stations – that is, it is not continuous – and one printer circuit connects London and White Plains directly. The other speaker and printer circuits are omnibus connexions to the principal stations on the route, including Montreal.

The target date for service, December 1, 1956, was settled during the negotiations in 1953 which led to the Agreement. At that time no specifications existed and the British factory, which was to make all but about 400 n.m. of the 4,500 n.m. of submarine cable required, was little more than a series of sheds, damaged by bombing and due to be stripped, largely rebuilt and equipped with the most modern cable-making machinery in the world. The American repeater factory, too, was little more than a shell needing to be reconditioned, air conditioned and equipped to accommodate over 300 highly-skilled staff at the peak of production.

In February, 1955, the first lengths of cable were manufactured and in March that year laying trials were conducted off Gibraltar with new cable laying gear on H.M.T.S. *Monarch*. Since then the cable and repeaters have been made; 4,250 n.m. of cable and 118 repeaters have been placed on the ocean bed and in Newfoundland.

In all there have been 13 series of joint technical discussions in London, New York and Montreal, the last two, in New York and Montreal, being limited almost entirely to maintenance matters.

Those parts of the internal telephone networks of the United Kingdom, the United States and Canada concerned with the new system have been overhauled in an endeavour to provide and maintain a standard of transmission which would match and be worthy of the submarine cable sections, whose efficiency is the highest which could be devised by the best transmission engineers on both sides of the Atlantic. Finally, each section has been lined-up and tested individually before bringing them all together as an integrated system. Now the work is complete and time alone can determine how well it has been done.

Time, too, will reveal the public reaction to a high-grade telephone service across the Atlantic. Will the traffic increase at an accelerated rate? There are many indications, as well as hopes and expectations, that it will do so and many well-informed people expect the system to be fully loaded within a short space of time. The future of transatlantic telephony will depend on such growth of traffic – and the implications will be world-wide. Now, within months or at the most a year or two, we shall be able to consider the pattern of the next transatlantic telephone cable and of transoceanic telephony in general. That another transatlantic cable system will provide more than 36 circuits is virtually certain; 80 to 100 circuits should now be practicable on a single cable and at least 200 on a pair of cables.

Technicians preparing radio-active isotope solution for tests to make certain repeaters are waterproof

Research Behind the Project

R. A. Brockbank, Ph.D., B.Sc. Eng., A.M.I.E.E. and G. H. Metson, Ph.D., B.Sc. Eng., A.M.I.E.E.

THE first meetings between technical representatives of the British Post Office and the Bell Telephone Laboratories, in 1952, consisted chiefly of a critical examination of each other's submerged repeaters and transmission methods. In particular the emphasis was on reliability and the experience and technical resources of both parties were pooled for the common benefit. It was agreed as a general principle that the design, circuiting and components should not deviate from previous tried practice without adequate justification.

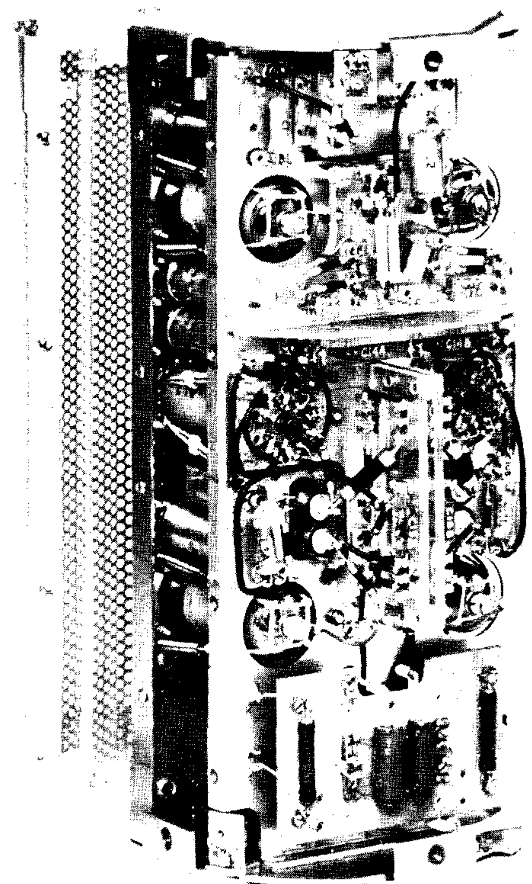
British practice on submerged repeaters dates back to 1938 when serious consideration was first given to the practicability of installing underwater repeaters in a shallow water cable. The Post Office appreciated that replacement after the cable was laid would be costly and lengthy, but concluded that if there was a reasonable possibility of obtaining a five year life the repeaters would be an economical proposition. Examination of the life capabilities of components which would need to be employed indicated that the commercial valves then available introduced by far the greatest hazard. The principle of negative feedback discovered in 1934 permitted certain variations and ageing to be absorbed but could do nothing once a valve started to "die".

Valve fears were reflected in the design of the first British repeater laid (1941), which had three alternative valves for each valve stage and which could be selected and switched into circuit from the terminal. Valves are still the heart of a submerged repeater but intensive research and development during recent years has resulted in most impressive progress.

British submerged repeater development has been wholly concerned with comparatively short and shallow schemes operating chiefly to the continent. Because of the vulnerability of such cables to trawls and anchors British designers have preferred to proceed on the lines of providing both directions of transmission on one cable, which therefore forms a self-contained system. This policy involves more components (up to 300) and necessitates the development of efficient and stable directional filters, and teeing networks for separating the two directions of transmission and feeding them through a common amplifier.

Research on components and valves backed up by the results of large scale life tests led to growing confidence in the exploitation of submerged repeaters and in 1948 a standardized shallow water repeater was produced which permitted 10 such units to be operated in tandem for long systems. The problem now arose of locating a faulty repeater in such a chain. Much work was done on this and finally a "radar" technique was evolved in which pulses, sent along the system in the low frequency band, returned from each amplifier in the high frequency band with an amplitude proportional to the level or the distortion of each repeater. This method has proved most successful for checking these two most important characteristics of each repeater in the link.

Early repeaters used proprietary radio-type components, such as capacitors and resistors, but it soon became clear that these were not of a design, quality or reproduceability to meet the growing standard of reliability expected from submerged repeaters. All components are now manufactured and tested to rigid specifications which have been drawn up to ensure uniformity and long life. Nearly all production is carried out in conditioned rooms which are dust, humidity and temperature controlled. Examples of components which have received a great deal of attention are the capacitors in each repeater, which may have continuously to withstand 2,500 volts d.c. Some of the more important introductions to the mechanical assembly of



Parallel amplifier developed in 1954

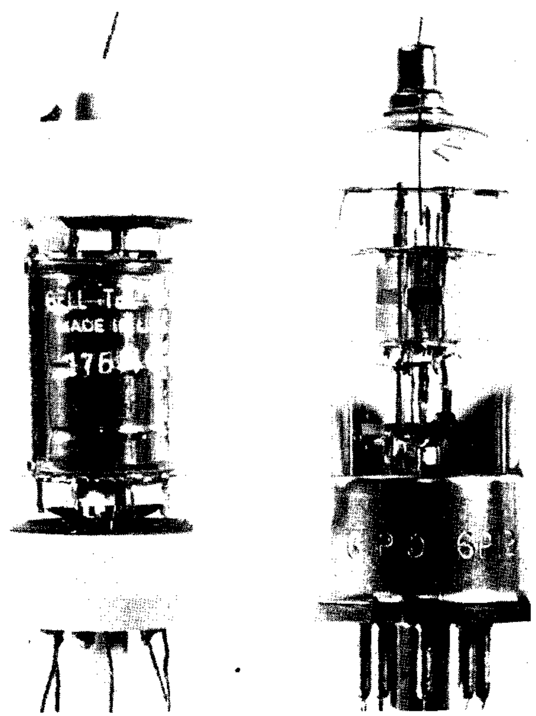
the electrical unit are the replacement by perspex of all bakelite type mouldings or laminated sheets, and elimination of whisker growths by gold plating all metal parts or, less preferably, ensuring a clearance between all conductors of at least $\frac{3}{8}$ inch.

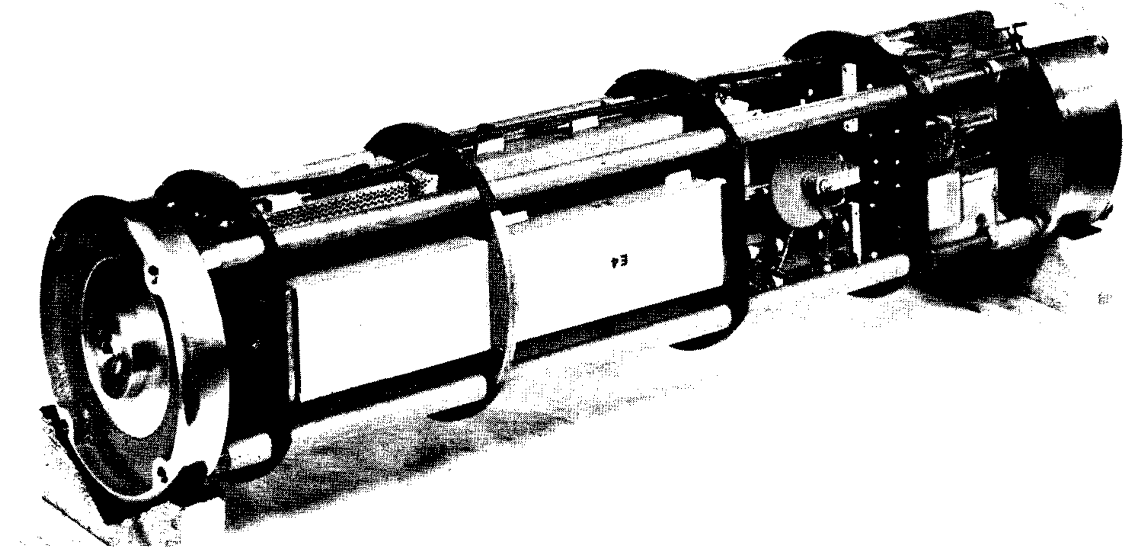
A major advance in 1954 was the introduction of the parallel amplifier (see above) consisting of two entirely separate amplifying paths with a common feedback path. This allows practically any type of fault to occur in one of the paths without noticeably affecting the gain of the amplifier as a whole. There is, in general, no need to replace a repeater having such a fault.

A great deal of research and development work have gone into the evolution of the present type of deep sea housing. Three features are particularly noteworthy: the glands which have to withstand an enormous water pressure combined with an electrical requirement to insulate the centre conductor for several kilovolts, brazing in the gland-carrying bulkheads without warming up the glands or the internal electrical unit and, finally, the joining of the gland tail to the sea cable. Early polythene glands in various forms proved unreliable until it was appreciated that one of the factors, temperature expansion coefficient, causing the trouble could form the basis for sealing the gland with entire success. Polythene insulated coaxial cables are inherently reliable, though their characteristics are not necessarily stable to the accuracy desirable for long distance systems. Apart from such factors as temperature and pressure coefficients there are other variations, on which much research work has been proceeding. The 63-mile coaxial land cable across Newfoundland had to be more adequately screened than the sea cable against natural lightning as well as possibly man-made interference. Research work finally led to the choice of soft iron tapes over the outer conductor.

American research and development which, like the British, also started before the second World War has proceeded in a somewhat different manner and with quite a different result. Before laying the

American and British valves

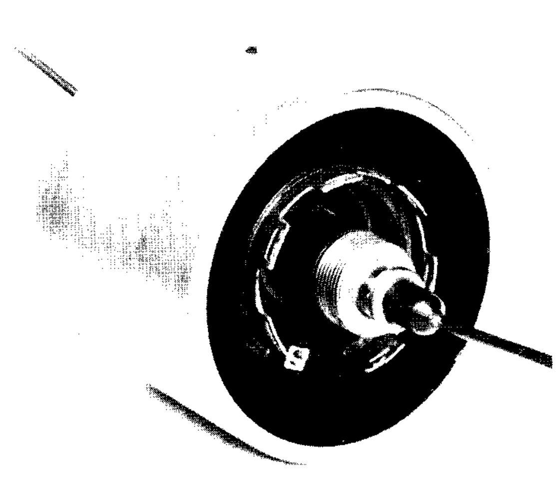




Shallow water repeater developed by the Post Office Research Station in 1948

Key West-Havana system with six repeaters in 1950, which is the only system they have in operation, the Bell Telephone Laboratories carried out a most exhaustive and detailed study of the problem, setting themselves the very highest standard of reliability. The result of all this concentrated development work is reflected in the fact that their first practical design, exploited on the Key West repeaters, was accepted several years after, virtually unchanged, for their transatlantic telephone repeaters. The amplifier components were modified to extend the frequency band from 24 to 36 channels and, using the same valve type, there is little doubt that

Bulkhead fitted with high pressure gland



their new design represents a model of efficiency with simplicity.

The method of repeater fault location which they have devised is extremely simple but very flexible. A quartz crystal in the feedback path removes feedback at a frequency unique to each repeater, resulting in a sharp gain peak which enables level, noise and overload to be examined. The valve again is the heart of the repeater and differs considerably from the British type now in use. Since in any repeater the valve has such an important role in determining the capabilities and reliability of the completed repeater it is of particular interest to study how the British and American types have evolved to their present high standard.

The basic reasons for valve fragility are the inherent mechanical complexity of their structure and the necessity for running the electron emitter (cathode) continuously at red heat. The approach to the life problem has been basically similar on both sides of the Atlantic and such differences as have arisen are due to local circumstances rather than different thinking. Both sides have paid great attention to the attainment of mechanical perfection and both appreciate that the red-hot cathode will only continue to emit its essential electron stream in a near-perfect vacuum.

It is in the manner of approach to these basic requirements that British and Americans have differed. The valves used are pentodes whose mechanical reliability can be progressively improved by increasing the separation between the five working

Lightweight cable with (l. to r.) central high tensile steel wire ; two layers of the same giving neutral strand ; single longitudinal copper tape outer conductor ; polythene insulation ; six aluminium tapes outer conductor ; cotton tape with common inhibitor; polythene protector sheath

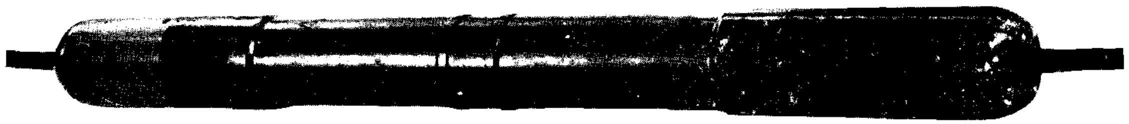
electrodes, by using thicker grid wires, stronger electrode support rods, and so on. It is, however, in the nature of electron optics that these desirable precautions lead to a decreased electrical performance and it becomes necessary to compromise between mechanical stability and electrical performance.

In the American repeater housing it is possible to insert only one set of valves and bias must inevitably shift away from high electrical performance towards a high level of mechanical reliability, since a single valve failure in the entire system will interrupt service. The British type of rigid repeater is able to house two sets of valves working independently and a number of valves in a cable system can fail with only a small probability of service interruption. In the British valve bias is, therefore, towards electrical performance.

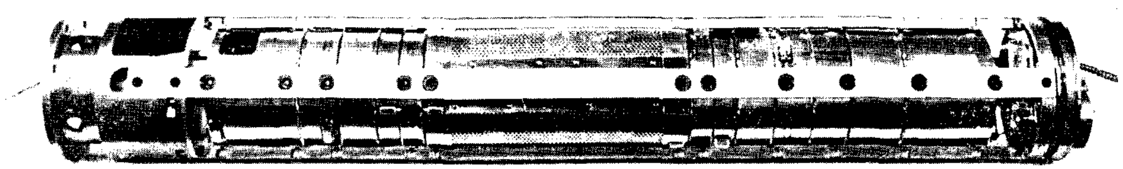
The second essential feature of the valves maintenance of a nearly perfect vacuum – is attained by both British and Americans in much the same way. All of the valve piece-parts are thermally preprocessed in vacuum or hydrogen to a gas-free condition before assembly, and the valves themselves are subjected to an extremely thorough pumping process. In one essential detail however the two valves differ and this is in the nature of the cathode core metal. Normal practice, followed by the Americans, is to use nickel containing small quantities of certain reducing agents to assist in the activation of the oxide cathode. Such core metals tend to give rise to an undesirable electrical resistance in the cathode itself and this leads to a deterioration in electrical performance. With valves of low mutual conductance (1.1 milliampere per volt) such as those used in the American repeater, this increase of cathode resistance is of negligible importance but in the high mutual conductance (6.5 milliampere per volt) British valve it must be eliminated. It has become practice, therefore, in British submarine repeater valves to use platinum as core metal for this gives freedom from the deleterious resistance effect.

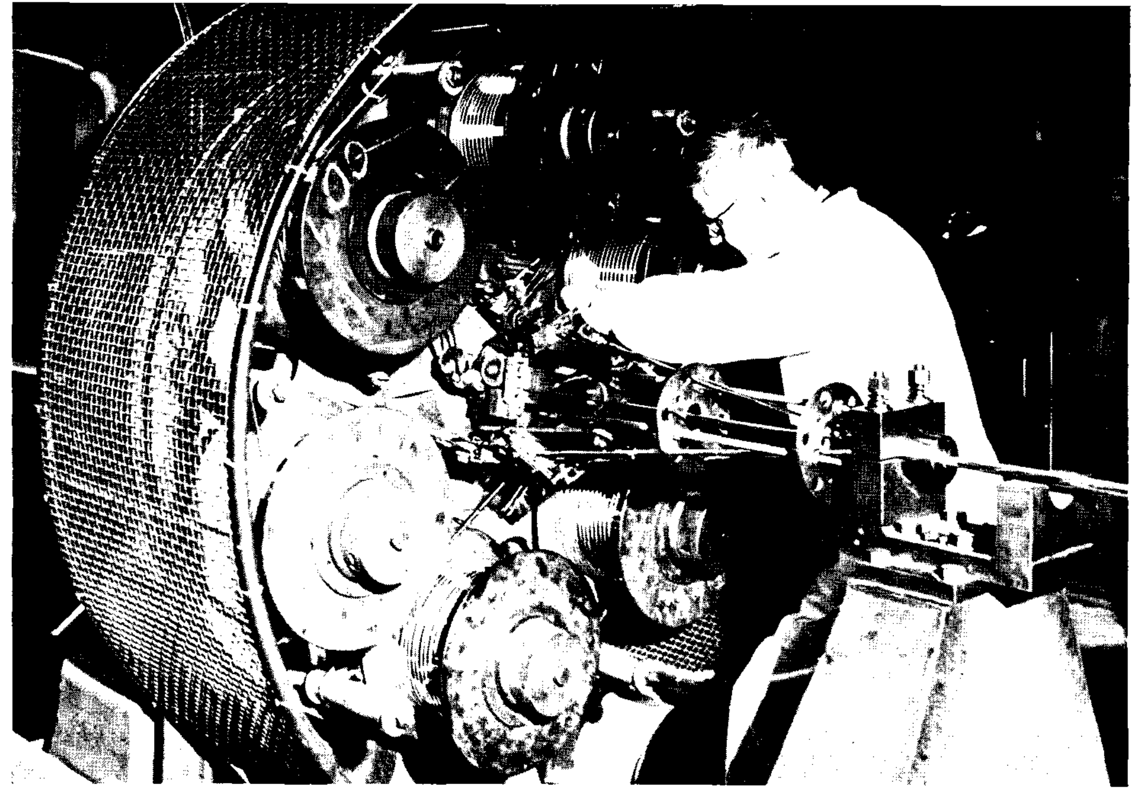
Even before the transatlantic telephone cable was brought into service plans were in hand for further long ocean crossings. There is a feeling that economic reliability requirements can be met, if the techniques and standards imposed for the first cable are not relaxed. The trend is towards wider and wider bandwidths with resulting shorter distances between repeaters. Research therefore will be primarily concerned with the many problems so raised.

Also, now that the practicability of long distance schemes seems reasonably assured the economics of such systems must be seriously studied. Cable costs are an important item in any system and research has already led to a new cable design which is appreciably cheaper than the present type. Repeaters using transistors are also being examined but it seems unlikely that they will oust the valve in the immediate future. Altogether a wide vista of research and development is opening up in this new field of telecommunications.



British transtlantic telephone cable repeater





Copper taping and serving machine being made ready for operation

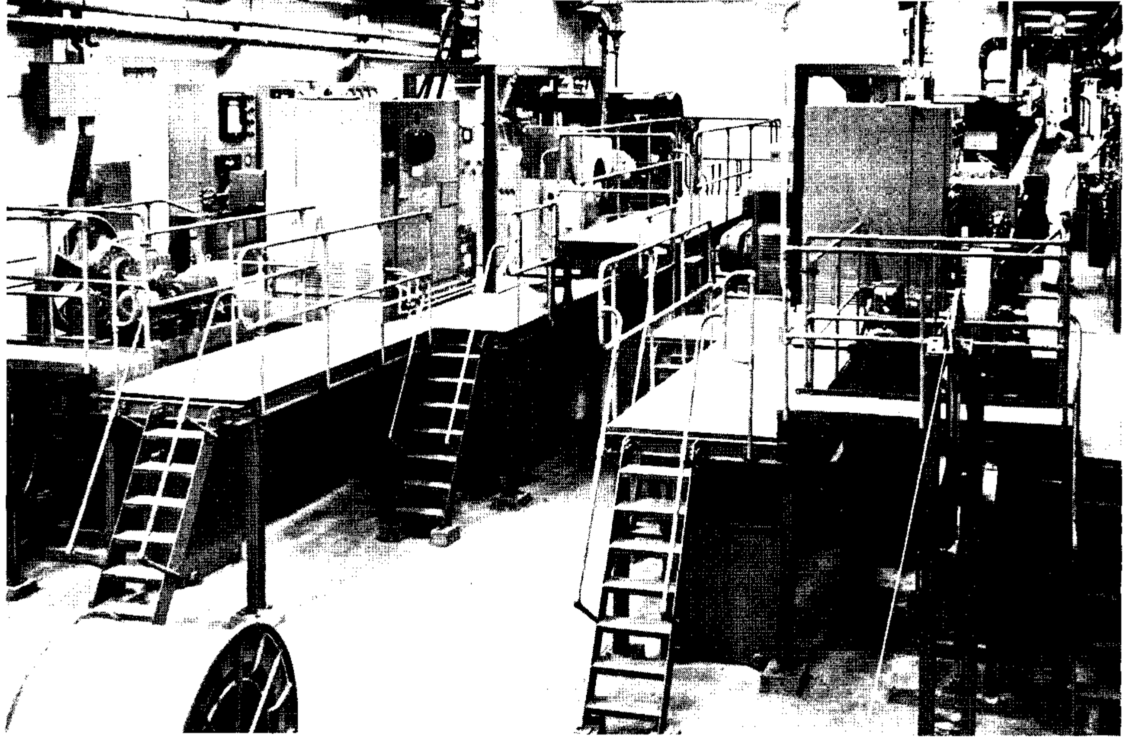
Making the Cable

E. F. H. Gould, B.Sc., A.C.G.I., M.I.E.E.

The design of the transatlantic telephone cable is not radically different from that of other repeatered submarine telephone cables which in recent years have been laid in shallow waters, but its importance requires the utmost reliability, and the length of the circuit makes it essential to ensure the utmost uniformity in the electrical characteristics. The outcome of these two requirements was the most exacting submarine cable specification ever prepared, and the successful completion of this venture marks a new epoch in cable making in which the modern techniques of the electronic engineer and scientist have been wedded to the skill of the cable maker born of years of experience.

The standards of cleanliness demanded could not be met in the normal type of cable factory since it was not enough to ensure that only materials complying with the specification were used, but great care had to be taken to see that no foreign matter was allowed to contaminate these materials in certain of the vital processes. Air conditioning was therefore incorporated in parts of a new works built by Submarine Cables at Erith in Kent, expressly for making modern submarine cable. This factory was built and equipped in an incredibly short time and is capable of producing 4,000 nautical miles (about 4,600 statute miles) of cable a year. Of the 4,499 nautical miles of transatlantic cable, Submarine Cables made no fewer than 4,167; the Simplex Wire & Cable Company made 332 at their works in New Hampshire, U.S.A.; and 60 nautical miles for the land section in Newfoundland were made by Southern United Telephone Cables at Dagenham, Essex.

A glance at the photograph on page 17 which shows the make-up of the cable, will perhaps make it easier to follow the processes involved in its manufacture.



Submarine Cables Ltd., Erith, Kent : where the central copper conductor passes through the extruder to receive an insulation of polythene compound

The composite central copper conductor is covered with polythene insulation, on which is laid the return coaxial conductor of six copper tapes around which there is a copper binder tape. This is lapped with an impregnated cotton tape followed by a jute serving to form a bed for the steel armour wires, which in turn are covered with outer jute servings and compounds. The number, size and type of the armouring wires are varied to suit the depth at which the cable is to be laid. It may be a little surprising to learn that the deep water section of this cable, by far the greatest part, has relatively light armouring. This is because, at great depths, the cable lies undisturbed and needs little protection. High tensile steel wires are used to reduce the weight of the cables and to withstand the strains involved in laying it, or picking it up later if necessary.

The composite conductor comprises a central copper wire (0.1318 inch diameter) around which are laid three copper tapes (0.148 x 0.0145 inch), pre-formed to make them fit snugly round the centre wire. The fit of these tapes on the centre wire is important; they had to meet a close specification for their profile and to be produced by rolling from wire so that there should be no risk of slivers of copper penetrating the polythene. The overall size of the composite conductor (0.160 inch diameter) had to be controlled to within five ten thousands of an inch, requiring close attention to the condition of the several dies through which it was drawn.

The central conductor was produced by four machines at Erith in 12 nautical mile lengths. It is not possible to produce this length of conductor without joints and great care had to be exercised in making them in the wire and the tapes. Improved brazing machines were developed for this purpose.

The clean bright centre conductor was insulated with a polythene compound produced by mixing pure polythene with 5 per cent. of butyl rubber to facilitate extrusion and 0.07 per cent. of an anti-oxidant to prevent oxidation during the extrusion process. The pure polythene, controlled within extremely close limits by Imperial Chemical Industries, was supplied in sealed polythene lined bags from which it was emptied into the large mixing machine with the additions already referred to, and there, while maintained at a pre-determined temperature, it was masticated for long enough to ensure complete mixing.

The compound was transferred to a strip extruder from which it emerged as a continuous band about 6 inches wide and ⅛ inch thick. It then passed through a cooling water trough to a machine in which it was cut into cubes about ⅛ inch in size. The cube cut compound was blown through a closed duct system to a battery of storage and blending silos, each with a capacity of five tons. From these the compound passed, by way of an electro-mechanical tester which automatically rejects any material containing metal impurities.

Before entering the extruder the centre conductor was heated by high frequency currents to bring it near to the temperature of the hot polythene in the extruder barrel and to remove any moisture. Close to where the core (as the insulated conductor is called) emerged from the extruder there was an electronic device which observed its diameter. At a point some 300 feet along the water troughs through which the core passed on its controlled cooling journey there was a second which measured and recorded the electrical capacity, and a third which measured and recorded the concentricity of the centre conductor within the insulation. Together the first two controlled the speed of extrusion, the first responding to short term changes and the second to any of long duration, so that the result was a uniform core which, on the average, was accurate to within three thousands of an inch of the nominal diameter of 0.621 inch, with the centre conductor located within 15 thousands of an inch of the centre.

Every inch of core passed through the hands of experienced examiners who felt it for any dimensional or surface irregularities and observed it for any other visible imperfection. At this stage the length of the core was checked for the first time before being coiled into large transportable pans, in which it was covered with de-aerated salt water and tested electrically. One of these tests was the application of a D.C. voltage of 90,000 volts to detect any weak spots which might develop into points of failure.

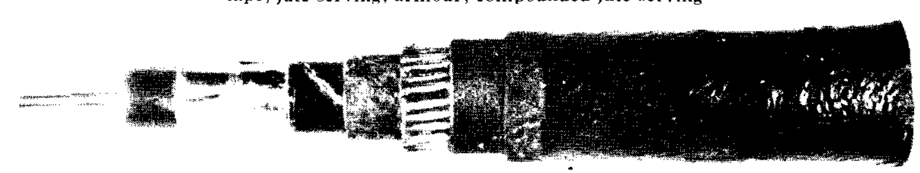
The approved lengths of core, varying from a quarter of a nautical mile to two nautical miles or more, were jointed together in air conditioned galleries to make the specified repeater lengths of about 37 nautical miles. This process was carried out by specially trained and qualified jointers who had to make a successful joint before each shift. Should they fail they had to re-qualify before being allowed to make a joint in the core for the cable. The core joint involved two distinct stages: brazing the centre conductor, and surrounding it with polythene compound, to the same size as the core, in a special injection moulding machine; also, every joint as well as being tested at 120,000 volts D.C., was examined by X-rays to see that it was perfectly executed and that no foreign matter was present.

The return conductor, which is coaxial with the centre conductor, comprises six copper tapes and a copper binder tape. The six copper tapes (0.320 inch x 0.016 inch) like the three tapes used for surrounding the centre wire had to have a particular profile and to be rolled from wire. A satisfactory technique for producing them to the close tolerances specified was evolved by Richard Johnson and Nephew.

The tapes were applied together to the core after pre-forming. The copper binding tape (1.75 inch x 0.003 inch) was applied on the same machine behind the six copper tapes and was followed by an impregnated cotton tape and servings of jute yarn which had been given a preservative treatment known as cutching. Each of the copper taping and serving machines can make up to four nautical miles a day and the served core as it emerged was coiled in intermediate storage tanks capable of holding about 20 nautical miles. The water level in these tanks was adjusted to keep the served core submerged and a full range of electrical tests was made to check the quality of the product armouring.

The deep sea portion of the transatlantic cable has 24 high tensile galvanised steel wires 0.086 inch diameter, whereas the shore ends have one or even two layers of galvanised mild steel wires 0.3 inch diameter. This is so stout that to the uninitiated it may appear more like a rod than wire. All

Deep sea cable: l. to r. centre wire; surround tapes; polythene insulation; return tape; binder tape; impregnated cotton tape; jute serving; armour; compounded jute serving



armour wires are coated with tar compound by immersion in a tank of the heated material and the lighter ones are lapped with an impregnated cotton tape to protect them. The cable was armoured in a machine to which it was fed from the intermediate storage tanks by a system of overhead sheaves and guides. The armour wires, wound on steel reels carried in a large revolving frame, were applied as contiguous helices along the core as it passed through the centre of the machine at a speed of 15 to 30 feet per minute, depending on the type of armour.

As it progressed through the machine the armoured cable was covered with tar compounds before, between and after the application of two tarred jute coverings. This process involved keeping the compounds at a temperature above the softening point of polythene and the armouring machine was therefore so arranged that the hot tar compounds were not allowed to flow on to the cable if the machine were stopped.

The finished cable was carried from the armouring machines above, over five feet diameter sheaves to the giant storage tanks each capable of holding many miles of cable. A view of those at the Simplex works in the U.S.A. is shown below. Those of the Submarine Cables works are similar (25 feet high and 30 feet in diameter) but in addition they have troughs for housing the American flexible repeaters through which repeater sections were joined together to form ocean blocks of cable, which were then ready for loading in *Monarch*.

Before the cables could be spliced they had to pass a most exhaustive series of tests to confirm the stability of their electrical characteristics and to provide information for fitting them together to form a satisfactory electrical system. To reduce the corrections to a minimum all measurements were made at as nearly as possible the same temperature; more important, it was necessary to maintain the same temperature throughout the cable, so the water in these tanks was kept constantly circulating.

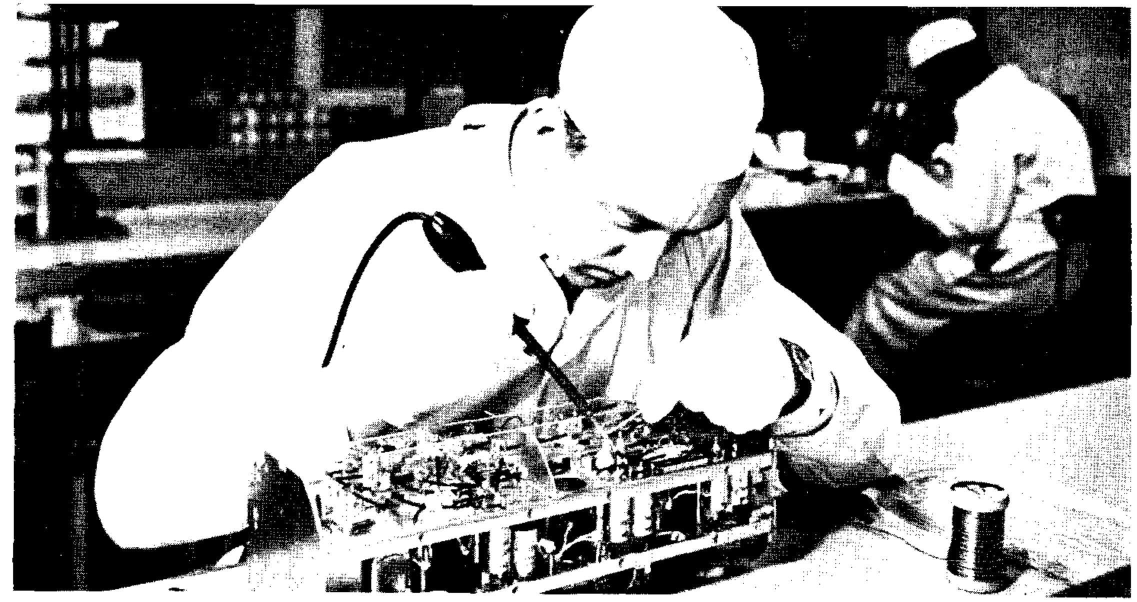
The sections of cable laid close inshore are liable to interference by high frequency voltages and they are therefore provided with a lead sheath to mitigate this nuisance. Core identical with that for the main part of the cable up to the copper binder tape was then covered with 0.090 inch thick polythene sheath and a double layer of cotton tape over which a lead alloy sheath 0.080 inch thick, was extruded. This was served with two layers of jute, armoured, and given an outer jute serving and compounded in the manner already described.

This cable may also suffer induction from nearby power supplies and shielding therefore had to be provided to reduce such interference. It was possible for the overland portion to relax slightly the electrical requirements of the cable, but core essentially the same as that already described so far as the copper binder tape was used. Over this five special soft iron steel tapes, 0.006 inch thick, were laid, the first longitudinally and the remainder with alternate direction of lay. This was then covered with a polythene sheath 0.080 inch thick, and served and armoured similarly to the main cable.

More than 20,000 tons of materials went into the making of the cable, of which some 11,000 tons were steel armour, a little over 2,600 tons copper and just under 1,500 tons polythene.

Finally, I must pay tribute to the way in which the Anglo-American inspection and testing team worked so harmoniously to achieve the high standard demanded.

Cable storage tanks—Simplex Wire Cable Company, New Hampshire, U.S.A.



Wiring a transatlantic telephone cable amplifier

Making the Repeaters

F. Scowen, B.Sc., A.Inst.P., A.M.I.E.E.

The hundred and twenty submerged repeaters in the submarine cables linking Scotland to Nova Scotia must have a life of at least 20 years, and without the regular maintenance given to repeaters in land repeater stations.

It was essential that reliability should be built into each repeater; this "component" is intangible, but it had to be present in every single piece of equipment and each worker who had anything to do with any phase of the manufacture and testing of the repeaters had to ensure that reliability was the keynote of his work. Special factories were set up on both sides of the Atlantic to manufacture the repeaters and, as would be expected, they had much in common.

The flexible repeaters for the main Atlantic crossing were built in the Western Electric plant at Hillside, New Jersey. This is in an air conditioned single-storied building. Around the walls are the offices and "non-restricted" service rooms; an inner core of "restricted" rooms is separated from the outer rooms by a corridor which encircles the inner core.

The repeaters were built in the "restricted" rooms in an air conditioned and dust-free atmosphere, maintained at a temperature between 73 and 77 F and a relative humidity of 40 per cent. The air pressure in the "restricted" rooms is slightly higher than that in the surrounding space, so that there is an air flow from the "restricted" rooms, across the corridor and through the outer rooms to atmosphere; this ensures that dust does not enter the "restricted" rooms every time a door is opened. Inside the inner core is a smaller space in which the relative humidity is maintained at 20 per cent.; capacitors are made in this space and the air is kept drier to avoid the wrinkling of the paper which would occur at a higher humidity.

The workers wore nylon clothes and special shoes which they put on before entering the inner rooms; when they left the "restricted" rooms for the cafeteria or the outer rooms they wore smocks over their nylon clothes. These precautions ensured that the workers did not bring dust into the "restricted" rooms; the floors of the rooms themselves were regularly machine scrubbed and vacuum dried. Special paper was used for recording the test results, to obviate the introduction of paper dust into the "restricted" space.

Each repeater had a history folder in which the history of each of the 60-odd components it contains were entered, and these folders will be kept during

Assembly of directional filters

the operating life of the repeaters. The workers were trained to act as their own inspectors, rejecting anything that did not come up to their own standards, and full time inspectors checked continually the workers' standards and performance. Engineers' inspection was made on each repeater before it was accepted. Many of the components were subjected to a series of temperature cycles over a period of days to remove internal strains; the range of this temperature variation was from 0 to 150 F, starting and finishing at room temperature. The paper capacitors were all life tested at a temperature of 39 F (the estimated temperature of the capacitors in a laid repeater) for six months. Consequently, the capacitor shop went into production first.

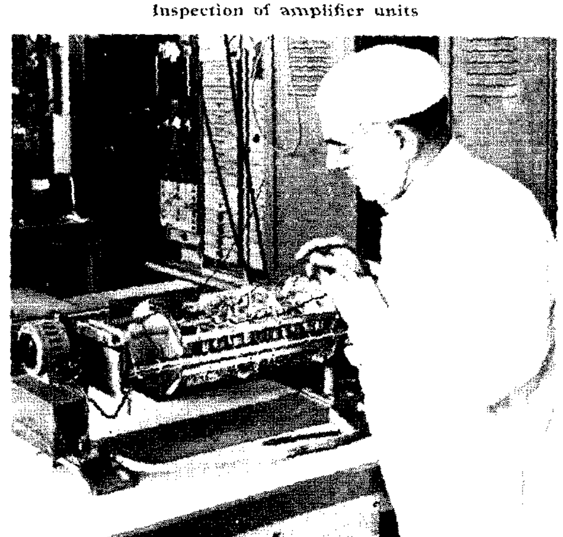
At each end of a repeater is a complex four-stage seal which keeps out the water. The maximum ocean bottom water pressure is three tons per square inch and each seal assembly and completed repeater was tested at 4½ tons a square inch to ensure that it could safely withstand the ocean bottom pressure.

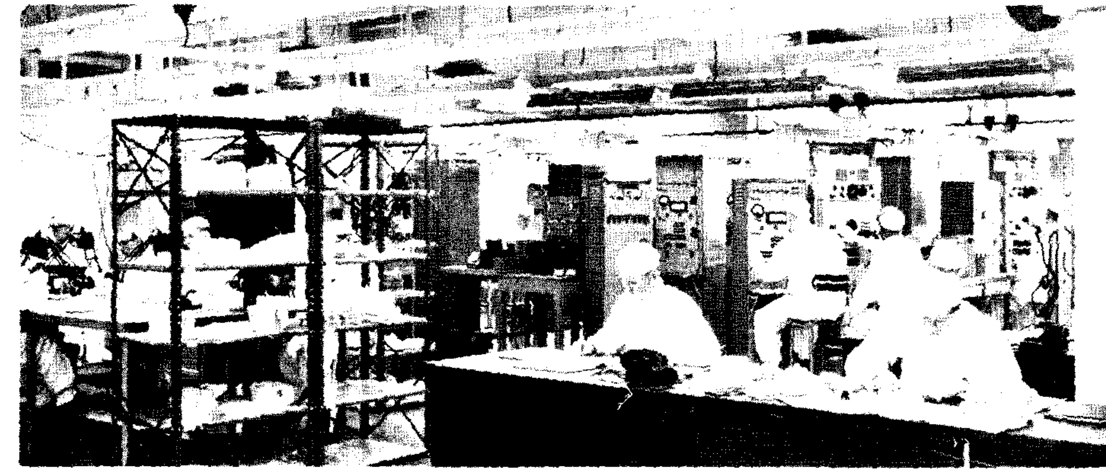
The 80-foot long repeaters (repeater, seals and stub cables) were sent to the Simplex Cable & Wire Company (who manufactured some of the submarine cable) for armouring, after which they were flown to England to be jointed into the cable before loading into H.M.T.S. *Monarch's* cable tanks.

The 16 submerged repeaters for the Clarenville (Newfoundland) to Sydney Mines (Nova Scotia) cable were made in the Standard Telephones and Cables factory at Woolwich, London. The company built two "dairies" in the factory which, as in the Hillside plant, are air conditioned, the temperature being maintained between 66 and 70 F and the relative humidity at 40 per cent. An inner room (2,300 square feet) in the upper "dairy" is used for component manufacture, where the temperature was maintained at 69 to 71 F with a relative humidity of 20 per cent; the air pressure in the component room is slightly above that in the rest of the "dairy" which in turn has its air pressure slightly above the external atmospheric pressure so giving a maximum degree of protection against the ingress of dust to the component production area. The air is filtered so that no particles larger than 1/5 micron (1/125,000 inch) could be left in the air of the component area and none larger than 5 microns (1/5,000 inch) in the air of the main area. Workers in the "dairy" wore white overalls and special shoes which they put on or removed in an air-lock changing room before entering or leaving the "dairy".

Each worker, as in the Hillside plant, was trained to act as his own inspector of raw material and finished product, and the company's inspectors were present to provide a continual check of the standard of construction and of the final product. In addition, the Post Office Research Branch at Dollis Hill, London, where the repeaters were designed, provided inspectors who had a roving commission to inspect any operation at any stage of production and they accepted the completed repeaters on behalf of the Post Office.

Inspection of amplifier units





A corner of the block in which the British repeaters were assembled

Each repeater contains 299 separate components. The majority of these were made in the "dairy"; some, however, were needed in small quantities and were made under the supervision of the Post Office and the company in outside factories which had set up controlled production units for this purpose in their own works. These components included carbon rod resistors (Erie), vitreous enamelled wire wound resistors (Berco and Painton) and sintox (ceramic) formers and parts (Lodge). The valves were made by the Post Office Research Branch valve group at Dollis Hill. The short circuiting fuses connected across the valve heater group were assembled at Dollis Hill from vitreous enamelled resistors and metal piece parts made in the Research Branch Workshop.

The 299 components require some 1,950 soldered joints to connect them together and each joint was inspected at some stage of production and marked to indicate that it had been inspected and accepted.

One third of the repeater components are paper or mica capacitors and some of the paper capacitors had to withstand 2,200 volts; 10 per cent. of each production batch was therefore tested under accelerated life test conditions at 5,000 volts and 65 C for 600 hours before the batch was passed as suitable for inclusion in a repeater. Each mica sheet was inspected for flaking, surface blemishes and solid or air inclusions before being printed with silver plates and fired, preparatory to being built up into mica capacitors.

Inductors, transformers and wire wound resistors form one-sixth of the components in a repeater and they were all hand-wound; after winding and adjustment to meet the electrical requirements they were vacuum dried and impregnated or sealed into screening cans which were then filled with dry nitrogen and hermetically sealed.

Each repeater comprises nine sub-units, each subunit containing a block of circuit components. The sub-units are one amplifier, two power separating filters, two bridge and equalizer units, a supervisory unit, two directional filter units and a resistor unit. All but the amplifier and the resistor unit are sealed into cylindrical cans which act as electrical screens and provide mechanical protection during assembly processes.

The lids of the cans are soldered on and it was essential that the surface finish of the cans should facilitate this soldering operation. Pure tin grows whiskers which are able to carry a current of about 10 milliamperes without fusing, so the metal parts of the repeater were gold plated (gold does not grow whiskers). If anything, this finish was easier to solder than the more usual pure tin coating used when a metal unit has to be soldered in a later operation.

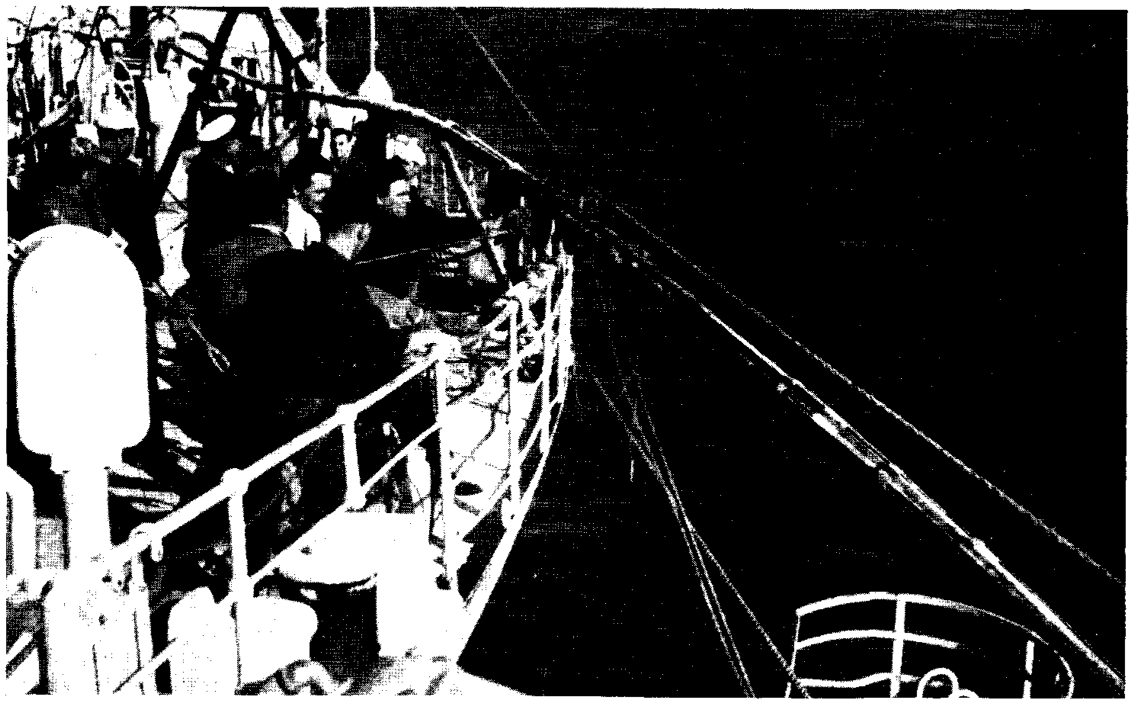
Normally, in electrical work pure tin coated connecting wire is used but because of the possibility of whisker growth only gold plated connecting wire was used in the repeaters. Carbon rod resistors have pure tin coated end caps and it was arranged for the coating to be changed to solder (tin-lead); for reliable sealing the paper capacitors were sealed into pure tin coated cases; where whiskers from these cans could have caused trouble, gold plated screens were placed around them to prevent possible whiskers from touching other points.

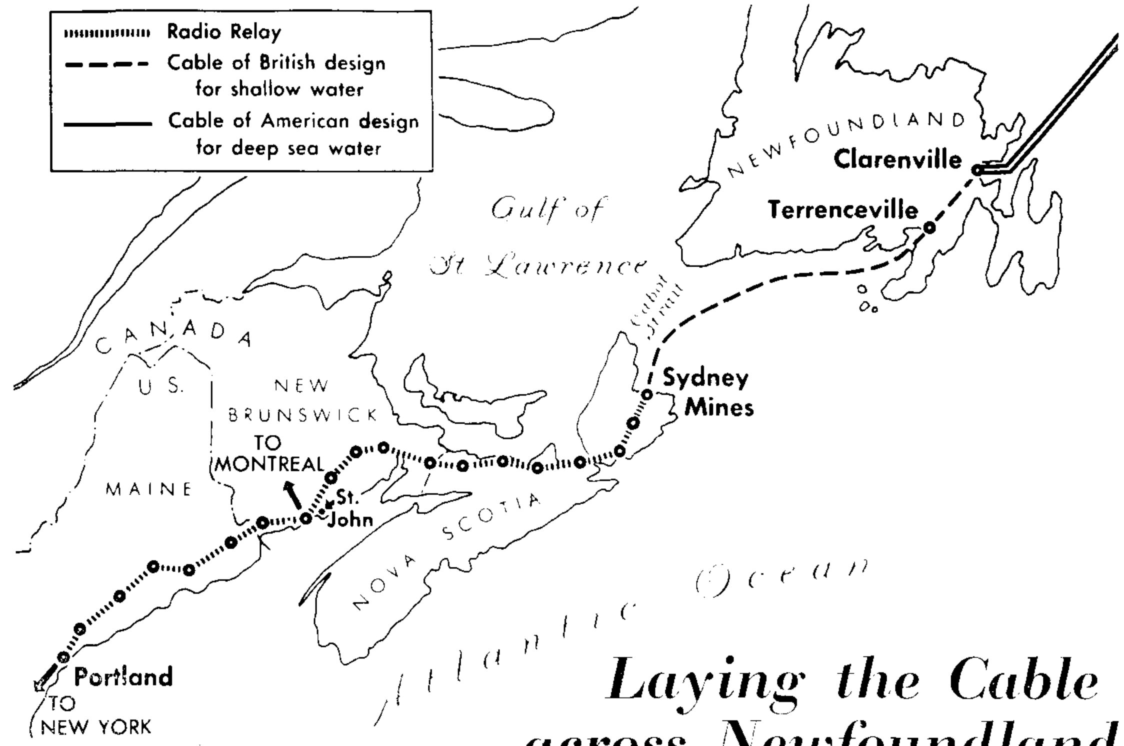
Each sub-unit was tested electrically and inspected visually and then stored, sealed in a polythene bag; when a complete set of sub-units was ready a repeater internal unit was built and, after preliminary electrical testing, sealed into a brass sleeve. The air inside this sleeve was replaced by dry nitrogen to reduce the possibility of oxidation; the sleeve was sealed hermetically and a series of electrical measurements was made on this sealed "repeater internal unit". After these tests the internal unit was sent for housing to the Submarine Cables factory at Erith, Kent, on the south bank of the Thames.

The hollow steel cylinders, 6 feet 3 inches long, and 10½ inches maximum external diameter, which contain the repeaters were machined at Greenwich from forged steel tubes and the bulkheads (the "stoppers" at each end of the cylindrical pressure housing) were machined and sent to the Post Office Research Branch at Dollis Hill where the tail cables were added and the gland moulded on. This gland has to maintain the insulation of the inner conductor of the cable which passes through it at a maximum voltage of some 2,400 volts and prevent the ingress of sea water into the steel housing under a maximum water pressure of ¼ of a ton per square inch. Each gland was X-rayed and then tested at a pressure of 5 tons a square inch for three months and, while still under pressure, it was given an electrical test at 40,000 volts D.C. and 20,000 volts A.C.; the bulkhead was then returned to Erith for sealing into a housing. Two bulkheads were brazed into the ends of a steel housing to enclose between them an internal repeater unit, and end caps were added; the complete repeater was then subjected to a pressure of 1½ tons a square inch for a week.

After this test period the repeater was returned to Woolwich for the last three months' confidence test period. During this period the repeater was in a water tank beside the lower "dairy" and the repeater was energized and watched for constancy of gain and noise generation to ensure that no intermittent fault was present and that no component was ageing.

An American flexible repeater being loaded on "Monarch" at Newington, U.S.A.





Laying the Cable across Newfoundland

H. E. Robinson and B. Ash

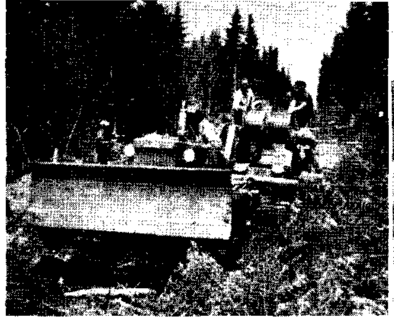
The men of the British Post Office who took part in laying and jointing the cable across Newfoundland will always remember with satisfaction the successful conclusion of their struggles against what at times appeared impossible odds to complete the 60-mile link between Clarenville and Terenceville, a route that was a challenge to both man and machine, offering many opportunities in a test of initiative and endurance.

From Clarenville for about 30 miles the cable route passes through three sea sections; the North and South Arms, west of Trinity Bay and the upper reaches of Placentia Bay; and through country which is hilly, wooded and boggy. Further west and north of the Burin Peninsular the country rises to a plateau of barren open country where the route meanders between rocky outcrops, across rivers, through two of the larger ponds (Long Pond and Sock Pond), and down some three miles of the Terrenceville highway to the cable hut.

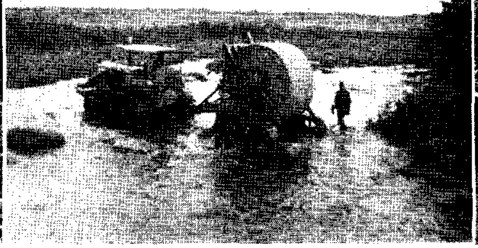
Early in May, 1955, ten experienced Newfoundland axe-men started at Adeyton to fell timber in the wooded sections to clear a 20-foot right-of-way along the 1954 survey line. The trees were cut as near to the ground as possible, leaving the roots to bind the unstable and often water-logged subsoil. Two D6 tractors with Hyster backhoe attachments started trenching operations a few days later. As the steel teeth of the backhoe buckets dug below the surface of the ground they exposed huge boulders in great numbers and it soon became apparent that it would be a rocky route to Terrenceville.

Fortunately the backhoe operators' skill was matched only by their enthusiasm and soon the cable trench was worming its way along the survey line, leaving the excavated boulders, large and small, littering the right-of-way as grim reminders of forthcoming difficulties in back-filling the trench. Natural water courses crossed the trench in many places, turning the surrounding ground into a morass of mud and slime. In these places the timber cut in clearing the right-of-way was used as a mat to support the heavy machines, but in spite of this, the digging and cabling machines became bogged down well over the caterpillar tracks. Bed-rock was effectively dealt with by explosives and the bogs, which were of every degree of consistency, were excavated by the machines supported on timber, by hand digging, or blasting according to conditions.

Perhaps the most outstanding feature of the trenching operations was along the Terrenceville highway, where it is built in the side of a hill



Laying copper guard wires



Tractor towing drum of cable

Beginning the armour splice

and the ground drops rapidly some 300 to 500 feet into a valley below. The road is narrow and winding and in places is supported on cantilevers of timber. To protect the cable from damage by landslides and road drainage work, it was necessary to cut the trench in virgin ground well below the foundations of the road. Much rock was encountered and many days were spent drilling and blasting before the trench was completed.

The cable was supplied in nominal 1,000-yard lengths on steel cable drums, which were mounted on a cable trailer with caterpillar tracks and was towed by a D6 tractor. Normally the cable was laid directly into the trench from the cable trailer, which had a boom to assist this operation. It was often necessary, however, to make a detour round the mud holes and soft places, lay the cable over the ground, and afterwards manhandle it into the trench. Owing to adverse weather and difficult terrain, cabling progress was slow for the first few weeks but by dogged determination and hard work the cabling crew narrowed the gap between themselves and the ditching crew, maintaining a reasonable spread throughout the period of the work.

Long Pond and Sock Pond, 5,700 and 3,400 yards long respectively, provided picturesque and exciting backgrounds for cabling and jointing. The method of laying the cable across the ponds was derived from field trials in Newfoundland by the Post Office party, and it was satisfying to see two miles of cable successfully floating in a straight line over Long Pond as a direct result. It was probably the longest length of submarine cable ever to be pulled through water on buoyant drums. Short wave radio sets ("walkie talkies") were used to control the operations.

A light armoured one-pair cable was laid in the trench about three inches from the main cable and looped out to speaker terminations at intervals along the route to provide telephone communication for field maintenance parties.

The main cable was jointed in seven operations: (i) electrically brazing the centre wire and surround tapes and spanning by safety conductor of 4-30 S.W.G. tinned copper wires wound helically and soldered to the surround tapes at each end; (ii) injection moulding the polythene dielectric; (iii) riveting and soldering the return tapes; (iv) relaying and soldering the teredo tape; (v) relaying and soldering the soft iron screening tapes; (vi) sealing the sheath with polythene and P.V.C. tapes; and (vii) splicing the armour wires.

Each completed core joint was subjected to X-ray examination to ensure concentricity of the centre conductor within the moulded area and that the polythene within that area should be free from voids and inclusions of dirt or metal. Visual examination in a specially designed light box was also made for the presence of hardened or charred polythene. A 40 kV. potential was then applied to ensure that there were no microscopic cracks in the moulding.

The equipment, tools and stores necessary to make a joint weighed approximately one ton and where distances were too great for manhandling they were loaded on a locally built wooden sleigh and towed by a light tractor.

The jointing staff, reinforced by hired local labour, was organized in four working parties operating at adjacent jointing positions: (i) a survey party located a suitable access way from the highway to the jointing position, delivered the jointing platform, bench, table, tent, and tarpaulins; they also decided how power could best be made available at the site and they set up the supply accordingly; (ii) a preparation party prepared the position and set up the cable for jointing, laid back the armour wires and assisted the testing officers to measure and record the insulation and the conductor resistances of each cable length; (iii) a jointing party was responsible for all jointing operations on the main cable except the armour splice; (iv) an armouring party made the armour splice and was also responsible for jointing and the insertion of loading coils in the speaker cable. Between May 29 and the end of August, 1955, the jointing party completed 96 main

cable joints; in the speaker cable they made 150 joints, inserted 90 loading coils and connected 40 pole terminating boxes.

To protect the cables against lightning in rocky country and in high ground, two 200 lb. hard drawn copper wires were laid in the trench 12 inches apart and six inches above the cable. This operation created quite a problem as hand-selected soil had to be found for the primary filling to cover the main and speaker cables and to support and cover the guard wires. To mark the cable route, 10-foot creosoted poles were erected at points where the trench changed direction and at intervals of approximately 1,000 feet on straight runs.

In Newfoundland in the late autumn weather conditions deteriorate very quickly, bringing icy winds and frequent snow showers, and it was in such conditions that the two repeaters were laid and jointed. Fortunately we were able to obtain the assistance of the local highways department, who kept the road open and so enabled both repeaters to be transported without undue difficulty.

The pit excavated in the edge of Fox Pond (the site for the first repeater) lies down hill approximately 200 feet from the road, and the ground, although rough and undulating, is reasonably firm. We therefore decided to manhandle the repeater from the road to the pit, and to help in this operation spruce poles were laid in the form of railway lines along which the repeater was manoeuvred a few feet at a time.

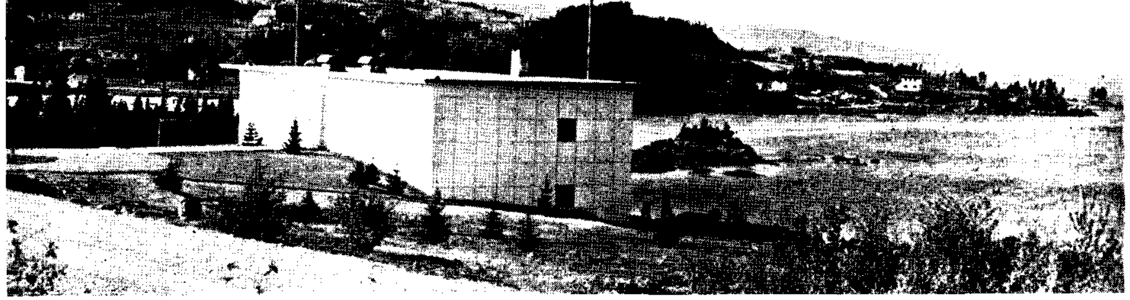
Cable coming ashore at Newfoundland

Cable laying in a flooded trench

At the edge of the pond the repeater was fastened by a rope harness to a light tractor to control the weight and, with men evenly spaced along the cable tails, it was carefully lowered into the water. The tails were then jointed into the main cable and, to facilitate transmission tests, the Clarenville side of the repeater was jointed first. Attenuation measurements placed the position of the second repeater exactly 20 nautical miles further along the cable route and in a pit which had been excavated on the Terrenceville side of one of the small ponds (Hargrove Pond).

To expose and cut the main cable and to insert the second repeater, a coffer dam was built to pump the water from the repeater pit. When pumping had been completed we found that a large quantity of silt had accumulated in the excavation and many hours of strenuous digging were necessary before the cable could be cut and lifted to a position where it could be jointed above ground level to the repeater tails.

The second repeater was transported from the highway to its site on a wooden sleigh towed by the light tractor and laid in a manner similar to that employed for the first repeater. When the tail cables had been jointed, overall transmission tests were made through each repeater from the cable test point; when these tests had been completed the spare cable from the trench to the test hut was cut away and the cable jointed through, thus completing the land cable link.



Clarenville Cable Station

Where the Cable Lands

A. W. Welsh

As the transatlantic telephone system involves two submarine cable systems, there are three terminal stations: Oban, Scotland; Clarenville, Newfoundland; and Sydney Mines, Nova Scotia. The stations are shown on the map on page 3.

The lay-out and economy of the two Canadian locations are quite different although the geographical settings are remarkably similar; the setting of each is austere and rugged, and this, allied to the severe climatic conditions, caused many a shivering Post Office engineer to wonder why the cable could not have been routed *via* the Bahamas!

A major consideration when choosing a submarine cable termination is the necessity to approach land by a route which will avoid damage to the cable by storms, ships' anchors and fishermen's trawls. Clarenville affords an almost ideal site in this respect, lying as it does on the sheltered side of Random Island, with two indirect channels to the open sea and negligible shipping activity.

A general view of the Clarenville station is seen in the first photograph. Behind the station can be seen part of Random Island across the water. The three submarine cables, two to Oban and one to Sydney Mines leave the rear of the station, enter the water and bear right, down the channel between the mainland and Random Island. The station is a two-storied building with the power equipment in the lower storey and the transmission equipment in the upper. On entering this transmission floor one gets a general impression of orderly ranks of shining grey equipment.

The second photograph shows the type of equipment, which the Post Office supplied, associated with the Clarenville-Sydney Mines cable section. Basically, the function of these submarine terminal stations is the same; therefore, a general description of the equipment in one station could equally well apply to the other.

The small cubicle in the centre foreground terminates the incoming cable and power for the submarine repeaters is fed into it from the two flanking power cubicles, designed to feed a precisely controlled current to the cable at very high voltage. Their operation is very complex and, according to the designer, they can do everything but talk!

Just visible in the background is the transmission equipment which provides the necessary amplification, frequency changing and adjustment for the signals passing over the cable.

On the extreme right is a testing cubicle (supplied at Sydney Mines only) for the submarine repeaters. A picture of the performance of all the repeaters can be seen on a large cathode ray tube, under the hood.

At Clarenville, in addition to the group of Post Office equipment, a corresponding group of equipment for the Clarenville-Oban system is installed. This was supplied by the American Telephone & Telegraph Company, and is similar to the equipment shown in the third photograph at Oban.

The cubicles (which are separate in the Post Office design) are, in the American Telephone & Telegraph Company installation, combined into one long suite as seen in the photograph. Two such suites are provided, one for each cable, since Oban-Clarenville is a two cable system. The transmission equipment is seen facing at the rear. It performs similar functions of amplifying and converting signals from one frequency band to another, as in the Post Office system. Both systems are automatically monitored and provided with audible and visible alarms which give immediate indication of a fault, including transmission performance changes far too small to affect speech over the systems. Continuously running recording instruments are also provided to give a permanent record of the performance of the systems. Other equipment in the station is concerned with the testing of the cable and submarine repeaters. Plant is also provided to supply emergency power should the public supply fail.

Leaving Clarenville the cable crosses Random Sound to Adeyton thence overland to Terrenceville. The overland route was necessary to avoid the famous Grand Banks fishing grounds to the south of Newfoundland, where the danger of cable interruption would have been extremely high as the telegraph companies have found to their cost so often in the past.

Terrenceville cable station is a small hut, normally unattended, serving as a junction for the land and submarine cables; it also contains equipment which, in conjunction with similar equipment at Clarenville and Sydney Mines, is used to correct transmission changes caused by the seasonal temperature cycle.

Following the cable to Nova Scotia we arrive at Cape Breton, a much more densely populated part of Canada. Sydney is the chief town with Sydney Mines about 20 miles away. With North Sydney, the three towns form "The Industrial Heart of the Maritimes", that is, the Maritime Provinces of Canada.

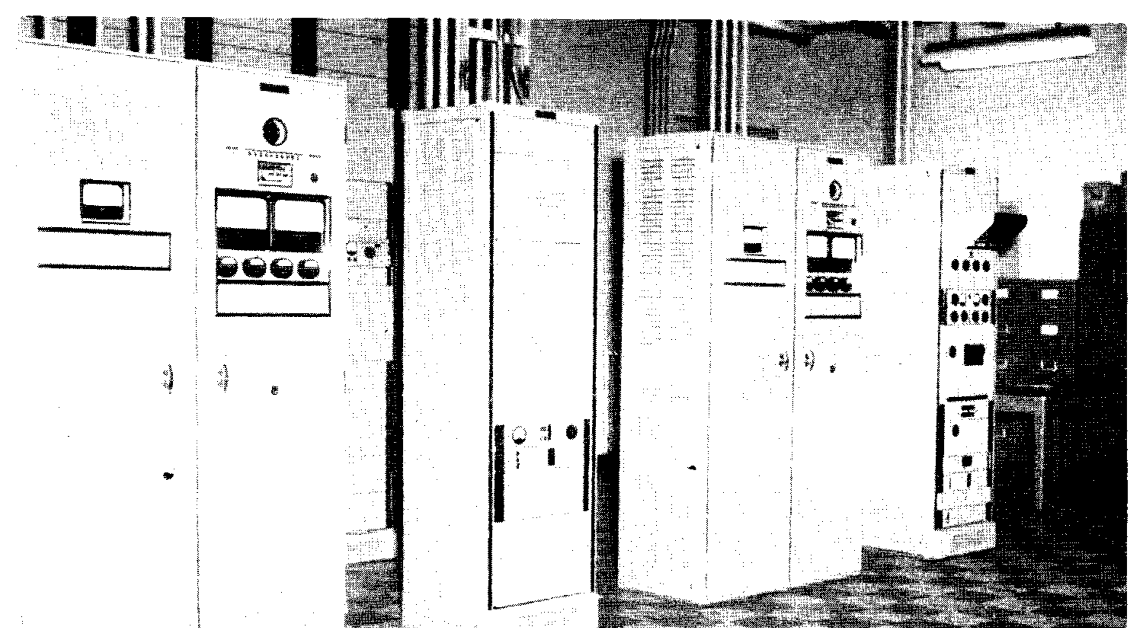
Sydney Mines terminal is a single-storey building, similar in appearance and construction to that at Clarenville. Some distance from the sea, it is dominated by the towering radio mast which beams signals to New York and Montreal. Inside, much of the equipment is similar to that at Clarenville. In place of the main Atlantic system equipment shown in photograph three, however, is the American radio relay equipment for extending the circuits on the next stage of their journey to New York and Montreal. The radio equipment itself operates at frequencies around 4,000 megacycles.

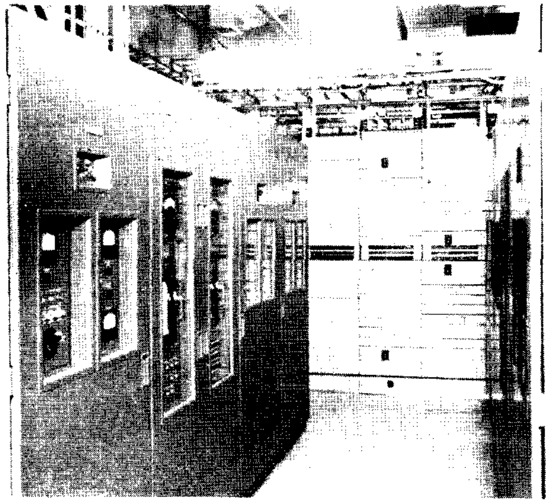
During the winter, the sea conditions around the coasts of Newfoundland and Nova Scotia are extraordinary. Ice floes, large enough to "ground" on the sea bottom, are an obvious danger to submarine cables and the closely packed ice field can severely hamper a cable ship trying to repair the resultant damage.

Finally, Oban Britain's terminal station in Scotland. Although the function of this station is the same, its setting and construction are vastly different from the Canadian stations. Oban is a small holiday resort set in some of the most beautiful country in Scotland. The station is approached by what the station staff believe to be the worst road in Scotland. It is built into a tunnel in the cliff face.

The view from the windows of the office in the surface accommodation is probably the most beautiful of any in the country and is some compensation

Post Office submarine terminal equipment at Sydney Mines





The American Telephone & Telegraph Company submarine terminal equipment at Oban

for the fact that most working hours are spent in the apparatus room, which is deep in the mountain-side; it is approached by a long walk along an entrance tunnel. As may be expected in this type of accommodation, generous spacing of equipment is not permissible because of the high cost of floor area, and the equipment room presents a more compact appearance than its fellows on the other side of the Atlantic. In addition to the submarine cable equipment there is a mass of other equipment providing telephone and telegraph circuits to London.

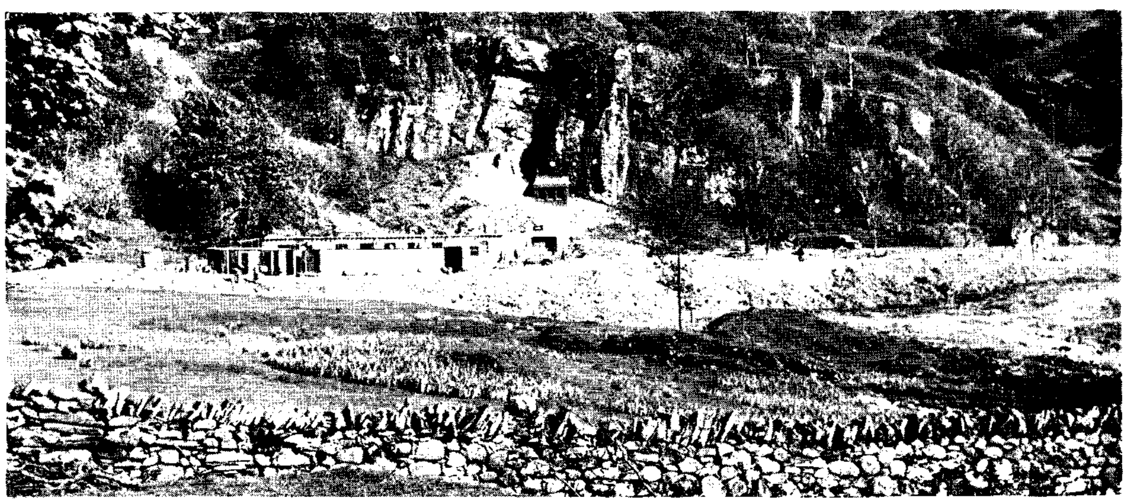
To ensure that service is maintained two completely separate routes to London have been installed, one *via* Glasgow and one *via* Inverness. The tunnel type construction has necessitated extensive ventilating plant, not found at the other stations. Because the station is widely dispersed it has been necessary to install multi-access telephone equipment to enable control engineers quickly to contact any member of the staff, it also serves to extend incoming telephone calls around the station.

The provision, installation and line-up of the equipment for the Oban-Clarenville system has been carried out by the American Telephone & Telegraph Company and for the Clarenville-Sydney Mines system by the Post Office. Thus there has been a useful mixing of staff and equipment at these stations, and we have been presented with an interesting side-by-side comparison of American and British construction and maintenance techniques.

From a roughly common practice of some 20 years ago there have been quite divergent developments. The American equipment is built on 11 foot 6 inch racks with very generous space allowance. Station wiring is taken straight to the equipment panels, often without the use of intermediate connexion blocks. Individual panels are, therefore, difficult to remove quickly. The British equipment on the other hand (51-type construction) has been developed into a compact unit type construction with standard plug-in panels. Both techniques have been applied to the T.A.T. project in such a way as to provide the greatest reliability of operation.

At Oban the maintenance staff are British while at Clarenville and Sydney Mines they are American and Canadian. They have the unique experience of maintaining, side by side, some of the most complex and advanced design equipment of two major telephone administrations. A lot of good-natured banter passes between the staffs, but behind this one feels there is a very real respect for the way each administration has tackled the technical problems which faced it.

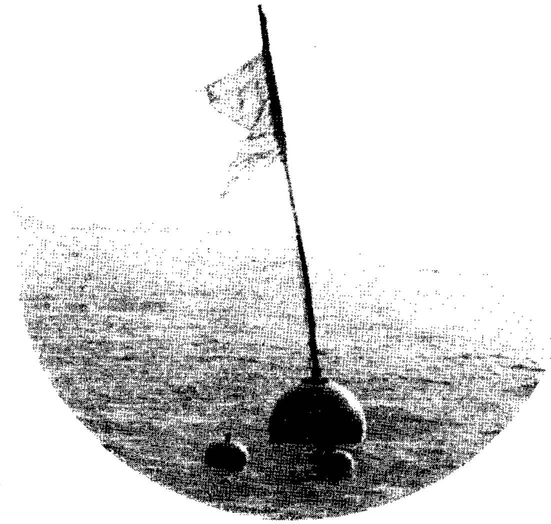
Oban Terminal Station



"Monarch" Lays the Cable

A Transatlantic Diary

Captain W. H. Leech, O.B.E., D.S.C.



ON June 22, 1955, Her Majesty's Telegraph Ship *Monarch* landed the Newfoundland shore ends of the cables which were to stretch for 1,941 nautical miles or 2,238 statute miles from Clarenville to Oban, and Mr. D. F. Bowie, President of the Canadian Overseas Telecommunication Corporation, christened the cable in the presence of the Lt. Governor of Newfoundland and Captain Betson of the *Monarch*. The first stage in laying the first transatlantic telephone cable had been completed and the cable ship sailed away into the Atlantic to continue the most exacting task she had ever undertaken.

H.M.T.S. *Monarch*, 8,056 tons, is the largest cable ship in the world: 484 feet overall with 55 feet 7 inches beam and capable of carrying some 2,600 miles of deep sea submarine cable. Driven by steam, she is the only cable ship fitted with electrically-operated cable machinery and the only ship afloat capable of carrying out the immense task which she completed 14 months later, on August 14, 1956.

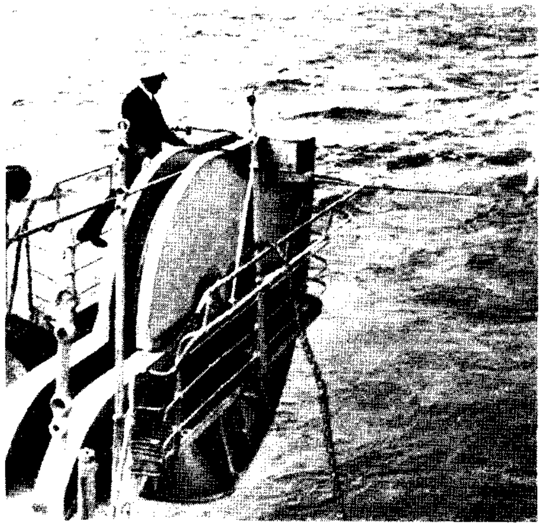
Before starting to lay the first cable, *Monarch* had completed successful trials, laying cable and repeaters in the deep waters off Gibraltar. After loading at Erith, she set out on May 21, 1955, to load more cable and American flexible repeaters at Newington, New Hampshire, taking soundings to verify the route of the second cable on the way across the Atlantic. Here she met her first Atlantic weather, steaming through a 24-hour gale with heavy swell and later being delayed by dense fog. Nevertheless, after laying several short cables on the south-east coast of Newfoundland, she reached Clarenville in good time.

Leaving Clarenville after the ceremony, she laid 203 miles of the first cable, containing five repeaters, towards Oban and, after refuelling at St. John's, arrived back in the Thames, on July 8, to load the long deep sea section of 1,155 miles, including 29 repeaters and six equalisers. Twenty-three days later she left Erith for the buoyed end off Clarenville, where she ran into thick fog and sighted a large iceberg. The chain attaching the cable to the buoy mooring had parted and *Monarch*, for part of the time in a southerly gale, had to grapple for the lost end in 350 fathoms. On the third day the gale dropped; she recovered the cable, spliced on to stock cable, and began laying towards Oban at 6-7 knots, slowing down to 2-3 knots while the repeaters were passing through the paying out gear and over the stern sheaves. Six repeaters were laid at over 2,100 fathoms. The greatest depth recorded during the lay was 2,360 fathoms.

With a total of 1,453 nautical miles of cable separating her from Clarenville, and a strong southerly gale blowing, *Monarch* buoyed the end at Rockall bank and sailed on to Erith through heavy seas and swell, and a wind reaching force 12—over 60 knots—arriving on August 22.

While the last main section was loaded into *Monarch's* tanks, H.M.T.S. *Iris*—a smaller vessel of the Post Office fleet—left Dalmuir for Kerrara Sound to lay the shore end cables into the Oban terminal. With the help of the Clyde puffer *Glenaray* and a diver, the ends were passed through steel pipes and hauled by winch into the repeater station. The cables were then paid out two miles seaward and, after being tested, the shore end of No. 1 was buoyed and the shore end of No. 2 terminated with a resistance and slipped.

Monarch left Erith again on September 12 with 509 miles of cable and 13 repeaters to splice on the end buoyed off Rockall. Sailing into a westerly gale, she found that the buoy had broken away. Several times she ran unsuccessfully across the line of the cable but failed to grapple. Then, on September 20, southerly gales blowing up to 90 knots hit her and for two days she had to abandon her attempts to



Commander Betson watching cable laying over stern sheaves

grapple, riding rough seas, buffeted by squalls of hurricane force and waves of up to 40 feet high. Then the storm abated sufficiently to enable her to continue grappling. The end was soon lifted to the bows, spliced on to the cable in her tanks, and she began paying out astern.

On September 26 *Monarch* reached *Iris's* buoyed end off Oban, made the final splice and slipped the cable in 15 fathoms. By then she had laid 1,941 nautical miles of cable, 51 repeaters and 6 equalisers to complete the first link, providing transmission in a west-east direction. *Monarch* returned to Erith after recovering the marker buoys, to unload surplus cable and spare repeaters in preparation for her annual refit on the Tyne.

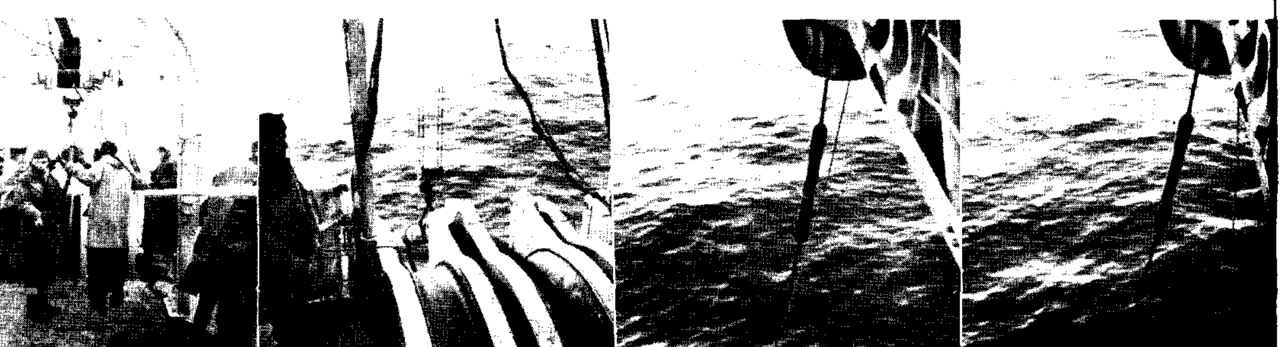
Next year, she started on February 1 to load the section between Newfoundland and Nova Scotia, sailing from Erith with about 280 miles of cable into which rigid repeaters of British manufacture had been jointed.

She ran into rough seas again on passage to Sydney, Nova Scotia, and crossed large areas of field ice off Penguin Island, Newfoundland. Having sounded the route on which the cable was to be laid, she berthed at Sydney on April 28. The shore end, of heavily armoured cable, was hauled ashore at Sydney Mines by two motor launches and the seaward end buoyed. The ship then proceeded to Terrenceville, Newfoundland, taking sea bottom temperatures on the way. When she anchored off Terrenceville on May 3, her launches towed the end ashore, supported by oil drums.

Monarch began laying out toward the buoyed end in heavy snow showers on the same day, continuing until May 7, when she recovered the buoyed end and made the final splice off Sydney Mines. Final tests overall revealed that the last repeater laid had developed a fault, so the ship returned to the repeater position, picked up the faulty repeater and inserted a replacement. After unloading equipment at Sydney on May 10 and 11, 1956, she set course for Erith, arriving on May 21. Between May 21 and 29 she loaded the first section of the No. 2 cable, for east to west transmission. This section was 476.3 nautical miles with 12 repeaters and one equaliser.

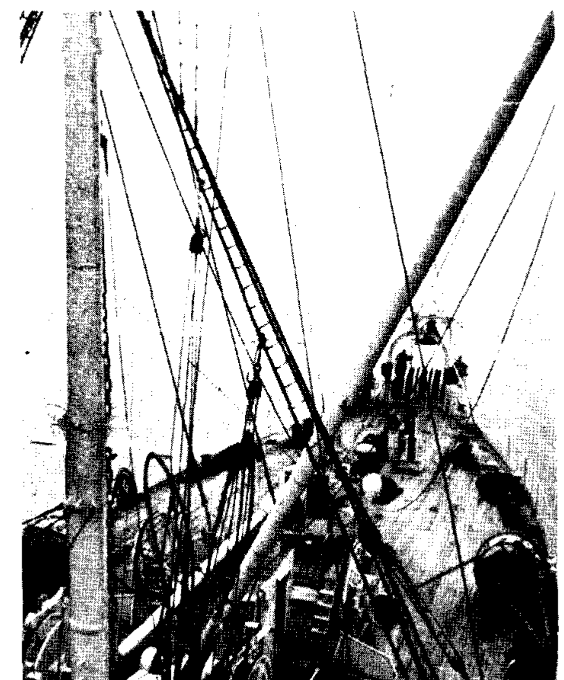
On May 24, 1956, *Iris* returned to a position two nautical miles westward of Oban, where she had laid the shore end in September, and recovered and buoyed the end of the remaining cable ready for *Monarch* to pick it up and joint and splice on the first main section.

Laying a rigid repeater : the repeater is traversed outboard and is seen passing over the bow sheaves ; the stoppering rope holds the repeater until the cable wholly takes the weight



Hauling cable ashore from " Monarch " at Clarenville, Newfoundland

" Monarch " in ice field



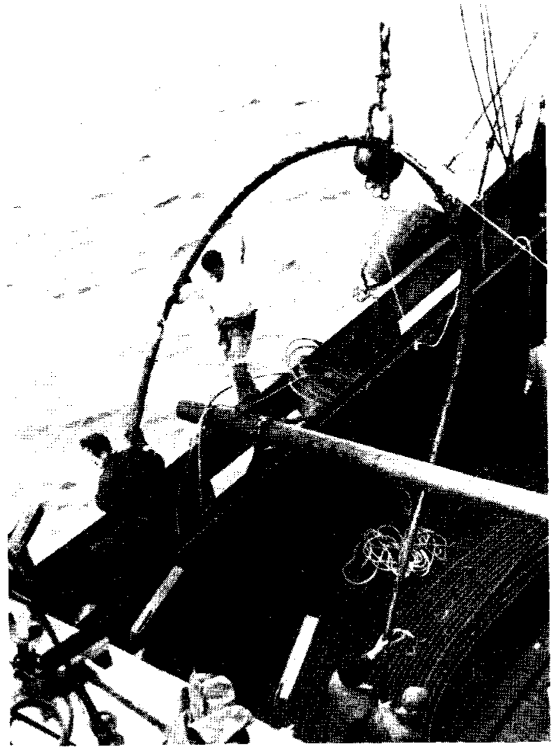
Duty Officer watching cable

On May 31 *Monarch* sailed from Erith and on June 4, recovered the end off Oban, jointed it to the cable in her tanks, and began to lay. By midnight on June 7 she had completed laying the first section, buoying the end on the western edge of the Rockall Bank and proceeded towards Erith, arriving on June 11.

Two days later *Monarch* began loading the main length, 1,280 nautical miles of cable, including 34 repeaters and two equalisers. On July 2 she sailed for the buoyed end off Rockall Bank arriving on July 6. After recovering the end and jointing it she began laying on the same day and on July 14 she buoyed the cable some 200 nautical miles east of Clarenville, completing the lay without incident. After calling at St. John's, Newfoundland, to refuel, she returned to Erith to load the final length.

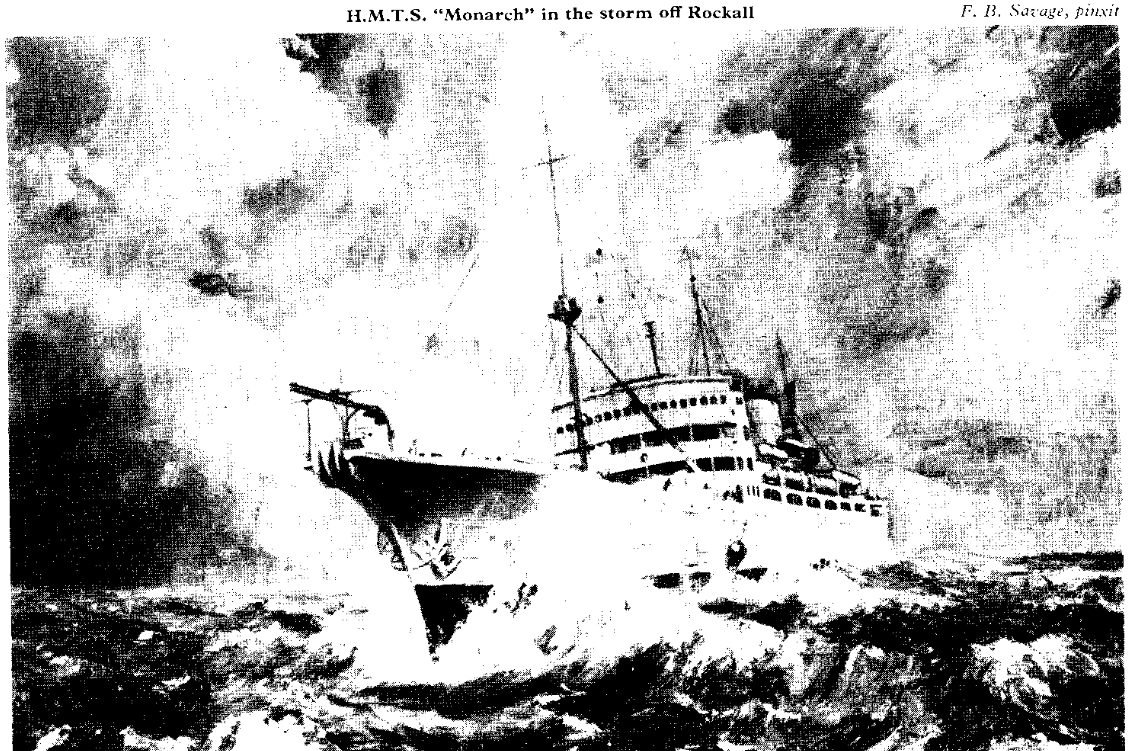
All was ready for the final stage. Loaded with cable, *Monarch* sailed on August 3 for the buoyed end off Newfoundland, picked it up and jointed it to the last 200 nautical miles in her tanks. Setting course for Clarenville she recovered the shore end, spliced on and, at 20.52 G.M.T. on August 14, 1956, she slipped the last splice into the Atlantic.

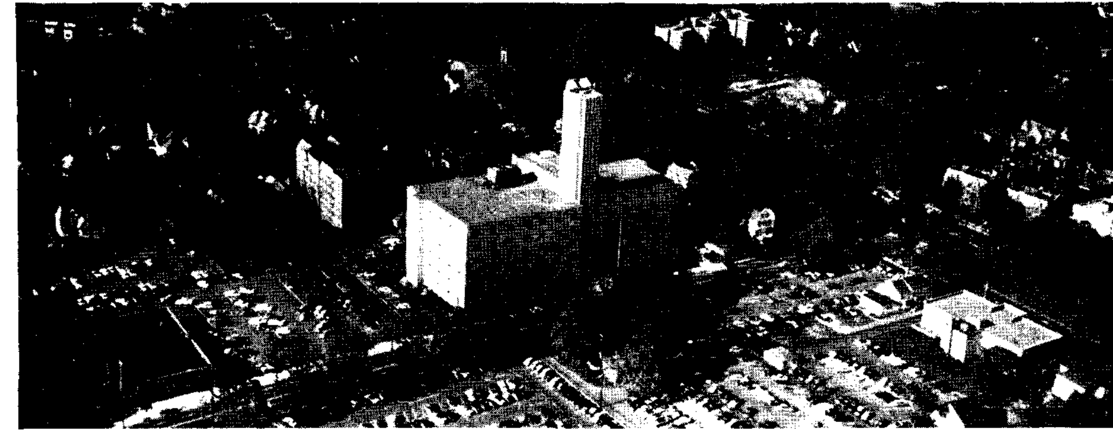
The first transatlantic telephone cable was ready for its final tests in preparation for public services. The laying was completed exactly 90 years, 18 days after the first successful transatlantic telegraph cable had been completed in 1866.



End of cable being passed ashore from s.s. " Glenaray " off Oban Station

H.M.T.S. "Monarch" in the storm off Rockall *F. B. Savage, pinxit*





Aerial view of White Plains, New York, some 40 miles north of New York City

Operating the New Telephone System

A. G. Sutherland

TWENTY-TWO of the thirty-six circuits of the transatlantic telephone cable system are available for telephone service between the United Kingdom and the United States, six are terminated in Montreal to augment facilities with Canada, and seven are permanently connected through London to give two direct circuits between the United States and Germany, one circuit each to France, Belgium, Holland and Switzerland, and one circuit to Denmark which also carries American traffic with Norway and Sweden.

The British terminal of the cable circuits between London and the United States and Canada is in the International Exchange at Wood Street in the City where 12 additional operating positions have been installed to cater for future growth.

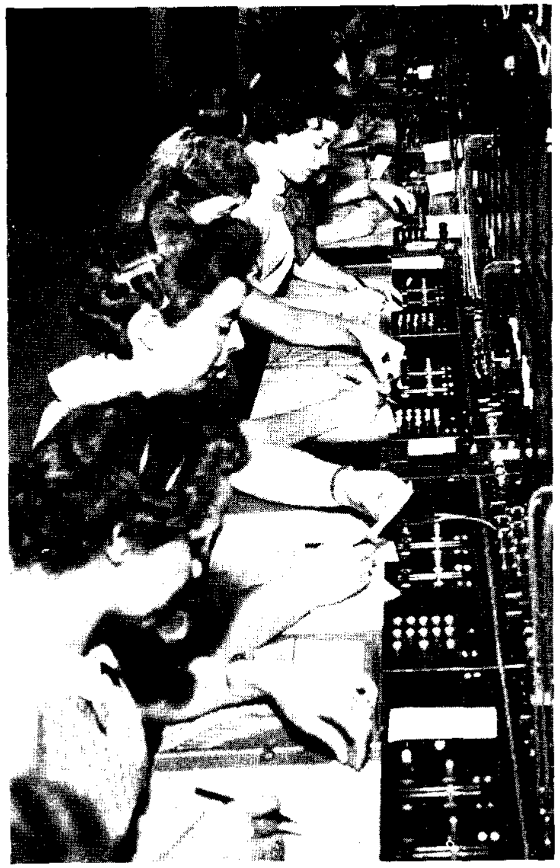
In the United States the cable circuits are operated by the American Telephone & Telegraph Company from the White Plains building, some 40 miles north of New York City, to which the existing London radiotelephone circuits have been transferred from Long Lines building in New York; the direct circuits between the United States and the European countries remain, however, in the Long Lines Building. The six circuits to Canada are terminated on the Toll switchboard of the Bell Telephone Company of Canada in Montreal, where the radiotelephone circuits are operated.

To cover any possible breakdown of the cable system the radiotelephone circuits are being retained and, to ensure that they may be available immediately against any eventuality, they will be used in the normal service in a regular rotation to supplement the cable circuits. Since transmission on the radio channels varies considerably from day to day and over the seasons depending on propagation conditions, they will not be brought into use for the normal day-to-day service unless transmission over the channels is of a high order of merit.

On the route from London to the United States, 14 of the 22 cable circuits, supplemented by six of the existing radio channels, will be used at first, although all the cable circuits will be available for traffic, on a bothway basis, should the need arise at exceptional traffic periods, such as Christmas. Possibly as a result of the publicity about the opening of the cable, there will be a large measure of "curiosity" traffic, and it may therefore prove necessary, temporarily, to bring into use more than the proposed 14 cable circuits. Similar arrangements for using cable circuits and radio channels apply on the London-Montreal route.

Before considering the operating methods on the cable circuits, it might be desirable to look first at the methods used in the early days of the radiotelephone service.

The first telephone circuit with New York opened in January 1927 when the Long Wave telephony transmitter at Rugby was brought into service. The charge for a call at that time was £15 for three minutes, with a report charge of £2. Staff had to be arranged in those days to obtain the maximum paid



Oversea switchboard in White Plains, New York, where United Kingdom-United States circuits terminate

time from the channels, and operating practice was governed by this requirement. In the beginning, three operators were employed for each radio channel, assisted by the technical operators at the radiotelephony terminal. One operator, known as the "channel operator", had charge of the radio channel itself; a second operator, "the advance caller", prepared the next call by obtaining the United Kingdom subscriber in advance and holding him until the radio channel became free; and a third monitored the actual call during its progress and recorded details to enable allowances to be made for interruptions caused by fading or noise on the radio channel. It was found possible later to dispense with the monitoring operator, but even now on certain of the more congested radiotelephone routes where the number of channels cannot be increased, an "advance caller" is still necessary.

Radiotelephone services tend to be unreliable, but the transatlantic telephone cable system provides circuits capable of carrying much more traffic with greater ease. In consequence a new approach has been necessary to operating methods.

Although over the years the operating procedure in the International Radio Exchange has been changed with a view to speeding the connexion of calls, it is still largely true that calls for the North American continent have been connected on a delay basis, and facilities have existed for bookings up to two days in advance. Admittedly there has also been a "Now" service that is, a call wanted at once but even this type of call was subjected to fairly involved radio operating procedures which hardly permitted immediate connexion. The radio calls were booked on a special suite and tickets were circulated to controlling positions for the various routes. The calls were handled at these positions in wanted time order and subscribers were kept advised of progress. When radio conditions were good and all 15 channels to New York, for example, were operating, delays were small but if bad conditions occurred at a busy time delays amounting to several hours were not uncommon.

With the coming of the cable we hope to give to Canada and the U.S.A. what will virtually be a demand service, although for technical reasons the calling subscriber must replace his receiver and be recalled. All calls, whatever their destinations, are answered by operators having outgoing cable circuits on their switchboards. If the booking proves to be for a radio route (for example, India) the operator merely books the call as hitherto and circulates the ticket for attention elsewhere; booking involves making an appointment from a "time assignment" chart and the allocation of a serial number. If a United Kingdom subscriber wants a call to North America the booking operator establishes the call unless the caller indicates a later time for completion. She continues to obtain a serial number because, for many types of call, an easy means of identification is still required, but there is no question of relating the call to a particular time.

On the majority of calls the operator plugs into a circuit and asks for the North American number. The North American operator routes the call up to the stage when the called number is rung and then the London operator takes over, dealing direct with the distant subscriber. As an overlapping operation the calling subscriber is regained and immediate connexion is then possible. This procedure was tested over the radio channels with both New York and Canada, with satisfactory results, and it is expected that calls between the United Kingdom and North America will usually be established in some two or three minutes, including inland switching at either end.

Of course a number of calls are not straightforward directory enquiries, no reply calls, required person not available, and so on and there are procedures for dealing with these; the arrangements permit personal contact by a controlling operator at all stages with consequent reduction in the doubt and misunderstandings inherent in methods involving divided responsibilities.

A point of particular interest concerns the use of the cable circuits for through traffic at either or both ends. In the radio service the connexion of two radio channels in tandem was about the practical limit to commercial speech so that, while calls from say India to the U.S.A. via London were fairly common, they would not normally extend beyond the U.S.A. to, say, Hawaii. With the cable circuits it may still be possible to employ long radio or land line connexions at both ends to effect such switchings. Operating procedures pose several problems and experience will be necessary before we are sure that we have the right solution. In general we work on the following basis: a call over the cable alone will be timed and controlled at the point of entry into the cable; a call over a radio circuit extended to the cable will be controlled at the out-going point of the radio portion; a call from radio via cable out to radio will be controlled at the outgoing cable point.

As an example of these arrangements, the proposal to use the cable circuits to Canada, to assist the present radiotelephone service to Australia, might particularly be mentioned. Transmission conditions over the long radio path on the direct circuits to Australia vary considerably with the time of day and the season of the year and there are often long periods when such transmission is not practicable. We now propose to gain experience with the routing of calls to Montreal over the cable circuits and thence to Australia via Vancouver, where a new transmitting station is available.

Although they are not strictly part of the cable, the 4-wire (that is, separate "go" and "return" path) switching facilities which have been provided to extend high quality transmission paths as far as possible, and to cut out cord circuit losses, should be mentioned. When an International operator in London wants to connect a cable call to say, Leeds, she will dial the Leeds number over selected circuits in the London-Leeds trunk route. When the call is connected the operator in ordinary course restores her speak key, and at this stage the call is switched direct from a cable termination to a Leeds 4-wire circuit. The speech path thus by-passes the switchboard and cord circuit but should the operator wish to re-enter circuit, she restores the speech through the switchboard by operating the speech key. The key in the monitoring position allows a low loss tapping across the remote 4-wire circuit. Similar 4-wire switching is provided between International and Continental exchanges and between Continental Exchange and European terminals for calls with the European continent.

Introduction of the cable allows the use of the familiar "clocks 44" for timing calls instead of the double stop watch used on radio calls. On cable calls the operator will be able to start the clock and leave subscribers on the straightforward call, much

International Exchange, London Terminal

as on an ordinary inland call. The clocks have been specially modified because the call will not be connected via the cord circuit, and control of the clock by the calling subscriber must come from the remote 4-wire switching point at Kingsway. The 3-minute tone signal moreover will be transmitted only to the inland subscriber and the operator can disconnect the pips entirely on, for example, transit calls.

Another feature of the cable which is of more than passing interest to the average citizen who never makes a transatlantic telephone call will be the use of selected circuits for programme broadcast purposes. Some 25 broadcasts a week were made during 1955-56, using normal North Atlantic radio-telephone channels. Reception has, of course, been limited by radio conditions, but the cable will provide music circuits which should be permanently reliable and which can be combined if necessary to given extra bandwidth (and hence quality) previously unobtainable. The music circuits will also be available as normal telephone circuits, but at the outset will be taken from the group of spare channels. When in use for programmes they will be extended from the White Plains building to the regular New York "Programme Office".

Although in the beginning manual methods of operation are being used, within about two years it is expected that automatic facilities will become available and at that stage London operators will dial New York and Montreal numbers, and *vice-versa*. Once dialling is extended beyond these points the problems of routing information become quite considerable. Nevertheless we hope gradually to make dialling access available, in addition, to inland trunk centres, with the result that a high percentage of the traffic will be connected very rapidly. The North American operators will not be dialling through London to points on the European Continent because of language difficulties; London operators will perform linguist duties as hitherto.

Although the new cable system is primarily a telephone project, it also provides eleven telegraph channels to Canada; eventually this number will be increased to 22. These telegraph channels are being used to supplement the existing wireless telegraph circuits and the two transatlantic telegraph cables operated from Electra House on the Victoria Embankment. In addition they will enable telex service to be extended in due course to Canada, and perhaps to Australia, and will meet requests for leased circuits. Tentative requests for such facilities have already been received.

The telegraph channels have been terminated in the Montreal telegraph office of the Canadian Overseas Telecommunication Corporation (C.O.T.C.) and in London, in such a way that they can be used to the best advantage and can readily be switched as between the public telegraph and telex services, and for leased circuits, some of which might be part time.

The C.O.T.C. has been supplied with a three-position telex switchboard of the standard Post Office type, as well as a number of normal Post Office telex subscribers' installations, and up to six of the telegraph channels with Montreal will be available for telex service with Canada. In addition three of the telegraph channels will be connected to Britain's Teleprinter Automatic Switching network (T.A.S.) to give direct access between certain London and provincial Cable & Wireless offices and Montreal.

Finally, a word about the phototelegraphy service. Hitherto, relatively few phototelegrams have been exchanged with Canada. The more reliable facilities of the cable as compared with radio may, however, attract more traffic and this new link with Canada may also provide a valuable routing to and from Australia especially during the Olympic Games. Two of the new telephone circuits in the cable have been nominated for picture telegraphy.