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A New Switching and Transmission Plan for the Inland Trunk Network

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The increasing proportion of telephone calls dialled by subscribers and the need to ensure satisfactory transmission on calls connected via several trunk circuits in tandem have made it necessary to plan changes to the inland trunk network. These include the provision of a separate transit trunk network to carry calls requiring the use of several circuits in tandem. The new network will have 4-wire switching at the transit switching centres and calls will be connected using rapid switching and signalling techniques. The reasons for formulating the new plan are discussed and its salient features are described.

INTRODUCTION

THE need to ensure rapid connexion and satisfactory transmission on subscriber-dialled trunk calls has made it necessary to plan changes to the inland trunk network. Although the routing of the majority of trunk calls will not be altered radically and existing equipment and trunk circuits will be used, the longer-distance multi-link trunk calls will be routed over a new transit trunk network; these calls will be connected using rapid signalling and switching techniques, with 4-wire switching at the transit exchanges.

This introductory article discusses some of the reasons which have led to the formulation of the new plan and gives an outline description of the transit trunk network, including the methods of signalling and switching to be used and some of the transmission features.

EXISTING TRUNK NETWORK

For the control and routing of trunk telephone traffic the United Kingdom is divided into zones and these are further divided into trunk groups, the trunk traffic originated at each exchange in a group being manually controlled from the trunk group centre exchange. There are 24 existing and authorized zone and sub-zone centres, approximately 250 group centres, and about 6,000 local telephone exchanges to which subscribers' lines are connected. The 6,000 local telephone exchanges are of two types: minor exchanges, which have direct circuits to their parent group centres; and dependent exchanges, each of which is connected to its group centre via a minor exchange.

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Each zone centre exchange, except Belfast, is connected by trunk circuits of low transmission loss to all other zone centre exchanges. The function of a sub-zone centre is to relieve the zone centre of part of its through traffic by collecting traffic from part of the zone and routing it to any destination to which the sub-zone centre has direct trunk circuits. All group centre exchanges with circuits to a sub-zone centre should also be provided with circuits to a zone centre for the connexion of trunk traffic that cannot be routed through the sub-zone centre.

Trunk calls are at present normally set up under the control of a telephone operator at the trunk group centre exchange. Where possible, calls are connected using direct circuits to other group centres or via one intermediate group centre; the longer distance calls which cannot be connected in this way are routed via one or two zone centres.

In the past an operator would have been required to switch a call at each trunk exchange through which it passed. The mechanization of the trunk service[1], involving the installation of automatic trunk exchanges at zone and group centres, is now well advanced and usually not more than one trunk operator, at the controlling group centre, is required for setting up a trunk call.

Subscriber Trunk Dialling and the Routing of Trunk Traffic

Having reduced to one the number of operators concerned with each trunk call, the next logical step is to replace the operator by automatic equipment and allow telephone subscribers to dial their own trunk calls. Subscriber trunk dialling (S.T.D.), which has already been provided at several centres and is being rapidly extended, will achieve this objective. The system has been described in detail in a special issue of the Journal[2].

To facilitate the introduction of S.T.D., the system of relating the charges for trunk and junction calls to the radial distances between exchanges has been replaced by a system under which the telephone exchanges in the United Kingdom are formed into 639 charging groups, with call charges common to all exchanges in a charging group. A charging group consists of one or more numbering groups, each of which will be identified by a code consisting of one, two or three digits.

The routing of S.T.D. calls to and from the exchanges in each numbering group will be via an exchange selected as the group switching centre (G.S.C.). A centre can, if necessary, deal with calls for more than one numbering group and, in the particular case of very large cities, there may be more than one G.S.C. handling the trunk traffic to and from a numbering group. G.S.C.s have not yet been selected for all numbering groups, but it seems likely that there will be about 400 of them, consisting of nearly all existing trunk group centres and some of the more important minor exchanges.

A subscriber wishing to make a trunk call will dial "0," which will connect his telephone to a controlling register-translator at the G.S.C. The register-translator will receive the digits dialled subsequently by the subscriber and determine the routing of the call and the call charge. For most calls it will be possible to use a direct route to the G.S.C. of the wanted subscriber or to route the call via one intermediate G.S.C. For the remaining calls, use of the present trunk network would result in undue delay occurring between the end of dialling and the receipt of a supervisory tone, and for the time being these calls will continue to be handled by an operator.

To enable these multi-link calls to be dialled by subscribers, a new trunk switching system, as described later, has therefore been planned.

Transmission Features of the Existing Trunk Network

The transmission features of the existing trunk network are, in general, in accordance with the transmission plan formulated in 1933[3]. It was then considered that the audibility should be not worse than that obtained from two standard telephones, with specified subscribers' lines and feeding bridges, and a nominal line loss of 15 db in the chain of trunk and junction circuits between terminal exchanges. To meet this standard it was intended that the various links in the trunk and junction network should comply with the following requirements.

Type of Link	*Transmission Loss (db)*
Zone centre to zone centre	0
Zone centre to group centre	3
Group centre to group centre	3 (Note 1)
Group centre to minor or dependent exchange	4·5 (Note 2)
Tandem exchange to minor exchange in a multi-exchange area (for traffic within the multi-exchange area)	6·5
Minor exchange to minor exchange for terminal traffic only	12

Note 1. A loss of 7·5 db was later allowed for circuits between group centres that carried terminal traffic only.

Note 2. For London, a loss of 6·5 db was later allowed between a minor exchange in the director area and a trunk exchange.

Note 3. The maximum nominal line loss (15 db) results on a call routed as follows: minor (or dependent)–group–zone–zone–group–minor (or dependent); i.e. $4{\cdot}5 + 3 + 0 + 3 + 4{\cdot}5 = 15$ db.

The intention in the original plan that the permissible line losses would eventually include the transmission losses in the exchange equipment has not been realized. In practice a loss of the order of 1 to 2 db is introduced at each switching centre, and there may be additional loss in cables connecting different apparatus rooms in a building or group of buildings.

In 1933 most zone centres were linked by audio-frequency circuits in underground cable or on open-wire overhead routes. Speech signals were transmitted over the cable circuits at relatively low velocity and echoes caused serious difficulties which, on low-loss circuits, made it necessary to fit echo suppressors. Zone centres are now linked by high-velocity carrier circuits which do not require the use of echo suppressors; the circuits are, however, adjusted to have a zero margin of stability (freedom from oscillation) when both ends are open-circuit, instead of the zero transmission loss originally visualized. This results in circuits connecting zone centres having a line loss of 1½ db or more at 800 c/s. In addition, it has proved too costly to provide routes from all group centres to fully interconnected zone centres and as a result a small proportion of calls have to be routed through three zone and sub-zone centres.

Although the points mentioned above have resulted in the transmission performance of the trunk network falling short of the standard set in 1933, the feature of the plan which has probably caused most difficulty is that of maintaining a line loss of 4·5 db from a dependent exchange, via a minor, to its group centre. The replacement of overhead routes by underground cables, with the economic desirability of avoiding the use of cables having 40 lb/mile or heavier conductors, has resulted in a worsening of transmission in some cases. With two independent circuits in tandem, amplifiers are of little help in obtaining a transmission loss of 4·5 db.

THE NEW PLAN

The new plan for the trunk network visualizes that local exchanges, to be known as "minor" exchanges, will each be directly connected to a G.S.C. via a single link. This is necessary for the following reasons.

(*a*) To allow periodic meter pulses to be relayed from the G.S.C. to the subscriber's meter at the minor exchange without the need for repetition at an intermediate exchange.

(*b*) To limit the number of digits needed to route a call to the objective exchange.

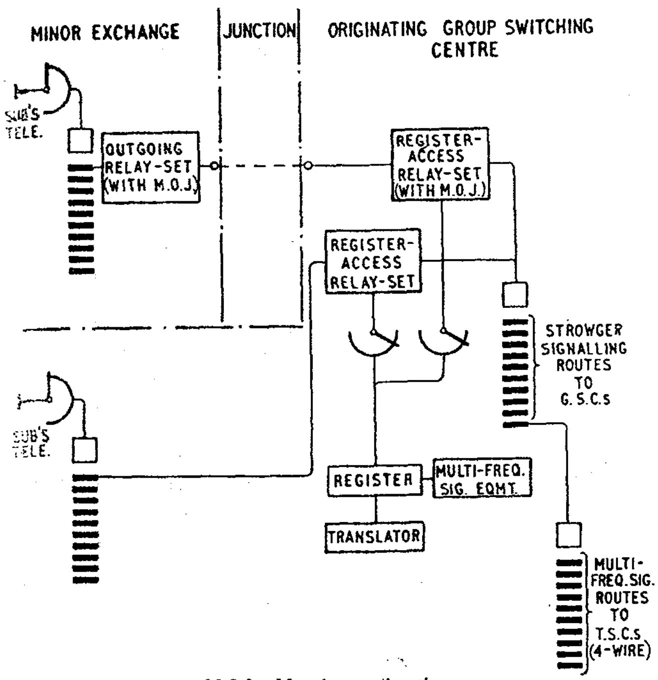
(*c*) To allow satisfactory transmission to be achieved without excessive expenditure on junction cables with heavy-gauge conductors.

It would be impracticable and unnecessary to convert the whole of the existing trunk network to a new system embodying fast setting-up of calls and improved transmission. Therefore G.S.C.s will continue to be interconnected by direct circuits wherever justified economically, and connexions may be set up with not more than two such circuits in tandem. The majority of trunk calls (possibly about three-quarters) will be routed in this way and will make full use of existing switching and signalling equipment. New equipment and a separate network of trunk circuits will be provided for the remaining calls to cater for the requirements of fast signalling and switching and to ensure satisfactory transmission.

Transit Trunk Network for Multi-Link Trunk Calls

The controlling register-translator at the originating G.S.C. will determine the routing of a call direct to the wanted G.S.C., via an intermediate G.S.C., or over the transit network. An outline trunking diagram of a G.S.C. is shown in Fig. 1.

This form of control will facilitate the provision of automatic alternative routing, which will permit traffic to be offered to a direct route and then, if all circuits are engaged, to overflow to the transit network. Direct circuits can then be economically provided for smaller quantities of traffic than would otherwise be possible; such direct routes could be economically justified on a



M.O.J.—Metering over junctions

FIG. 1—OUTLINE TRUNKING DIAGRAM OF GROUP SWITCHING CENTRE

"high usage" principle, i.e. more traffic would be offered to the route than could be carried by the circuits in the route at the standard grade of service, overflow traffic being diverted to the transit network. It follows that the routes in the transit network to which calls may be alternatively routed must be "fully provided" to carry traffic normally routed in this way as well as the overflow traffic from the direct routes.

Automatic alternative routing will also be used at transit centres, but the extent to which this will be desirable has yet to be determined. A maximum of two alternatives per route is being considered.

Four-Wire Switching

The use of a separate relatively small transit trunk network, carrying only a small proportion of the trunk traffic, makes it practicable to use 4-wire switching techniques at transit centres without undue cost or complication. This will be advantageous for rapid signalling, it will ensure that transmission is satisfactory and will enable more transit trunk circuits to be connected in tandem than would be possible with simple 2-wire switching. At present the number of circuits in tandem between trunk group centres is normally limited to three, i.e. when connexion is made via two zone centres. Under the new plan, group switching centres may be connected via five transit trunk circuits in tandem; exceptionally, for some calls to the Scottish islands, six links may be connected in tandem.

Transit Switching Centres

There will be 42 transit switching centres (T.S.C.s), located in the following cities and towns.

Some of the T.S.C.s (possibly six, though this has yet to be decided) will be fully interconnected to enable the number of transit trunk circuits in tandem to be normally limited to five. Each T.S.C. will have a route to one or more of these fully-interconnected T.S.C.s

‡Aberdeen	*Edinburgh	Lincoln	Peterborough
§Belfast	Exeter	*London	‡Plymouth
*Birmingham	*Glasgow	*Manchester	Preston
*Bristol	Hereford	Middlesbrough	*Reading
*Cambridge	Hull	*Newcastle	‡Salisbury
*Cardiff	‡Inverness	Norwich	*Sheffield
‡Carlisle	Kirkwall	*Nottingham	Shrewsbury
*Chester	Kyle	Oban	Stornoway
Colchester	*Leeds	Oxford	‡Swansea
Colwyn Bay	*Leicester	Perth	*Tunbridge Wells
Dumfries	Lerwick		

*Existing or authorized zone centres.
‡Existing or authorized sub-zone centres.
§Partially-connected zone centre.

SWITCHING AND SIGNALLING

At G.S.C.s 2-wire switching will be used for access to and from the transit trunk network; full use will be made of existing equipment, level 1 of the 1st trunk selectors being used for access to 2nd trunk selectors serving transit routes. For the transit switching centre exchanges new switching and signalling systems are being designed, as described below.

Setting Up Multi-Link Trunk Calls

When setting up a call over the transit network a free circuit to the required T.S.C. will be selected at the originating G.S.C. At the T.S.C. a transit register-translator will be connected to the trunk circuit and a "transit-proceed-to-send" signal will be returned to the controlling register-translator at the originating G.S.C., which will then transmit the information needed by the transit register-translator to route the call through the T.S.C. If the call is to be routed through further T.S.C.s the process will be repeated until the terminal G.S.C. is reached. A "terminal-proceed-to-send" signal will then be returned to the controlling register-translator, which will transmit the "local" part of the required subscriber's national number.

Rapid Switching at Transit Centres

The speed of switching required at T.S.C.s can be achieved with the type of motor-uniselector[4] that is already being used at trunk mechanization centres. The connexion through the exchange will be established via a link circuit consisting of two motor-uniselectors connected "wiper-to-wiper," as shown in Fig. 2. One motor-uniselector will act as a "finder" to connect the incoming trunk-circuit line relay-set to the link circuit; the other motor-uniselector will select a free outgoing circuit to the next centre.

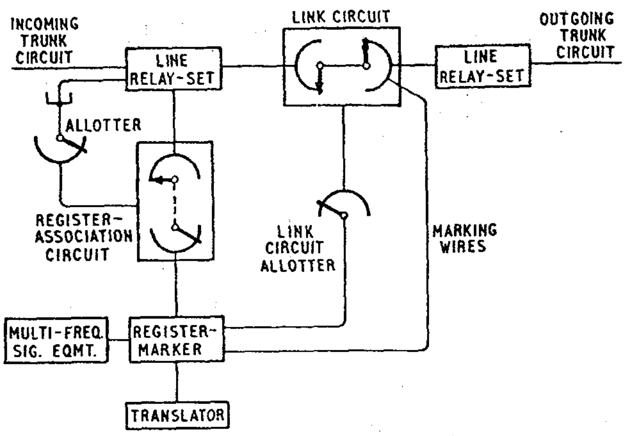


FIG. 2—BLOCK SCHEMATIC DIAGRAM OF TRANSIT SWITCHING CENTRE

Inter-Register Signalling

A 2-out-of-5 code multi-frequency signalling system will be used to transmit the digital information in the forward direction. This signalling equipment will be associated with the registers and not directly with the trunk line circuits.

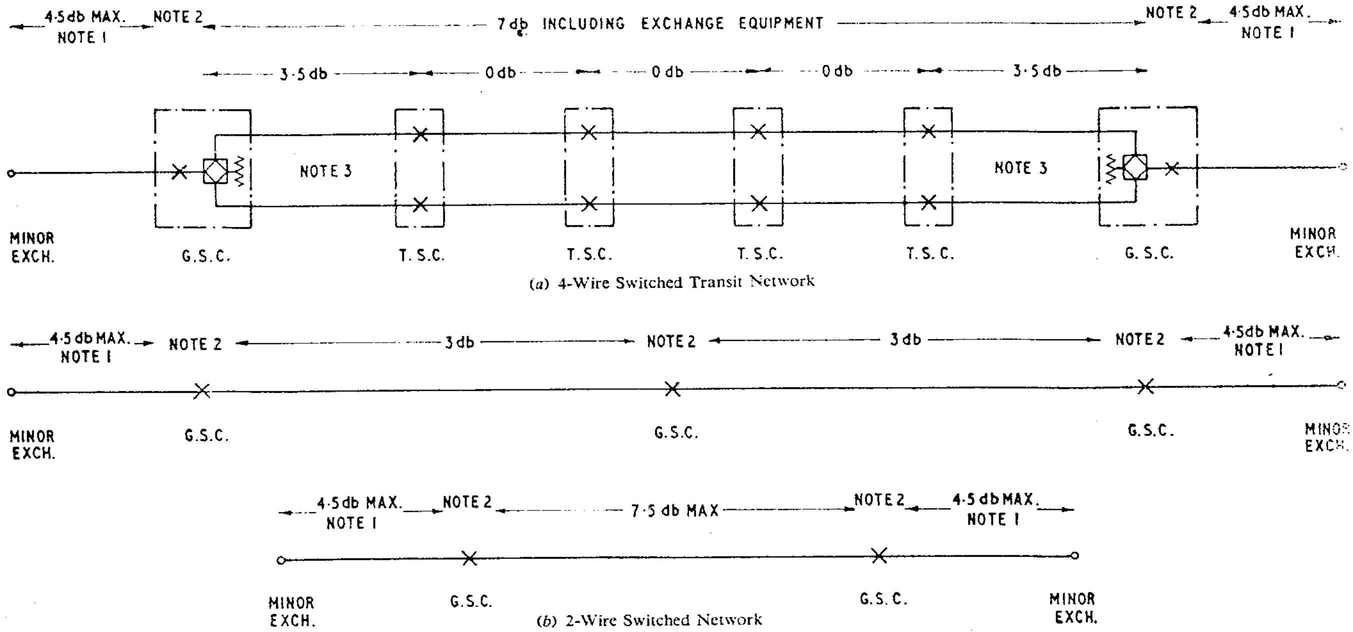
Two frequencies, different from those used in the forward direction, will be used for signals in the backward direction (proceed-to-send, etc.).

Line Signalling

The seizure, release and supervisory functions will be effected by means of line signalling systems which will be individual to the circuits concerned. The majority of the circuits will employ a 1 v.f. in-band signalling system. Exceptionally, an out-of-speech-band voice-frequency signalling system (similar to Signalling System, A.C., No. 8[5]) may be used on some of the h.f. circuits and a d.c. signalling system on audio circuits.

there will be some error due to limited accuracy of adjustment, and subsequently there will be changes due to power supply variations, component changes (particularly valve aging and replacement) and temperature changes. Consequently, when several independent circuits are connected together to set up a call, the transmission loss between G.S.C.s is unlikely to be exactly 7 db and it may be appreciably more or less. It is, however, planned to provide automatic gain control of the longer-distance carrier groups to restrict the range of variation.

The nominal loss between G.S.C.s (7 db) is a compromise: it must be sufficiently high to ensure that there is little chance of instability (i.e. oscillation round the loop path formed by the separate go and return paths and the 4-wire/2-wire terminating sets) if some of the component circuits have a transmission loss less than the nominal; but on the other hand it must be as low as possible so that speech and signalling currents are not



Notes:
1. In London there may be a maximum loss of 6·5 db for minor to G.S.C. links.
2. The switching-point loss at a G.S.C. will be approximately 1 to 2 db. At T.S.C.s the transmission loss of exchange equipment will be included with the line loss.
3. It will be possible to use 2-wire circuits between a G.S.C. and its T.S.C. in special cases where the distance is short. Each such link will be provided with a 2-wire/4-wire terminating set at the T.S.C. to allow connexion to the 4-wire switching equipment.
4. X denotes 2-wire switching equipment; x denotes 4-wire switching equipment.

FIG. 3—NEW TRANSMISSION PLAN

TRANSMISSION

The more important transmission features of the new plan are illustrated in Fig. 3. It will be seen that for the majority of calls, which make use of direct circuits between G.S.C.s, the arrangement is similar to that of the existing plan, except that there are no dependent exchanges, and group switching centres take the place of trunk group centres. The main change is for calls over the 4-wire switched transit network. The arrangement adopted will provide more uniform transmission for long-distance multi-link trunk calls than the present trunk network and will ensure that transmission is satisfactory between subscribers connected to exchanges on the fringe of the network.

Although the transmission loss of each trunk circuit between T.S.C.s will be adjusted to a nominal 0 db (measured between 4-wire switching points), initially unduly attenuated when the component circuits have a greater than nominal loss (or so that the number of links that can be connected in tandem is not unduly restricted). Also, the transmission loss or gain of the 4-wire part of the connexion when added to the loss (go to return) of the 4-wire/2-wire terminating sets must not be such that there is likelihood of objectionable echoes being heard by the talker or listener.

Nearly all the longer-distance circuits of the transit network will be high-velocity circuits on carrier or coaxial cables and, with the loss chosen for the 4-wire part of the connexion, echo suppressors will not be needed.

As previously mentioned, avoiding the arrangement whereby two junctions in tandem are required to have a transmission loss not greater than 4·5 db will help ensure that the new plan can be followed without incurring excessive expenditure on junction cables with heavy-gauge conductors, although some additional circuits will be necessary.

AUTOMANUAL CENTRES

Telephone switchboards are at present located at trunk group centres and at such other places as are necessary for the normal connexion of trunk traffic and for dealing with the queries and difficulties of subscribers. With the increasing proportion of calls being dialled by subscribers, due to the introduction of group charging and S.T.D. and the replacement of manual exchanges by automatic equipment, the amount of telephone traffic handled by operators will be progressively reduced and fewer automanual centres will be needed.

Consideration of transmission requirements leads to the conclusion that the automanual centre for a group of exchanges should generally be either at the G.S.C. serving the exchanges or at the T.S.C. Automanual switchboards at G.S.C.s will normally use conventional 2-wire switching, but at T.S.C.s the switchboard will control 4-wire switching equipment. Similar 4-wire switching equipment will be required for association with a switchboard at a G.S.C. to enable it to handle automanual traffic from another G.S.C. where this is the most economical way of giving automanual service.

CONCLUSIONS

The new trunk switching and transmission plan will enable multi-link trunk calls, particularly those dialled by subscribers, to be connected quickly and economically and with satisfactory transmission performance. The principal features of the new plan have been decided and development work has been started, though it will be some time before the first transit switching centre is in use.

Further articles will describe in more detail the different features of the plan and the new equipment that is being developed.

ACKNOWLEDGEMENTS

The new plan has resulted from co-operation between several branches of the Engineering Department and the Inland Telecommunications Department. In particular, the Telephone Exchange Systems Development Branch is responsible for switching and signalling, the Main Lines Development and Maintenance Branch and the Main Lines Planning and Provision Branch for the transmission aspects of the new plan, and the Exchange Equipment and Accommodation Branch for trunking aspects and the implementation of the plan.

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Book Review

"Theoretical Electromagnetism." W. R. Myers, M.Sc. Butterworths Scientific Publications. xii + 274 pp. 117 ill. 42s.

Some years ago we were delighted by a book from the pen of an engineer, Prof. E. G. Cullwick, about fundamental electromagnetism. Here is the complementary volume, written from an equally delightful standpoint, although the author does not claim to have attempted what in fact he has actually achieved.

Mr. Myers is a physicist writing for undergraduates who aspire to an honours degree in physics. However, unlike most of his colleagues in the academic world of physics the author, unashamedly and without any apologetic attitude, bases his treatment on the rationalized M.K.S. system of units. He assumes no previous knowledge of this system as he is presuming that most of his readers will have come straight from school where they will have studied physics up to G.C.E. advanced or scholarship level using only c.g.s. units.

His treatment starts traditionally with electrostatics based on Coulomb's inverse square law, and proceeds at once to the development of the conception of electric fields and field theory with due regard to, and emphasis upon, energy conditions. The concept of electric displacement and polarization is clearly developed and lucidly treated in his opening chapter.

The second chapter deals with magnetostatics, and in order to emphasize to the student the highly artificial nature of magnetic poles in contrast to electric charges, the author indicates the temptation to start with magnetic poles because of the identity of the field equations of electrostatics and magnetostatics, but refuses to do so and bases his magnetostatics firmly on the more practical idea of electric currents and the mutual forces between conductors carrying currents. Having established his basis in this way, by means of Ampere's Theorem, he introduces, in this order, magnetic potential, magnetic moment, magnetic shells and, finally, magnetic poles.

Throughout his treatment of elementary field theory the author is most careful to point out to the student the distinction between scalar and vector parameters using the parameters themselves as illustrations. This is all too frequently omitted, students learning about scalars and vectors in their mathematics but failing to apply their mathematical knowledge correctly when studying its application to more advanced physics.

At the end of the chapter on magnetostatics, the author includes an elementary but rigid treatment of magnetization, the conception of the magnetic vectors B and H and their relation to the electric vectors D and E. There follows a short chapter on electromagnetic induction in which the application of magnetic vector potential is most clearly explained and the betatron is used as an illustration of the connexion of Faraday's Law with static field theory.

Alternative ways of defining inductance are next discussed and the conception of magnetic energy is explained.

The subject of alternating currents is introduced via Ampere's Law, the conception of displacement current and wave propagation. Low frequency alternating currents thus emerge as a special case where radiation effects are small. A reasonably complete treatment of resonance and

(*Continued on p.* 81)